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Compendium

The Chemical Weapons Programme

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CHAPTER III.I

INITIATION OF IRAQ'S CHEMICAL WEAPONS ACTIVITIES

Prerequisites for the chemical weapons programme (1964 – 1970) [1]

Iraq ratified the 1925 Geneva Protocol on the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare in 1931. In 1972, Iraq signed the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction (BWC). However, Iraq only ratified this treaty in June 1991, following the 1991 Gulf War and the adoption of Security Council resolution 687 (1991).

The Chemical Corps was formed within Iraq's Armed Forces in the 1960s. Its task was to provide for the nuclear, biological and chemical (NBC) protection of troops. A number of Iraqi Chemical Corps officers were educated or trained in foreign military institutions specializing in NBC defence (in both western and eastern foreign military establishments). The teaching included the properties of chemical and biological warfare agents, their medical effects, and identification and detection methods. Usage of individual and collective protective and decontamination equipment, and appropriate prophylactic measures were also covered.

With minor adjustments, Iraq's Chemical Corps adopted foreign field manuals on NBC defence and acquired relevant equipment and materials, from abroad including individual protective equipment, portable field laboratories and decontamination stations. The Chemical Corps further introduced NBC training procedures for all other units within Iraq's Armed Forces. Such military training involved the use of CW agent simulants in field exercises. By the end of the 1960s, the Iraqi Chemical Corps had gained some general knowledge in this field. This general CW knowledge provided a valuable foundation when Iraq later embarked on an offensive CW capability.

Practical familiarization with chemical warfare agents (1971-1973)

The general knowledge of chemical warfare obtained by Iraqi NBC officers did not cover practical experience in the handling of live CW agents, neither did it comprise specific information on how CW agents could be produced and weaponized.

In 1971, to gain such knowledge, Iraq's Chemical Corps established a chemical laboratory complex at a site called Al Rashad village in the Northern-East suburbs of Baghdad. This laboratory was set up to obtain experience in the synthesis of some chemical warfare agents and the evaluation of their properties. In the period from 1971 to 1973, some laboratory quantities of CW agents, mustard, tabun and CS (a riot control

[1] Chemical FFCD June 1996, Chapter I and Addendum; Chemical CAFCD December 2002, Chapter I and Addendum

agent), were synthesized at Al Rashad. The laboratory was staffed by Chemical Corps officers. By the end of 1973, it consisted of four sections that worked with nerve agents, blister agents, irritants and defoliants.

Laboratory work with live CW agents constituted a formative step in the training of a national cadre for more focused future CW research and production. In addition, initial synthetic work was required to allow personnel to become more familiar with published synthetic procedures for CW agents. At this time, Iraq also established its first analytical capabilities to be able to identify CW agents synthesized and evaluate their properties. Micro quantities of very pure (more than 99%) CW agents were also required as reference standards for the calibration of analytical instruments. It is unknown whether Iraq received any samples of CW agents from abroad in the 1970's.

Comment
NBC defence is a legitimate area of military activity aimed at protecting troops and civilian populations from potential nuclear, biological and chemical threats. There was nothing unusual in Iraq's efforts during that period. Iraq followed the pattern that many other countries applied, sending their cadres for studies and buying materials from big players in the WMD and NBC Defence areas. On the other hand, this step was necessary to launch later a full scale CW programme.

There is little information available on the extent of CW-related activities at Al Rashad laboratory, since no documents or other evidence relating to its operations remain. In general, the synthesis of CW agents at a laboratory scale should not necessarily be interpreted as an initiation of the offensive CW programme. Small quantities of CW agents might also be required for legitimate goals of chemical defence, such as the calibration of detection instruments and testing of individual protective equipment. It is unknown which side of the dividing line the Al Rashad laboratories stood at the earlier years of its functioning, given the data available. It is, however, known through Iraq's declarations that at the end of its existence during the period 1981-1982 Al Rashad facility was capable of producing up to few hundred kg of sulphur mustard per day, which were consumed in the battlefield during Iran-Iraq war.

Al Hazen Ibn Al Haitham Institute (1974-1978)

Iraq declared that, in 1974 the Al Hazen Ibn Al Haitham Institute was created by a Governmental decree to conduct scientific, academic and applied research in the fields of chemistry, physics and micro-organisms.[2] The new organization was attached to the Ministry of Higher Education and Scientific Research, but in practice it was affiliated to the State Security Apparatus. The Institute received sufficient funding from the government. Its board of directors consisted of representatives from various governmental ministries and agencies, including the Chemical Corps.

[2] UNSCOM inquiries and Iraq's explanations on the matter are included in UNSCOM 193 Inspection Report and Biological TEM of March 1998.

Chemical activities at Al Hazen Ibn Al Haitham Institute[3]

In response to rising military threats from the outside, Iraq declared that the objectives of the Institute in the chemical area included research on CW agent synthesis, development of production technology, development and acquisition of the equipment necessary to proceed with pilot-scale CW agent production. The Al Hazen Ibn Al Haitham Institute was organized into three Centres and a separate headquarters, and the laboratories associated with these Centres were at different locations around the Baghdad area. The Institute's First Centre was responsible for CW-related activities. In 1974, it took over the site at Al Rashad village, which was previously operated by the Chemical Corps.

Although no records from the Al Hazen Ibn Al Haitham Institute remain on its chemical activities, the following was established on the basis of declarations provided by Iraq and from interviews with Iraqi scientists. [4]

Work at the First Centre of Al Hazen Ibn Al Haitham Institute began with the upgrading of four chemical synthesis laboratories, the construction of an additional analytical laboratory, the foundation of a mechanical workshop and other support structures, the procurement of laboratory equipment and analytical instruments and the acquisition of a scientific reference library. In addition, this facility procured laboratory quantities of raw materials for the synthesis of CW agents.

The four chemical synthesis laboratories were equipped with fume hoods and laboratory glassware. In 1975, Al Rashad acquired several rotary evaporation units (500 ml each).

Priority was given to the establishment of an analytical laboratory for Al Hazen Ibn Al Haitham. Experience from the Al Rashad laboratory from 1971 to 1973 had demonstrated that optimisation of chemical agent production could only be achieved if some chemical analysis capability was present. Instrumentation was needed to identify the materials synthesized, determine their purity, reaction yields and to identify the composition of other mixture components. Instrumentation was also necessary for quality control of related precursor chemicals. The analytical data provided by these instruments and techniques gave essential information on the kinetics of chemical reactions so as to enable an adjustment of synthetic procedures to obtain better quality final products. Subsequently, several analytical instruments were procured and installed in the laboratory, including ultra violet (UV) and infra-red (IR) spectroscopy, gas chromatography (GC) and nuclear magnetic resonance (NMR) instruments.

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[3] Chemical CAFCD December 2002 Chapter I
[4] UNSCOM 074/CW15, April 1994

In the period from 1974 to 1978, Al Hazen laboratories attempted to synthesize many of the known CW agents. The major progress was achieved in the laboratory production of the CW agents mustard, tabun, and, to some degree, sarin.[5]

The Al Hazen Institute was able to procure a variety of chemicals that required a minimal number of stages to produce either the CW agents themselves or their key precursors[6]. The availability and purity of specific precursors predetermined the synthesis routes adopted for the production of each agent and the degree of success in their synthesis.

In 1975, the Al Hazen Institute produced mustard, tabun and sarin in laboratory quantities, using equipment then available. As part of the plan for larger-scale production, pilot scale glass reactors and vessels were procured in 1976. It seems likely that toxicological evaluations of the CW agents synthesized were conducted before the scaling-up of their production. UNSCOM could not find any information on animal tests carried out by Al Hazen Institute.

In the mid-1970's, Al Hazen Institute established contacts and business relations with major suppliers that provided precursor chemicals, laboratory equipment and analytical instruments, pilot-scale and industrial size chemical process equipment for Iraq's future large-scale CW programme. These contacts included some 30 major foreign organizations and companies.

Following progress in the scale-up in CW agent synthesis, the Al Hazen Institute expanded its chemical base at Al Rashad and placed larger, pilot-scale and industrial scale production capabilities at a new site located in a remote desert area south of the town of Samarra. Four CW production plants were installed there. These included a dedicated plant (later known as P-8) for the production of the CW agent mustard, the plant for the final stage of tabun/sarin production (later known as P-7), and two multipurpose plants for the production of precursors for tabun and sarin (later known as Ahmed 2 and 3). The work began in 1975 by the general contractor, Iraq's State Company for Construction Projects (later known as Al Fao General Establishment) affiliated to the State Organization for Technical Industries (SOTI). It included the construction of roads and engineering support infrastructure, including power and water supplies. The P-7 and P-8 plants were designed by an Iraqi chemical engineering company; two multipurpose plants were designed by a foreign company under a contract with Al Hazen Institute. The procurement of chemical process equipment for these plants from two foreign companies also began in 1975. It ranged from a 200 litre pilot-scale glass reactors to 3 m^3 Hastalloy lined vessels for the production of nerve agents.

[5] Regarding VX, Iraq claimed that it was only synthesized in 1984, although its structure had been known from 1978 – Technical Evaluation Meeting (TEM) 2-6 Feb 1998. Some work with VX precursors was mentioned by Al Hazen staff interviewed by UNSCOM.
[6] In the 1970's, there were no international trade regulations and restrictions other than those specified in the Geneva protocol.

The Al Hazen Institute did not finalize the construction of new facilities prior to its closure in late 1978/early 1979 and some earlier procured equipment and materials remained uninstalled and construction work unfinished. However, the Institute achieved considerable progress in the CW area. In the period of four years (1974-1978) it was able to identify suitable synthetic procedures for the production of CW agents and even though production was only at research-levels for CW agents, with the exception probably of the chemical agent mustard,[7] the planning occurred for production at an industrial level and construction of relevant plants. The installation of four specific production plants at the Samarra site suggested that the Al Hazen Institute had succeeded in pilot production of CW agents mustard, tabun and sarin and their major precursors. This statement was never confirmed in the official Iraqi declarations – in its declaration of March 1995 Iraq claims that it did not succeed in the pilot scale.

Comment
The fact that NMR technology was already available at Al Hazen Institute in the mid 1970's suggests that this organization was well funded and was given priority to procure all items and materials required for the implementation of its tasks.

The Al Hazen Institute achieved progress in three major areas which allowed Iraq to accelerate the developments of its future chemical weapons programme. Firstly, the laboratory synthesis was scaled up from grams to kilograms. Secondly, the introduction of analytical procedures allowed Iraq to optimize synthetic processes. Finally, pilot-scale production allowed Iraq to further adjust its chemical process to industrial size production.

Chemical activities carried out by Al Hazen Institute from the beginning were bearing signs of its work in the direction of an offensive chemical warfare programme. These signs included:

- *Procurement of chemical synthesis laboratory equipment in combination with a variety of analytical instruments and chemicals known to be major CW precursors,*
- *Procurement of pilot scale equipment in combination with kilogram quantities of precursor chemicals, and*
- *The specific layout, design and chemical process equipment of facilities under construction at the Samarra site.*

Iraq has indicated that it considers the establishment of Al Hazen Institute as the foundation of Iraq's offensive CW programme.

There is conflicting data regarding the extent of CW agent production during the period of the Al Hazen Ibn Al Haitham Institute. According to Iraqi declarations, only small (laboratory) quantities of CW agents were produced. Yet when interviewed by UN

[7] UNSCOM 74/CW15 found that 5 tonnes of mustard agent remained in Al Hazen after its closure.

inspectors, the Director General of Muthanna indicated the Institute produced that five tonnes of mustard. Iraq declared 10 tonnes of mustard produced during 1981(see Chapter III.II) but nothing prior to this year.

The full extent of the foreign assistance received by Al Hazen Institute remains unknown. If reference standards of CW agents were made available, it could have significantly accelerated the laboratory phase of CW research. This can possibly explain how Al Hazen Institute was able to plan pilot scale facilities after only one year of laboratory research.

Abolition of Al Hazen Ibn Al Haitham Institute

Iraq declared that, in 1978, Al Hazen Ibn Al Haitham Institute was abolished and a number of the staff was imprisoned for scientific fraud. [8] Although its assets were transferred to SOTI, the name of the Institute was still used after its dissolution for the purchase of equipment for some SOTI and Scientific and Technical Research Centre (STRC) projects.

Iraq stated that there were no direct links or continuity between this organization and later developments in the field of biological and chemical weapons. However, as it became evident from interviews[9] with its former employees, the assets[10] and most personnel of Al Rashad laboratory and Ibn Sina Centre (the "Second" Centre for biological research) were taken over by other organizations and continued to operate. Thus, the demise of the Al Hazen Institute did not imply a termination of its substantive activities, but in reality its functions continued with the transfer of some personnel and assets to other organizational structures.

Period of uncertainty in CW developments (1979-1981)

The Al Rashad site, established by the Chemical Corps in 1971 was returned to the same organisation in 1979. According to Iraq's declarations, the Chemical Corps continued to operate laboratories at the Al Rashad site after the abolition of the Al Hazen Institute. Laboratories were used for the production of laboratory-scale quantities of CW agents required for the calibration and testing of NBC defence equipment and materials. The Samarra site, with all its equipment and materials procured for the four CW production plants by Al Hazen Ibn Al Haitham Institute, was placed under the administrative control of SOTI. The construction work for the production plants however, was suspended after the closure of the Al Hazen Ibn Al Haitham Institute in 1978 and was not resumed until 1981. From 1979 to 1981, some civil construction and development of this site was continued by SOTI as Project 1-75.

[8] UNSCOM 193/BW-53 Inspection Report provides information, that the Institute was abolished in January 1979

[9] Ibid

[10] According to General Nizar Attar, some equipment was stolen and others scattered around.

Meanwhile, the practice of training of Chemical Corps officers overseas continued. In addition to regular military NBC training, NBC officers were enrolled in postgraduate and PhD studies in the fields of chemical engineering, organic and analytical chemistry and toxicology.

The role of the Chemical Corps with regard to NBC troop protection was also expanded. Several senior officers of the Chemical Corps were assigned to the Analysis and Research Laboratory, which was later transformed into the Central Military Medical Laboratory under Military Affairs Directorate of the Administration and Provisions Department of the Ministry of Defence. The functions of this laboratory included the medical protection of troops from CW agents and the treatment of possible casualties. There is no evidence that the Central Military Medical Laboratory was involved in the CW programme, however several of its personnel were reassigned to the CW programme at Al Rashad after 1981.

Between 1979 and 1981, Iraq's intelligence agencies were involved in attempts to collect additional information on CW production technology and know-how.

Comment

By 1979, Iraq had already obtained the capacity to begin a large-scale CW programme. It acquired knowledge in: laboratory synthesis of CW agents, scaling-up production, building CW research capabilities, training personnel, forming a procurement network, founding several production plants and obtaining a number of key pieces of pilot and industrial size equipment.

No information is available regarding weaponization attempts, tests or even the preliminary selection of CW delivery means prior to 1981. It seems unusual that the Al Hazen institute planned CW production plants without simultaneously evaluating weaponization technology (filling of munitions and devices with CW agents) and selecting specific delivery systems.

CHAPTER III.II

FOUNDATION OF THE LARGE-SCALE MILITARY CW PROGRAMME

Project 922

In June 1981, Iraq was faced with emerging complications in its war with Iran while also having a significant manpower disadvantage. To mitigate this disadvantage, Iraq decided to produce and deploy chemical weapons. To achieve this aim, Iraq established Project 922 within the Ministry of Defence. [1]

The Commander of the Chemical Corps was appointed as the Chairman of the Board of Directors of Project 922. The Project inherited the assets of the Al Rashad chemical laboratory complex left from the Al Hazen Ibn Al Haitham Institute and operated by the Chemical Corps as well as the partially completed Samarra site[2] previously founded by the Al Hazen Ibn Al Haitham Institute.

The laboratory and pilot scale equipment available at Al Rashad laboratories were used for the production of CW agents immediately after the foundation of the project. Although the laboratory was able to produce tens of tonnes of the CW agent mustard in the period from 1981 to 1983, it had very limited production capabilities, and was not capable of producing more than hundreds of kilograms of the agent per day. This was far less than the military requirements or expectations.

In addition, Iraq did not have dedicated facilities and equipment for chemical munitions production or CW agent filling. In the early period of Project 922, selected conventional munitions were manually filled with CW agents at remote locations.

In order to satisfy military demands due to Iran-Iraq war and to scale-up the level of the CW programme, Project 922 staff recognized the need to acquire necessary foreign technology and raw materials for all aspects of the programme. Acquisitions included chemical process and support equipment, CW agent precursors and other related chemicals. Also equipment to scale-up the production from gram and kilogram to tonne scale per day, quality control methods and the equipment necessary to perform toxicological evaluation of final agents were acquired. Project 922 personnel also realized that, delivery means, weaponization and storage capacity, as well as handling and deployment procedures of filled munitions also had to be developed.

In order to create a CW programme large enough to have an impact on the ongoing war with Iran several pre-conditions were necessary. Firstly, the project needed to have sizable and flexible government funding as well as a certain degree of financial freedom

[1] Chemical CAFCD December 2002 Chapter I and earlier declarations
[2] The term “Samarra site” was used by Iraq and UNSCOM/UNMOVIC in various documents interchangeably with “Muthanna site” and “SEPP” and also “MSE”. All refer to the same location: the main production facility of Iraq’s CW programme.

to operate bank accounts to support procurement, construction costs and operational expenses.

Secondly, in order to succeed, the CW programme required a national priority status to be able to utilize all relevant national resources: scientific, technical and industrial capabilities available in both the military and civilian sectors. Additionally it included the training of a cadre of scientists and technicians, military industries to supply the project with suitable munitions, the security apparatus to provide protection, intelligence to gather relevant information, know-how acquired from foreign sources or developed indigenously and the development of a procurement network.

Thirdly, a convincing cover story was needed to engage contractors and providers of equipment, technology and materials without compromising the true nature of the project. The production of agricultural chemicals such as fertilizers, pesticides, herbicides and fungicides were selected as an appropriate cover for a number of reasons. By its nature and design (batch production and corrosion resistance) the chemical process equipment required for their production was also suitable for the production of CW agents. Raw materials for the production of agricultural chemicals were also, to a large degree, suitable as major precursors for the production of CW agents. In addition, there were no international regulations preventing the procurement of such equipment and raw materials at that time and such imports could have occurred without raising suspicions. Moreover, Iraq had a legitimate need for the production of agricultural chemicals.

All of the above considerations were reflected in the decision by the Revolutionary Command Council (RCC) of Iraq of 27 August 1981 # 1156 which founded the State Establishment for Pesticide Production (SEPP). [3]

State Establishment for Pesticide Production (SEPP)

The above decision on the foundation of SEPP signed by Saddam Hussein and published in the official bulletin of the Ministry of Justice gave Project 922 the legal status of a national establishment operated under the Ministry of Industries and Minerals without changing its military affiliation.

In accordance with the RCC decision, SEPP (later known as the Muthanna State Establishment (MSE)) was given full authority to exploit any local resources and to develop production capabilities with other agencies that it deemed necessary. SEPP was also authorized to import and purchase locally all necessary materials, substances and equipment, to interact with governmental, local and foreign agencies and entities both inside and outside Iraq. SEPP was also given the right to own and possess funds and property, enter into contractual obligations either directly or on behalf of other agencies, build and rent stores, depots and other facilities relevant to its functions, borrow any funds required for the implementation of its tasks from banks and other financial

[3] UNMOVIC Doc No 200107.016

institutions, recruit and train cadre of scientists and technicians, and maintain working contacts with foreign experts and scientists.

Having dual chain of command, the newly formed establishment continued to report directly to the Minister of Defence on issues of chemical weapons and to the Ministry of Industries and Minerals on issues concerning commercial products.

Foundation of the CW production complex near Samarra

The Al Hazen Ibn Al Haitham Institute acquired the Samarra site in the 1970s. It comprised an area 5x5 km in the desert some 20 km south of the town of Samarra (Figure III.I). The construction of an administrative area and four production plants was started but not completed in the 1970s. By 1981, the civilian construction phase, which included levelling the area, construction of access roads and the preparation for supply of utilities, was partly completed.

This site was selected by Project 922 to be Iraq’s major CW research, development, production, weaponization and temporary storage complex. The plan of the site included a production area with multiple plants for the manufacture of precursors and CW agents as well as commercial products and a research and development area comprising laboratories and pilot plants to scale-up the production. Also included was an administrative complex, with a general storage area, mechanical workshops, a transportation department and an administration building. The chemical weapons storage area with well-protected air-conditioned bunkers was constructed separately from the munitions filling area. Enhanced security and an air defence system protected the whole complex [4] (Figure III.II).

Construction of CW production capabilities at Samarra site

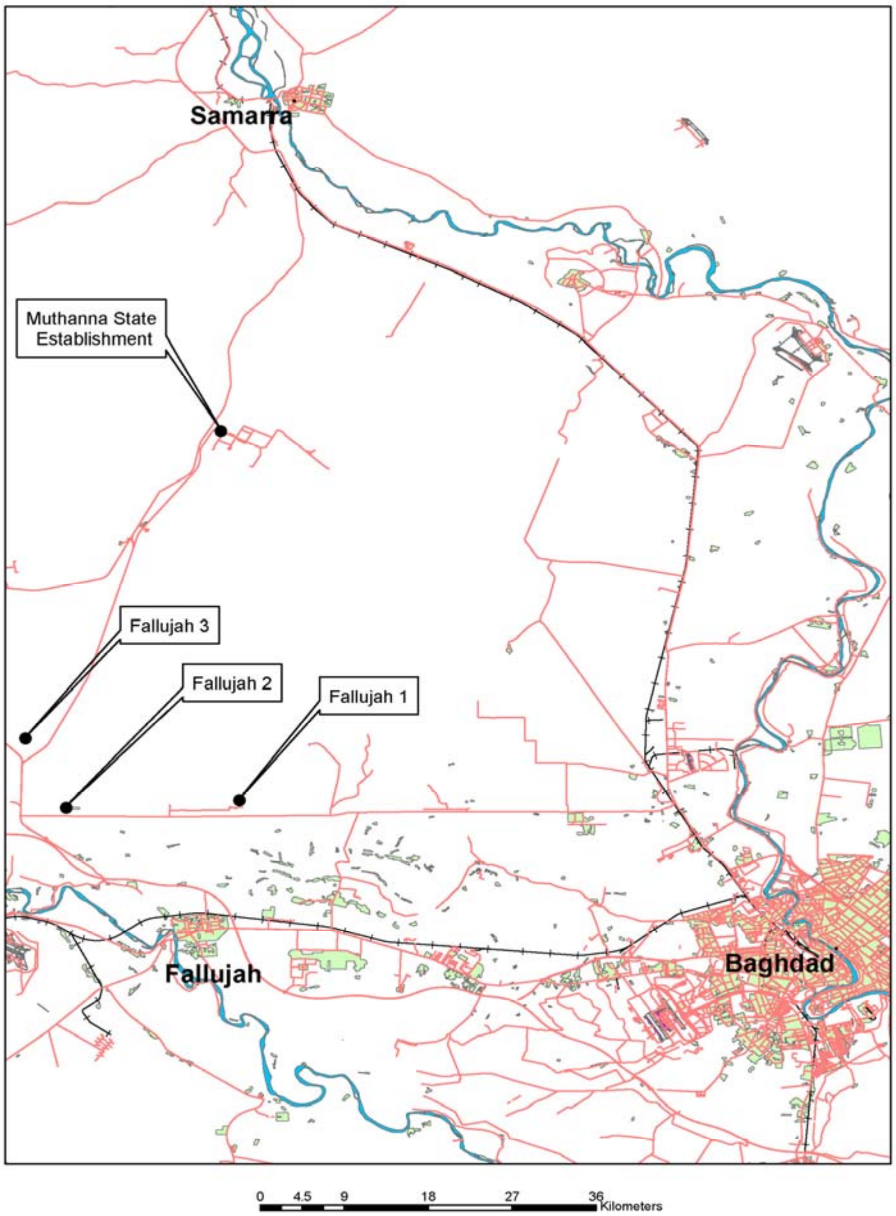
First Phase of construction

In September 1981, SEPP resumed the construction of the four production plants earlier started at the Samarra site by the Al Hazen Ibn Al Haitham Institute. These plants were re-designed in order to meet immediate production requirements. According to Iraq, in the first phase, SEPP planned to build one plant for the production of the CW agent mustard from imported key precursors, thiodiglycol (TDG) and thionyl chloride, and one multipurpose plant for the final stage of the production of two nerve agents, tabun and sarin. Plans also included the building of two plants for the production of key precursors for tabun and sarin that were not available on the international market, dimethylphosphoroamidic-dichloride (D4), methylphosphonyldichloride (MPC), and methylphosphonyldifluoride (MPF). The equipment from SOTI, together with laboratory chemicals and a small amount of precursors were transferred from Al-Rashad to

[4] UNSCOM 017/CW-5 Inspection Report contains detailed description of the site as found in 1991

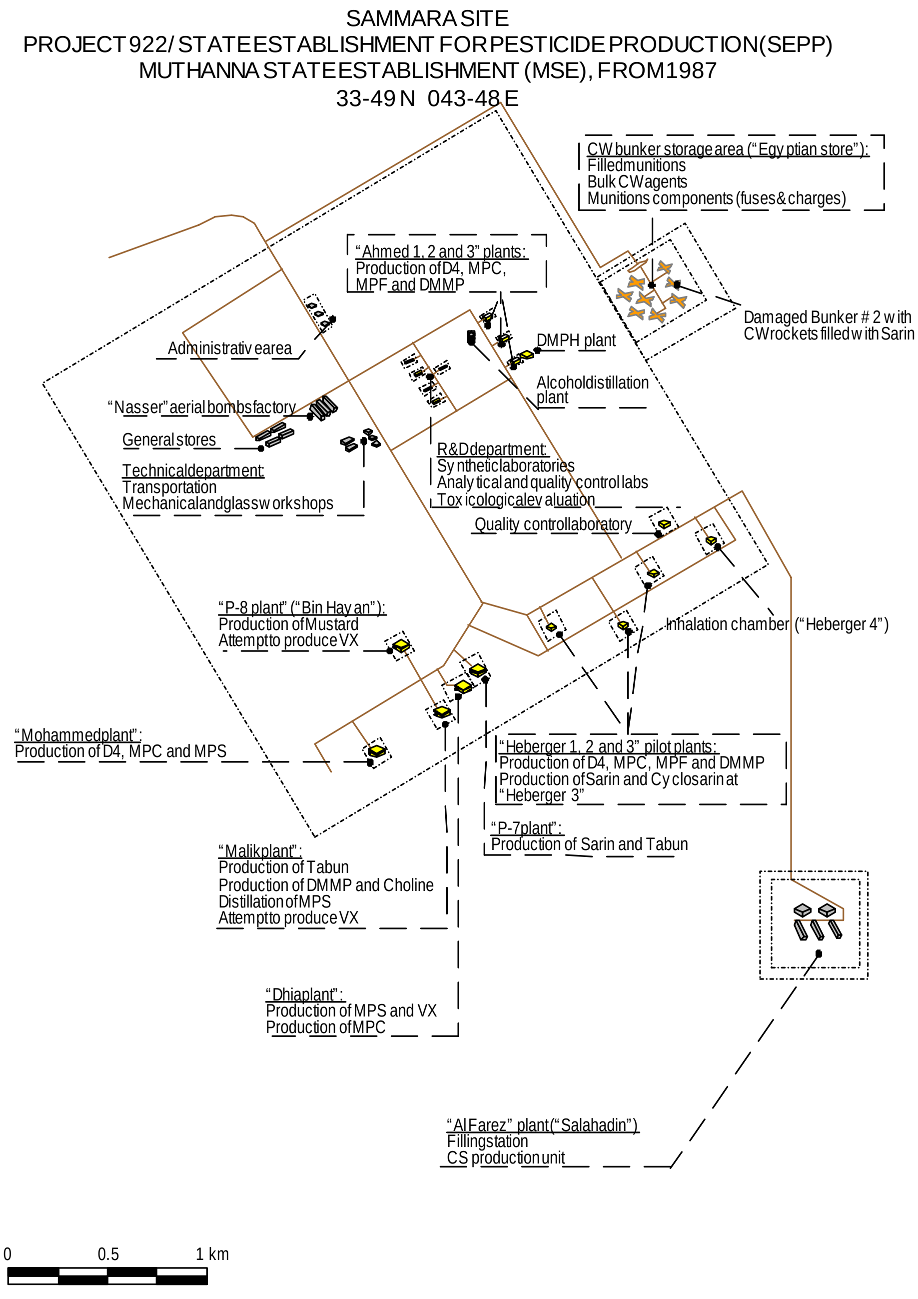
SEPP/MSE in the summer of 1983, when most of the Samarra CW plants designed and executed by both Iraqi and foreign companies had already became operational.[5]

Figure III.I Location of the SEPP/MSE Samarra site and the later constructed Fallujah sites



[5] UNSCOM 074/ CW-15 April 1994

FigureIII.IITheSamarraSite



Mustard plant (P-8 plant, Bin Hayan 1 plant after 1987)

The plant was first designed by an Iraqi chemical engineering company in 1975 and then re-designed by SEPP in 1981. The State Company for Construction Projects did the civil construction work as Project 1-75. Two foreign companies supplied equipment in 1982. The plant became operational in 1983. Mustard was produced at this plant from 1983 to 1988 and from 1990 until January 1991.

The production started with the use of two reactors capable of producing 750 kg of mustard per batch. In 1984, the plant was upgraded with the installation of two more reactors, each capable of producing up to two tonnes of mustard per batch. In 1987, another two reactors were added to the P-8 plant bringing the production rate to eight tonnes of mustard per day[6].

One trial batch of the CW agent VX was produced at the P-8 plant in December 1987. The plant was found to be unsuitable for the production of VX. At the end of 1990 the plant produced mustard at a rate of eight tonnes per day.

Tabun/Sarin production plant P7 plant, (Mutassim 4 after 1987)

Like the mustard plant, the tabun/sarin plant was also first designed by an Iraqi chemical engineering company in 1975 and then re-designed by SEPP in 1981. The State Company for Construction Projects also accomplished the civil construction work under Project 1-75. Two foreign companies supplied equipment in 1982. The plant became operational in 1984. It was equipped with three reactors.

Sarin was produced at this plant in 1984, 1985 and 1988 and again from 1990 to January 1991[7]. The production capacity per batch was up to 600 kg of sarin. Tabun[8] was produced in 1985 and 1986 using two reactors at the rate of one tonne per day with the batch capacity of about 500 kg. Since tabun was produced as slurry the third reactor was used for the removal of salt from tabun.

Multipurpose precursor plants (Ahmed 1 and Ahmed 2 plants, Mutassim 2 after 1987)

A foreign company designed these twin plants. The same company also provided and installed process equipment, which included two reactors for each plant. These reactors were later replaced with larger ones. The plants began the production of precursors for sarin and tabun in 1983 and continued to be operational until 1987. They produced tabun and sarin precursors D4, MPC, MPF and the MPC precursor dimethylmethylphosphonate (DMMP) at maximum capacity up to two tonnes per day.

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[6] UNSCOM 140/CW-29, August 1996 (Interview No 6)
[7] Ditto (Interviews No 5 and No 11)
[8] Chemical CAFCD December 2002, Chapter VI, para 6.2.2.2. Tabun was produced starting from 1982 at R&D facilities and for one month in 1984 at P7

Pilot plants (H1, H2 and H3 pilot plants, Mutassim 1 after 1987)

In addition to the four existing production plants, the construction of three pilot plants began in 1981-1982. These pilot plants were constructed to optimize the production of the key precursors for tabun and sarin at the two Ahmed plants. The precursor D4 (for tabun) was produced using imported dimethylamine hydrochloride and phosphorus oxychloride, and the precursor MPC (for sarin, cyclosarin and VX) was produced using DMMP and thionylchloride.

Figure III.III One general view of the pilot plants.

These identical pilot plants, H1, H2, and H3 were designed and constructed by one foreign company and the equipment was supplied and installed by another foreign company (Figure III.III). The H1, H2 pilot plants became operational in 1983. Originally, two small reactors made of glass were installed at each plant. In 1984 and 1985, larger vessels replaced them. In 1983, the plants were used for the development and optimization of the technology for the production of the precursors D4, DMMP and MPC. After 1984 they were used to produce those precursors.

The H3 pilot plant became operational in 1985. It produced sarin precursors DMMP and MPF at a capacity of up to 500 kg per day from 1985 to 1987. In 1988 and in 1990, H3 produced MPF, sarin and cyclosarin.[9,10]

A fourth structure, identical by design, was built together with the pilot plants but no production equipment was installed in it. An inhalation chamber was placed there instead (see below for more details).

Four dummy ones accompanied those four “real” plants.

Each pilot plant was a bunker type structure, partially underground. The aboveground part was covered with earth. It had a main entrance and one emergency exit**.** An airlock system was installed at the main entrance of the building. The ventilation system replaced the air in the building 10 to 25 times per hour. The high air turnover rate in the sealed

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[9] in addition to the quantities of these CW agents produced by the P-7 plant
[10] UNSCOM 140 CW-29, August 1996

operating area caused a negative pressure. The outgoing flow was not cleaned, but directly discharged to the atmosphere.

Expansion of precursor production capabilities

Mohammed plant (Mutassim 3 after 1987)

Also in 1982, another multipurpose production plant for the production of D4, MPC, MPF and final CW agents was established to increase the production rate if required in the future (a surge capacity). The plant was designed, constructed and provided with equipment by foreign companies.

In 1985 and 1986, the plant began the production of tabun precursor D4 at the rate 1.5 tonnes per day using two reactors. In 1987, two newly installed reactors were intended for the production of additional quantities of tabun (Iraq declared it stopped tabun production in 1986). In 1988 and 1990, plant produced MPC to meet growing demand in precursors for sarin production.

In 1987 and 1988, several batches of precursor methylphosphonyldichlorothionite (MPS) were produced at the Mohammed plant from MPC and phosphorus penthasulphide for the further production of VX.

Comment
From 1981 to 1983 SEPP employed foreign contractors under the guise of commercial activities, to create significant CW production capabilities. This allowed SEPP to produce CW agents at the rate 1-2 tonnes per day.

By 1985, SEPP was able to produce up to several tonnes of both nerve and blister CW agents per day.

SEPP carefully planned their CW production infrastructure, procurement and contracting. Both agent and precursor plant construction plans were coordinated with each other and with procurement plans for raw materials.

CS plant

Figure III.IV MSE, Part of Area "E" – CS production and filling buildings

A small production unit utilized for the manufacturing of the agent CS called Al Fariz,[11] was located near to the newly constructed munitions filling station and was built using the excess of the equipment delivered by foreign suppliers for the construction of other major CW production plants. CS was produced at this plant starting in 1983[12].

Alcohol distillation plant

In 1984, a foreign company supplied the alcohol distillation plant comprising two identical distillation units to SEPP. This plant was procured for the distillation of indigenously produced 95% ethanol to obtain absolute ethanol for the production of tabun at the P-7 plant. The distillation plant's capacity was 15 litres of alcohol per hour.

The plant however, failed to deliver a product with the sufficient purity that was required for use in the production of tabun. One of the reasons why SEPP was not able to produce absolute alcohol at the imported plant may have been again a lack of precise details in the technical specification given to the foreign company regarding the characteristics of alcohol to be distilled (the plant was designed to distil alcohol containing not more than 2% of water, but the feed stock for distillation contained 5% of water). Subsequently the plant was never used for its intended purpose; SEPP used only imported absolute alcohol for the production of tabun.

Other facilities at the Samarra site

CW storage area

At the beginning of the CW programme, there were no munitions stores designed for chemical weapons. Buildings allocated within conventional munitions depots served the

[11] UNSCOM 153/CW31, May 1997
[12] Later, production of this agent was transferred to buildings located near the Dhia plant.

purpose. A storage area comprising eight reinforced concrete bunkers with air conditioning and temperature control was constructed at the Samarra site in the period from 1981 to 1983 (Figure III.V). It was used for the temporary storage of filled chemical munitions, bulk agents and munitions components, such as fuses and charges. Six dummy bunkers surrounded the storage bunkers. The area was fenced-off and several air defence units were also stationed in the vicinity.

Figure III.V Storage Bunkers at SEPP/MSE

The storage bunkers were semi-underground structures covered with a protective layer of sandy clay. They resembled a truncated pyramid. The main storage room, sunken 5 metres below the ground level, was approximately 60m x 18m x 10m. A 7-tonne crane was mounted on the rails below the roof. The walls and roof were constructed with one-metre thick reinforced concrete. The roof slab was covered with a three-metre layer of sandy clay.

The central tunnel entrance was built as a vehicle ramp, which led into the main chamber: vehicles were required to exit through the same tunnel, as there was no drive through capability. Each bunker also had two side entrances that allowed personnel (not vehicle) access to the main chamber. The main storage room was protected from external explosions by reinforced doors and flameproof electrical fittings minimized the risk of fire damage. The service room, which had two separate entrances, contained an emergency power generator, fuel tank, compressor and cooling unit. It was located to the rear and separate from the main storage room and was accessed by its own dual entrance.

Administrative area and support infrastructure

The administrative and technical support areas were developed between 1981 and 1984. Those buildings comprised warehouses for receiving, storage and distribution of imported equipment and chemicals, a fire station, a vehicle maintenance area, mechanical and glass workshops as well as administrative buildings to house the management, financial and procurement departments.

Research laboratories

Five laboratory buildings were designed and equipped by a foreign company for the R&D department of SEPP between 1982 and 1984. These included several chemical synthesis laboratories, a toxicological evaluation section with an animal house and analytical laboratory that was also used as a quality control unit for the establishment. Later, an additional quality control laboratory was constructed in the area adjacent to pilot plants.

Inhalation chamber

Figure III.VI Inhalation Chamber at Muthanna

An inhalation chamber was installed in one of the buildings designed as a pilot plant. It significantly enhanced the capabilities of the R&D department in areas of research related to toxicological evaluation of CW agents.

Aerial bomb production factory

The aerial bomb production workshop at the Samarra site of the SEPP, also known as the "Nasser Factory" was designed for the manufacture of low drag general-purpose aerial bombs, to be modified and filled with CW agents. The imported equipment mainly included different presses and welding, cutting and drilling machines. The imported raw materials included semi-finished metal plates, un-machined forged parts, and a set of moulds to form bomb components. This facility was ready to start production by 1986. Several modifications to the production process were introduced during the course of bomb manufacture (see also Chapter III.X).

Second phase of construction

Dhia plant (Bin Hayan 3 after 1987)

In 1983, after completing the construction of the P-7 plant for the production of tabun and sarin, SEPP decided to build another plant for the production of sarin and its precursors. Foreign companies did all the civil engineering design, the construction work and the chemical engineering design. Also, a foreign company provided the equipment. However, because the foreign company was not informed of the specific materials to be produced by the plant, they withdrew from the project and Iraq was forced to complete the construction. As a result, the plant was less than ideal for the production of sarin and its precursors. Many problems appeared in the plant, later in May 1988, the plant was modified to produce VX and its precursors.

Comment
This was one of the examples when a cover story used by SEPP proved inadequate. SEPP misled the contractors with regard to the intended use of the building. As a result, the plant, which was designed, originally for the production of agricultural pesticides by the foreign supplier required major modifications before any CW production started.

In the first half of 1988, three batches of MPS, about two tonnes, and three batches of VX, about 1.7 tonnes, were produced at the Dhia plant. According to Iraq's declarations, another two batches of about 1.5 tonnes, of VX were produced in April 1990[13]. However, Iraq stated that Dhia plant remained ready to re-start VX production till the January 1991 when it was severely damaged by the aerial bombardment during the Gulf War.

In 1990, the Dhia plant produced MPC by making dimethylphosphite (DMPH) from available stocks of PCl_3. This method was an alternative to Iraq's previously established technique and was applied to compensate for the shortage of imported trimethylphosphite (TMP).

[13] UNSCOM 171/CW-34, January 1996

Malik multipurpose plant (Bin Hayan 2 after 1987)

Iraq declared that the construction of the Malik plant to produce sarin precursors began in 1982; and that “technical works” were completed in 1985. Three foreign companies participated in the construction. The first completed the civil engineering design, the second performed the construction work and the chemical engineering design was undertaken by the third, which also provided the equipment. The plant became operational in 1986.

Tabun was produced at the Malik plant in 1986 since the Dhia plant was not yet operational. In 1987, the Malik plant started production of DMMP, which was used for the production of sarin precursor MPC at the Ahmed plants.

According to Iraq from 1987 to 1989, the Malik plant produced about 60 tonnes of diisopropylaminoethanol (Iraqi choline), a key precursor for the production of VX, and distilled MPS, another VX precursor in 1988, which was produced at Dhia plant. One attempt was made to produce VX in 1988 but this failed, as did another attempt to concentrate VX produced at the P-7 plant.

Ahmed 3 plant (Mutassim 2 after 1987)

The Ahmed 3 plant was founded in 1987 to meet the needs for the expanding production of sarin. The plant was indigenously designed and constructed by SEPP/MSE using spare pieces of equipment earlier delivered by a foreign company for the construction of the Malik and Dhia plants. Two reactors were installed at the plant. The Ahmed 3 plant started production of MPC from DMMP in 1988. In 1990, after the imported TMP used for the indigenous production of DMMP was consumed, the plant was used to distil PCl_3.

DMPH plant

This plant was built within the Ahmed 3 plant in 1988-1989 to produce sarin precursor DMPH from PCl_3. DMPH was produced there in the second half of that year and then was used to produce insecticides such as Deptrix, or converted into pyrophosphate, from which MPC was produced and then sarin. This plant became operational in 1989. In the period from 1989 to January 1991, it produced 75 tonnes of DMPH. It was designed and constructed by MSE personnel.

Al Tahadi plant

After successful DMPH production at the plant described above, a dedicated plant for that purpose was built at Muthanna. Designed and constructed by its own personnel at the end of 1990, the plant was not finalized prior to the 1991 Gulf war.

Comment
In 1987 SEPP was renamed as the Muthanna State Establishment (MSE) and placed under the control of the newly established Military Industrialization Commission (MIC). After the end of the Iran-Iraq war in August 1988, MIC, clearly adopted technical policies aiming at the creation of dual-use capabilities that could be used for both, the production of commercial chemicals and CW agents and their precursors.
By 1988, MSE obtained sufficient experience mainly through its interactions with foreign chemical engineering companies and through modifications of procured process units to make its own design of chemical production lines of both CW and commercial nature and to successfully assemble them.

Expansion of the CW programme beyond the Samarra site

In 1985, in addition to the developing the Samarra site, SEPP founded three satellite facilities to produce raw materials and precursors for the manufacture of CW agents and commercial products. These sites were called Fallujah 1, 2 and 3 located at the distance of 40-50 kilometres from the main site (see map above) and 15-20 kilometres north of Fallujah city.

The three facilities[14] had many features in common: the size and shape of the site; the fencing; the layout, the function of the buildings; and utility distribution (see Figure III.VII as an example). The boundaries of the facilities consisted of an outer wire mesh fence and an inner wall two metres in height separated by a fifteen-metre gap. The wall had several built-in watchtowers.

The central production building located in the middle of each facility had a unique design for handling toxic chemicals and was identical for all three sites. It was called the multipurpose plant. Four warehouses in the eastern part of each site were of identical design and size. The western parts of the facilities were different in each case.

[14] UNSCOM 09/CW- 02 August 1991

Fallujah 2 (also known as the Chlorine Plant)

Al Mamun plant

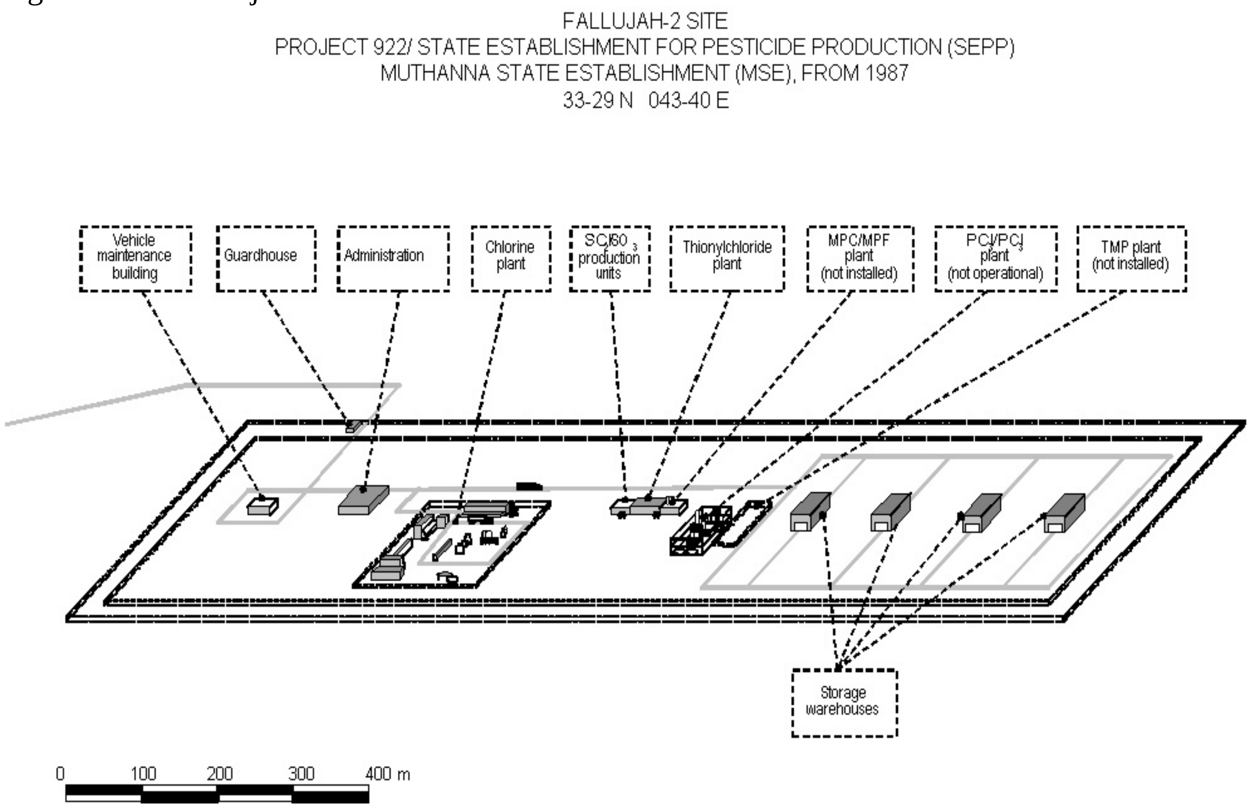
The plant was constructed in 1986 and 1987 at Fallujah 2 to produce thionyl chloride, a chlorinating agent that could be used for the production of MPC and mustard. From the start of CW agent production, Iraq had only used imported thionyl chloride and did not produce this chemical indigenously. The construction of the Al Mamun plant represented an attempt by SEPP to achieve self-reliance in the production of that important chemical.

The Al Mamun plant was designed by a foreign company and constructed by SEPP with the help of this company using equipment supplied by it. Thionyl chloride was produced from sulphur chloride and sulphur trioxide. Its distillation was carried out on site. Sulphur chloride was also produced on site from sulphur and chlorine. The Al Qaa Qaa State Establishment provided Sulphur trioxide, where it was produced from the oleum.

From 1988 to 1989, about 70 tonnes[15] of thionyl chloride was produced at the Al Mamun plant, which was used for the production of MPC at Dhia and Ahmed plants in 1990.

[15] Chemical CAFCD December 2002, Chapter XI and UNMOVIC Doc. No.904008. UNSCOM 074/CW-15 found a document mentioning 120 tonnes produced

Figure III.VII Fallujah 2



A plus B plant

Also in 1986, a foreign company provided SEPP with the design and equipment for a PCl_3/$POCl_3$ plant named A + B. The plant was constructed by SEPP from 1987 to 1988 at Fallujah 2. However, not all equipment was shipped. Pumps and pipes were not delivered by the company and were replaced with "under-specification" components. The designed production capacity was 17 tonnes of PCl_3 per day.

The idea of the project was to produce indigenously raw materials that could be used for both the production of mustard agent and nerve agent precursors, such as MPC as well as for the production of commercial chemicals. However, this facility was not commissioned prior to the 1991 Gulf war.[16]

TMP plant

The TMP plant at Fallujah 2 was designed by a foreign company to produce three tonnes of TMP per day. The construction work was undertaken from 1988 to 1989. However, the equipment received was not installed prior to the 1991 Gulf War. The concept was to produce TMP from PCl_3 manufactured at the A+B plant and absolute methanol in the presence of locally available ammonia. A methanol distillation unit was incorporated into the plant's configuration.

Chlorine production plant

The chlorine production plant designed by a foreign company was installed at Fallujah 2 in 1990. It was not operational prior to the 1991 Gulf war. Its purpose was to produce chlorine for general commercial applications for the manufacture of detergents and disinfectants as well as for dual-use precursors such as PCl_3, $POCl_3$, and thionyl chloride and key precursors such as MPC.

Comment
The chemical production plants installed at Fallujah 2 were designed as dual-use facilities capable of supplying both the CW programme and commercial projects with chemicals. Such chemicals could be used for legitimate industrial purposes or to manufacture CW agent. This probably reflected MIC's decision to merge newly constructed CW capabilities into commercial industries.

This dual-use approach allowed Iraq to retain some equipment at Fallujah 2 after 1991. All the surviving equipment at the Samarra site that was part of the CW programme and was transferred to Fallujah 2 for commercial purposes in 1994 was later, in 1997 destroyed by Iraq under international supervision. The rationale was that the equipment had been used or planned to be used for the production of CW and their precursors.

[16] UNSCOM 09/CW-02, August 1991

Equipment used in the $PCl_3/POCl_3$ plant and thionyl chloride plant was also destroyed for the same reason. The chlorine plant and equipment installed for the production of TMP however, was not destroyed since it had never been used for the production of any materials for CW programme. The chlorine plant at Fallujah 2 was operational during UNMOVIC's inspections of 2002-2003.

Fallujah 3 (also known as the Al Farouk plant)

This facility was located 80 km northwest of Baghdad; 35 km southwest of the Muthanna Site. The site was used as a formulation plant for pesticides and herbicides and as a storage depot for CW precursor chemicals consumed at the Muthanna site. The Fallujah 3 site was never used for its original purpose, that is, the production of CW precursors. The buildings on the site were completed at the end of 1987.

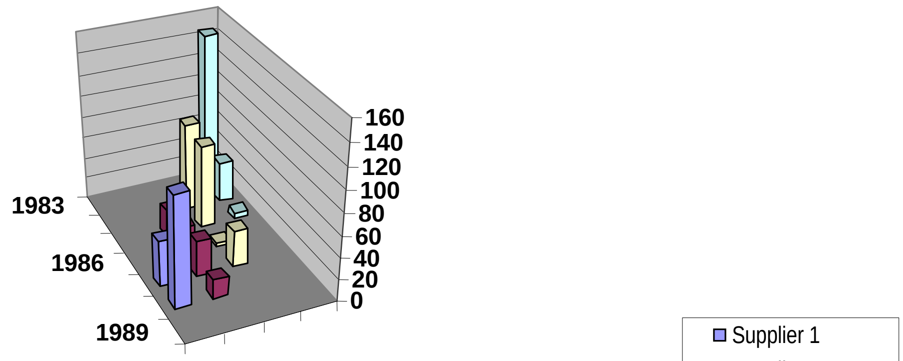
Fallujah 1

This was the least developed plant site. Construction at the site had started early in 1985. It was discontinued at the end of 1987. No CW agents were produced at the site. Some precursors were stored there[17]. With the end of the Iran-Iraq war no further use was made of the site.

[17] UNSCOM 09/CW-02, August 1991

Figure III.VIII

Procurement of main types of production chemical equipment for CW programme from major suppliers (in absolute numbers)**:**

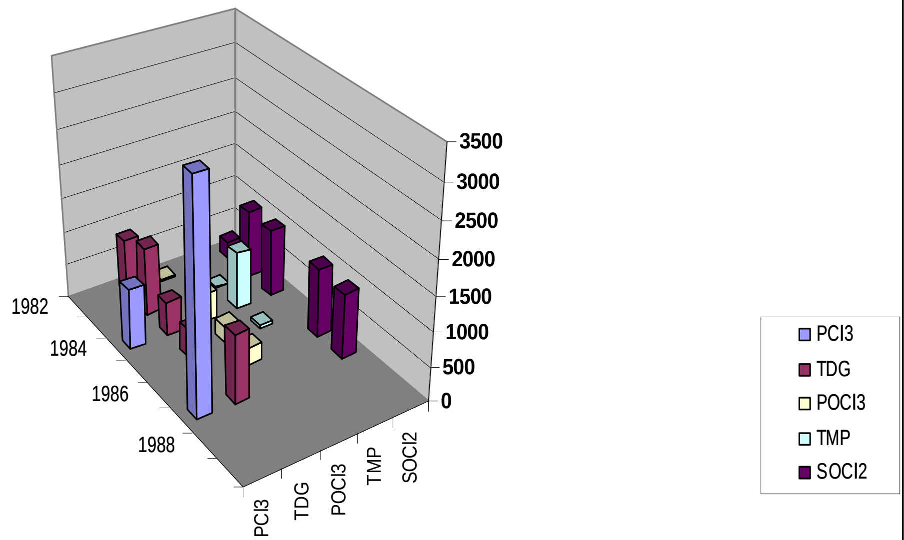


	1983	1984	1985	1986	1987	1988	1989
Supplier 1					42	103	
Supplier 2			25	27	34	18	
Supplier 3		83	79	3	34		
Supplier 4	146	39	6				

All equipment with very few exceptions was procured from foreign chemical engineering companies, but not directly from manufactures.

The procurement by SEPP/MSE of critical precursor chemicals for the production of CW agents and their key precursors was carried out by SEPP/MSE as shown in Figure III.IX.

Figure III.IX Procurement of critical precursors in metric tonnes:

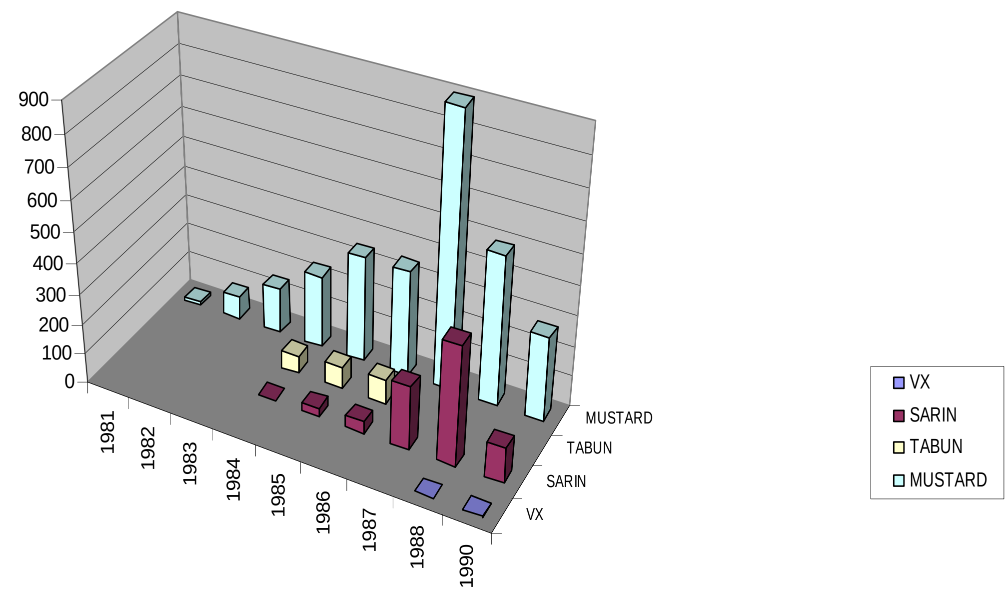


	1982	1983	1984	1985	1986	1987	1988	1989
PCl_3			887			3300		
TDG	825	1000	500	400		1000		
$POCl_3$	40		407	250	250			
TMP		20	845	56				
$SOCl_2$	250	1000	1000		1000	950		

Production of CW agents by SEPP/MSE

From June 1981 to January 1991, Iraq declared that SEPP/MSE produced 3,859 tonnes of CW agents. This does not include riot control agents CS and chloroacetophenon that were produced. The production of CW agent was declared as shown in Figure III.X.

Figure III.X Production of CW agents in metric tonnes as declared by Iraq:



	1981	1982	1983	1984	1985	1986	1987	1988	1990
VX								2.4	1.5
SARIN				5	30	40	209	394	117
TABUN				60	70	80			
MUSTARD	10	75	150	240	350	350	899	494	280

There was no bulk production of CW agents declared for 1989 year, following the end of war with Iran in August 1988.

CHAPTER III.III

RESEARCH ON CHEMICAL AGENTS

Introduction

Iraq had an extensive as well as application focused CW research and development (R&D) programme which was mainly implemented at Muthanna (MSE) from 1981. In the late 1980s, the period of highest CW-related activity, the R&D department of MSE consisted of several specialized sections dedicated to research on nerve agents, blister agents, psychological agents, analytical support, toxicological evaluation and applied research.[1]

In general, Iraq did not develop its own methods for the production of chemical warfare agents. At the beginning of the programme, Iraq tried to replicate, on an industrial scale, known foreign methods and techniques for the production of chemical warfare agents. It did so, using commercially available technology, equipment and raw materials. Later, however, for some agents (for example VX) Iraq applied modified processes to suit its own capabilities.

The Iraqi chemical agent research and development programme experienced highly variable success rates in providing synthesis strategies for the production of chemical agents and precursor compounds. [In fact,] Unlike the blister agents programme, the majority of Iraqi [chemical warfare agent] production programmes related to nerve agents could not produce chemical compounds of a sufficient purity that would allow them to be stored for longer than a few weeks without decomposition. Despite the fact that Iraqi projects were well-funded and well resourced, and upper-level [technical] scientific personnel were well educated, serious problems existed in the final execution of the programmes because of [poor] insufficient engineering capabilities of MSE and poor technical skills [levels] of those involved in the large-scale production of agents.

Iraqi scientists involved in the CW programme obtained much of their information on basic CW production technology from training courses held in foreign institutions, open source publications, foreign patents, international conferences and international forums. This information obtained from open source material was first tested by Iraq at the laboratory level to identify and adjust unknown parameters of the synthesis of chemical warfare agents that could not be found in open sources, such as kinetics of chemical reactions, combinations of catalysts, equipment specifications and scale-up procedures.

Iraq conducted research on the number of CW agents and their precursors, focusing efforts on sulfur mustard, tabun, sarin and VX. All these agents, with the exception of VX[2], were later produced in hundreds of tonnes quantities. The research was not restricted to CW agents alone but also encompassed their analogs and precursors: many

[1] Letter of General Amer M. Rasheed to UNSCOM dated 5 April 1997
[2] Iraq declared the unsuccessful production of 3.9 tonnes of VX (see chapter III for details)

of these research studies according to Iraq were either terminated at certain stage, remained unfinished or failed.

Because the very nature of Iraq's research and development programme and its associated technical description is proliferation sensitive, information provided in this chapter has been limited to basic facts and comments.

Sulfur Mustard[3] and its precursors[4]

Sulfur Mustard

Iraqi research on sulfur mustard synthesis was fast-paced and successful. This was largely due to the commercial availability of precursors at that time (pre-Chemical Weapons Convention and pre-Australia Group export restrictions), and the relatively simple nature of the synthesis. Details of this synthesis were readily available in the open literature at the time.

The initial research into sulfur mustard synthesis, focused mainly on reproducing published techniques was done during the early 1970's at the Al Rashad laboratory-scaled facility in the Baghdad area. In 1980 and 1981, as Iraq declared in its 1996 FFCD, the method for the synthesis of mustard from thiodiglycol (TDG) was accepted for production on an industrial scale.[5]

Mustard was manufactured from imported thiodiglycol using imported chlorination agents. Due to the simplicity of this one-step process, Iraq was able to produce high quality mustard. However it was comparatively unsuccessful in its efforts to perform chlorination using indigenously available chlorination chemicals. Such research was performed in 1981 in parallel with the method involving imported chemicals. Iraqi research found that by using indigenously available chlorination chemicals the yield was low and the reaction was slow and therefore this method was not adopted for the bulk production of mustard.

In 1985 and then again in 1989-1990 [6] Iraq undertook efforts to synthesize mustard without using TDG, starting from locally produced ethylene.[7] There were plans to continue the research beyond laboratory scale but these plans never reached fruition.

Because Iraq faced a potential shortage in one of its main chlorinating agents (thionyl chloride), basic research was conducted in 1985 and 1986 on using another imported chlorinating agent, phosphorus trichloride (PCl_3). Laboratory and pilot scale research was successfully undertaken in 1987 in order to estimate the parameters required for large-scale production.

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[3] Chemical CAFCD December 2002, , Chapter IV, para 4.4.1
[4] Chemical CAFCD December 2002, Chapter IV, paras 4.4.2, 4.4.3
[5] UNSCOM Doc No 200096-037-CW-2
[6] UNSCOM Doc No 200095.001
[7] UNSCOM Doc No 200071.020-CW-2

Iraq declared that in 1988, an effort was made to produce binary mustard munitions. Experiments [were] performed in the laboratory[8] and in the field [trials] were conducted using 155mm artillery shells, which contained two canisters, each with a binary agent. This research was stopped due to low concentration of mustard obtained.[9]

Thiodiglycol (TDG) Research[10]

In 1984[11], efforts began to indigenously produce thiodiglycol – an important precursor for production of mustard by the Iraqi production methods.[12] [13] None of the chosen synthetic routes gave a product suitable for mustard production.

Comment
It is likely that Iraq considered the indigenous production of TDG as the most probable way of solving acquisition problems with this precursor. If Iraq had decided to restore its CW programme after 1991, this was also the most likely path. Based on calculations by UN inspectors, shortly before the Gulf War Iraq had some 300-400 tonnes of TDG in stock. If Iraq had decided to continue mustard production at the 1987-1988 and 1990 scale, there would have been an urgent need for TDG. UN inspectors assessed whether Iraq's existing chemical plants in 2002 were suitable [to be utilized] for TDG production and none were found to be capable of doing that without major reconfiguration.

Thionyl chloride research[14]

In 1987 and 1988, MSE conducted research to see if they could domestically produce thionyl chloride. The research results provided Iraqi industry with an acceptable way to manufacture this chemical using sulfur monochloride. Based on the research results achieved, Iraq built a dedicated plant for the production of thionyl chloride at the Fallujah 2 site.

Mustard Stabilizers and Thickener Research[15]

Several different chemicals were tested as possible mustard stabilizers in order to produce a chemical warfare agent with a longer storage life. At least two chemicals were found helpful for this purpose.

In order to increase the viscosity and persistence of mustard in the environment, a polymer substance was investigated as a thickener for mustard. The improvement was

[8] UNSCOM Doc No 135015.041
[9] Chemical CAFCD December 2002, Chapter IV, para 4.4.1.6
[10] Chemical CAFCD December 2002, Chapter IV, para 4.4.2
[11] Chemical CAFCD December 2002, Chapter IV, para 4.4.2.2
[12] UNSCOM Doc No 200071.027
[13] UNSCOM Doc No 200096.029
[14] Chemical CAFCD December 2002, Chapter IV, para 4.4.3
[15] Chemical CAFCD December 2002, Chapter IV, para 4.4.5.3

not, however, adopted because Iraq stated that it was not deemed important enough to carry this successful research project over into an indigenous production effort.

Comment
Sulfur mustard was the most successful of all chemical agent synthesis programmes undertaken by Iraq. This programme successfully led to the manufacturing of a product with a high degree of purity and Iraqi research successfully helped the CW programme use alternative precursors over time.

It is unclear whether the change in production method by using a different chlorinating agent resulted from the SEPP/MSE research project, which promised higher yields and simpler purification or because stocks of a previously used chlorinating agent were running low. Therefore, there are open questions as to whether Iraq switched to PCl_3 because it was available, because it was easier to work with (despite higher costs), or because it was to be indigenously produced in the future by one of Iraq's new turnkey facilities that were purchased for this purpose from abroad .

Nitrogen Mustard Research[16]

Nitrogen mustard was never produced in quantity, according to Iraqi declarations. This chemical agent was produced in a laboratory in 1984 and 1987 to study its "chemical and physical specification". According to declarations, research was stopped at the stage of final neutralization required to obtain final nitrogen mustard.

Beyond efforts to produce the actual agent, Iraq tried the synthesis of the precursor triethanolamine.[17]

Comment
Unlike sulfur mustard, based on the available data it does not appear that nitrogen mustard was a priority. Iraq conducted only few experiments and overall efforts were limited, but the results achieved were promising. This comparatively simple reaction (when compared with nerve agent synthesis) never appeared to have advanced to a large production stage, even though it was in the original 5-year plans in the early 1980's. A probable reason might be the fact that nitrogen mustard did not offer anything new in the Iraqi CW arsenal in comparison to sulfur mustard.

Lewisite Research[18]

Iraqi declarations indicate that in 1987 a short research project was conducted to produce distilled Lewisite. This process, however, was not carried into production. No information was given on efforts to produce the precursors. UNSCOM inspectors during

[16] Chemical CAFCD December 2002, Chapter IV, para 4.5
[17] UNSCOM Doc No 200068.001 CW-1
[18] UNSCOM Doc No 200071.020

the period 1992-1994 identified some tens of kilograms of Arsenic salt, a toxic Lewisite precursor procured by Iraq from abroad. This compound was placed in one of the MSE bunkers and sealed under procedures of Hand-Over protocol for MSE site in 1994. The Protocol describes Commission destruction actions and future Iraqi obligations with respect to the site.

Comment
Most likely, research on Lewisite represented a very low-level effort since the UN Commission identified no stockpiles of this agent. The absence of indigenous arsenic sources and final agent poor yield lead UN inspectors to believe that probably there was no further interest in pursuing the synthesis of this agent on an industrial scale.

Tabun Research

According to Iraqi declarations, tabun was first synthesized in 1982.[19] The main problem was Iraq's inability to separate and purify the main product at the industrial level. As tabun production yielded impure material, and this material degraded over time, methods were researched to find a suitable stabilizer. It was found that one solvent, used during the synthesis process, was also a good stabilizer[20]. Therefore, this solvent was adopted as a solvent for synthesis of tabun and was not removed from the final product. Beyond synthesis, tabun was tested for its corrosive properties on materials used for aerial bombs and production equipment.[21].

Industrial scale tabun production was cancelled in 1986 (Iraq declared production of 210 tonnes of this agent), however the R&D projects to improve the production technology continued. Thus, in 1987, the use of various cyanide sources for tabun production was tested.[22] [23] However, due to the poor yield and purity of the final tabun product, the small experimental line was cancelled that same year.

Tabun Precursors Research

Dimethylamine hydrochloride (DMA*HCl)

In 1985, DMA*HCl was researched for production in order to assure a reliable source of this chemical. Due to the low yield of the product, research was stopped.

Phosphorus Oxychloride ($POCl_3$),

[19] Chemical CAFCD December 2002, Chapter IV, para 4.1.1
[20] Chemical CAFCD December 2002, Chapter IV, para 4.1.1.3
[21] Chemical CAFCD December 2002, Chapter IV, para 4.1.1.5
[22] UNSCOM Doc No 200071.020
[23] UNSCOM Doc No 200095.001

$POCl_3$ was first synthesized in 1984 simply by bubbling O_2 gas into a solution of phosphorus trichloride (PCl_3). Iraq encountered no problems at the R&D level in the synthesis of $POCl_3$. The quality of final product was acceptable, but the major problem was the lack of self-sufficiency with PCl_3.

Phosphorus trichloride (PCl_3)

Synthesis of PCl_3 was attempted and stopped due to low purity of the final product – which was much less than the imported PCl_3 used for the CW programme - and the problems encountered in applying the research results on an industrial scale. Iraq therefore decided to buy a "turn-key", dedicated PCl_3 and $POCl_3$ plant. Such a production facility was almost completed at Fallujah 2 as part of the so-called "A+B project". Due to the lack of some equipment, the plant never produced any PCl_3. All significant quantities of PCl_3 used for the CW programme (for sulphur mustard and DMPH production, precursor of nerve agent sarin and cyclosarin) were imported.

In addition to phosphorous containing precursor of tabun, in 1987, Iraq also attempted to produce cyanogen chloride (ClCN), another tabun precursor. Only two or three experiments were conducted according to Iraq.

Comment
Ultimately, tabun research never managed to contribute to a reliable, stable product. Numerous reactions were attempted (beginning with PCl_3) but the intermediate compounds were never properly purified. The subsequent steps of these processes produced reaction liquors with increasing amounts of reactive impurities, yielding a rapidly degrading product. The main weakness of the Iraqi tabun research process was the lack of knowledge of what by-products and impurities the intermediate and final product contained and finding a way of purifying the product.

Iraq claimed it never resumed a large-scale tabun production after 1986. During its destruction mission UN inspectors in 1994 identified in one of the aerial bombs at MSE the presence of tabun of purity 44%. This finding contradicts Iraq's declared data on tabun degradation rates for both R&D and industrially produced agent.

Sarin Research

The first attempts to produce sarin at the R&D level in Iraq occurred shortly after the nerve agent programme began, in 1983.[24] The synthetic route chosen by Iraq was well known from open scientific literature and was based on imported trimethylphosphite (TMP). R&D efforts in this specific area were successful and were transferred into sarin production on an industrial scale. But the industrially produced sarin had a quality/purity that was not sufficient for its long-term storage. At the same time, according to Iraqi military requirements the quality of the produced sarin was acceptable for its immediate use during the Iran-Iraq war.

[24] Chemical CAFCD December 2002, Chapter IV, para 4.2.1.1

Similar R&D results were achieved with another synthetic route for sarin based on PCl_3 (through DMPH and pyrophosphates). According to Iraq it could not reproduce the R&D results for sarin production through above mentioned route on an industrial scale due to difficulties in obtaining high quality precursors used in the intermediate stages of sarin production. Iraq, however declared production of 22 tonnes of pyrophosphonates in 1990, a stable solid material, 19 tonnes of which was processed into sarin precursor MPC that same year.

In an effort to increase the yield and purity of sarin, Iraq also researched an alternate reaction for the final stage of sarin production by a method based on the sarin precursor TMP. This route was adopted for the production of sarin in 1987 despite the fact that the purities and yields were not significantly improved,.

The same method was used also for some binary sarin munitions. Iraq mixed two key sarin precursors directly in munitions; one was pre-loaded and the second was added shortly (hours – days) before use. Such an approach was however only applied by Iraq to aerial bombs and ballistic missiles warheads and had nothing in common with "true" binary systems developed by other countries. This local method is referred to as an "Iraqi binary".

In 1995, Iraq declared that it had previously carried out research on the "true" binary sarin munitions. The 2002 CAFCD contains details on its development of 155-mm binary artillery shells filled with sarin precursors[25]. The declaration describes the successful results Iraq obtained in the synthesis of sarin and cyclosarin agents in artillery shells. The same CAFCD provides information on modifications and field tests carried out with binary 155mm and 152mm artillery shells. According to that declaration, research on binary systems for artillery shells started in 1983 with 10 imported prototypes. Iraq stated that attempts had produced negative results and the project was cancelled. Around the end of 1987 or the beginning of 1988, research re-started. After successful trials with 152mm shells, at the end of 1988, Iraq began testing 155mm extended range shells. In 1989, a firing test was conducted at a firing range, using 120 shells: the results were positive.

Iraq supported this information with sketches of the shells but did not provide any technical drawings. However, Iraq provided a report by the Technical Research Centre (TRC) "On the progress of research into Binary Chemical Weapons"[26]

In 1996, UN inspectors recovered some binary 155-mm shells at MSE [27] and their assessment partly confirmed Iraq's declarations. Based on information and documents supplied by Iraq, MSE had conducted successful field tests of binary artillery systems for sarin and had finished its work on 14 January 1989, before the TRC started similar tests.

[25] ibid
[26] UNMOVIC Document No. 701004
[27] UNSCOM 172/CW-35, March 1997, and UNSCOM 190/CBW-04, June 1997

The TRC, according to its own report and interviews with UN inspectors, also achieved significant results in static and dynamic tests for binary sarin artillery shells.

According to Iraq, there was no mass production of any "true" binary artillery munitions, although MSE reported to the Ministry of Defence in December 1988 that "MSE…may probably enter into the standardized production…of the binary artillery munitions that are of long range and are safe to work"[28] .

Comment
Iraq was aware that binary munitions systems were easier and safer to handle and had significant advantages in terms of long-term storage. Iraq's apparent success in developing some binary systems for different types of munitions suggests that its CW programme was maturing. The information provided by Iraq and gathered by UN inspectors does not shed light on why Iraq did not more fully exploited its successful research and development results regarding binary artillery systems. The ISG reported that one 152mm binary sarin round was used as Improvised Explosive Device against coalition forces after March, 2003.

Sarin Analogs Research[29]

Throughout the whole sarin programme, Iraq researched number of routes and variations for production of sarin analogs including:

- In 1987-1988 Iraq found that a cyclohexyl analog of sarin (so called cyclosarin), and its mixture with sarin are more toxic than sarin itself. Moreover it was possible to use the same production line for cyclosarin and/or its mixture with sarin production. [30]
- Another substance chemically similar to sarin – ethylsarin - was produced on a laboratory scale using a similar sarin synthetic route. Because of the poor toxic properties obtained in comparison with sarin and cyclosarin, Iraq did not pursue industrial production of ethylsarin. [31]
- Iraq successfully produced both thiosarin and so called tammelin esters at a research level. From a toxicological point of view there were no significant benefits in these sarin analogs over sarin itself. However, to some extent this R&D activity was a preliminary stage of VX-related research. It helped the Iraqi scientists learn how to introduce sulfur into the phosphorus-containing fragment and how to attach choline. [32]

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[28] UNSCOM Doc No 701004
[29] UNSCOM Doc No 200071.023
[30] UNSCOM Doc No 200072.001
[31] UNSCOM Doc No 200095 .002
[32] Chemical CAFCD December2002, Chapter IV, para 4.2.2.4, para 4.2.2.5

Sarin Precursors Research

Iraq researched almost all known sarin precursors. Research was conducted mainly in the SEPP/MSE laboratories but also in other research centres[33].

Trimethylphosphite (TMP): Research in synthesizing TMP was undertaken in 1985, and again from 1987 to 1990.[34] Being partly successful at the laboratory scale in synthesis of TMP by at least two different routes Iraq subsequently failed to reproduce these results at an industrial scale.

Dimethylmethyl phosphonate (DMMP): In 1984, Iraq attempted to synthesize DMMP from domestically sourced trimethylphosphite of an unknown purity. The synthesis of DMMP from TMP was conducted via a catalyzed reaction.[35]

Dimethyl phosphonate (DMPH): Two synthetic methods for DMPH were attempted in the 1984 - 1989 timeframe.[36] Iraq was successful with synthesis of DMPH by one of the tested synthetic routes on a laboratory scale and succeeded also to transfer its R&D results to industrial scale. This achievement, although not fully exploited, gave Iraq the potential to produce MPC without using TMP, which was in short supply by the end of 1990.

Pyrophosphate: In 1985 and 1988, Iraq attempted the pyrolysis of DMPH to produce the pyrophosphate which is an intermediate precursor for MPC production.[37] Iraq was successful in this project.

Hydrogen Fluoride (HF): Indigenous production of hydrofluoric acid was researched in 1987 and 1989.[38] The research was stopped due to low yield and a large quantity of by-products. According to Iraq, the by-products were not identified because of the difficulties in their analysis by spectral methods.

Methylphosphonyl dichloride (MPC): Iraq researched several processes for MPC production.[39] In 1984, the research focused on producing MPC from DMMP (which was obtained indigenously from imported precursor TMP) and a method was applied for industrial production. Iraq also attempted to synthesize MPC from pyrophosphate on small-scale in 1985 and 1988.[40] This project advanced further and resulted in industrial scale production of MPC from 19 tonnes of pyrophosphates in 1990.

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[33] It was probably initiated in Al Rashad
[34] UNSCOM Doc No 200071.013
[35] UNSCOM Doc No 200071.001
[36] UNSCOM Doc No 200071.007
[37] UNSCOM Doc No 200071.023
[38] UNSCOM Doc No 200071.023
[39] UNSCOM Doc No 200071.023, Doc No 200071.025
[40] UNSCOM Doc No 135015.040

Methylphosphonyl difluoride (MPF): MPF was synthesized using different fluorinating agents.[41] One particular fluorination procedure was adopted in the production of MPF.

Comment
The initial research period for sarin was comparatively short, since the Iraqis relied solely on available precursor chemicals, and moved on to production of relatively low purity agent, although accepted for use in the battlefield during Iran-Iraq war. It was also evident that Iraqi researchers tried to increase the purity of their products during this first phase. They attempted to increase yields by modifying synthesis procedures in the final step of sarin production. The result of the modification in the opinion of the UN inspectors did not bring the expected results; it increased cost of production but not yields, nevertheless Iraq adopted it.

Iraq's CW programme was able to produce sarin-filled weapons that were useful on the battlefield even if they were of relatively low quality. Iraq was not able to indigenously produce most of the sarin precursors with sufficient purity nor was it able to purify a final agent to enable the final product to have a long shelf-life.

Research on VX[42]

Iraqi interest in VX dates back before the MSE era, possibly as early as the mid or late 1970's with the Chemical Corps' activities at the Al Rashad laboratory-scale facility. However, the first documented evidence of VX is from 1984. [43] Iraqi research efforts to make the chemical warfare agent VX were significant.[44] The VX programme involved several research teams of MSE.

The direction of the research was started using information available from the open literature. This information presented many routes for the production of V-agents. To some degree Iraq investigated all of them but focused on four pathways:
A – final agent was produced from choline derivative and so called monoester;
B – final agent was produced from choline derivative, ethanol and so-called MPS (simplified variation of previous pathway A);
C – final agent was produced from thiocholine derivative and so called oxymonoester;
D - final agent was produced from chlorocholine derivative and phosphonoester containing thiol fragment (could be considered as "chemical mirror" of previous pathway C).
At the end of 1987 MSE was ordered to move VX production to an industrial level by route A. A trial using VX produced by route A was made with the available munitions at MSE: this involved three 500 gauge aerial bombs and one 122mm rocket to test for corrosion effects and stability of the agent. The VX produced was of a purity comparable to that of sarin and had degraded quickly, but nevertheless it could have been effective for immediate use in the battlefield.

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[41] UNSCOM Doc No 200071.021-CW-2
[42] UNSCOM Doc No 200071.023
[43] Report on VX TEM, 2-6 February 1998
[44] UNSCOM Doc No 200107.001, UNSCOM Doc No 200107.008

The VX produced by route A degraded quickly because of impurities in the final precursors and respectively in the final product. Therefore Iraq decided to switch to another simpler route, route B that involved two steps less than route A.

In this case, the method selected by Iraq was the simplest method containing the least number of stages (route B). Iraq attempted several batch experiments to produce this compound[45] via route B. The results however, were also unsatisfactory because of the poor stability of the final product. To solve the problem of stability, Iraq pursued the concept of producing a semi-final product, 'dibis', from which VX can be produced in one easy step..

An eight-month trial using VX produced by route B was conducted at Muthanna Research and Development Directorate. The results of this trial demonstrated that the intermediate product ('dibis') was stable and therefore the R&D Directorate of MSE suggested considering it as a potentially strategic source of VX for long-term storage.

Iraqi officials admitted that the government had a long-term programme for VX research and development. It is unclear when exactly the VX programme ended. Iraq declared that in addition to two production trials of VX in April 1990 the efforts to improve quality of the VX precursor MPS on a laboratory scale continued until as late as the end of 1990.[46]

Additionally, Iraq acknowledged that it had considered another route (route C), which might result in good quality VX[47]. In 1992 the Iraqi government approved the patent for production of VX precursor thiocholine (a chemical for which the only known use is as precursor for VX production via route C) from commercially available chemical thiourea.

Comment
It is not certain if all components of Iraq's synthetic research have been declared. Based on what is known about Iraq's research programme on VX, it seems as though the only one precursor, Choline, was produced with the high purity. The major outstanding problem for Iraqi researchers was the formation of the Phosphorus-Sulfur-alkyl fragment in VX.

Documents provided by Iraq show that it had succeeded in obtaining high purity VX at the R&D level using a chemical route (route D) different from those that it declared it had used at the production level (A and B)[48].

In August 1988, when the war with Iran ended, there was no immediate demand for chemical weapons. What was needed was self-sufficiency for precursors, improved

[45] UNMOVIC Doc No 904009
[46] UNMOVIC Doc No 700057
[47] UNSCOM 202, September 1997 "The choice of Route C and its production"
[48] UNMOVIC Document Nos 200071.023, 200127, 200130 and Letter from Iraq reference 2/1/234

production methods, binary weapons, strategic stores and new delivery means. Developmental efforts along all of these lines proceeded throughout 1989 and 1990.

Additionally Iraq pursued a binary VX project for artillery systems, applying route C. Iraq's level of progress in producing binary VX weapons systems is unclear. Research of VX binary systems was conducted in parallel to sarin binary munitions by MSE and TRC. Both research centres reported positive results. According to information obtained by UN inspectors in an interview, TRC personnel had wanted to continue their binary VX research to the next stage, which would have involved using 152mm artillery shells in field trials. However, Iraq stated that all research work was terminated[49]. TRC had developed a prototype for VX artillery shells and had conducted static tests in the laboratory. In spite on the encouraging results Iraq clamed it never conducted field trials with the use of VX binary systems.

Comment

Based upon published synthetic techniques and the available chemical stocks, Iraq attempted to devise a simplified synthetic pathway for VX to satisfy its ambition of possessing one of the most toxic nerve agents possible.

Due to the lack of supporting evidence on production levels and purities of agent, it is not possible for UN inspectors to make a complete assessment of how far the long-term research goals of the VX programme had progressed.

Additional Research into CW agents

Iraq researched many agents. The aim of the research and development programme was to familiarize scientists with as many agents as possible in order to provide a range of options to fit both production capabilities and military requirements.

As mentioned earlier, in the area of nerve agents, analogs of sarin (iso- and n-butyl-, ethyl- thio-), diisopropyl fluoro phosphonate, soman and tammelin esters as well as V agents, were studied. Within V-agents related research activities VXO-agent (oxygen analog of VX)[50] and O-isopropyl analog of VX[51] were synthesized.

Iraq also studied synthesis techniques for cyanogen chloride and adamsite. There is no evidence that any of these were produced at levels beyond the laboratory scale. Chemicals with less potential as CW agents such as phencyclidine (PCP), a hallucinogenic compound known as "angel dust", as well as incapacitants such as BZ and its analogues were also investigated.

[49] UNSCOM 202 September 1997
[50] Chemical CAFCD December 2002, Chapter IV, para 4.9.3.7.1
[51] UNSCOM Doc No 200071.023

After the Gulf War in 1991, MSE directed part of its R&D efforts towards civilian projects including chlorine based disinfectants and insecticides.

Comment
To a certain extent, the Iraqis were able to produce most CW related compounds in the laboratory, but in many cases failed to produce them on a larger scale with qualities achieved at laboratory level, even with batch-based process engineering. Although it is difficult to make an evaluation of Iraq's achievements during 1990 due to the lack of the original MSE documentation for this period of time, it is Commission's understanding that the impediment to the Iraq's pre-1991 CW programme was the lack of expertise and other capabilities at industrial level.

Despite Iraq's insufficient capabilities to indigenously produce industrial-scale quantities of good quality and stable precursors and chemical warfare agents, Iraq did produce chemical weapons that inflicted severe casualties during its war with Iran in the 1980s and impacted on the course of the war.

CS PRODUCTION

Introduction

According to the CWC, although CS does not constitute a chemical weapon it is nevertheless prohibited for use in combat. CS known chemically as o-chlorobenzyl-malononitrile is used widely as a riot control agent. CS is usually produced in either a dry (powder) form or dissolved in a liquid solvent. The powder form is aerosolized by using pyrotechnic mixtures, while the liquid form is aerosolized by explosion or by using an aerosol generator.

Although Iraq declared that it started CS research at the beginning of the1970s, it stated that the first production trials at the Al Rashad laboratory scaled site were not conducted until the end of the decade. Despite CS being regarded as a (non-lethal) riot control agent, Iraq declared that it used CS for military purposes. Iraq declared that CS was weaponized in mortar shells, rocket propelled grenades and aerial bombs and used in combat during Iran-Iraq war. There are conflicting claims as to whether Iraq used CS or other chemical warfare agents as early as during the first few weeks of the Iran/Iraq war. In some open source articles it is claimed that Iraq started using CS at least at the beginning of 1982.[1]

Iraq's declarations regarding CS were very general and. many aspects of Iraq's CS production and use were unsupported with documentary evidence. In addition, some of the information provided by Iraq proved to be incorrect when investigated by UN inspectors.

Process

Iraq imported precursors to synthesize CS in tonne quantities through a process available in open-source literature.[2] SEPP/MSE produced CS in a slurry form. The slurry was exposed to the air and sunlight, dried and then the dry powder was ground by a mill[3] and the milled product was stored in 40 litre drums. In 1992, Iraq declared that no specialized plant was used for its past production of CS. The production process was not complicated and was not demanding in terms of specialized technical knowledge or purpose produced equipment. A simple, small reactor was used to produce up to three batches a day.

Comment
Iraq did not have technical problems with the final stage of CS production, which was simply based on the mixing of two imported key precursors. On laboratory/small scale Iraq could successfully synthesize one of the key precursors, malononitrile, by a five-stage route. Iraq had planned to achieve self-sufficiency on an industrial scale with this CS precursor but to extent of UNMOVIC's knowledge did not achieve this. At the same

[1] Anthony H. Cordesman, Abraham R. Wagner The Lessons of Modern War, Volume II: Iran-Iraq War, West view Press,1990
[2] Chemical FFCD 1996 Para. 4.7.1
[3] Chemical FFCR May 1992, paras. 3.6.4.1-3.6.4. 3

time Iraq could not overcome problems with the synthesis of another key CS precursor - O-chlorobenzaldehyde. For this reason, the import of key precursors was crucial for production of CS by Iraq.

Quality

Iraq used high-quality imported precursors[4] to produce CS with approximately 90% purity. This quality was military acceptable and CS was filled into several types of munitions.

Precursors

Iraq procured chemicals for its CS programme from foreign companies in the mid and late 1980s.[5] Documentary evidence provided by Iraq indicates that on the basis of research results, Iraq had intended to modify one of the production sites at Muthanna to manufacture cyanoacetamid (for syntheses of malononitrile).[6] Iraq intended to produce malononitrile,[7] at a semi-industrial scale at the Malik plant at SEPP/MSE[8].

Chronology of CS Activity

Laboratory-scale research and familiarization with CS began at Al Rashad site in 1971.[9] This research provided the chemical corps staff at Al Rashad with the necessary experience and confidence to progress into the more toxic chemical agent production.[10]

In 1974 when the Al Rashad facility was absorbed into the Al-Hazen Ibn Al-Haitham Institute, this research continued. One synthesis laboratory was used by the "chemical group" for the first small-scale efforts to produce CS. This group was also responsible for the purchase of pilot plants. In 1979, the Al-Rashad site was returned to the chemical corps (following the demise of the Al-Hazen Ibn Al-Haitham Institute). The Al-Rashad facility contained a small reactor for the production of CS and a simple CS filling unit[11].

Iraq declared that later there was a special riot control agent laboratory at the research and development directorate of SEPP/MSE.[12] Iraq further declared that most of the work with CS was devoted to producing bulk agent although the first tonne of CS was not produced there until 1983 (see table III.IV.I). Much of the research and development with regard to CS had already been done prior to the formation of Project 922 and the establishment of SEPP in 1981. Iraq did provide information about some continued CS

[4] UNSCOM 153/CW-31 June 1997, Annex B appendix 4
[5] Chemical CAFCD December 2002, Chapter IIIB
[6] UNMOVIC Document No 901012
[7] UNSCOM Doc No 200068.00.
[8] UNSCOM Doc No 200096.009
[9] Chemical FFCD June 1996, Chapter I para 1.1.1
[10] Chemical FFCD June 1992, para 1.8
[11] Chemical FFCD June 1996, Chapter I para. 1.5.5.1
[12] Chemical FFCR May 1992, Annex 1

research at SEPP: two reactors were used for research in the Salah al Din and Al Waleed divisions of SEPP/MSE on different compounds and agents including CS.[13]

In addition to the research and production of CS both at the Al Rashad facility and later at Muthanna, CS was also under development at the Technical Research Centre (TRC) at Salman Pak. The TRC operated as a technical agency in support of the intelligence and security apparatus of Iraq. Iraq declared that in 1981 about one tonne of CS was produced at the Al-Salman site (Table III.IV.I).[14] Although scant details are available regarding the extent of research, development and production at the Salman Pak facility Iraq declared that this agent was produced during a two-month period. CS was manufactured in a metal container, then the mix was filtered and the agent packed in plastic containers.[15]

Iraq stated that it conducted tests with CS in both liquid form and as a powder. In the early 1980's, Iraq conducted basic CS-filled munitions tests using mortar shells, rocket propelled grenades and aerial bombs. SEPP/MSE cooperated with the Al Qaa Qaa facility to produce and test smoke canisters and rockets.[16]

Field trials were carried out with munitions filled with liquid or powder CS. Smoke generators from the armed forces were modified to spray CS liquid. A test of this device was conducted in the Al Hasua area in 1982.[17] The result was positive.

Iraq declared that SEPP/MSE cooperated with TRC at Salman Pak in studying the effects of mixing CS with biological agents, in particular aflatoxin. This was a research project as declared by Iraq but results from this did not lead to weaponization.

In 1983-1984 the production of CS began at SEPP/MSE as the Ghasi project[18], which was known by UN inspectors to be a project for the processing of crystalline products. CS was produced in the open area of the filling station (area "E" on the Muthanna map).[19]

In 1988, a test for smoke canister containing mixture of Adamsite and CS and smoke generation chemicals occurred at a chemical proving ground .[20] According to Iraqi, the result was not encouraging.

In its 1992 Declaration, Iraq stated that it had produced two tonnes of CS at MSE in 1990. In 1992 the reactor used for CS production was moved from MSE to Fallujah 3.[21] Iraq declared that in summer of 1991 that it destroyed unilaterally by demolition explosives at Airfield 37, 125 type 250 aerial bombs filled with CS.

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[13] UNSCOM 239/CW-47, May 1998, page B-3-1
[14] Chemical CAFCD Decemnber 2002, Chapter XIII, para. 13.3
[15] Chemical FFCD June 1996, Chapter XIII para. 13.3
[16] UNSCOM Doc. No.200095.001
[17] Chemical FFCD June 1996, Chapter VIII para. 8.8.1
[18] UNSCOM 239/CW-47, May 1998
[19] UNSCOM 02/CW-01, June 1991, Executive Summary
[20] Chemical FFCD June 1996, Chapter VIII para. 8.8.5.1
[21] UNSCOM 153/CW-31, June 1997, Annex B, appendix 4

According to 1992 Iraq's declarations the total quantity of CS produced in the period from 1981 to 1990 was about 12.5 tonnes (Table III.IV.I).[22]

Table III.IV.I CS production in the years declared by Iraq

Year	**Tonnes**
1983	1
1984	3
1987	5
1988	1.5
1990	2
Total	12.5

From1983 to 1990 CS was produced at MSE. No details are provided for 1982, 1985 or 1986.

In 2002 Iraq declared that one tonne of CS was produced at Salman Pak in 1981.

Comment
Despite Iraq's declaration that it produced about 13.5 tonnes of CS, even a very rough calculation based on munitions declared as filled, casts doubt on this estimate. Iraq declared that it had weaponized CS into: 21,600 x 120mm mortar shells, each contained about 0.4kg giving a total of 8,640kg CS; 125 x "250" type aerial bombs with each bomb having about a 60kg capacity, giving a total 7,500 kg of CS; 253 x "500" type aerial bombs with each bomb having a capacity of about 102kg, giving a total of 23,970kg CS required. Taking a conservative estimate of the CS purity at 85% the total quantity of CS needed would be about 34 tonnes, not 13.5 tonnes as declared. Moreover, Iraq declared it had filled 82mm mortar shells and RPG-7 grenades with CS. The quantity of these munitions is unknown. MSE also supplied the chemical corps with the following: tablets of CS for testing the tightness of the gas mask in 1985, smoke canisters of CS for training during 1988 and 20 litre containers holding a solution of 10% CS in dichloroethane for training.[23]

When UN inspectors raised the anomalies mentioned above during meetings with Iraqi representatives, Iraq later declared in 1997 that the estimated amount of produced CS from 1984 to 1988 was about 40 tonnes.[24]

[22] Chemical FFCR May 1992, para. 1.12, Chemical CAFCD December 2002
[23] Chemical CAFCD December 2002, Chapter II, para. 2.1.1.4.2
[24] Iraq letter 2/1/C/266, General A. M. Rasheed to UNSCOM 24 May 1997

Weaponization and storage

According to Iraq, CS was used to fill into 21,600 munitions[25] although from the comment box this figure relates only to the 120mm mortars.

MSE filled mortar shells in building E10 ("E" area) prior to 1988. The shells were filled with CS using barrel pumps and then closed with a mechanical press.[26] A CS canister-filling machine was located[27] outside the building. A special line was used for aerial bombs.[28]

In early 1980s, ammunition filled with CS was stored at the Al Rashad site.[29] Iraq declared that aerial bombs were partly consumed in 1986.[30] In the period just prior to the Gulf War in 1991, Iraq declared that mortar shells and aerial bombs were stored at Muhammadiyat ammunition depot[31] and that aerial bombs were also stored at the airstrip 37.[32] At the end of December 1990, MSE had over four tonnes of CS in storage yet to be weaponized.[33] A UN inspection report mentions building C57 of MSE as the CS storage place. The same place in another Iraqi[34] document is called Bin Hayan 4 and presented as CS production site. This caused confusion with regard to the final location of this agent. The explanations Iraq provided to UN inspectors lacked supporting evidence.

[25] Chemical FFCD June 1996, Chapter XI, Table; Chemical CAFCD December 2002, Chapter XI
[26] Chemical FFCD June 1996, Chapter I, para 1.5.6.2
[27] UNSCOM 02/CW-01, June 1991
[28] Chemical FFCR May 1992, Annex 28
[29] Chemical FFCD June 1996, Chapter I para. 1.5.3.1
[30] Chemical FFCD June 1996, Chapter XI, Table VI
[31] UNMOVIC Doc. No 700029, 700030
[32] Chemical FFCD June 1996, Chapter I para. 4
[33] UNMOVIC Doc No 700007
[34] Iraq letter 2/1/C/266, General Amer .M.Rasheed to UNSCOM 24 May 1997

Comment

Iraq had a good knowledge of CS. They realized that this agent could be dispersed as aerosols obtained from either powder or liquid after the CS powder was dissolved in a specific solvent. CS was also used as a component of smoke mixture.

It appears that Iraq's CS programme was carried out in two phases. The first phase (from the early 1970s until 1981) included the initial research and development of the agent, a survey of chemical synthesis methods and developing capabilities for the large-scale production of CS based on the imported key precursors available.

The second phase (after 1981 until the end of Gulf War) included the production of CS, its use in combination with other agents and filling CS into munitions such as mortal shells, rocket warheads and aerial bombs. The use in bombs and mortars suggests that Iraq considered CS as a chemical warfare agent. Given its ability to hinder unprotected personnel for short periods of time (several minutes) when exposed to the requisite concentration,[35] CS according to Iraq's declarations was used in conjunction with other chemical agents and conventional ammunition to cause confusion among enemy ground troops during Iran-Iraq war.

At the beginning of the CW programme, Iraq faced few constraints in importing key precursors and chemicals required for CS production. Moreover, in the period up to 1988, Iraq attempted to develop its own routes to produce two precursors on the basis of domestic and imported raw chemicals. Iraq also considered sites for the production of precursors although there is no evidence that the production of precursors was ever carried out.

Iraq was not only able to produce quantities of CS to be used as a single agent; it also experimented combining CS with other agents. It is possible that Iraq considered CS as a prospective chemical warfare agent or perhaps CS was an agent of opportunity, successfully produced before other CW agents and available to be filled in the abundant munitions, which were available.

[35] UNSCOM Doc No 200108.003

MUSTARD PRODUCTION[1]

Introduction

In military terminology, the common names "Mustard" or "Mustard Gas" refer to a specific family of chemical warfare agents comprising a variety of compounds that are similar in chemical structure. Sulphur mustard, bis (2-chloroethyl) sulfide, is one member of this family of agents; it is an oily liquid with a characteristic garlic smell and yellow to dark-brown colour.

Sulphur mustard is a systemic poison that affects all human tissues. It is a strong blistering agent when in contact with the skin and lethal when inhaled. Due to its low volatility, it is classified as a persistent CW agent. Despite a century of research, there is still no antidote against it. This is one of the reasons why it is still considered to be one of the most important chemical warfare agents. Mustard was the first CW agent produced by Iraq for its CW programme in bulk. It was manufactured in the largest quantities (mustard constituted about 70% of Iraq's CW arsenal) and in the best quality of all chemical warfare agents Iraq acquired.

Iraq showed interest in the synthesis of nitrogen mustard, (tris(2-chloroethyl)amine)[2] and its analogs, but no evidence is available to UNMOVIC that Iraq produced nitrogen mustard on a large scale. Therefore, when the name "mustard" is used in the text, it refers to sulphur mustard.

Process

Several mustard industrial production routes are known. They lead to the same principal chemical, but with different purity and composition of by-products.

According to Iraq's declarations, the first process selected by Iraq was the chlorination of thiodiglycol (TDG**)** using thionyl chloride **(**$SOCl_2$**),** which gave a high purity agent[3].

Because of the low availability of thionyl chloride, Iraqi scientists performed chlorination using phosphorus trichloride. The quality of mustard obtained with this method was similar to that obtained using thionyl chloride. Additional technological steps were however required[4].

Method 1: **TDG + 2SOCl$_2$ $\leftrightarrow$ Mustard + 2 HCl + 2 SO$_2$ (1981 – 1987)**
Method 2: **3 TDG + 2 PCl$_3$ $\leftrightarrow$ 3 Mustard + 2 H$_3$PO$_3$ (after 1987 –1991)**

Iraq studied two alternative routes for the production of sulphur mustard from locally available materials. The first involved the reaction of TDG using hydrogen chloride (HCl) as the chlorinating agent - either in the gaseous state or as aqueous solution; the second involved another synthesis route of reacting ethylene with sulphur-chloride

[1] The term "mustard" is used throughout this article for sulphur-mustard (NATO code H). See chapter III.I.
[2] UNSCOM Doc No 200163.001, 135015.003
[3] UNSCOM Doc No 200096, 11306, 113071, 113075, 113081, 113117
[4] UNSCOM Doc No 200096.037

(SCl_2/S_2Cl_2)[5]. Iraq declared research on this process for 1985 and 1989-1990. All raw materials for making mustard by this route were locally available in Iraq[6].

Documentary evidence (a letter written by the director of MSE to his superior) indicates that Iraq had been interested in pursuing this process as late as in December 1990[7]. The letter states that 'there was a coordination with PC3 group for the purpose of preparing and modifying the ethylene gas vehicles when needed to resume the mustard production using Iraqi local substances'.

UN inspectors did not find evidence suggesting that this process had actually been used by Iraq on an industrial scale, most likely because the process it had followed was somewhat simpler and necessary precursors were available [8]

Quality

There is substantial evidence[9] to show that Iraq was able to produce good quality mustard, suitable for long-term storage[10]. The same evidence however, shows instances of few batches of low quality agent or, agent which was "spoiled" during storage. With respect to method two (above) used for large –scale production of mustard Iraq declared that it had problems with process control with respect to "burning[11]". Also, it faced the problem of mustard polymerization (the formation of the viscous tar inside the liquid agent) during the long-term storage.

While the most of the mustard filled artillery shells were well preserved and contained high purity agent, although sometimes polymerized to various degrees, aerial bombs filled with mustard were in many cases heavily leaking due to the growing pressure inside munitions, caused by degradation of the agent. Corrosion of the material of construction of munitions, growing pressure inside the munitions[12], or agent polymerization[13], was the most common evidence of the lower purity agent.

During its activities in Iraq UNMOVIC analyzed the contents of the artillery shells that had been stored for at least twelve years and later destroyed by inspectors in February 2003. The results revealed that the shells still contained high purity (more than 90%) mustard.[14]

[5] UNSCOM Doc No 200159.001

[6] Ethylene was produced in the Basra petrochemical plant, sulphur was mined at Mishraq and also recovered from natural gas according to Iraq's December 2002 semi-annual declaration (2002-2\F7\S)].

[7] UNMOVIC Doc No 700057

[8] Chemical CAFCD December 2002, Chapter IV, Para 4.4.1.5

[9] UNMOVIC Doc No 102001, 113003, 113011, 113035, 113045, 113060, 113066, 113070, 113081, 113087, 113091, 113092, 113093, 113095, 113117, 113133, 115012, 115112, 120032, 126001, 127001, 129001, 131001, 132001, 140001, 142001, UNSCOM Doc No 200096.001

[10] The Iraqi Quality Control documents and UN findings show that degradation rate of some mustard produced was so low that it and munitions containing it might still be viable now.

[11] Burning means overheating due to the fact that a lot of heat is being generated during exothermic reaction of PCl_3 with TDG.

[12] UNSCOM 11/CW-03 August 1991

[13] UNSCOM 11/CW-03 August 1991

[14] UNSCOM 11/CW-03 August 1991

High quality mustard production was achieved by Iraq through the acquisition and use of high quality starting materials, high quality corrosion resistant chemical process equipment and practical experience gained by Iraqi personnel over several years of mustard production.

The quality control of the production was relatively simple. For routine determination of mustard purity a colorimetric method was used and the results were "confirmed" using a gas chromatography method with an internal standard[15].

Precursors

Thiodiglycol

The thiodiglycol used for the production of mustard was imported. Iraq studied the preparation method of this chemical[16] (see chapter III.III). While some experiments had been carried out at the research level, no further development had been pursued according to Iraq. Although Iraq declared the import of thiodiglycol, it did not provide any precise figures for the quantities imported. Letters of Credit [LCs] quoted in the 1996 CW FFCD suggests that at least 3,225 tonnes may have been supplied to Iraq[17]. In the same FFCD, Iraq declared the processing of 2,848 tonnes of thiodiglycol into sulphur mustard during the period 1981 to 1990[18]. The reminder (188 tonnes) had been destroyed under UNSCOM supervision and UNSCOM saw the evidence of the destruction of another 120 tonnes declared destroyed through armed action during the Gulf War, but accounting was not possible due to the state of destruction.[19]

Thionyl chloride

Thionyl chloride was the major chlorinating agent that Iraq used in the production of various CW agents[20]. Out of some 5,000 tonnes of thionyl chloride, which were used in the CW programme only 70 tonnes had been produced by Iraq. This was in 1988 at Fallujah II but the production was stopped "*for several technical reasons*" [21].

[15] UNSCOM 11/CW- 03 August 1991
[16] UNSCOM 11/ CW-03 August 1991
[17] Chemical CAFCD December 2002, Chapter IIIA. There are fourteen LC documents listed. Ten of these documents suggest 2875 tonnes were imported. Of the remaining four LC documents, two LC documents [82/3/979 & 82/3/1090] relating to supply of 350 tonnes, Iraq have the notation "probably supplied"; one LC document [81/3/1321] relating to an unspecified quantity of the chemical, Iraq has the notation "probably supplied" and the remaining LC [84/3/416] relating to supply of 500 tonnes of the chemical, Iraq has the notation "probably cancelled"
[18] Such as GB – Sarin, GF – Cyclosarin, GE – Ethylsarin, VX and Mustard.
[19] UN document S/1999/94, p.85
[20] Such as GB – Sarin, GF – Cyclosarin, GE – Ethylsarin, VX and Mustard.
[21] Such as GB – Sarin, GF – Cyclosarin, GE – Ethylsarin, VX and Mustard.

Phosphorus Trichloride

Iraq had constructed a PCl_3/$POCl_3$ production plant at Fallujah II, which was mechanically complete but not became operational because the instrumentation critical to its safe operation was missing[22]. It is unlikely that Iraq ever indigenously produced PCl_3.

About 4,000 tonnes of PCl_3 [23] , which was imported as early as 1984, (according to LCs) was not used until 1987. In 1987 export controls imposed by a number of countries threatened to halt the supply of thionyl chloride to Iraq and therefore threatened the continued production of mustard agent. An alternative chlorinating agent was therefore sought, and Iraq declared that it easily managed to make use of PCl_3 as a chlorinating agent for mustard gas production (280 tonnes). Some quantities of PCl_3 were also used in the synthesis of the MPC precursor DMPH (67 tonnes)[24]. Large quantities of the PCl_3 stock, about 30% of this chemical, were declared by Iraq as lost due to the spillage and leakage from the storage containers at MSE[25]. The UNSCOM Chemical Destruction Group destroyed only 650 tonnes of PCl_3 at the MSE, some 690 tonnes less than had been observed approximately a year earlier.

Chronology

Second half of 1981[26]:
During this time mustard was produced using four small reactors at the Al Rashad laboratory-scale site. The reported daily capacity was about 50 to 60 kg and according to Iraq, the quantity produced during 1981 was 10 tonnes.

1982
During this period of time more reactors of the same type were installed at Al Rashad. The production capacity was 430 kg per day: 75 tonnes was declared produced in 1982.

1983
The production rates of mustard during 1983 are unclear from Iraq's declarations. It appears that at the Al Rashad facility corrosion problems prevented the use of some equipment during 1983. During this year, production started at the P-8 plant[27] at Muthanna. Iraq estimated the total production for the year at 150 tonnes.

Comment
The information is ambiguous with respect to the activities at the Al Rashad site. In general, the declared activities refer to second half of 1983 so it can be assumed that Al

[22] UNSCOM supervised the destruction of key elements of the PCl_3/$POCl_3$ plant.
[23] Such as GB – Sarin, GF – Cyclosarin, GE – Ethylsarin, VX and Mustard.
[24] See Chapter III.VII Sarin and Cyclosarin Production
[25] Such as GB – Sarin, GF – Cyclosarin, GE – Ethylsarin, VX and Mustard.
[26] Chemical FFCD June, 1996
[27] Also known as Bin Hayan I

Rashad was producing during this time. However, when discussing the history of the chemical programme in its declarations, Iraq stated that Al Rashad was closed in the summer of 1983.[28] *These two possibly conflicting statements should be taken into account for any calculations of mustard produced.*

1984

During 1984, mustard was only produced at the P-8 site: the capacity of this plant was 1.5 tonnes per day. During the third quarter of the year production was stopped while new equipment was installed. The plant became operational again in December bringing the total production capacity at P-8 to four tonnes of mustard daily. Iraq declared that during 1984 it produced 240 tonnes of mustard.

1985

During the first half-year the production continued at the same rate as the latter part of the previous year. According to Iraq, during the third quarter of the year there was no production. Although mustard production resumed in December it was not at the full capacity. Nevertheless, the yearly production was 350 tonnes.

1986

The production of mustard at the P-8 plant continued during the first three months of the year with only one reactor operating: the plant was then shut down due to a lack of thionyl chloride. Iraq declared that the total output for the three months was 350 tonnes.

Comment
When calculating a daily output for the time the plant was active the result is about 3.8 tonnes per day (operational period assumed to equal 90 days). However, during an inspection, Iraq clarified to UNSCOM that the operational period was actually six months and therefore the daily output is estimated at about two tonnes.

1987

During 1987, Iraq started to produce mustard using phosphorus trichloride as the chlorinating agent. The declared daily production was four tonnes, so the change in the production method did not appear to affect the capacity. In the last quarter of 1987, more reactors were added to the production line which yielded an overall capacity of eight tonnes per day. According to Iraq, the total quantity produced throughout 1987 was 899 tonnes.

1988

The production of mustard continued during the first half of the year. The plant was shut down during the second half of the year possibly because of the ceasefire arrangements in the Iraq-Iran war. Iraq estimated that it produced 494 tonnes of mustard during 1988 and had a daily production capacity of four tonnes.[29]

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[28] Chemical FFCD June 1996 Chapter I. para. 1.1.4
[29] It has to be questioned, why the daily production was cut in half, although no changes in the process were specified.

1989
Iraq never officially declared any production of mustard during 1989. However, UN inspectors learned during interviews that one or two batches of mustard may have been produced in 1989, but this has not been substantiated.

1990
Following its invasion of Kuwait in August 1990, Iraq resumed the production of mustard in the second half of the year. Iraq declared a daily capacity of eight tonnes of mustard with a total production estimated at 280 tonnes.

Comment
Iraq declared a daily output of 50-60 kg of mustard using "small scale" or "non industrial scale" equipment at the beginning of the programme. The pilot-scale equipment used by Iraq had the capability to produce significant quantities over an extended period of time.

According to the June 1996 FFCD, corrosion, lack of spare parts and shortages in starting materials limited the production of mustard. But due to lack of production records, such claims could not be verified.

Reliable verification of the quantities of mustard produced was a difficult task. The declared periods of production are sometimes vague and the information about the processes themselves lack essential details. The technical capacity of the plants involved in mustard production was subject to study and assessment. Even rough calculations led UN inspectors to the conclusion that Iraq had potential capabilities to produce much more mustard than declared.

For example in 1986 the lack of thionyl chloride interrupted the production of mustard, but production was resumed in 1987 by using PCl_3 as a chlorinating agent. By the end of 1987 more reactors were added to the production line, and so the daily output increased – not so the annual production figures, declared by Iraq.

Of the total of 3,950 tonnes of CW agents declared produced during the period 1982 to 1990, 2,850 tonnes were sulphur mustard. According to Iraq, 2,443 tonnes of this mustard were weaponized in artillery shells and aerial bombs. The uncertainty in the accounting of mustard declared as remaining in 1991 include up to 550 artillery projectiles filled with this agent.[30]

[30] UNMOVIC - Unresolved Disarmament Issues, March, 2003

UNMOVIC
CHAPTER III.VI

TABUN PRODUCTION

Introduction

Tabun (GA)[1] has the chemical name O-ethyl N, N-dimethylphosphoramidocyanidate. Tabun was the first chemical warfare nerve agent produced and weaponized by Iraq. It has a lethal effect if inhaled or deposited on the skin. It is a colourless to brownish liquid that gives off a colourless vapour that has a faintly fruity smell (odourless when pure).

When it embarked on a chemical warfare agent programme, Iraq did what other CW state-possessors had done before, and started with the production of the simplest first generation agents before progressing to more complex and more lethal agents. Iraq had some familiarity with producing agents such as CS and mustard prior to starting its tabun bulk production.

In March 1984, during the Iran-Iraq war, a sample of liquid allegedly associated with an aerial bombing attack on Iranian forces was taken in Iran by experts appointed by the UN Secretary-General. They investigated allegations made by the Islamic Republic of Iran concerning the use of chemical weapons by Iraq. Samples analyzed by a designated laboratory, showed that they contained tabun[2].

Process

At the research and development level, Iraq studied several routes to synthesize tabun and for industrial production, according to Iraqi declarations,[3] selected the method based on the reaction of the N, N-dimethylphosphoramidic dichloride (D4) with sodium cyanide and ethanol. In 1987, Iraq attempted to improve the production process by altering the cyanation reagent, but this effort failed to improve yields.

> *Comment*
> *Iraq was not aware of the fact that the quantities of substrates as presented by the stoichiometric equation declared were not optimal for industrial production. Only through empirical analysis did Iraq find a ratio of substrates, which resulted in a better quality product.*

Quality

Despite synthesizing high purity tabun at laboratory scale, Iraq could not reproduce these results when producing industrial quantities. According to Iraq, the samples, which it analyzed at Muthanna in March 1984 from first batches, contained only a small percentage of GA along with the solvent and many decomposition products[4]. At a later

[1]The NATO code designator for tabun is GA, but in its internal documents Iraq used the acronym GF until 1987 (see Chemical CAFCD December 2002,Chapter IV, UNMOVIC Doc. No. 200163, which is NATO code for cyclosarin. The cryptonym for tabun was “Red”).
[2] UN Doc No S/16433
[3] Chemical CAFCD December 2002 Chapter IV, Para. 4.1.1.1
[4] Report on the Technical Evaluation Meeting on Chemical Warfare Agent VX, Attachment 1 Para 11.4.8 17 February 1998

stage, the final product contained an average of 50% to 60% of tabun and about 40% of solvent at the industrial level. Iraq mastered neither vacuum distillation[5] nor filtration to improve the quality of the final product[6].

The tabun programme faced technical difficulties from the beginning, owing primarily to filtration and purification problems in production. Efforts were made to increase production quality, but improvements were insufficient to merit further effort. According to Iraq, the tabun production was cancelled in 1986, most likely in favour of increasing the efforts in the Iraqi sarin and cyclosarin production, which were ongoing at the same facility. The research and development efforts to improve the production technology however, continued after the industrial production of tabun was abandoned.[7]

Precursors

From the beginning of its programme, Iraq appeared to want to produce all the precursors for their agents indigenously, and did so with varying degrees of success. Iraqi scientists were aware of the fact that the key to good quality tabun was the quality of precursors[8].

D4[9]: D4, the last stage precursor for tabun was researched in the early 1980's alongside the synthesis of the agent itself. In 1981, Iraq attempted to produce D4 using Phosphorus oxychloride ($POCl_3$) and Dimethylamine hydrochloride (DMA*HCl) as reagents with relatively good yields and purity. This process was adopted for industrial production in 1982[10]. The drawbacks such as the necessity to deal with large amount of HCl liberated, hygroscopicity of the salt and its instability, prompted the Iraqi engineers to search for other methods. However, no alternative was adopted[11].

DMA*HCl: In 1985, Iraq attempted to produce dimethylamine hydrochloride in order to ensure a reliable source of this chemical for D4 synthesis beyond the amount of DMA*HCl that had been declared imported (570 tonnes).[12] Research in this area failed however and according to Iraq's declarations,[13] the programme relied solely on imported DMA*HCl.

$POCl_3$: Phosphorous oxychloride, the primary phosphorous source employed to synthesize D4, was first attempted in 1984. Product purity and yield were good.[14] Production was never scaled up using the technique applied, due to a governmental decision to build a dedicated PCl_3 and $POCl_3$ plant at Fallujah 2 using foreign technology

[5] UNSCOM Doc No 200163.017, 200163.016
[6] Chemical FFCD June 1996 para 6.2.2.5
[7] UNSCOM Doc No 200163.011, No.200163.011, 200096.036,
[8] Chemical CAFCD December 2002 Chapter IV, Para 4.1.4
[9] D4 designated as DX (Chemical CAFCD December 2002 Chapter IV, page 4-89
[10] Chemical CAFCD December 2002 Chapter VI, Para 6.2.1.1 and Para 6.2.1.2
[11] Chemical CAFCD December 2002 Chapter IV, Para 4.1.2.2
[12] Chemical CAFCD December 2002 Chapter IIIA, Page 6.
[13] Chemical CAFCD December 2002 Chapter IV, Para 4.1.3
[14] Chemical CAFCD December 2002 Chapter IV, Para 4.1.4

and equipment.[15] This production plant at Fallujah 2, however, never became operational prior to the 1991 Gulf War. Much of the Fallujah 2 facility suffered bomb damage during the Gulf War including parts of this production plant, which was further destroyed by Iraq under UN supervision..

Iraq declared that all phosphorous oxychloride used in the production of tabun had been imported[16].

Ethanol:

Iraq imported an alcohol distillation unit[17] from a foreign supplier, which should have been capable of producing absolute alcohol. However, according to Iraq's declarations, the best purity ever obtained was 97.5 % and this was insufficient for producing tabun. Iraq stated that the reason why they failed to obtain higher purity ethanol was that they neglected to mention the specification of their feedstock to the unit supplier (alcohol derived through a biological process rather than from a petrochemical plant). Although Iraq declared that they tried repeatedly from the end of 1984 to 1986 to improve the purity of the compound, they were not successful. Iraq used only imported absolute ethanol for the production of tabun.[18]

Chronology of Tabun Production[19]

1970s: Tabun was among the chemical warfare agents being researched by the officers of the chemical corps in the 1970s at Al Rashad laboratory-scaled facility.

1982: Tabun was first produced in laboratory-scale quantities at Al Rashad.[20]

1984: Tabun was produced using equipment installed at the SEPP/MSE research and development laboratories. The capacity was 320 litres per day[21]. By using such equipment, 30 to 40 tonnes of tabun were produced during the first half of 1984.

After tabun production was transferred to P-7 at Muthanna, a multipurpose plant was built at the site. In either August or September 1984, the plant operated 24 hours per day, 7 days per week and with 2 to 3 shifts per day. It produced 20 tonnes of tabun at a rate of one tonne per day. According to Iraq, there were 20 production days in that month with 10 days of downtime for maintenance and settling of the product. One batch production time was 1-3 days, with regular delays due to mechanical problems such as pipe blockages, leaks, temperature control problems and salt solidification. The best batch processing speed achieved was one tonne per day. Purification of this industrial product

[15] Chemical CAFCD December 2002 Chapter IV, Para. 4.1.6; Chapter I, Para. 1.4.8.1
[16] Chemical CAFCD December 2002, Part I, Chapter IIIA, item 7.
[17] Chemical CAFCD December 2002, Chapter V, Page 5-16.
[18] UNSCOM 153/CW-31, May 1997
[19] UNSCOM 153/CW-31 May 1997
[20] Chemical CAFCD December 2002, Chapter IV, Para 4.1.1
[21] UNSCOM 239/CW-47, May 1998

was performed.[22] The total quantity of tabun produced in 1984 was approximately 60 tonnes. In December 1984, new reactors were installed at the P-7 plant. [23]

1985: In the second quarter, production of tabun continued at P-7 with a capacity of one tonne per day. Soon afterwards however, production halted once again because of damage to one of the reactor agitators. After the reactor was replaced, production was restarted. The total quantity of agent produced over six to seven months[24] in 1985 was approximately 70 tonnes. No official explanation was given by Iraq for the decline in production efficiency between 1984 (20 tonnes per month) and 1985 (10 tonnes per month). In all likelihood, Iraq judged that solving the technical problems relating to sarin was more important than the difficulties it faced with respect to tabun[25].

1986: Production of tabun continued at the P-7 plant for five to six months of the year (Iraq also declared some unsuccessful attempts to produce tabun it had carried out at the Mohammed and Malik plants). A centrifuge was installed at the P-7 plant in 1986 in order to filter the slurry produced along with tabun, rather than only using decantation. The total quantity of tabun produced during the year was approximately 80 tonnes.[26] Purity was evaluated at 40-50%. Due to repeated technical problems, tabun production was terminated in the second half 1986 and never resumed, according to Iraq.

Comment
It is likely that Iraq intended to produce chemical nerve agents from the mid-1970s, when the President authorized the establishment of the Al Hazen Ibn Al Haitham Institute. In order to build chemical plants, Iraq employed domestic designers and engineers to construct facilities at the Samarra site (future MSE) and later imported necessary equipment. . During the time lapse between making plans for such a production site and its actual construction and use for agent production at the beginning of 1980, Iraq increased its expertise in chemistry and chemical engineering by sending chemical corps and other technical personnel to seek advanced education in foreign countries and by continuing intense research and development activities even after the demise of the Al Haitham Institute.

Once begun, it appears that tabun manufacture and the refitting of the P-7 plant were undertaken to fulfil the immediate requirements of wartime. Although this impure product had sufficient utility for immediate use on the battlefield, it was not pure enough for long-term storage. The problems of purity and longer-term storage were not unique to tabun. These difficulties for nerve agents in general are addressed later in Chapter III.
One stage of the tabun production associated with the problems Iraq faced with filtration deserves attention. Separating solids from liquids using industrial separators is considered relatively simple. However, Iraq in its declarations and during interviews

[22] UNSCOM 153/CW-31 May 1997
[23] UNSCOM 153/CW-31 May 1997
[24] UNSCOM 153/CW-31 May 1997
[25] UNSCOM 153/CW-31 May 1997
[26] UNSCOM 153/CW-31 May 1997

with scientists stated that this was a primary problem in the manufacture of agent. This difficulty could have been addressed in the initial design phase of the production using simple engineering solutions. No attempts to resolve the problem in this manner were declared. One reason for this may have been the comparative success Iraq had, using the same equipment and expertise to manufacture sarin of higher toxicity.

In the early years of its production, Iraq appeared to have used the same reactors for tabun that it employed for its mustard programme It seems that the main reason for stopping Iraq's tabun programme was the lack of knowledge in the purification and stabilization process during the synthesis of the final product. This problem plagued Iraq throughout its entire nerve agent programme.

UNMOVIC assesses that Iraq had difficulties to produce a high purity stable tabun on a large-scale, and that it displayed limited capabilities in the manufacture of its key precursors. Iraqi scientists claimed that this was due to their inability to produce pure D4.. Also, according to Iraq it was the lack of knowledge of how to perform effective purification of the final agent and its precursors.

CHAPTER III.VII

SARIN AND CYCLOSARIN PRODUCTION

Introduction

Iraq declared industrial-scale production and weaponization of sarin and cyclosarin[1]. Both of them are lethal chemical warfare agents, belonging to a group of agents known as nerve agents, which are powerful cholinesterase inhibitors.

Sarin (GB)[2], O-isopropyl methylphosphonofluoridate, is volatile and therefore disperses quickly in the atmosphere. Its analogue Cyclosarin (GF)[3], O-cyclohexyl methylphosphonofluoridate is more persistent[4].

Iraq declared that during the period from 1984 to 1990, it produced 795 tonnes of sarin-type agents (GB, GF and a mixture of GB/GF), approximately 732 tonnes of these agents were weaponized. According to Iraq's declarations, the production of cyclosarin and a mixture of sarin and cyclosarin started in the beginning of 1988.

In addition to sarin and cyclosarin, Iraq researched other sarin analogues[5]. This was done, according to Iraq for two reasons: to overcome the non-persistent features of sarin and to add an element of surprise on the battlefield by including a novel agent[6]. UN inspectors found some evidence suggesting that certain analogues were produced in more than laboratory quantities.[7, 8]

Iraq also declared research and development work on sarin binary weapons systems (see Chapter III.III on Research and Development) for both. According to Iraq, it carried out experiments on 'true' binary systems using artillery shells and rockets between 1983 and 1990. These binary systems involved the precursors MPF and alcohol being kept separate in the munitions. Sarin precursors separated by a membrane, mixed and reacted with one another after the membrane was ruptured after firing. [9]. Iraq declared it never produced such munitions for its CW stockpiles.

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[1] Chemical CAFCD December 2002 Part I, Chapter V and VI

[2] GB is a NATO code for sarin

[3] GF is a NATO code for cyclosarin

[4] The term "sarin" is sometimes used to denote both sarin and cyclosarin

[5] Letter from Iraq Ref. 2/1/C/388

[6] UNSCOM Doc No 20007123

[7] In November 1991 UNSCOM, while analyzing the content of sarin storage containers, found s-butyl, n-butyl and ethyl sarin mixed with GB or with GB+GF in some of the containers.

[8] Iraqi document 113054 mentions "Substance: GS via "Secondary Butanol""; UNSCOM Bahrain Analytical Results,

[9] Chemical CAFCD December 2002 Part I Chapter VIII, Para 8.9

In addition, Iraq declared that 1024 aerial bombs and 34 missile warheads were filled with alcohols in 1990, as a crude type of binary system for sarin-type agents. This binary-type system involved filling a munition with alcohol and then manually adding the other precursor (MPF) just prior to the munition being used in battle. This system is known as the “Iraqi binary”.[10].

Comment

Results of the chemical analysis conducted by UNSCOM [11]in 1991 indicated that sarin might have been mixed with mustard for use in the battlefield. This was not confirmed by Iraq. Iraq explained that such results were possible due to the fact that the same storage containers had been used for mustard and sarin without any cleaning in between. The UN Commission could not confirm whether it was true or not, however a pre-1991MSE quality control document taken from Iraq states that a storage container in which mustard would normally be expected, contained sarin instead[12].

Documentary evidence[13] suggests that after the conclusion of its war with Iran, Iraq intended to continue l aspects of sarin programme related to improvement of the quality of this agent in order to achieve its strategic stockpiles. Although there are gaps in the information provided by Iraq on the extent of its sarin programme especially in the post Iran-Iraq war period, Iraq’s sarin programme was one for which the Commission has accumulated considerable details. In general, sarin was one of the two agents that was produced, weaponized and used by Iraq in the largest quantities (after mustard).

Process

Iraq declared that it had used two methods to produce all of its sarin-type agents.

From 1984 to 1987 Iraq applied a “classic” production method for sarin, widely known from open literature.

The production process started with the imported trimethylphosphite (TMP) from which dimethylmethylphosphonate (DMMP)[14] was produced.

Then, DMMP was transformed into methylphosphonyldichloride (MPC)[15].

MPC was fluorinated to methylphosphonyldifluoride (MPF).

Then the mixture of MPF with MPC was reacted with alcohol to produce sarin.

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[10] Chemical CAFCD December 2002, Addendum, Para. 6.1

[11] UNSCOM 17/CW-05, August 1992

[12] UNMOVIC Doc. No 113011

[13] Letter from Iraq Ref. 2/1/C/388

[14] This reaction is known as the Arbusov’s rearrangement

[15] In 1990 some MPC was produced from pyrophosphate, see “Alternative methods” Section.

In the end of 1987, Iraq adopted the "only MPF" method (reaction of MPF with the alcohol), which was also used in the production of the "Iraqi binary".

Details of the above processes were included into Iraq's declarations and assessed by the UN Commission. A number of meetings were held with Iraq's experts and officials in order to map and account for the production part of Iraq's sarin programme. Below, only the most significant comments regarding sarin production are included.

Quality

When Iraq embarked on nerve agent production, during the first three years, sarin was produced alternately with tabun, but in smaller quantities. Later, due to difficulties in the production of good quality tabun [16], Iraq directed its attention entirely to the production of sarin, which was more toxic but also more volatile than tabun. The lack of persistency of sarin is one of the reasons why Iraq later decided to produce the more persistent cyclosarin. Additionally, the toxicological and biological evaluation of GF and its mixtures, conducted by Iraq, showed that the toxicity of GF and GB/GF mixture was greater than that of sarin[17]. This phenomenon was associated with an increase in the percutaneous activity of cyclosarin[18].

On average, the purity of sarin and cyclosarin produced by Iraq was in the range of 45-60%. This level of purity dropped below Iraq's established quality control acceptance level of 40%, some 3 to 12 months after production[19] with the creation of gaseous and solid (jelly) degradation products[20].

The shelf life of sarin could be extended through purification and stabilisation. Iraq declared that the only purification method it tried was distillation, which it could not apply with success. Iraq tried to concentrate its efforts on improvement of the quality of the immediate organophosphorous precursors, in particular MPC, but claimed that it did not succeed even at the latest stage of its CW programme.

The "possibility of chemically enhancing" the purity levels of the stored sarin was considered[21] but probably never implemented.

Iraq acknowledged that they studied the stability and the storability of sarin-type agents produced at the - industrial level in 1989. The results were discouraging and were not implemented. To overcome these difficulties, in 1990 MSE decided to limit sarin production by the stage of its immediate precursor MPF and only proceed further

[16] See CHAPTER III.VI, "Tabun Production"

[17] Iraqi document 200095.001

[18] UNSCOM Doc No 200098

[19] UNSCOM Doc 200096.014

[20] Iraqi document 113054

[21] Iraqi document 115112

(reacting this precursor with the alcohol) shortly before the nerve agent munitions would be needed (‘Iraqi binary’ system).[22]

Comment

Iraq stated that in the initial years of sarin production, quality control didn’t practically exist[23][24]*. The evaluation of some analytical reports may suggest that before 1986, Iraq did not have a full understanding of the analytical methods required. With the establishment of the Quality Control (QC) Department*[25] *in 1987, Iraq made some improvements in the consistency and quality of its sarin production. An Iraqi official stated that only around 1987-88 reproducible results were obtained, but that these results were still much below the results found in literature.*

There is documentary evidence from 1988 that Iraq, while still engaged in its war with Iran, recognized the importance of QC and technological operational procedures. Sampling and testing of all materials received, stored and produced then became a routine activity.

An extensive amount of experience and know-how was gathered by Iraq during the production of sarin and sarin-type agents. Unless Iraq substantially improved its quality control and production processes for sarin-type agents during the period 1989-1990, it would not have been able to produce a storable quality product. With respect to the unaccounted for weaponized sarin-type agents, it is unlikely that they would still viable in 2007although they still may represent a health hazard.

Chronology of sarin production

1970s Iraq found the basic information regarding sarin production in open source literature. Iraq’s scientists started their familiarization with sarin’s characteristics and its preparation technologies in 1974. One of the Iraqi officials stated that "the literature was the source of so much data that we did not need to test or check so much."[26] Iraq was aware that the immediate (last stage) precursors of sarin, methylphosphonyldifluoride (MPF) and/or methylphosphonyldichloride (MPC) were not commercially available. To produce them domestically, Iraq had to construct new production plants. Iraq also required precursors for them and these were available on the international market at that time.

[22] UNSCOM 30, July 1991

[23] UNSCOM 170/CW-33, April 1992

[24] It was not an impediment to its “successful” immediate use.

[25] 9 person strong

[26] UNSCOM 74/CW-15, April 1994

1984 Iraq declared that the development work on sarin, consisting mainly of testing and implementation of known[27] methods at the pilot scale, started in 1984. Iraq purchased from foreign supplier about 20 tonnes of trimethylphosphite (TMP) for the production of MPC in March 1984. This initial quantity acquired was intended according to Iraq for a pilot-scale plant; however a year later, Iraq imported another 100 tonnes of TMP[28]. In December 1984, larger scale production of sarin began[29] at the new P-7 plant, which had a production capacity of 500-600kg/batch. By the end of the year, 5 tonnes of sarin were produced.

1985 The production of sarin continued at the P-7 plant for the first half of the year. Production of sarin was then halted and the plant was used for tabun production. About 30 tonnes of sarin was declared as produced during that year.

Comment

Iraq was probably experimenting with the production parameters of both sarin and tabun during this time and hence the alternating production patterns at the P-7 plant. This may support the concept that the development of agent production technology was spontaneous although having planned elements. The CW programme was driven by war requirements and production capability (technological experience and availability of raw material and equipment).

1986 In the second half of the year, production of sarin was resumed at the P-7 plant with the previous capacity of 500-600 kg a batch. Another 40 tonnes were produced and it was not until later that year that some of the technical problems were solved.

1987 MSE staff spent the first half of the year engaged in the modernisation and repairs of the plant. Iraq replaced a damaged reactor and installed new, bigger capacity and a better quality reactor at the P-7 plant raising its capacity to two tonnes/batch. New production technique was applied at the end of the year, which significantly shortened the production time of each batch. The improved plant equipment plus the new production method together resulted in about 209 tonnes of the agent being produced. The first batch of sarin/cyclosarin mixture was produced as part of an experimental study.

1988 Cyclosarin was produced in significant quantities at the beginning of 1988, in addition to the production of a sarin/ cyclosarin mixture. Iraq declared that it produced over 333 tonnes of sarin and its mixture and 60 tonnes of cyclosarin. According to Iraq, production was stopped in August 1988[30].

1989 Iraq declared no sarin production for the year 1989.

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[27] mainly from literature studies

[28] Chemical CAFCD December 2002, Chapter IIIA, item 4

[29] Chemical CAFCD December 2002, Chapter VI, Para. 6.3.1.4

[30] The time of the end of the Iran Iraq war.

Comment

Iraqi scientists provided conflicting statements to the UN inspectors in 1995[31] stating that bulk production of sarin took place at the first half of 1989 at MSE. A document found by UNSCOM[32] confirms that claim. Officially, however, Iraq has never admitted any sarin production in 1989. .

1990 Sarin production was resumed in the second half of the year at the MSE at the rate of one tonne/day. Sarin was produced both at H3 and at the P-7 plant. A total quantity of 117 tonnes was produced before production was interrupted in January 1991 on the outbreak of Gulf War. Iraq's concept of an "Iraqi binary" sarin was implemented in mid-1990[33].

Production facilities

The following plants are mentioned in the CAFCD-CW 2002 as being involved in the production of sarin, cyclosarin and its precursors: pilot plants H1, H2 and H3, Malik, Mohammed, Ahmed 1, Ahmed 2, Ahmed 3 and P-7. All of these plants were located within the Muthanna site (greater detail of these production plants at Muthanna site is contained in Chapter III.II). The Iraqi designed and constructed P-7 plant was the main, dedicated and most capable plant for the production of sarin-type agents. It contained some general equipment necessary for the basic production processes but lacked some specialized equipment such as vacuum and control instrumentation. The plant was designed by engineers at Muthanna based on the data from its R&D Department and using equipment available at that time. SEPP's technical cadre also installed the process equipment. Iraq considered the P-7 plant as its principle production site for sarin, and frequently referred to it as the "sarin plant".

Comment

Iraq declared many technical problems during the production process such as "corrosion, unsuitable construction materials" of the process equipment (which was replaced from time to time) and the lack of sufficient utilities in the plant. These conditions, together with Iraq's inability to purify effectively the precursors and absence of the purification stage at the final step of production might have affected the quality of intermediate and final products and many batches were "spoiled".

The information available to UNMOVIC regarding the location of the plants, in which sarin and its precursors were produced, appears reasonably accurate as well as the

[31] UNSCOM 153/CW-31, May 1997

[32] Iraqi Doc No 129131.001

[33] Chemical CAFCD 2002, Addendum, Para. 6.1 and Chapter I, Para 1.8

timescale of its production. Some uncertainties remain, despite efforts to clarify the inconsistencies in information provided by Iraq; these inconsistencies include the differences found within the Chemical CAFCD of December 2002, between Chapter V, "The Production Buildings and the Equipment Installed", and Chapter VI, "Production of Chemical Warfare Agents", concerning timelines and locations.

Most of the production plants declared by Iraq to have been involved in sarin-type agent production were found by UNSCOM to be damaged by aerial bombardment during the Gulf War. Remaining chemical process equipment from these plants was subsequently destroyed under UNSCOM supervision. One plant (P-7) was undamaged and was later converted into the destruction facility.

Precursors

Dimethylmethylphosphonate (DMMP)

Iraq selected a well-known method for the production of dimethylmethylphosphonate (DMMP). Iraqi scientists modified this method to make it compatible with the available equipment and to increase the production capacity.

Iraq declared that it had produced 1025 tonnes of DMMP and achieved satisfactory yield and purity[34] (Table III.VII.I). The Iraqi production of DMMP was affected by the purity of the imported precursor TMP.

[34] Iraqi document 126001

Table III.VII.I DMMP production capacity

Time	**Production Capacity [Kg/day]**	**Quantity Produced [Metric tonnes]**	**Plant**
1984	60 L/day	15	H3
	350 L/day		H1
1985	350 L/day	60	H1
1986	850	250	H3
			H2
Second half of 1987	6,000	586	Malik
January 1988		114	
1989 and 1990	No production declared		

Comment

The gas-chromatograph analysis of TMP and DMMP is relatively simple and most probably Iraq did not experience any problems and the quality control results obtained were reliable. The results of the analysis performed by UN inspectors during the destruction activities in 1992-1994 were compatible with Iraqi analytical results.

Methylphosphonyldichloride (MPC)

Iraq declared that it started MPC production in 1984 using small capacity equipment. Production continued to the end of 1990 with output expanding. Various facilities and equipment were involved. The majority of MPC was produced from DMMP. Iraq declared that in 1990 it produced 19 tonnes of MPC through DMPH – pyrophosphate route (Table III.VII.II). According to Iraq, the shortage of imported TMP and availability of large quantities of PCl_3 (which served as a starting material for the latter method) at MSE in 1990 resulted in the necessary technology change.

There were no significant quantities of MPC remaining in Muthanna in January 1991 according to Iraq's declarations, nor were such quantities found in inventory documents that related to the last few months of 1990.

Table III.VII.II MPC production capacity

Time	Production Capacity [kg/day]	Quantity Produced [metric tones]	Plant
1984	112	25	H3
First half of 1985	200	60	H2
Second half of 1985	300		Ahmed
1986	500	90	Ahmed 1
	130		H1
First half of 1987	130	229	H1
Second half of 1987	2,000		Mohammed
1988		285	Mohammed, Malik, Ahmed-3
1990		75	Mohammed, Ahmed-3
		19	Dhia

Comment

The analysis of MPC purity presented a problem to Iraq because of its volatility and reactivity. For this reason Iraq used a combination of analytical methods, each with its own limitations.

The examination of Iraqi Quality Control documents shows that the problem of finding a reliable method for the analysis of the yield and purity of MPC was not solved at least until 1988. This played a role in the quality of the next sarin precursor, MPF and the sarin itself.

Methylphosphonyldifluoride (MPF)

Production of MPF has the same timeframe as MPC since both chemicals are key, immediate sarin precursors. MPF was used by Iraq both for the production of unitary sarin and as one component of the “Iraqi binary” system. Iraq declared the production of 530 tonnes of MPF using two production methods (Table III.VII.III). Its storage required highly corrosion-resistant equipment and for that reason it was not stockpiled in high quantities.

Production samples were routinely analyzed but the results fluctuated. Iraq concluded that these fluctuations were the result of inconsistent sample preparation[35]. The analytical methods mentioned to test the quality of the product included the gas chromatographic methods and a colorimetric method similar to the one used for the determination of MPC. Infra red analysis was also used for product identification but probably only at the R&D level[36].

Table III.VII.III MPF production

Time	**Production Capacity [Kg/day]**	**Quantity Produced [Metric tonnes]**	**Plant**
End of 1984	300	10	Ahmed
1985		30	
1986	600	34	Ahmed
1987	600	127	Ahmed
	400-500		H3
1988		229	Ahmed and H3
1990		100	Ahmed-2 and H3

Comment

Iraq declared extremely good and somewhat surprising results regarding the yield and purity of MPF (declared purity was within 60-90% range) while using conditions other than that considered optimal. But there is a possibility that its results of the chemical analysis of MPF were not correct.

Analyses of MPF samples taken by UN inspectors showed that this chemical produced in late 1990 largely degraded after a year of storage. The fast degradation of MPF, however, could partially be explained by the way it was stored. Observations made by

[35] UNSCOM Doc. No. 200095.017, UNMOVIC Doc.No.200213

[36] UNMOVIC Doc No. 200213

UNSCOM in 1991 indicated that MPF was stored in jerry cans and consequently had corroded most of the containers that were holding the chemical. For this reason, it seems very unlikely that any MPF produced in 1990 or earlier is likely to be viable in 2007.

Sarin binary system

Iraq also studied a true binary system for sarin using artillery shells and rockets and obtained encouraging results[37]. Iraq firmly denied any large-scale production of such systems declaring: "The success reported was on a small scale for the field trials. Mass production of munition suitable for the binary sarin involved large-scale modification and additional manufacturing requirements at the munition manufacturing facility that needed time and capital investments. By 1990, no decision on the investments was made and consequently the results achieved were not utilized in mass production."[38] No such munitions were found by UNMOVIC during its activities in Iraq. However, in the absence of the documentation for the MSE production activities during 1990 period it can not be ascertained whether Iraq developed its true binary weapons systems for sarin into large-scale production or not.

Comment

According to Iraq's quality control documentation the test results of stored sarin type agents conducted by Iraq in 1988 were in the range of 1%[39] - 80%[40]. This wide range values shows that the reproducibility of product parameters was low. Iraq declared that many batches "were spoiled". Iraq was aware of the production problems and a study[41] was launched to find the reasons the failure to produce high quality stable sarin. But the results of the study did not give answers, which would have helped introduce changes in the production department. It is not clear whether Iraqi researchers were familiar with the methods suitable to analyze the highly polar by-products of sarin by the gas-chromatograph method. Improper removal of HCl during the production process and the fluctuating quality of the immediate precursors obtained in the batch type processes contributed to the low quality of many batches of produced agent. The by-products, solvents and impurities left behind in the "crude sarin" because of the absence of the final purification stage contributed to the degradation of the agent over time.

The screening of samples of sarin-type agents taken by the Special Commission from various types of munitions and storage containers during the period 1991-1994 showed that agents had degraded to various levels and that the agent content was generally below 10% and sometimes below 1%. In few cases the agent purity remained around 20

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[37] Chemical CAFCD December 2002, Chapter XIII

[38] Chemical CAFCD December 2002 Chapter XIII, Ref. 2/1/C/234

[39] UNSCOM Doc. No 142001

[40] UNSCOM Doc. No 126001

[41] UNSCOM Doc. No 129161.002

to 30 percent. The key parts of 2006 US National Ground Intelligence Center report mentioned the recovery of approximately 500 chemical munitions in Iraq since 2003, which contained degraded mustard or sarin nerve agent. However, the declassified parts gave no details regarding the purity of the agents.[42]

According to Iraqi declarations[43] *the results for the purity of "Iraqi binary" were good, reached its peak some hours after the mixing but was degraded below the required level three days later. MSE personnel may have believed that by creating this type of binary munitions, they were achieving two goals - the fulfilment of the President's statement*[44] *and probably his expectations as well as resolving the stability and storability problem. The last problem was only partially solved because the storability of "Iraqi binary" weapons depended on the construction material for the storage containers for MPF, which is an aggressive chemical. MPF stored in jerry cans quickly degraded (lifetime measured in months)*[45].

UNSCOM, and later UNMOVIC could not fully verify Iraq's accounting for precursors it had acquired for the production of sarin-type agents due to the manner in which they were destroyed and stored. Iraq may have retained imported chemicals to produce MPC. Such imported chemicals, thionyl chloride and phosphorus trichloride (if redistilled) may be still viable.[46] *Documentary evidence and properties of* PCl_3 *support to some extent Iraq's assertion that the chemical was lost during storage. No findings of these two chemicals were reported by the ISG group.*

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[42] UNMOVIC Quarterly Report to the SC, S/2006/701

[43] Chemical CAFCD December 2002 Chapter XIII, Ref 2/1/C/432

[44] The President announced that "binary" technology was available to Iraq and that Iraq had now joined the ranks of advanced nations.

[45] In the absence of water and in special containers is possible to store MPF for a long period of time. The problems here are more related to the proper storage much less to its stability. MPF is very corrosive and because of this difficult to store.

[46] UNMOVIC UDIs document, March 2003

CHAPTER III.VIII

VX

Introduction

Iraq declared that it had planned to produce nerve agents including VX since the beginning of its CW programme. VX has the chemical name O-ethyl S-(2-diisopropylamino) ethyl methylphosphonothiolate. It is a colourless to mildly yellow coloured liquid, without an odour. The toxicity of VX is much higher than the toxicity of the G-agents (such as sarin and tabun), and it can cause a lethal effect if inhaled or absorbed through the skin[1].

Iraq declared that it included VX in its CW programme both for military and technical reasons. VX was a new generation of nerve agent with much higher toxicity[2]; VX is more stable in various atmospheric conditions than other nerve agents and is more persistent (the affected area remains contaminated for longer time). In addition, Iraq by the mid-1980s had already acquired an extensive experience with G-agents including related research and development and production activities, which encouraged MSE personnel to consider VX as a natural follow-on agent in the CW area.

Process

Based on information available (including original documents provided by Iraq or found by the Commission, declarations, inspection reports and technical assessments produced by the Commission) the UN Commission concluded that Iraq mainly concentrated its efforts on four major synthetic routes for acquisition of VX[3]: route A, route B, route C and route D. The description of these routes was taken by Iraq from the open literature.

Route A: The reaction of 2-(diisopropylamino) ethanol ["Iraqi Choline"] and O-ethyl methylphosphonothioic chloride [monoester]. The product of this reaction known as O-ethyl O-2-(diisopropylamino) ethyl methylphosphonothionate 'false' VX, is received in the form of the salt [VX·HCl]. Final product VX or O-ethyl S – (2-diisopropylamino) ethyl methylphosphonothiolate, also known as 'true' VX could be obtained in one easy step by reaction of VX salt with sodium carbonate followed by thion-thiol isomerization;

Route B: The reaction of 2-(diisopropylamino) ethanol and ethanol with methylphosphonothioic dichloride ["MPS"]. The product of this reaction is the same as for route A.

[1] Material Safety Data Sheet, US Army Soldier & Bio/Chem Command, Edgewood Chem/Bio Center, 29 Sep 1999
[2] UNMOVIC Document "VX UDI", April 2003
[3] UNMOVIC Document "VX UDI", April 2003

Route C: The reaction of 2-(diisopropylamino) ethanethiol ["Thiocholine"] with O-ethyl methylphosphonyl chloride ["oxymonoester"]. The product of this reaction - salt of 'true' VX - can be converted into VX via reaction with sodium carbonate. Iraq also considered this reaction as suitable for obtaining binary VX.

Route D: The reaction of 2-(diisopropylamino)ethyl chloride ["Chlorocholine"] with the sodium salt (or acid) of O-ethyl methylphosphonothioate. The product of this reaction is salt of "true VX".

Iraq declared the production of a total of 3.9 tonnes of VX and VX-hydrochloride ('VX salt') in seven industrial size batches in the period of late 1987 to early 1988 and in April 1990 at three plants of the MSE, using routes A and B. Iraq also stated that no weaponization of VX took place due to the poor quality of the VX produced, except for three AALD-500 aerial bombs and one 122mm rocket warhead filled with VX for storage (agent degradation) and corrosion tests. According to Iraq, two other routes, C and D, were studied only on a laboratory scale.

Quality

Iraq declared[4] that all VX and 'VX salt' produced on an industrial scale via routes A and B had been of purity below 50% and had degraded rapidly and that the VX produced in 1988 and in 1990 had been unilaterally destroyed by Iraq either in 1988 or in 1991. Iraq stated that the reasons which lead to the failure to produce good quality stable VX included the improper scaling up of the VX production process, a lack of understanding of large scale VX production process kinetics, an inability to produce good quality final organophosphorous precursors and the lack of the experience in the purification of nerve agents on a large scale. The other VX precursor, Iraqi choline, was of a very good quality (the purity of more that 90%), stable during long-term storage and was produced by Iraq in bulk quantities.

Chronology of VX production

During a technical evaluation meeting (TEM) in 1998, the Iraqi delegation indicated that research on VX started even before the MSE era, as early as in the middle of 1970's[5]. The earliest documentary evidence regarding any activities on VX in Iraq, however, is the SEPP Research Plan for the period of 1983-1984[6]. This Plan outlines the scope of research and development activities in the CW area at the MSE including the development of the best industrial production methods for sulfur mustard, nitrogen mustard, tabun, DFP, sarin, VX and BZ.

[4] Chemical CAFCD December 2002, Chapter VI
[5] UNMOVIC Doc. No.GP001794D, Report on the TEM - 17 February 1998
[6] UNMOVIC Doc No 200163.001

1987-1988

Route A

Iraq declared that at the end of 1987 it had produced one experimental batch of VX using pilot scale equipment[7]. Route A was chosen for this experiment after successful efforts to synthesize VX and its precursors, monoester and choline, at the laboratory scale at the Research and Development Directorate of MSE. When VX salt was produced via route A it was converted into final product VX via one simple step

The MSE Director General reported to the Presidency of the Republic Special Security Apparatus on 10 September 1987 that in order to verify VX preparation methods 12 experiments had been performed on the final and intermediate products at Salah al Din laboratories of the Research and Development Directorate at the Muthanna State Establishment[8]. The report suggested that it was technically possible to produce VX either at the newly constructed production unit or at one of the available MSE production units after its modification; VX could also be produced in the available glass reactors at the pilot plants. According to the report some measures were undertaken by MSE to start construction of the VX production unit and the modification of some existing production lines in order to produce VX at the rate of 1 to 1.5 tonnes per day, while maintaining the current production capacity of sarin.

Iraq declared that, at the end of 1987, route A was selected for the VX production for the following reasons: simplicity of the process with acceptable yield and purity; availability of precursor chemicals MPS (MPC) and choline; the method was well described in the literature and this was thought to be applicable to the production plants available at MSE[9].

The report of 13 September 1987 from the Director of the Ibn Hayan Plant to the General Manager of MSE outlined the proposed course for industrial scale[10] VX production by route A. It suggested that since the reactors of the 'Bin-Hayan–1' (P8) plant did not require many modifications, the agent 'Blue' (*Iraqi code for VX*) could be produced there. According to the report the plant had necessary separation units from the one side and reactors from the other. The P-8 plant was the MSE designated mustard production plant constructed by the State Company for Construction Contracts. The technological procedures for the VX production through route A were also proposed by MSE personnel, including a final step when 'AALD-500 bombs can be filled directly after the completion of the production process.[11]

As of December 1987 the Head of Salah al Din section of the Research and Development Directorate provided the details on route A noting that he would refrain from the discussing

[7] Chemical CAFCD December 2002, Chapter IV
[8] UNMOVIC Doc No 200036.001
[9] Chemical CAFCD December 2002, Chapter IV
[10] UNMOVIC Doc No 200107.004
[11] UNMOVIC Doc No 200107.004

other VX production methods since route A was selected for preparing VX[12]. He gave the following comments regarding route A: ‘the preparation of this agent (VX) is simple; there is a further study on the storage effects when using or non-using stabilizers”.

According to the report signed by the Deputy of the Director General of MSE on 5 January 1988, the first batch of VX was produced on 29 December 1987 at the P-8 plant through the reaction of choline and monoester.[13] It also provided data on the preparation of VX precursors at the Bin-Hayan-2 (Malek) plant.

Iraq declared that the purity of VX produced at the P-8 plant in January 1988 was as low as 20% and after 4 hours of stirring it decreased even further. After the organic layer with VX was obtained (about 600 kg) VX was transferred to Malik plant for removal of the solvent. The remaining quantity (400kg of VX) was filled in three AALD-500 bombs for stability test and one 122mm artillery rocket for corrosion and stability studies according to Iraq.[14] After a one-month period the purity of VX decreased to 1%. Iraq declared that three aerial bombs were destroyed in 1988 by draining the bomb’s content in the MSE graveyard followed by the treatment of the drainage area with a solution of NaOH. Iraq also declared that technical problems made this process unsuitable for the existing MSE equipment[15].

The original report from the Director of Bin-Hayan plant of 26 January 1988[16] found at Haidar Farm, also accounted for the problems which led to the failure to produce good quality VX via route A. The report mentioned that the reaction conditions had changed with the increase of the amounts in the reactor (temperature, pressure, type of solvents). But the major reason why the production run at the P-8 plant resulted in spoilt VX was the poor quality of the primary precursor monoester. According to the report the purity of monoester used for VX production was identified incorrectly. The report concluded that the concentration of monoester was measured incorrectly due to the fact that the purity of MPS (the primary precursor for monoester) was wrongly identified as well. The report mentioned that there were no problems with scaling-up of another VX primary precursor, choline. The report also noted that in an attempt to decrease the addition time during VX production process, at least two other production runs had been conducted at the plant using reverse order for reagents. These two production runs were not declared by Iraq.

Comment
Given the above information, Iraq’s declarations on the number of batches produced via route A (one batch only) are puzzling.

It is most likely that the VX produced via route A at the P-8 plant during December 1987 to January 1988 was of poor quality due to the impurities in monoester and the inability of Iraq to effectively remove the excess of the process heat.

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[12] UNMOVIC Doc No 200143.027
[13] UNMOVIC Doc no 200107-CW-007
[14] Chemical FFCD June 1996, p.1.14.1
[15] CAFCD December 2002 Chapter VI, Addendum
[16] UNMOVIC Doc No 200107.014

Follow-up activities on route A

Iraq declared that shortly after the January 1988, production attempt, MSE decided to scale-up VX production using another method (route B). However the original MSE documents indicate that at least during January-February 1988, MSE Production and Research & Development Directorates continued its efforts on the improvement of the quality of the monoester used in route A utilizing the Malek site, in parallel with the production of VX via route B[17]. Iraq did not declare these activities. The report found at the Haidar Farm outlined the problems that the personnel of the Malek plant faced. After about 240 kg of monoester was obtained it became clear that in order to produce monoester of high purity, MSE was faced with two scenarios for the distillation phase. Distillation could be completed either through:

1. the concentration of the monoester in the reactors at the Malek site and then followed by pilot-scale distillation at the R&D Directorate, or

2. in order to conduct the large-scale distillation process at the Malek site enough monoester was needed to fill the reactor connected with the distillation column.

Comment
As follows from the report, Iraqi opted for the second scenario and made a number of technological suggestions regarding optimization of the distillation process. It is not known whether the suggested modifications took place at the Malek site or if Iraq was able to overcome problems with the industrial scaling-up of monoester production and was able to optimize the parameters of the process A by which a better quality VX could be obtained. If such modifications could be achieved, it could also result in the production of good quality sodium salt (or acid) of O-ethyl methylphosphonothioate, a primary precursor considered by Iraqi for VX production through route D.

Route B

The MSE leadership decided to simplify the process of VX production and instead of route A opted for route B or the so-called “direct” method. This route allowed MSE to skip the stage of the monoester production and the associated distillation step.

During the period from 16 February 1988 to 15 March 1988, MSE conducted about 50 optimization experiments for route B, including one run with its pilot scale reactor[18]. This also included work with stabilizers, which are chemicals used to preserve the quality of the VX produced. Seven VX samples prepared at Salah al Din section were stored, using several types of solvents and stabilizers. After 10 days of storage the percentage of VX in all seven samples remained stable. Later Iraq declared (TEM of February 1998) that it had purchased a total of 2 kg of the VX stabilizer DCC (1,3-dicyclohexylcarbodiimide) and that

[17] UNMOVIC Doc No 200107.008
[18] UNMOVIC Doc No 904009.001

in March-April 1988 it conducted several laboratory experiments on VX stabilization using only 2 grams of the DCC procured[19]. As a result of this research, the R&D Directorate recommended the route B for industrial scaling-up concluding that the production process was not difficult to implement.

Comment

Iraq explained to UNSCOM that it did not know the disposition of the remaining 1.998kg of DCC after the Gulf War. In April 1997 traces of DCC and its degradation product were found, along with VX degradation products, in soil samples taken by UNSCOM. Due to the wide spread and depth of area over which DCC and its degradation product had been detected, the Commission concluded that the analytical results were not consistent with Iraq's statement that it had only conducted gram-scale experiments with DCC.[20] *The Commission concluded that the possibility existed that Iraq used more DCC to stabilize higher quality VX that it produced by other than A and B routes, since it was aware that DCC added to VX of purity below 40% would only extend the viability of the agent for a few weeks.*

UNMOVIC met with Iraqi counterparts in March 2003 to discuss Iraq's proposal to quantify Choline and VX unilaterally destroyed in 1991. Iraq presented a plan of sampling the area where VX was destroyed, in order to establish the quantity of the agent and DCC dumped there. That operation however was not completed before UNMOVIC's withdrawal in 2003. Moreover, UNMOVIC considered that the results would be charged with a high margin of error.

According to the document[21] , production of VX via route B started on 1 February 1988 at the Malek site. However, according to Iraq's declarations "an attempt to produce a batch of VX carried out by process B took place in March, 1988"[22]. This plant was initially designed as a multipurpose plant, and then was modified to produce precursors for sarin and tabun. Earlier the plant had been recommended for the VX production through route A as being 'the most appropriate'[23].

The MSE R&D Directorate planned to study the possibility of the storage of intermediary product (VX salt) and "if the storage does not influence the substance, then bigger quantities of VX salt could be produced and stored".

Iraq's declared that 350 kg of VX obtained at the Malek plant through route B (or 325 kg according to the MSE original report[24]) were collected and filled in chlorine cylinders and stored at the same site[25]. After a short period of time the purity of VX decreased. MSE

[19] UNMOVIC Doc. No.GP001794D, Report on the TEM,17 February 1998
[20] UNSCOM 186/CW-37 April 1997
[21] UNMOVIC Doc No 200107.001
[22] Chemical CAFCD December 2002, Chapter VI
[23] UNMOVIC Doc No 200107.005
[24] UNMOVIC Doc No 200107.001
[25] Chemical CAFCD December 2002, Chapter VI

concluded that the degradation of VX within such a short time may have been due to the long time of the production process which resulted in many side reactions. A concentrated solution of NaOH was added to the spoiled VX in chlorine cylinders in 1988 and left at the Malek plant.

According to Iraq's December 2002 CAFCD the MSE Director General decided to limit the VX activities to one production plant in order to prevent interference with other activities at Muthanna and to solve technical problems affecting the VX production process at one place. As result, the Dhia plant was chosen. The Dhia plant was initially designed with sufficient capacity, which would allow for increasing the production capacity of sarin and its precursors. The SEPP technical personnel chose and installed the suitable equipment in the two production buildings of the plant.

In February 1988 a technical group from MSE started some modifications at the Dhia plant in order to make it suitable for the production of VX and its precursor MPS[26]. These modifications included installing various types of process equipment in addition to that which already existed (Figure III.VIII.I).

Figure III.VIII.I Remnants of Dhia Plant located at MSE as of June 1994

Iraq declared that in May 1988 it had three attempts to produce VX via process B: batch 1 took place on 1 May 1988 (VX of purity 30% was produced); batch 2 and 3 took place on

[26] Chemical CAFCD December 2002, Chapter VI

20 May and 24 May of 1988, respectively (with respective purities of final agent 33% and 41%). In total, 1,670 kg of VX were produced[27].

Although all VX produced was not of good quality, according to the declarations the third attempt gave the best result. All VX produced was filled in carbon steel chlorine cylinders and stored at the site. The VX deteriorated within 17 days time to very low purity. The R&D Directorate suggested that another two batches of VX should be prepared: one with the use of a re-boiler and another one without it. It also proposed that the quantities of precursors used for the VX production at the Malek plant and at the Dhia plant (batch #3) should be adopted as a basis for the quantities entering the reactor, in order to arrive at a final conclusion about the approximate time needed to produce one batch of VX. According to Iraq it was not implemented[28].

According to declarations, about 1,670 kg of VX of purity less than 1% produced at the Dhia plant was filled into three chlorine cylinders and left at the site in 1988. It was discarded in 1990 by adding NaOH solution and dumped at the MSE graveyard. This statement by Iraq contradicts its other statement that neutralized VX was filled into three cylinders, transferred to the bunkers and destroyed by Iraq in 1993[29].

Iraq declared that while the R&D Directorate insisted that method B was a suitable way to produce VX, production personnel suggested that the VX production process was not suitable due to the low yield, low purity and instability of MPS and the consumption of a large quantity of MPC which was needed at that time for G-agent production. According to Iraq, the Director General of MSE decided to stop VX and MPS production activities in July 1988, except for choline because 'its stability was not affected during long-term storage and in order to justify the import of large quantities of materials before perfecting the production process'. The R&D Directorate was to concentrate its efforts on solving the problem of VX stability and finding another route for VX production.

Stability Study

Iraq declared it produced 4-5 litres of 'VX salt' around middle of 1988 via route B, which were kept in polyethylene containers for monitoring the VX salt stability. Over the period from mid-1988 to the first quarter of 1989, samples of VX salt were neutralized with Na_2CO_3 solution and sent to the analytical department. The results of analysis proved that the VX salt was stable for months (VX of purity 41% was obtained)[30]. This information correlates with data included in the report of the Salah al Din section of the MSE R&D Directorate on activities performed in 1988[31].

The report contains two references on the VX stability study. The first study called "Preparing Blue VX by a new method and controlling its storage" mentions that route B

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[27] Chemical CAFCD December 2002 Chapter VI, UNMOVIC Doc No 904049
[28] Chemical CAFCD December 2002, p.6.4.3.7
[29] Chemical CAFCD December 2002, p.6.14
[30] Chemical CAFCD December 2002, Chapter 6
[31] UNMOVIC Doc No 200071.023

"led to a new good storing method which helped preserve the Blue agent for a long period of time". The second study called 'Storing VX using a new method' recommended eliminating the final step at the VX production process via route B. It suggested that the product could be stored in the form of VX salts which Iraq named "dibis". The storage of the dibis was observed during eight months (May – December, 1988). Upon treating the dibis, VX was obtained. No significant decrease in the purity of the VX over months of storage was observed. Therefore it was recommended that route B could be used to establish strategic stores of VX agent and that when needed the required amount of dibis could be taken and converted via one easy step into the final VX. Another advantage of the VX salt was related to its safe storage conditions.

Binary VX systems

The MSE R&D report found as part of the Haidar Farm cache of documents, and the TRC report provided by Iraq to the UN Commission suggest that in 1988 Iraq became interested in acquiring binary VX technology[32]. Two parallel projects on VX binary systems were set up at the MSE and TRC. Both establishments came to the conclusion that route C was the most suitable one for the VX binary artillery systems. According to the reports, some static tests with VX binary systems for artillery shells were conducted and "results were found encouraging". It is not clear why Iraq cancelled the projects at the beginning of 1989 given their successful outcome. Later, however, Iraq declared that the work on the binary VX systems was continued by MSE through to 1990[33].

Comment
It is possible that Iraq had a plan to apply the same approach to binary VX as it had used for sarin that is, an "Iraqi binary", when one component was preloaded into munitions and the second was added shortly before the munitions was to be used. Such a system however was suitable only for aerial bombs or missile warheads, not for artillery munitions.

1989-1990

According to data in the possession of the Commission, after the end of Iran-Iraq war the MSE tried to find some commercial application for its capabilities. In 1989 MSE started various commercial projects, mostly in the area of pesticides and pharmaceuticals and also collaborated with the Al Qaa Qaa Complex in the hydrazine research and development area. There is no evidence that Iraq conducted any activities associated with the VX programme during 1989, either on a pilot or industrial scale. At the same time the MSE continued its R&D work associated with the nerve agents programme on a laboratory scale[34] For the 1989 period there is a significant lack of evidence that could confirm Iraq's statements regarding MSE activities, compare with the pre-1989 period. Iraq declared that in April 1990, following the orders of General Hussein Kamel to resume VX production

[32] UNMOVIC Doc No 200130, #701004
[33] Chemical CAFCD December 2002, Chapter 4, Addendum
[34] UNMOVIC Doc No 00130

activity, Iraq made two attempts to produce VX at the Dhia plant using process route B[35]. This plant although used for production of pesticides during 1989 kept its modified configuration for any future requirement for VX production[36]. In total, 1,500 kg of VX salt was produced in April 1990 using 800 kg of MPS redistilled from the stock of 1988. The VX salt produced was unstable, according to Iraq. Several samples were taken from the two batches of VX salt at different times and were tested for stability. The analysis results showed that VX deteriorated rapidly within two days of the production (or, according to other statements in the December 2002 CAFCD, VX purity decreased to 1% after two months of storage).[37] Iraq declared that this result, which was unexpectedly worse than the previous attempts of 1988 clearly showed that serious problems existed with the production of VX and there was no time to resolve the problems given Iraq's imminent invasion of Kuwait. According to Iraq, the stock of remaining MPC was needed for the production of G-agents. The quantity of 1500 kg of VX salt produced in 1990 spoilt rapidly and was considered nonexistent and therefore, according to Iraq, there was no record of such stock in 1990 MSE storage inventories.

Comment
These inventories provided to the Commission by Iraq constitute a significant portion of information about MSE activities during 1990 (although they refer only to the few last month of 1990).

All VX of about 0.03% purity was stored in two chlorine containers at the Dhia plant until May 1991 when it was unilaterally destroyed by Iraq in the MSE graveyard by adding concentrated NaOH and draining the solution into the soil. Iraqi declarations conclude that the grand total of 3,875 kg of VX produced over the years 1987-1990 were completely degraded and no VX remained in Iraq.

Comment
No original documents related to the CW production or R&D activities conducted by MSE during the period 1989-1990 similar to those of 1988 have been identified by the UN inspectors, despite the fact that the existence of such records in 1990 was confirmed by Iraqi personnel[38]. On one of the documents, "The report on Follow up activities of MSE for 1990 of December, 10 1990" General Hussein Kamel made a hand-written comment which gave directions to concentrate on the production of MPC, the main precursor for G-agents as well as on final product VX[39]. The UN Commission was unable to verify whether any activities associated with this order took place at MSE.

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[35] 2002 CAFCD, Chapter VI
[36] UNMOVIC Doc. No.GP001796D, 17 February 1998, Attachment 9
[37] Chemical CAFCD December 2002, p.6.4.3.9 and p.4.48
[38] UN Doc No S/1998/1106, 1998 TEM
[39] UNMOVIC Doc No 700057

Precursors

Iraq declared the following material balance of precursors imported, produced and processed for VX production as shown in Table III.VIII.I[40]:

Table III.VIII.I Material Balance for Precursors place of this table to be adjusted

Precursor Type (Qty. tonnes)	Imported	Produced	Processed	Destroyed during Gulf War	Destroyed by Iraq unilaterally	Used to produce other chemicals	Destroyed under UN supervision
P_2S_5	250	-	8	85	157	-	-
Ethylene oxide	39	-	29	-	-	-	10 tonnes remained & returned to Iraq
Di-isopropyl amine*	250	-	40	174	-	-	22
2-chloro ethanol	202	-	-	200	-	-	1.9
MPC	-	784	22	-	-	757	-
MPS	-	6 (85-90%)	3.85 (80-85%)	-	1.625 (85-90%)	-	-
Monoester	-	0.8 (50%)	0.35	0.05	-	-	-
Choline	-	58	3.1	-	55	-	-

*12 tonnes of diisopropylamine was sent by Iraq to a modern paint company in 1991 and later destroyed under UNSCOM supervision.

MPS (methylphosphonothioic dichloride) production

MPS is an important precursor used by Iraq for VX production. It was used as a primary precursor for route B and as a secondary precursor for route A. It can also be used for VX production via route D.

According to its declarations, Iraq produced about six tonnes of MPS of good quality in total in 1988, 2.5 tonnes of which were used for VX production in 1988. Another 1.4 tonnes were redistilled in April 1990 and the resultant high purity MPS was used for VX production. Iraq declared that 0.5 tonnes of MPS was polymerized and discarded in 1988 at Fallujah/Saqlayia and 1.6 tonnes of MPS had been hydrolyzed and drained into the soil at the MSE dump site in 1991[41]. The analysis of soil sample taken in 1997 by UN inspectors

[40] Chemical CAFCD December 2002, Chapter XI
[41] Chemical CAFCD December 2002, Chapter VI

confirmed the presence of the degradation products of MPS. No quantification of the destroyed MPS was possible[42].

Iraq declared that at the end of 1987, MPS was produced at the Mohammed Plant using the Kabachnik process through the reaction of phosphorus pentasulfide and MPC. In total three batches were produced. The Mohammed plant was equipped for the production of precursors for sarin and tabun. It contained corrosive resistant process equipment.

In his report of 13 September 1987 to the General Manager of the MSE, the Director of the Ibn Hayan plant proposed technological procedures for the production of MPS at the Mohammed plant consisting of several steps.[43]

According to Iraq, the first batch of MPS was polymerized due to improper process conditions. The crude MPS obtained from the next two batches was transferred to the Malik plant for distillation. About 700 kg of distilled MPS was used to produce the VX precursor monoester. In the beginning of 1988, the production of MPS via the Kabachnik process continued at the Mohammed plant. In total, after distillation at the Malik plant 1322 kg of MPS of good quality was produced.[44]. Iraq declared that in February and March of 1988, two batches of distilled MPS were produced at the same plant (820 kg and 1000 kg respectively). Those quantities were subject to further purification and, finally, a total of about 1400 kg were produced.

In May 1988 three batches of MPS were produced and distilled at Dhia plant after VX related modifications took place. The total quantity of distilled MPS of purity 85-90% obtained was about 2000 kg. According to a document provided by Iraq, the MPS preparation process lasted for 24 hours while the distillation of one batch lasted for another 24 hours. The MPS produced was filled into 200 litre barrels for storage[45]. The document suggested that another batch of MPS should have been prepared taking into account the quantities of the materials entering the reaction, their percentages, quantities of the substances produced and the percentage of conversion into MPS.

Probably because of the stoichiometry problem associated with the Kabachnik process and the need for the import of P_2S_5 banned worldwide by that time Iraq was also looking for alternative methods to produce MPS, that is,. from locally available elemental sulphur. MPS was prepared at the laboratory scale through the reaction of MPC with sulphur. Iraq stated that no further scaling –up for this process happened.

Comment
Iraq declared that during storage period of about one month the purity of MPS decreased. A likely cause of this decrease would have been the reaction stoichiometry for the

[42] UNSCOM 186/CW-37 April 1997
[43] UNMOVIC Doc No 0107.004
[44] Chemical CAFCD December 2002, Chapter VI
[45] UNMOVIC Doc No 700005.004

Kabachnik process that Iraq declared it had used, which was incorrectly described in open literature[46]. However, it is not clear whether Iraq was aware of the problem with the stoichiometry for the Kabachnik process or not since previously Iraq declared a correct amount of reagents for MPS production and claimed it obtained MPS of higher purity and better yield.[47].

Iraq has accounted for the limitations of the MPS production process at the Dhia plant: problems with the manual addition of MPS precursors, insufficient mixing rate and problems with the temperature control.

The role of MPS in the VX programme can hardly be overestimated. Iraq's researchers knew very well how important it was and put a lot of effort into improving its quality. UNMOVIC considers that at that time, that is, in 1990, there was still room for improvements in the MPS. Such improvement may have been less for its application in routes A and B, but even for these two processes, results could have led to an acceptable quality of VX as the final product. Such improvement if successful, would have, however be of key importance for route D.

"Iraqi Choline" (2-(diisopropylamino) ethanol) production process

"Iraqi Choline" is a primary precursor of VX, which is required for the production of this CW agent via routes studied by Iraq.

Iraq declared that it had produced in total 58 tonnes of 'Iraqi Choline' during the period from the end of 1987 to the first quarter of 1988 and again in the fourth quarter of 1988 and then again in the beginning of 1989[48].

According to Iraq's declarations, choline was produced from the DIPA and ethylene oxide using a modified chlorine gas cylinder. The process first took place at the end of 1987 outside of the Malek plant. The organic layer containing choline of purity 90-95% was collected, 120 kg per batch. The total quantity of choline produced in 1987 was about 4,400 kg. In the first quarter of 1988 choline was produced by the same procedure at MSE; the total quantity produced was about 2,400 kg and then production was stopped. Production of choline started again in the fourth quarter of 1988 until the beginning of 1989 with production capacity of 360 kg/day (3 batches daily) or 240 kg/day (2 batches daily). According to Iraq, the stability of choline was not affected during the long-term storage. Choline produced was filled mainly into empty DIPA barrels. The production process for choline was simple except for the necessity to use large quantities of ethylene oxide during the process.

Iraq declared that 3.1 tonnes of choline had been processed into the VX and 55 tonnes destroyed unilaterally by draining into an open pit near Samarra in 1991. The UN

[46] Chemical CAFCD December 2002, Chapter VI
[47] Chemical FFCD March 1995
[48] Chemical CAFCD December 2002 Chapter VI

Commission through sampling and analyses did confirm the presence of traces of choline and its degradation products but was unable to quantify the amount of choline destroyed by Iraq.

UN inspectors have no additional data relating to any further attempts to produce choline by Iraq. UN inspectors found a draft protocol of an official meeting of 29 July 1990 between representatives of the ministries involved in Iraq's CW program, which stated 'substance N27 ('Iraqi Choline') is currently being prepared at MSE plant'[49]. Iraq stated that the Arabic original of the protocol should be translated as 'the substance N27 is currently present at MSE, as opposed to 'currently being prepared'. UN inspectors accepted this translation.

Comment
The MSE report[50] provides information regarding MSE's interest in acquiring dimethylamino ethanol (the "true" Choline) on a large scale, which could be used instead of Iraqi Choline as 'a raw material to prepare VX'. MSE had 'large quantities of dimethylamine hydrochloride in storage' (about 570 tonnes was procured – 1996 FFCD) and it had to be used for the production of the VX precursor "in order to prevent this material from the deterioration". It is not known whether Iraq utilized this compound for its VX program, but had capabilities to do so since the production process for dimethylamino ethanol would be similar to the one for choline.

Monoester (O-ethyl methylphosphonothioic chloride) production process

Iraq declared two attempts to produce monoester, which is a primary precursor for VX production process via route A.

According to its declarations, Iraq made two attempts to produce monoester at the end of 1987. The first attempt was at the Mohammed plant. The second attempt was at the Malek plant by the same procedure. The total quantity of monoester produced was about 400 kg and this quantity was used to produce VX via route A.[51]

The MSE report of September 1987 described the production procedure for monoester at the Malek plant. It also mentions the production outcome for monoester: about 290 kg for one reactor and 580 kg if two reactors were used.[52]

Iraq declared no further attempts to produce monoester, although the MSE personnel had planned to improve monoester quality through the modifications of the Malek plant. Table III.VIII.II shows the MSE plants associated with VX production activities and respective timelines.

[49] UNMOVIC Doc No FOTO 5123
[50] UNMOVIC Doc No 200096.027
[51] Chemical CAFCD December 2002, Chapter VI
[52] UNMOVIC Doc No 200107.004

Table III.VIII.II VX production activities

Substance / Plant	MPS	Choline	Monoester	VX
P-8	-	-	-	Dec, 1987
Mohammed	End of 1987 – beginning of 1988	-	End of 1987	-
Malek	- distillation – end of 1987-beginning of 1988 -production – Feb-Mar, 1988	-End of 1987; -beginning of 1988; - end of 1988 - beginning of 1989 (p.6.4.3.2)	End of 1987	Feb, 1988
Dhia	- May, 1988 - distillation-Apr 1990	-	-	-May, 1988 -Apr, 1990

Technical requirements for VX and its primary precursors

Iraq declared that technical specifications for VX primary precursors MPS and choline were established by the Director General of MSE, based on the results of R&D trials and recommendations of the leading technical staff. According to Iraq no decision was made regarding the accepted level of purity for VX, since all VX produced deteriorated within days while in storage[53].

Comment
This explanation given by Iraq to the UN Commission demonstrates an inconsistency in their declarations for nerve agents. For example, there was an accepted level of purity for sarin during and after the Iran-Iraq war. Given that the first order from MOD to produce and weaponize VX into aerial bombs came in late 1987 it is possible that VX of similar purity was sufficient for the purposes of 'immediate consumption', given that VX itself is more toxic than sarin. It also can not be excluded that based on the fact that 'VX salt' remained stable during storage (according to the experiments conducted by MSE's R&D Directorate) Iraq may have acquired such salt in quantities for long-term storage.

Other issues

The need for the immediate "consumption" of large quantities of the toxic agents in the battlefield during the Iran-Iraq war put the pressure on MSE to operate on a large scale, without giving much priority to the quality of the agents produced. In November, 1987

[53] Chemical CAFCD December 2002, Chapter IV

MOD provided MIC with the special munitions requirements for an upcoming battle. Amongst others, the requirement to produce 750 BR-250 bombs filled with VX (which constitutes about 70 tonnes of the agent) was outlined[54]. No VX was weaponized according to Iraq since all VX produced by MSE was of low purity and not stable.

After the end of the Iran-Iraq war in 1988 the defining criteria for the CW programme changed. A new long-term concept of this programme was developed by the Iraqi leadership in the second half of 1988. New military requirements for the CW programme were established including acquisition of strategic stores of stable CW agents. During the period of the second half of 1988 and beginning of 1989 MSE started a few research projects in order to improve technology for the VX production and to obtain a pure and stable agent through various routes. Iraq studied the concept of the VX binary artillery systems as well during the period 1988-1990[55].

According to Iraq, there were no military requirements for CW established by MOD for the period of 1989-1990[56]. After August 1988 large-scale production of CW agents at the MSE was stopped due to the fact that "the CW agents produced by MSE through the previous years was in the crude state containing many impurities which affected the stability and the storability of the agents". MSE in the 1989 concentrated mostly on the civilian application of its production capabilities. According to Iraq, in the CW area, MSE conducted only research projects related either to synthesis of some new CW agents or to improving stability and storability of known agents.

The Iraqi leadership's re-evaluation of its strategic perceptions in the beginning of 1990 prompted the resumption of the CW activities at MSE at the production level including VX production.

In 1996, referring to the VX issue, General Amer al Sa'adi stated to UN inspectors that "Hussein Kamel (God bless his heart!) could not distinguish between success on the laboratory scale and success at the production scale"[57]. And, that most likely, the report of General Hussein Kamel leading to the statement of the Iraqi leadership on 2 April 1990 referred to the success with VX at the R&D level but not on a large scale. Another statement by General Sa'adi to the inspection team that the 'VX programme was under immense pressure' from the Iraqi leadership, was not consistent with the picture of the VX related efforts painted by Iraq in their declarations

Comment
In February 1998, UNSCOM convened a Technical Evaluation Meeting (TEM) in Baghdad to discuss the VX issue with Iraqi technical experts and senior government officials. The TEM concluded inter alia that, "Iraq was capable of producing significant quantities of VX before January 1991. This may have been as much as 50 to 100 tonnes of VX, albeit of an

54 UNMOVIC Doc No 138008
55 Chemical CAFCD December 2002, Chapter IV
56 UNSCOM 138/CW-28 May 1996
57 UNSCOM 170/CW33, December 1996

uncertain quality". The TEM also assessed that "Iraq had the capability to stabilize the VX produced, and may have done so".

The UN inspection teams conducted sampling as well in an attempt to verify unilateral destruction of VX and its precursors; however no quantification was possible with regard to VX and its key precursor, choline.

In UNMOVIC's view, it would have made no sense for Iraq to conceal a programme that in its estimation was a failure and in which it had no future interest. It is possible that the programme was not quite the failure claimed by Iraq or Iraq wished to retain some capability to restart the programme in the future, for example, through the retention of precursors and know-how.

CHAPTER III.IX

FURTHER DEVELOPMENT OF IRAQ'S CW PROGRAMME

Introduction

In the second half of 1988, Iraq's high-level authorities established a policy for the further development of chemical weapons. This was articulated in a letter to the President dated 20 July 1988 from Iraq's Ministry of Defence. The following two excerpts reflect the main idea of that document: "The possession and development of chemical and bacteriological weapons by our country are considered the best weapon to deter the enemy in this domain." Further, the letter mentions some active measures that should be undertaken, the first of which was: "Develop and expand the chemical weapons, both quantitatively and qualitatively in terms of munitions, delivery methods and storage, according to the capabilities made available by the Military Industrialization Commission".[1]

Changes in operational requirements

Iraq's chemical warfare doctrine was developed gradually[2]. At the beginning of the programme, Iraq gained knowledge about chemical weapons in the course of their studies and training abroad, from the open source publications, foreign patents and international conferences and forums. But this knowledge often theoretical and lacking many important technical details was not copied or applied by Iraq automatically. It was rather a process, which started with general ideas first tested on a small scale to identify and adjust unknown parameters of the synthesis of CW agents that could not be found in the open sources and then developed and scaled up to chemical weapons production in bulk and its combat use. In general, Iraq did not develop its own methods for the production of CW agents. At the beginning of its programme, Iraq's main concept was to replicate, at an industrial scale, known foreign methods and techniques of the production of CW agents. Later, however, when Iraq gained more experience both in the area of the CW production and the combat use of chemical weapons, it applied modified technologies to suit its own capabilities (for example VX production or 'Iraqi binary' concept).

One type of evidence supporting such an evolution in doctrine is official documents pertaining to Chemical Corps units, their role, tasks and combat doctrine issued by Iraq in 1984 and 1985, which replaced doctrine from 1974. Only some of these documents were made available to the Commission.[3]

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[1] UNMOVIC Doc No 902024
[2] Assessment regarding Iraq's chemical warfare doctrine is based on various sources including open publications, declassified intelligence reports, Iraqi armed forces manuals and number of statements by Iraqi officials
[3] Manual of Instructions and operating procedures of chemical units
Guide to the use of the Chemical Corps in all phases of combat

One of the reasons, given by Iraq for its use of chemical weapons against Iran was to combat and deter the so-called “human waves” that, according to senior Iraqi officials, could not be countered using conventional weapons. Iraq used this argument to explain how it tried to overcome overwhelming dominance of Iran in manpower during the war. But as was eventually confirmed by Iraqi officials, Iraq did not consider chemical weapons used during the Iran-Iraq war as weapons of mass destruction but rather saw it as a supplement to conventional weapons in achieving specific tactical and operational goals. As known from reports at the time, various Iranian military units such as artillery positions, command posts and logistics bases were among frequent targets of Iraq’s CW attacks.

It took Iraq many years to improve the effectiveness of its use of chemical weapons and so to take greater advantage of its physical and psychological impact. From isolated, poorly coordinated attacks of chemical weapons Iraq gradually moved to the use of CW as an element of combined arms operations. Iraq maximized the use and effectiveness of its CW in the second half of 1987 and in 1988.

Iraq gained much of its experience in the use of CW through trial and error, suffering sometimes from its own weapons, when used improperly. Iraq declared that it gave priority to Muthanna to increase the production and weaponization of chemical agents during the Iran/Iraq war especially when the benefits of the use of CW became apparent. These benefits included the psychological impact of CW, which created a fear factor, according to Iraq as powerful as the chemical weapons itself. Although Iraq used weapons systems for both tactical and strategic purposes, the chemical weapons gradually became of greater strategic value. There were, however, difficulties in chemical weapons production and use that Iraq was not able to overcome till the end of the Iran-Iraq war. Thus, during the Iran-Iraq war Iraq’s CW programme was not able to produce nerve agents of sufficient quality to be stored as strategic reserves.

The escalating use of chemical weapons in 1987 and 1988 was a result of its proven effectiveness against mostly unprotected Iranian troops. Such success resulted in a growing demand for chemical weapons and its use in the battlefield. Such demand provided an incentive for further improvements in the quantity and quality of both CW agents and munitions.

Iraq declared that based on its experience from the war with Iran, it considered chemical weapons as an important factor in building its predominant role in the Middle East and also as a deterrent against potential enemies. Chemical weapons were seen as an important element in a protective shield of national security. After the end of the war with Iran, Iraq was convinced that chemical weapons were an effective force multiplier and supplement to its conventional combat capabilities.

Iraq declared that despite the important role played by CW, the end of the war with Iran created an immediate vacuum within Iraq’s CW programme. The continuous demand for both chemical warfare agents and munitions suddenly stopped. For some time Muthanna continued the production of empty bombs but the continued production of CW agents made no sense, according to Iraq. Also it was stated to the Commission that the production of phosphor containing immediate precursors for nerve agents was stopped due to their deterioration rate if held in storage. "Iraqi Choline", a VX precursor was an exception because it had high purity (over 90%) and stability in long-term storage. Thus, Iraq claimed that after 1988 a large portion of existing CW production capacities at MSE remained unused.

Comment
This statement of Iraq could not be verified by the Commission due to the lack of the original documentation associated with the MSE activities during the period 1989-1990. However, during interview taken by the UN inspectors in 1995, MSE personnel stated that they produced sarin and sarin-type agents at the first half of 1989 on a large scale. Later this information was confirmed in the original quality control record of MSE of 1989.

Although Iraq considered CW a supplement and not the main factor of military capabilities and force projection, after the end of the war Iraq's chemical programme was focused on the improvement of previously produced agents and on the development of more powerful and better quality agents.

In order to take advantage of a period where there was no demand to produce and use CW agents immediately, Iraq focused on the weaknesses and shortcomings of the production of CW agents and chemical munitions. These weaknesses were known to Iraq and so Iraq incorporated a plan to address them. The existing scientific and technical potential of the CW programme was used to improve existing weapons and to build the foundation of a future CW potential. Iraq declared that there was a new concept of its CW programme including:

- Development of better quality CW agents
- Production of reliable chemical munitions
- Development of binary weapons
- Development of new CW agents and means of their delivery
- Indigenous production of precursors
- Maintenance of industrial capabilities for the resumption of chemical weapons production when needed.
- Chemical weapons stockpiles suitable for long-term storage

Better quality agents

During the Iran-Iraq war, Iraq gained substantial experience in using chemical weapons both in offensive and defensive operations. It also learned how various parameters of weather, terrain and means of delivery might affect the weapons effectiveness. Although there is little documentary evidence in this field, these factors became the challenges for Iraqi military scientists and efforts were undertaken to face them after the war was ended. Those efforts included:

- Persistency of chemical agents. High temperatures and direct sunlight caused fast evaporation of the nerve agent sarin and strong atmosphere convection led to the prompt removal of the agent cloud. Iraq recognized these problems but was not able to overcome them. One of the methods used by Iraq to partly solve the issue was the use of a mixture of sarin and cyclosarin, which had lower volatility in comparison to pure sarin. According to Iraq[4], usually the mixture of two alcohols was used in production process but some 60 tonnes of cyclosarin was also produced separately. Following this direction, other sarin derivatives were subject to research and tests after the war.[5]

- Stability of chemical agents. The low purity of chemical nerve agents was one of the main problems of Iraq's CW programme. After August 1988, MSE was tasked to improve the quality of sarin-type agents to ensure their longer storage. This work was conducted in 1989 and 1990. Sarin and its derivatives as well as VX were subject to such studies and production trials.[6] Iraq stated that these attempts however did not make a break through and were not able to significantly improve agent quality. In order to effectively stabilize chemical agents, their purity needed to be much better and the type of impurities needed to be well known before appropriate stabilizers could be selected. Iraq was able to produce good quality nerve agents on laboratory or pilot-scale levels but had difficulties with industrial scale production. Therefore, according to Iraq it decided in 1990 to develop and produce in bulk a 'Iraqi binary' system for aerial bombs and missile warheads in order to overcome the problems of stability for unitary sarin-type weapons. Iraq also decided in 1990 to concentrate its efforts on production high quality MPC – a vital precursor for both sarin-type and VX agents.

Chemical munitions

Iraq's approach to chemical munitions production during war time was very pragmatic in terms of taking advantage of any existing shortcuts that could allow the munitions to be produced quickly and in quantities. Simple adaptations of conventional types for chemical agent filling and reverse engineering were the most common. The critical components that made these munitions technically suitable for CW applications were optimized buster charges of specific size and shape and other components, such as sealing rings, filling ports and agent containers. But such modified conventional munitions could not meet all the requirements of long storage with regard to agents and their degradation products being usually aggressive chemicals. The use of chemical weapons by Iraq during the Iran-Iraq was driven by the specific conditions of that war and the related operational requirements. However, the optimal efficiency of munitions

[4] UNSCOM 239/CW-47, April 1998
[5] UNSCOM 17/CW-05, August 1992
[6] UNSCOM 153/CW-31, May 1997

was not in itself the prime criteria for the selection of munitions for use with a chemical warfare agent. The core of Iraq's CW arsenal of Iran-Iraq war period was comprised of modified conventional aerial bombs and artillery projectiles and rockets.

After the end of the war Iraq considered new types of chemical munitions. The research on more sophisticated types of chemical munitions was initiated. In order to achieve self-reliance in munitions, Iraq's CW programme produced indigenously munitions casings, including a variety of aerial bombs, using raw materials for the production of conventional munitions and manufacturing equipment procured from foreign suppliers. The production of CW munitions was linked directly to the design and production of conventional munitions by Iraq.

Iraq stated that it considered its 122mm CW rockets as very effective weapons and had decided to continue their development. Although cooperation with some of the foreign suppliers discontinued by the end of the war, some suppliers were still offering either warheads suitable for chemical fill or conventional rockets, the motors of which could be used to launch indigenously manufactured warheads.

Being aware of the short shelf life of nerve agents produced, Iraq knew it could not keep large chemical weapons stockpiles for a long period of time. To maintain a certain level of operational readiness, the nerve agents stocks would have to be replaced almost every year. In addition to the problem of stability of nerve chemical agents produced, many of Iraq's chemical munitions suffered from the corrosion caused by chemical agents, their degradation products or impurities and from leaking. These problems caused further difficulties in the handling and storing of such munitions. With the exception of 155mm artillery shells filled with mustard many of the other types of munitions used for filling with chemical agents had those defects.

Comment
A survey by the UN Commission of the Iraqi chemical weapons arsenal in 1991 revealed that the condition of filled munitions (including aerial bombs, artillery projectiles and rockets) remaining after the Gulf war varied from site to site. While some locations had well-preserved chemical munitions, at other places they were corroded and leaking.

Binary munitions

Iraq declared that it considered binary chemical munitions as a solution to the issue of stability of nerve agents. Iraq was aware of all the benefits of binary weapons, including easy and safe handling and longer shelf life.

Iraq undertook efforts to develop true binary chemical weapons, in 1983 for the first time but abandoned it due to poor results[7]. Further work was resumed in late 1987 and early 1988 and continued with selected weapons types throughout 1990. All groups of weapons used for unitary chemical agent dissemination: 152mm and 155mm artillery shells,

[7] Chemical CAFCD December 2002, Chapter VIII, paragraph. 8.9

122mm rockets, "250"-type bombs were included in the programme and subject to research and tests. The most advanced and promising results were achieved for artillery shells but in spite of that, no large production followed according to Iraq. Only around 200 prototype shells and twenty 122mm rockets were produced and tested. Iraq declared that it needed time and resources before any type of reliable true binary munitions could be produced in quantities.

During 1990 period Iraq developed an approach, which it called "Iraqi binary", involving the filling of munitions with one binary component and having another binary component separately stored and available for the loading onto these munitions immediately before their planned deployment. Thus, the mixing of binary components and the formation of CW agents inside munitions would take place prior to their combat release.

This concept materialized in the filling of special missile warheads for the Al Hussein missile and R-400 aerial bombs with binary components of sarin and cyclosarin. This very simple and easy way of building stockpiles also required high quality, stable precursors and could not be applied to artillery shells or rockets due to filling problems.

Regarding chemical warfare agents, an Iraqi laboratory tested all three main compounds: sarin, mustard and VX. Research results and field tests on binary systems for these agents were often declared as "positive"[8], however, they were not implemented according to Iraq.

Comment
According to UN inspectors, Iraq's achievements in the field of binary systems remain unclear due to limited technical documentation related to such weapons. Those documents available for example, the Technical Research Centre report[9] on development of sarin true binary systems for artillery projectiles suggests that Iraq attached high importance to binary projects in the post-war period. On the other hand, Iraq claimed[10] that between 1988 and 1991, unitary V and G agents were a more likely direction, than binary or "Iraqi binary" due to problems with storage and mixing problems with both G and V type precursors in munitions.

New chemical agents - VX as strategic weapons

The first industrial-scale trials to produce VX took place in the late 1987 – beginning 1988. The war with Iran ended in August 1988 thus Iraq declared that it had only limited time to develop VX production and weaponization prior the beginning of the Gulf war in 1991. However, in May 1988 MSE finalized the modifications at the Dhia plant – the VX dedicated production facility. The nature of these modifications was never fully explained by Iraq to the UN Commission thus causing questions on extent and advancement of the VX programme. The Dhia facility according to Iraq's technical personnel was kept ready

8 Chemical CAFCD December 2002, Chapter VIII
9 UNMOVIC Doc No. 200130
10 Report on the TEM, 17 February 1998, para. 10.2

to restart VX production until the beginning of 1991 Gulf war. Iraq always maintained that it had not weaponized any of its chemical munitions with VX.[11] Iraq admitted that development efforts associated with various aspects of VX programme however were continued throughout 1989 and 1990.

Iraqi officials stated that the CW agent VX was not planned as a simple replacement for other CW available agents (sarin and mustard), but it was considered for use in strategic weapons. Iraq considered mustard and sarin to be tactical weapons[12]. On the other hand Iraq intended to use the same types of munitions it used for mustard or sarin and no special types of munitions were produced for VX. It was the possession of VX per se as the most advanced and most toxic agent available that made it more important than others.

Iraq denied that any dynamic tests involving binary VX weapons took place[13], although in September 1997 during meetings and interviews conducted by UNSCOM some efforts involving static tests were described[14]. A binary VX study was also included into MSE research plan for 1989[15]. Later Iraq declared that it continued development of a VX binary system on a laboratory scale through 1990 period.

Indigenous production of precursors

Figure III.IX.I A precursor plant at Muthanna

Indigenous production of precursors was of primary importance for Iraq after 1986, when it faced problems and interruptions in the acquisition of precursor chemicals from foreign suppliers. Stockpiles of chemicals bought in the mid-1980's were running out and further acquisitions became increasingly difficult due to limitations on export-import of dual-use chemicals imposed by international groups.

[11] Chemical CAFCD December 2002, Chapter VI, para 6.4.3.8
[12] Report on the TEM, 17 February 1998, para. 11.2.50
[13] Report on the TEM, 17 February 1998, para. 11.3.14
[14] UNSCOM 202/CW-41, September 1997
[15] UNMOVIC Doc No 200130

Thus, Iraq attempted to procure equipment and technology for the indigenous production of critical precursors and had largely succeeded in its efforts. By 1990, Iraq had constructed a production plant for the manufacture of thionyl chloride, the precursor for the production of mustard and sarin. The construction of a phosphorus trichloride and phosphorus oxychloride (precursors for the production of tabun, sarin and VX) production plant was at the final stage. The construction of the trimethylphosphite (starting material for the production of G-agent and VX precursors) production plant was still in progress. (Figure III.IX.I shows a precursor plant at the Muthanna State Establishment).

Comment
In UNMOVIC's view, if these efforts had not been interrupted by the 1991 Gulf war and following international monitoring and verification, Iraq would have achieved a substantial degree of self-reliance in the production of major chemical precursors by 1992.

In the period from 1988 to 1990, Iraq made other inquiries to acquire both starting materials and technologies to indigenously produce precursors for chemical weapons even those for very basic ones like elemental phosphor. Since Iraq possesses large deposits of phosphate ore, its production would create conditions for unconstrained development of the phosphor – a necessary element for production of G and V agent precursors. But, according to Iraq's declarations and verification conducted by UNSCOM, those efforts were not successful[16].

Chemical agents for long-term storage

According to Iraq, the majority of mustard produced by Iraq throughout the period of its CW programme was of high purity (over 80%-90%) although some of it formed a viscous tar (polymerized material) while in storage. It was unable, however, to produce high purity, stable nerve agents in bulk quantities. For example, the average purity of tabun produced was within the range of 50-60%. Iraq stated that it had abandoned the tabun programme in 1986 because it had decided to concentrate on the production of the more toxic agent, sarin. On average, the purity of sarin and sarin-type agents produced by different methods both during and after the Iran-Iraq war was within the range of 45-60%, although some batches could contain up to 80% of this agent.

Besides failing to achieve the production of high purity nerve agents, the level of purity varied from batch to batch. Iraq explained that this variation and the failure to achieve production of high purity tabun, sarin, cyclosarin and a sarin/cyclosarin mixture was due to both the poor quality of the immediate precursors used and to technical problems associated with the production steps. Iraq further explained that the overall technological problems included difficulties with the optimization of the configuration of production equipment and process parameters for agents and their immediate precursors.

[16] Chemical CAFCD December 2002, Chapter III B

Iraq monitored the quality of both bulk and weaponized chemical warfare agent. However, Iraq provided only a small part of its quality control records to inspectors, stating that the rest had been destroyed. Fragmentary information provided in these records indicates that the mustard filled in munitions or stored in bulk containers had a very low rate of degradation and was therefore suitable for long-term storage. The records for nerve agents show that sarin had a tendency to degrade to varying degrees over a few months of storage because of the presence of large quantities of impurities. The Iraqi data[17] indicated that while sarin of initial purity 45-60% degraded rapidly during the first two months of storage (by 25 to 30%), it degraded further by only 3 to 5% during the third and fourth months of storage. In the absence of more comprehensive quality control records however, it is not possible to extrapolate degradation rates for Iraq's nerve agents over longer periods of time.

Building chemical weapons stockpiles

In order to be able to fulfill the military requirements of future battles with chemical weapons, MSE was informed in advance of the MOD requirements specifying types and quantities of weapons to be produced and deployed. Documents issued by Iraq's Ministry of Defence on this issue provided an insight into Iraq's offensive CW doctrine and planning. According to these documents[18], requirements for 7 and 23-day full operations with the use of chemical weapons prepared by the MOD in December 1988 and communicated to the MSE comprised some 150,000 chemical munitions requested by the armed forces. This quantity of chemical munitions was larger by 50% than a total number of chemical munitions declared by Iraq as used during the Iran-Iraq war.

The document reflected a growing interest of the MOD in chemical weapons. For the wartime operational readiness, the MOD required a combination of various types of chemical munitions filled with different CW agents. It may also indicate that quantities of chemical weapons supplied previously by the MSE to the army during the war with Iran were considered, as insufficient and actual required quantities were much larger. At the end of 1990, the MSE achieved a capacity to produce up to 10 tonnes of mustard and one tonne of sarin per day[19]. And yet this capacity would not be sufficient to meet the military requirements within a short period of time. Thus, increasing production on the one hand and improving storability of agents and filled munitions on the other, was a matter of strategic importance.

Commercial activities at MSE after Iran-Iraq war

According to Iraq, immediately after the end of Iran-Iraq war MSE could not consider further production of agents or munitions without orders placed by the MOD. Consequently, production was stopped. Iraq claimed that the establishment found itself in

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[17] UNMOVIC Doc No.129140.001
[18] UNMOVIC Doc No 700037
[19] UNMOVIC Doc No 700031

situation where there was no demand for its main production output and, subsequently, its source of income.

In February, 1989 the General Director of MSE, Major General Faiz Shahine addressed the Senior Deputy to the Minister of Industry and Military Manufacture regarding merging of Iraq's drug establishments and MSE.[20] Noting that such merging will present future benefits for Iraq, Shahine stated that MSE capabilities would allow expanding the medicine production base significantly. The plan outlines that 'connecting the drug industry with the MSE will create a state of joint responsibility in conditions of peace and the diminishing of the demands of armed forces' and that 'skilled and capable manpower in MSE should be employed in support of drug industry; ….some of them are at present holding senior responsibility in most of the factories belonging to the drug industry'.

Further the plan suggests that 'the activities must take place in merged MSE and drug establishment factories independent from each other, with priority for the production of drugs, general chemical material and toxic agents. The activities of research and development should be in the sphere of chemistry, drugs and lethal agents and military research '.

Additionally this plan stated that "Indeed the drug industry can provide a suitable cover for importing activities of MSE in dealing with the companies and in particular as that this industry has been established for a number of years and is known to a large number of companies and has extensive dealing with them'.

Figure III.IX.II Fallujah-2, a satellite of MSE

Thus, the MSE turned to commercial activities. Since its infrastructure from the beginning was constructed as a dual-use complex no major changes were required to start manufacturing commercial chemicals. There are documents describing these efforts.[21]

To achieve that goal, alternative facilities were needed to change its production profile into civilian applications. Iraq had a plan called "4 x 2" which meant four sites with two production units in each prepared to produce precursors and agents.[22] This project however was not implemented due to problems with the acquisition of equipment.

[20] Iraqi Doc. No 904014 Merging of joint Activities for the al-Muthanna and Drug Establishments.
[21] UNMOVIC Doc Nos. 60030, 904009.003, 200071.023, 200098, 700057
[22] Chemical CAFCD December 2002, para 13.8

Although CW-related activities were reduced at MSE, by no means, however, was the establishment deprived of its central role in Iraq's CW programme. It was rather heading towards a concept of dual-use facilities in order to preserve CW production capabilities.

In the field of commercial production by MSE, the goals were to produce basic chemicals important for civilian chemical industries. At the same time their production was to be useful in sustaining their capacity as CW precursors. One of the main tasks in this field was to finalize the construction of multipurpose satellite facilities at Fallujah 1, 2 and 3, (Figure III.IX.II) and to produce final commercial products, mainly pesticides and insecticides, at these facilities while maintaining the chemical weapons production capabilities.

Resumption of chemical weapons production in 1990

According to Iraq's declaration, in late 1989 and early 1990, there was a marked increase in media attacks on Iraq and growing threats of preemptive strikes. The tense military situation in the region presumably led up to the statement made by President Saddam Hussein, in April 1990 threatening any potential aggressor to retaliate with "binary". There is strong evidence that the statement rekindled the CW programme since the MSE officials explained that instructions to resume the CW production were also issued by MIC in April 1990. From May, MSE started intensive production of chemical munitions and in April it also produced VX at Dhia plant although according to Iraq without any specific orders from the MOD. Only late in the year did the Ministry of Defence use the previously submitted munitions requirement and set its orders according to the 7-day option.[23]

In addition to chemical munitions produced by the MSE during the Iran-Iraq war, two new types of munitions that were under the development and testing by that time were included into the production schedule for 1990. These included types of weapons considered as strategic by their nature, capable to deter potential foes from taking any steps against Iraq for fear of consequences. The perceived deterrent role of CW in 1990 concentrated more on new delivery means (the Al Hussein warhead and R-400 bomb) but not on new CW agents, except for the concept of 'Iraqi binary' for sarin. These systems are discussed in more detail in the following chapter on weaponization.

Comment
In general, at the end of 1990 MSE was again a fully operational CW production facility with growing capabilities given CW's role and importance in Iraq's political and military doctrine. The above facts and assessment were either declared by Iraq or revealed by UNSCOM and verified to the extend possible. In most cases it was corroborated by the ISG report. But still some questions remained open due to Iraq's lack of transparency, unilateral destruction and lack of documentary evidence.

[23] Chemical CAFCD December 2002, Addendum para 4.2 and 4.3

CHAPTER III.X

CHEMICAL WEAPONS

Introduction

Selection of CW delivery means

The selection of suitable munitions and delivery systems for CW agent's commenced in 1981, following the establishment of SEPP and Project 922. Prior to this date, pilot production of CW agents had occurred at the Al Rashad laboratory-scaled facility and CW agents had undergone laboratory testing, however, there is no evidence to suggest that Iraq had attempted weaponization.

For the weaponisation of its CW agents, Iraq relied mainly on its available and sustainable delivery systems. Iraq's main delivery systems included artillery guns and howitzers, multiple launched rocket systems (MLRS) and a variety of both Eastern and Western designed aircraft. The production limitations of munitions that would most effectively disperse chemical agents and issues such as munitons production technology and material supply were certainly important but were secondary considerations to the initial acceptance of a suitable means of delivery.

Within the constraints set by the availability of sustainable delivery systems, operational, tactical and technical considerations underpinned the selection process for Iraq's chemical munitions. Specific operational goals, combined with target characteristics, were the main determinants behind the selection of many munitions filled with CW agents: the optimal efficiency of dissemination of CW agents was not in itself the prime criteria for the selection of munitions for use with a particular CW agent.

The Special Tactical Group (STG), formed as part of Project 922, prepared the operational requirements for chemical weapons and selected suitable delivery means. During the Iran-Iraq war, the group was responsible for targeting information required for chemical attacks, and the identification of logistics requirements for operations. The STG was comprised of senior staffers from Project 922 and representatives from various departments and services of the Ministry of Defence (MoD), responsible for Armament and Supplies.

The Salah Al Din section of the research and development (R&D) department of SEPP/MSE was responsible for all studies related to weaponization and dissemination of CW agents, including static and dynamic testing. Dynamic testing of CW munitions was coordinated with the Iraqi Air Force (IAF) and artillery units of the Armed Forces, and was primarily conducted to determine the ability of an explosive charge to rupture a munitions case, or to assess flight characteristics of bombs, and firing tables for artillery systems.

In 1981 when SEPP and Project 922 were established, neither the Army nor the Iraq's scientific community had much experience with the production, storage or weaponisation of chemical agents. A number of munitions were tested before the decision was made to select a particular type of munition for combat use based on the criteria mentioned above.

Trials of CW weapons systems continued up until the 1991 Gulf War.

Major Munitions Weaponized

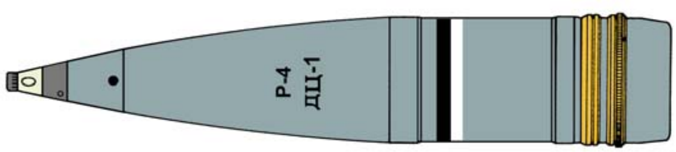
A. Artillery Projectiles and artillery rockets

130mm artillery projectile

The selection of the 130mm as a prototype munition was based on the availability of the M-46 130mm field gun within Iraq's armed forces (Figure III.X.I and II).

Figure III.X.I 130mm artillery projectile

Figure III.X.II 130mm artillery projectile ("DTS-1 SMK" type)



In 1982, SEPP conducted the first successful field trials of 130mm artillery projectiles filled with agent simulants. However, later tests of 130mm projectiles filled with tabun were not as encouraging. These poor results were attributed to tabun's low flash point; tabun was ignited by the thermal effects of the explosive burster charge However, additional testing of 130mm projectiles filled with mustard proved the viability of agent dissemination using this munition.

In 1983, according to Iraq, a conventional 130mm artillery projectile was modified for filling with mustard. Only minor technical modifications were required. The Hutteen State Establishment indigenously produced and supplied SEPP with 4000 empty 130mm smoke artillery projectile bodies. Components, including modified explosive charges and fuses, were produced and supplied by the Al Qaa Qaa State Establishment. The projectile was manually filled with approximately 1.9 litres of agent through the open nose section, and sealed. Iraq declared that all 4,000 of these munitions were filled with mustard in 1983 and consumed during the Iran-Iraq war.

Evaluation of other delivery means

In order to increase a single CW payload, SEPP continued its evaluation of other available delivery means within Iraq's armed forces, whilst still evaluating the 130mm projectile for dissemination of CW agents. Delivery systems under consideration included the 122mm rockets for MLRS and artillery projectiles for 155mm howitzers.

In July 1982, Iraq declared that it conducted with a help of the foreign company a number of static tests of 8 inch and 155mm artillery projectiles and 122mm rockets, filled with liquid and dry stimulants. Test goals were to evaluate the extent of dispersion of liquid payloads and to establish the optimal bursting charge, whilst considering dissemination size and shape. The tests confirmed the feasibility of liquid dispersion through detonation of 122mm rockets and 155mm projectiles using extended length buster tubes.

155-mm artillery projectile[1]

Following acceptance of tests results by Iraq's MoD on behalf of SEPP, Iraq's armed forces procured 40,000 empty 155mm empty smoke projectile bodies. This included all accessories and components required for the final assembly.

Figure III.X.III 155-mm artillery projectile

Figure III.X.IV Filling of *155mm projectiles with Mustard*

The procurement contract was completed in 1983. An additional batch of 10,000 projectiles was procured in 1984 by SOTI on behalf of SEPP, and in 1985 a further 35,000

[1] UNSCOM Doc No 200110

projectiles, with accessories and components were procured by the MoD for SEPP. In total, 85,000 155mm projectiles were received by SEPP from foreign suppliers.

Originally, SEPP had planned to fill 155mm projectiles with sarin however; multiple static tests conducted by SEPP did not produce acceptable results, according to Iraq. Therefore, the 155mm projectiles were filled with mustard, using similar filling technology tested and used with the 130mm projectiles. The 155mm projectiles had a payload of 3.5 litres by volume, significantly increasing the total quantity of CW agent capable of being delivered by a single artillery unit, when compared to 130mm projectile.

Iraq declared that from 1984 until 1990, SEPP/MSE filled some 68,000 155mm projectiles with mustard. Of these, 54,550, as declared by Iraq, were used between 1984 and 1988.

Comment
The 155mm projectiles filled with mustard were the most reliable chemical munitions ever produced by Iraq's CW programme. Emerging at the earlier stages of production, in 1984-1986, problems with the leakage of agent, through the fuse pocket, were eventually solved. In contrast to other types of chemical munitions, a solid projectile body with thick walls, combined with high purity mustard, assured the reliability of this projectile and its suitability for long-term storage. Several analyses of agent samples taken from some remaining munitions in 1997 and 2003, revealed high purity of mustard (over 90%).

Evidence exist that Iraq filled 155mm projectiles, marked externally as smoke rounds, with chemical warfare agent. These projectiles were filled through the nose opening and subsequently sealed. These projectiles appear to be similar to conventional smoke munitions, however they differ in that they do not have the telltale signature of the burster cup assembly visible from the outside. The possibility that munitions filled with chemical agent, may have been mistaken with smoke rounds made their determination as chemical munitions problematic not only for UN inspectors and later the Iraq Survey Group personnel, but also for Iraq itself.

122mm rockets[2]

Flight dynamics limited the use of chemical agents in artillery projectiles. SEPP recognized this fact and evaluated the use of artillery rockets as an alternative to artillery projectiles. Artillery rockets have the advantage of being simpler to produce, experience much slower acceleration forces, and can carry far greater agent payloads than artillery projectiles such as the 130mm and 155mm shells. Batteries of MLRS can launch a salvo of rockets against a target from multiple launch tubes, mounted on a mobile vehicle. The feasibility of the use of liquid payload in a 122mm rocket was already confirmed in 1982 by tests. In addition a single payload of a 122mm rocket, depending on its design and number of internal containers, can carry from five to eight litres of agent, in comparison to the 3.5 litre volume of a 155mm projectile. Moreover, few battalions of MLRS are capable of firing a large number of rockets within short period of time, creating an agent cloud with high concentrations of such agents as sarin.

[2] UNSCOM Doc No 200126

“Firos-25” type 122mm rockets

Figure III.X.V Firos-25” type 122mm (body and plastic containers)

In 1985, SEPP procured 10,000 empty 122mm “Firos- 25” type rockets, including warheads, motors, and components (Figure III.X.V). Another 15,000 rocket assemblies were procured by SEPP in 1986. The foreign producer, made several modifications to these warheads including a longitude buster tube and two plastic containers used for the filling of a liquid payload. The volume of the two plastic containers totaled approximately six litres.

"SAKR-18" type 122mm rockets

Figure III.X.VI "SAKR-18" type 122mm rockets

In 1986, SEPP procured 10,000 122mm, "SAKR-18"type rockets. Another 12,000 rockets were procured in 1989[3] (Figures III.X.VI and VII) from the same company. The warhead was designed to hold liquids with a density of between 0.8 and 1.2 gm/cm^3. There were several warhead configurations, which varied the warhead payload capacity from between six to eight litres. Most warheads contained two plastic agent containers although some were know to have up to three agent containers.

Figure III.X.VII "SAKR 18" type (upper) "Firos 25" type (lower) rocket warheads

[3] UNSCOM Doc No IQ 000258

"SAKR-30" type 122mm rockets

A comparison between SAKR-18 and SAKR-30 rockets is shown in Figure (III.X.VIII)

Figure III.X.VIII "SAKR-18" type (L) and "SAKR-30" type (R) rockets

Figure III.X.IX "SAKR-30" type 122mm rockets; warhead, motor and one section of the agent container

The "SAKR-30" type 122mm rocket was specifically intended for filling with sarin. Its design and construction, was far more complex than either "SAKR-18" type or "Firos-25" type. The "SAKR-30" type warhead comprised three individually fused sub-munitions. Within each of these sub-munitions, was a plastic agent container, and an all-ways acting fuse. The forward sub-munition was shorter and smaller in capacity than the two rear identical sub-munitions. A mechanical time fuse was used to dispense the sub-munitions above the ground, and the subsequent impact of the individual sub-munitions with the ground would initiate the burster by means of the all-ways acting fuse. In 1986 SEPP procured 6,500 "SAKR-30" type rockets. Iraq later made attempts to reverse engineer the 'all-ways' acting fuse for use in other special munitions.

Indigenously assembled 122mm rockets

Iraq developed the "Al Borak" type 122mm warhead (Figure III.X.X) as well as its own copies of "Firos-25" type and "SAKR-18" type warheads in steel and aluminium.[4] Iraq declared that it produced 16,000 aluminium warheads up until the end of August 1988. Production recommenced in 1990 with a new design, utilizing two aluminium agent containers with a steel warhead body; 4,500 of these warheads were produced.

Figure III.X.X Iraq developed "Al Borak" type 122mm warhead

In addition to 122mm rockets, which Iraq procured, SEPP assembled additional quantities of rockets from imported and locally produced components. In 1985, SEPP procured 5,000 complete 122mm rockets, with the intention of using only the motor and electrical components in an indigenously assembled CW munition. Additionally, 30,000 122mm rockets from within the Iraqi armed forces stockpiles were transferred to SEPP for use in the indigenous production of chemical rockets. Project 144, Iraq's missile establishment, produced some 18,000 aluminum 122mm warheads, between 1988 and 1990. These warheads were required as part of the final assembly to complete the chemical rocket.

Weaponization of 122mm rockets

From 1986 until January 1991, about 38,000 122mm rockets of various designs were declared by Iraq as filled by SEPP with sarin. According to Iraq, 27,000 of these were used during the Iran-Iraq war, between 1986 and 1988.

Comment
Chemical rockets for the 122mm MLRS constituted the most powerful tactical chemical weapons developed by Iraq. They were especially effective against unprotected and untrained troops.

The "Firos-25" type 122-mm rocket was trialed in 1984 to evaluate the correct size and strength

[4] UNSCOM Doc No IO 000460, UNSCOM Doc No 200063

of burster tube. From the technical documents issued by the foreign company follows that the Firos-25 was used with liquids of a specific gravity of 1.2, similar to that of mustard; however, Iraq declared that they only used these rockets with sarin, which has a specific gravity of 1.01

Multiple leakage problems occurred after the filling of rockets with sarin. "SAKR-30" type rockets were extremely difficult to handle once filled. Due to their containerized design involving sub-munition fuses and electrical wiring, it was virtually impossible to prevent agent leaking. Because of difficulties involved in handling and leakage, SAKR-30 rockets were considered as less reliable.

B. Aerial Bombs

Evaluation of aerial delivery means

Experience in the adaptation of conventional artillery munitions mainly smoke munitions filled with white phosphorus (WP), for CW purposes set the groundwork for Project 922 when Iraq embarked on the evaluation of a number of foreign aerial bombs. The munitions evaluated were chosen on the basis that they could be loaded and released from both Western and Eastern designed aircraft, thus allowing greater tactical flexibility. "BR-250" type and "BR-500" type aerial bombs, originally designed for use with WP, were considered suitable for filling with CW agents, and required only minor modifications (Figure III.X.XI).

"BR-250" type and "BR-500"type aerial bombs

Figure III.X.XI "BR-500"type aerial bombs

In 1982, without preliminary testing, Iraq's MoD procured, for SEPP, 5,000, "BR-250" type and 2,500 "BR-500" type empty bomb casings. The materials were delivered in 1983, and successfully tested with CW agents by SEPP. As the BR series of bombs were constructed of steel, SEPP experienced a number of technical and logistic problems with bombs associated with corrosion. Filling of these bombs with mustard began in 1983.

In 1983 and 1984, Iraq carried out a number of static tests, using the BR series of bombs filled with oil at Al Muhammadiyat. According to Iraq, the results were encouraging. Similarly, dynamic tests were performed at both Al Muhammadiyat and Al Razaza with the same positive outcomes. Further tests were conducted using liquids of varying densities to ensure validation of the initial test data, which used oil alone. Testing continued with bombs filled with CS (liquid) to establish the extent of agent dissemination.

Iraq conducted a number of dynamic tests into the effects of temperature due to air friction during flight, on bombs and their liquid contents. The tests involved the use of temperature strips mounted both internally and externally on the bomb's body. The bombs were then subjected to a number of tactical flight scenarios ranging from 15 to 30 minutes. In 1987, Iraq performed the first dynamic tests of sarin-filled BR bomb using live animals housed in caravans at Al Razaza as a target.

"AALD-250" type aerial bomb

"AALD-250" type aerial bomb was modified to simplify its manufacture and to optimize its efficiency and effectiveness as a means of delivery. Initially it was filled through the nose with mustard. The bomb was modified by the addition of a filling port, which allowed for easier filling of the bomb at unit level. This modification meant that filling the bomb did not require the aid of specialized machinery. The filling process itself was very crude. An individual dressed in protective clothing filled the bombs manually. Once the burster tube was installed and the bomb was sealed, the bomb would be transported to the dispatch area for removal to storage or issued directly to combat units.

Figure III.X.XII A frame from a video recording of flight tests of a modified "AALD-250" type aerial bomb

In 1988, flight tests of a modified "AALD-250" type aerial bomb, designated the Al Muthanna-3, fitted with aluminium agent containers were performed at the Habaniyah air base (Figure III.X.XII). Iraq experienced stability problems with the flight characteristics of the bomb, which were fixed in later versions.

Indigenous production of aerial bombs, "AALD-250" type and "AALD-500" types

With intent to increase its self-reliance in CW munitions, SEPP established an indigenous capability for the manufacture of aerial bombs. Raw materials were received for the production of 10,000 "AALD-250" type low drag general-purpose aerial bombs in 1983 from a foreign contractor. However, the supporting technical documentation and additional machinery requested by SEPP were not supplied.

In 1984, SEPP procured technical documentation, equipment and additional raw materials for the construction of an aerial bomb production workshop. This facility was designed for the manufacture of "AALD-250" type and "AALD-500" type low drag general-purpose aerial bombs, which could be modified and filled with CW agents. Raw materials included semi-finished metal plates, un-machined forged parts, and a set of moulds to form bomb components. SEPP received raw materials for the production of 2,000 "AALD-500" type bombs, 3,000 "AALD-250" type aerial bombs (Figure III.X.XIII) in 1985. Also in 1985, the remaining equipment and technical documentation was delivered. Raw materials for the production of an additional 10,000 "AALD-500" type bombs (Figure III.X.XIV) were delivered 1986. The aerial bomb production workshop at the Samarra site of SEPP, also known as the "Nasr Factory", was ready to start the production by 1986.

Figure III.X.XIII "AALD-250" type low drag general-purpose aerial bombs

In 1986, Iraqi technicians were trained on production and assembly procedures with trial assembly runs for 2,000 "AALD-250" type bombs. However, the mass production of 10,000 "AALD- 250" type did not start until the first quarter of 1987. Several modifications to the production process were introduced during the course of the bombs manufacture. The first modification was to simplify the nose section. Additionally the steel booster cover was welded directly to the nose. The second modification involved reducing the number of parts for the nose assembly to a single unit. The fin was welded directly to the bomb body because of some problems with tail section during flight.

The Nasr Factory in the course of manufacture of AALD-250 and AALD-500 aerial bombs performed the numerous production operations.

In order to complete the production line for “AALD-500” type bombs, SEPP tried to procure additional equipment and technical documentation, including 400 and 100 tonne hydraulic presses, a 400 tonne mechanical press, a circular submerged arc welding machine, two sets of dies and assembling tools and equipment. According to Iraq, this equipment was not received by Iraq by August 1988 when hostilities with Iran had ceased.

Figure III.X.XIV “AALD-500” type low drag general-purpose aerial bombs

Filling of “BR-250”, “BR-500” and “AALD-250”, “AALD-500” type aerial bombs with CW agents

The “BR-250” and “AALD-250” type bombs, which had a capacity of 60 litres of agent, were filled by SEPP/MSE with mustard, tabun and sarin from 1984 until January 1991. In total, nearly 8,000 250 kg bombs were filled with CW agents, of which some 6,500 were declared as used by Iraq during the war. A few hundred of BR-250 and AALD-250s were filled with CS.

The “BR-500” and “AALD-500” type bombs, which had a capacity of 120 litres of agent, were filled by SEPP/MSE with mustard, tabun and sarin from 1983 until January 1991. In total, over 14,000 bombs were filled with CW agents, with over 12,000 used by Iraq during the Iran-Iraq war. Additionally, according to Iraq, in 1988, three bombs were filled with VX for corrosion and stability tests. A few hundred were also filled with CS.

Comment
Despite a number of technical issues with the above mentioned bombs: corrosion, relatively fast degradation of G-agents, polymerization of mustard, and leakage of agents, these munitions formed the cornerstone of Iraq's chemical weapons arsenal. These bombs were filled with almost 75% of all agents weaponized by SEPP/MSE. The bombs were not intended for long-term storage and, in fact, were used within months of production, during the Iran-Iraq war. However, they were accepted by the air force and fitted to all available aircraft. They were simple to produce, handle and deploy. The use of these bombs for weaponization of CW agents represents an example of the adaptation of conventional munitions, requiring only minor technical modifications and adjustments, for CW purposes.

According to Iraq's original documentation, in the second half of the 1987 Iraq's MoD requested MSE to fill 750 AALD-250 bombs with VX. The Director –General of MSE reported back that it would be possible after sufficient quantities of VX precursors would be produced by MSE. However, the Commission cannot confirm whether such order was ever fulfilled during the first half of 1988, when VX production was conducted. Iraq always denied weaponization of any chemical munitions with VX.

Aerial bombs reverse engineered for dissemination of CW agents

DB-2 aerial bombs

Figure III.X.XV "SKS-360" type incendiary bomb

Another group of aerial weapons evaluated by the SEPP/MSE for use with chemical agents comprised multiple versions of incendiary bombs and tanks. The major advantage of these devices was their large (several hundred litre) payload. "SKS-360" type incendiary bomb was selected as a prototype (Figure III.X.XV). In 1987, it was reverse engineered by the State Establishment for Mechanical Industries (SEMI) at the request of MSE, and given the designator DB-2. The DB-2 had a capacity of 260 litres of agent which was almost two times larger than the 140 litre capacity of the "BR-500" and "AALD-500" type bombs. Iraq planned to fill the DB-2 bombs with sarin. The construction material of the original prototype had been changed by SEMI from steel to aluminum to prevent body corrosion and reduce the degradation rate of the chemical agent. The DB-2 was armed with either mechanical impact fuse or airburst proximity fuse. However, due to the design and structural restrictions of the bomb it was manufactured with Eastern block suspension points only (Figure III.X.XVI).

Figure III.X.XVI DB-2 aerial bomb

Production of the DB-2 bombs began in February 1988. Iraq declared that it produced 1,389 bombs until August of that year when production was suspended. Due to its extremely soft and thin aluminum body, the DB-2 bomb presented problems for the Iraqi Air Force. Because of its thin body, when being jettisoned the bomb could rupture releasing the chemical agent. Additionally the agent –filled bomb was susceptible to damage during routine handling by ground staff because of its payload weight and was therefore deemed unacceptable by the Iraqi Air Force command. However, according to Iraq, 155 DB-2 bombs were filled with sarin[5] and used in combat in 1988. UN inspectors found evidence that a dozen of these bombs were also filled with sarin/cyclosarin in 1990.

[5] UNSCOM Doc No 700024

"R-400" type aerial bombs [6]

Figure III.X.XVII "R-400" type aerial bombs

In April 1990, MIC, through its Air Force and Navy armament departments, investigated the development of a chemical bomb capable of being dropped from low altitudes and suitable for deep ground penetration.

The "BRIP-400" type a foreign-designed conventional high explosive bomb (Figure III.X.XVII) was used as a template for the design and construction of a new chemical bomb. This bomb was designated the M-400, or Muthanna 400/Challanger, and was later called the R-400, R standing for (parachute or "high drag") retarded. The conventional BRIP-400 bombs had already been flight and release tested by the Iraqi Air Force several times between 1986 and 1989. The bomb had passed acceptance trials and was cleared for flight. The Iraqi Air Force tested 123 bombs in a number of configurations, using different fuses and types of tails.

[6] UNSCOM Doc No 700044

Figure III.X.XVIII R 400 Filling port

Once selected, the prototype and components of two sets of bomb bodies and tail assemblies were sent to the Al Nasr State Establishment for reverse engineering (as distinct from the Nasser bomb factory at SEPP/MSE). The project commencing in April 1990[7] was rushed into production in May of the same year. The bomb was constructed from carbon steel, made up of three sections welded together. Finally a high drag, parachute retardation tail was attached. A longitudinal booster tube was fitted from the front of the bomb and secured by welding and a filling port added (Figure III.X.XVIII). Finally the tail and parachute assembly were fitted; the tail and parachute were not manufactured by Iraq but came from the stocks of the conventional "BRIP-400" type bomb. Iraq claimed that the tail assemblies were too complex to indigenously manufacture in the time available, and accordingly were sourced from exiting Iraqi Air Force stocks. The foreign contractor delivered a number of variants of these tails to Iraq in the mid-1980s. The R-400 bomb was suitable for fitment to both Western and Eastern aircraft, and after successful flight and drop testing MSE ordered 1000 bombs in May/June of 1990[8], followed by an additional 24 bombs, for quality control testing. The production of the R-400 was carried out in June, July, and the order completed and delivered in July of 1990.[9]

In 1990, over 1,000 R-400 bombs, each having about a 100 litre capacity, were filled with a mixture of alcohols, isopropyl alcohol (20 litres) and cyclohexanol (20 litres) which were components of a binary sarin-type nerve agents. Forty litres of MPF, the other binary component, was to be added to each bomb at airfields prior to loading the bombs onto the aircraft.

(R-400 bombs filled with BW agents are discussed in another chapter)

Comment
The development and production of R-400 bombs significantly upgraded Iraq's arsenal of chemical munitions in terms of expanded operational parameters of their deployment rather than efficiency in dissemination of CW agents. Using the "binary" system allowed the bombs to be pre-deployed to airbase and shorten the time for their use. However, this was only true whilst Iraq maintained air superiority. In comparison to the previous generation of low drug aerial bombs, R-400 bombs were capable of ensuring a higher precision in covering selected targets and allowing carrying aircraft to penetrate enemy air defense at a low flight altitude.

The new bomb did not bring additional benefits for the optimal dispersion of agents. However, with its 12mm steel body it was more robust and easily handled by ground crews with minimum

[7] UNSCOM Doc No 700056
[8] UNSCOM Doc No 700060
[9] UNSCOM Doc No 700101.097

fear of leakage or agent release through accidents. In addition, bombs without toxic agents could be handled with greater ease and less conspicuously. As long as the R-400 bomb was filled with the mixture of alcohols only it was suitable for a longer storage period. This was not true however if the full binary mixture was already loaded in to the bomb as corrosion and agent degradation would occur in a similar manner as for other carbon steel bombs. The efficiency with which the binary components would mix during flight was largely unknown.

C. Missile Warheads

Al Hussein chemical warhead[10]

In April 1990, MIC instructed MSE and Project 144 to investigate the use of an Al Hussein conventional warhead for use with CW agents (Figure III.X.XIX). Tests were conducted in April and May of 1990, beginning with static tests and later flight tests using warheads filled with water, oil or spoilt sarin.

Figure III.X.XIX "SCUD" type missile

Initial studies by Iraq indicated that in order to maximize the effectiveness of the chemical agent, the warhead would need to explode above the ground. However, the fusing system for the conventional Al Hussein high explosive warhead was an impact fuse rather than a proximity fuse. Since no proximity fuse was available for the Al Hussein warhead in Iraq at the time, nor was it likely that one be procured in the near future, a decision was made to retain the existing impact fuses. On 8 and 18 April 1990, Iraq conducted two flight tests, one warhead with oil and water and the second test with live agent.

[10] UNSCOM Doc No 700061, UNSCOM Doc No 700033

Following these field trials, an agreement was reached between MSE and Project 144, to initiate production of the warhead. Of the approximately 80 containers manufactured for sarin, five were consumed for ground tests; three in warheads for a static test, and another two containers during hydrostatic tests as part of Project 144. In all 20 containers were rejected because they failed pressure tests. Some agent containers were made from aluminium because of Iraq's experiences with other chemical munitions and corrosion and some were made from stainless steel because it was easier to manufacture than from aluminium.

There is no difference between the chemical and conventional warhead airframe design for the Al Hussein missile. The chemical (and biological) agent warheads have internal containers made of aluminium or stainless steel and three burster tubes but externally the airframes have the same appearance.

Special warheads for the Al-Hussein missile

Figure III.X.XX Al Hussein Agent Containers

In 1990, Project 144 modified 75 warheads for the Al-Hussein missile, by placing an internal 150-litre container, made of aluminum or stainless steel, inside the warhead airframe (Figure III.X.XX). Modifications included balancing of the warheads, to maintain a similar center of gravity to the conventional version. MSE filled 50 of these warheads with CW agents and binary components. Sarin and cyclosarin were filled into 16 warheads and another 34 warheads were filled with alcohols as a binary component similar to the one used in the R-400 bomb. The concept involved alcohol, as one binary component being loaded into each warhead, then prior to launch, MPF, the second binary component would be added to the alcohol, which would mix together in flight to produce sarin. This concept did constitute what became colloquially known as an “Iraqi binary” munition (Figure III.X.XXI)[11].

Figure III.X.XXI Al Hussein Chemical Warhead

D. Binary Munitions

In addition to weaponizing unitary CW agents, SEPP evaluated filling binary agents into different types of munitions including projectiles, rockets and bombs. In August 1988, after the successful test of the 152mm binary projectiles, a recommendation to the Special Munitions Committee, stated that the system worked and that it would be suitable for other artillery munitions like 155mm.

Binary artillery projectile

In 1983, prototype “binary” 155mm projectiles (10 items) were supplied to Iraq. These projectiles were fitted with two carbon steel containers and two fuses. One fuse was required to allow mixing of the binary agents after firing, and the other to dissemination of the mixed agent

[11] Biological warheads are addressed in another chapter

after an appropriate flight time. According to Iraq[12] however, these prototypes were not effective in the mixing of agent and no contract was signed with the company for further production. Iraq continued studies into producing a binary artillery projectile. By the end of 1987 or the beginning of 1988, Iraq was developing a system that used the acceleration and spin forces of the projectile in flight to mix binary components. Further trails, using both 155mm and 152mm projectiles were conducted at a number of sites in Iraq in 1988 and 1989, with nearly 200 projectiles being tested.

Comment
It is likely that the initial designs and concepts for Iraq's binary munitions were acquired through the technology transfer from the foreign company, whose 155mm binary designs were used and modified with some success by Iraq.

152mm Binary Mustard

According to Iraq, as a result of a joint research project between MSE, MIC, and Al Noaman[13] a binary munition was tested in July 1989. The main aim of this project was to include a design characteristic for the projectile, which would allow the mixing of two binary components in flight to produce a toxic agent prior to arrival at the target. The concept was for the "Binary" system to have the following characteristics:[14]

a. Chemicals must be easy to produce, transport, and store,

b. Chemicals must preserve their potency over long periods of storage,

c. Weapons must be easily accessible when needed,

d. General cost will be reduced because of the lack or need for preventative measures.

Iraq declared[15] that it modified a number of 152mm propaganda, base ejection projectiles to carry two aluminium containers. The containers were filled with the raw materials for the production of mustard agent. However, according to Iraq, during testing of the projectiles, they experienced difficulties controlling the rate of reaction between the two agent precursors. Iraq declared that it did not pursue a solution to this problem for mustard, and UN inspectors found no further evidence to the contrary.

Comment

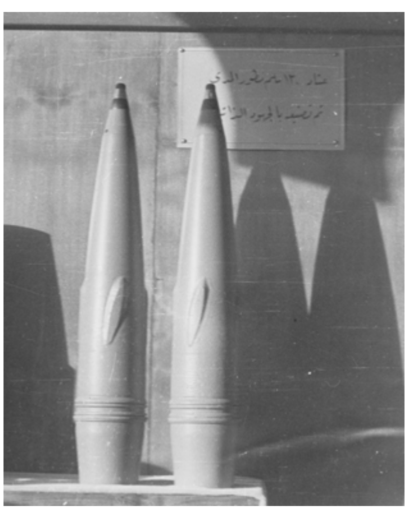
Assessment by UNMOVIC experts has concluded that sufficient energy could be produced from such a reaction to prematurely initiate the projectile fusing system.

[12] Chemical FCFD February 1998, 8.12.3
[13] UNSCOM Doc No 904009.003 Attachment III.2 to the Verification chapter Chemical FFCD of June 1996
[14] TRC document on binary munitions 1988
[15] Chemical FCFD 1996 8.9.1.5

Figure III.X.XXII Base ejection for 152mm artillery projectile

155mm Extended Range Full Bore Boat Tail (ERFB-BT) Binary Sarin

Figure III.X.XXIII 155mm Extended Range Full Bore Boat Tail (ERFB-BT) Binary Sarin



In 1989, following the lessons learnt with the 152mm binary mustard tests, Iraq fitted and fired at least 120 items of the 155mm ERBB artillery projectiles (Figure III.X.XXIII). These projectiles were fitted with two aluminium containers similar to those in the 152mm projectile tests for binary mustard. The binary components for sarin were loaded and the projectiles fired at a target area containing live animals. According to Iraq’s declaration, these tests were more positive than the 152mm tests, however Iraq did indicate that these munitions never went into series production.

152mm Binary VX[16]

Iraq declared that a foreign 152mm illumination projectile was used in these tests. The illumination charge was removed from the projectile, and replaced by a two-piece aluminum, copper or polystyrene, container separated by two barriers each having a specified density, thickness and shape, and made of either aluminum or thick plastic. This design was chosen to examine the efficiency of the deterioration in the separating membrane due to the acceleration and centrifugal forces imparted on the projectile upon firing. The containers filled with binary components were fitted into the projectile from the rear. Three laboratory tests conducted using the aluminum and plastic barriers showed encouraging preliminary results, surpassing the original design concept, which required a glass container and electrical circuitry to break the membrane barrier. The reaction of some of the VX agent preparations using a catalyst, gave encouraging results, which Iraq thought, may be suitable for binary weapons use.[17]

122mm binary rockets

In 1989, a workshop at MSE tested 122mm binary rockets, which contained two plastic canisters each. A mechanical valve designed to control the mixture of the binary sarin-type components separated the two containers in the warhead. The results of tests were positive. In the light of the above, a number of aluminum containers were manufactured with a ball made of carbon steel for rupturing the membrane between the containers.

A test of modified 122mm warheads filled with coloured liquid, achieved encouraging results. The tests were re-conducted in 1990 using MPF and isopropanol, by launching five rockets without explosives; once again, the results were encouraging, but not reliable enough for production, according to Iraq.

Prototype binary bomb

Iraq modified a number of indigenously produced aerial bombs (Nasr-250, CB-250) in an attempt to produce a binary aircraft bomb. In 1989, Iraq tested a number of prototypes to establish the mixing efficiency of binary agent precursors. Additionally a CB-250 bomb was also modified in much the same way. Only a few of these prototypes were produced and according to Iraq, destroyed during the bombing campaigns of the 1991 Gulf War. The designs provided by Iraq lack the inclusion of any centralized burster tube, indicative of all Iraqi chemical bombs.

[16] UNSCOM Doc No 701004
[17] UNSCOM Doc No 701004

E. Other Munitions Evaluated

Artillery Rockets

122mm chemical warheads

In 1987 Iraq declared that it received from the foreign contractor aluminium made samples of its version of the "SAKR-18" type rockets. This version used a steel adapter to attach the warhead to the rocket motor. These warheads were provided to Iraq with documentation indicating that they were, at the very least tested if not specifically designed, for use with liquids of a specific gravity similar to that of mustard. The offer from that foreign company was not taken up by Iraq and Iraq pursued the development of its own aluminum warheads. Also in 1987 discussions were held between Iraq and the foreign contractor on the use of common agent containers for both SAKR-18 and SAKR-30 chemical warheads; however, no procurement happened.

107mm rocket

Iraq declared that, "Other ideas presented by Project 144, for binary systems were conversion of warheads for C-24, and 107mm rockets", and that no prototypes were produced." UN inspectors observed the 107mm rockets with conventional warheads in Iraqi ammunition depots. The 107mm rocket is similar to the larger 122mm rocket; however, it has a much smaller payload and shorter range.

Comment

The components found at the Al Taji munitions depot in 2003 by UNMOVIC appear to be unfinished base assemblies for a rocket of approximately 107mm in diameter. The similarity in design of this item, when compared to the base assembly of the 122mm Firos-type chemical warhead, and other 122mm base plates for chemical warheads, suggests that this item is indeed a component of a chemical warhead.

Larger Rockets

Iraq considered a number of artillery rocket systems offered by foreign companies including "SAKR-80", "SAKR-100", "SAKR-200" and "Firos-60" types. A number of tests were conducted with these rockets. Their warheads were filled with liquids of a specific gravity of around 1.2 grams per cubic centimeter, similar to the chemical agent, mustard.

450mm FROG artillery rocket

In May 1988, Project 144 offered to design a cluster warhead for CW agents to be used on the FROG-7 rocket. A mock-up prototype was made and according to Iraq, the project was abandoned because of a lack of interest. Iraq declared, that in May 1988 a project designated "*Luna S*" was initiated to convert the FROG rocket warhead into a cluster warhead constructed of aluminum and using certain components of the Ababil-50 rocket. According to Iraq, MSE rejected the proposal to use an aluminum projectile as a container for CW agents and the project was abandoned in July 1988. Iraq stated that only sketches had been produced and that no prototypes had been built.

UNMOVIC discovered a cluster warhead fitted with live explosive cord, for the FROG (Luna) rocket, at the Al Naoman factory in Baghdad in 2003. The warhead was empty and therefore could not be conclusively linked to prohibited use, however was fitted with live explosive detonating cord which would indicate that this was more than just a mock up version.

Aerial Bombs

DB-0 and DB-1 aerial bombs

Figure III.X.XXIV indigenously produced aircraft drop tanks

From 1984 until the end of Iraq-Iran war in 1988, SEMI at Iskandariyah produced over 4,500 aluminium bombs. These bombs were similar to the foreign “BIN” type[18], and provided to the Iraqi Air Force. Consequently 61 such bombs, designated the DB-0, were subjected to trials at

[18] Note: a carbon steel napalm tank was recommended by Air Forces as a prototype. It was reverse engineered by the bomb workshop at MSE and produced from aluminum. An original MF-1000 fuse was used. Components were produced at the Hutteen State Establishment.

MSE, for possible use as a large capacity chemical munition. Iraq planned to drop this bomb from transport planes in a stacked in a pile with a parachute (Figure III.X.XXIV). Therefore, the DB-0 and DB-1 bomb had no suspension holders. For the purpose of mechanical stability the bomb was covered with a fiberglass. The DB-0 proved to be unsuitable for safety reasons[19], and according to Iraq's declarations, the project was abandoned. Also trials with the DB-1 bomb did not produce the desired results.

SDN aerial bombs[20]

Figure III.X.XXV SDN aerial bombs

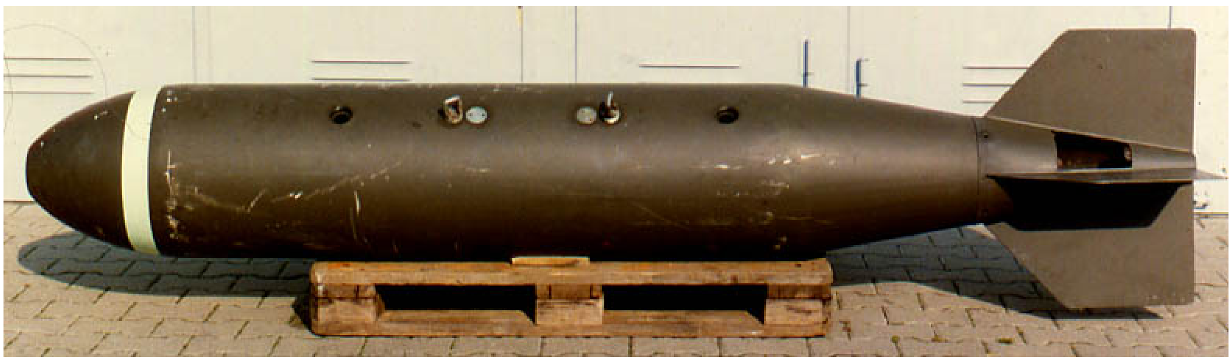


Figure III.X.XXVI DB-1 bomb –body covered with fiberglass

In 1986 Iraq was supplied with 12 "SDN-750" and "SDN-500" type bombs. Iraq filled a number of these bombs with agent for corrosion resistance evaluation (Figures III.X.XXV and VI). In 1987, "SDN-750" type bombs were filled with oil and tested at Al Habaniyah for their suitability for use as a chemical weapon. The bomb was not pursued as a means of chemical agent delivery because of problems encountered during flight tests. Iraq had two versions of "SDN" type bomb: one produced in steel and the other in aluminium.

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[19] It was produced from 2mm thick aluminum and the soft body of the bomb was not able to withstand the forces it experienced when filled and piled into the configuration Iraq had chosen.
[20] UNSCOM 12/CW-04, September 1991; Chemical CAFCD December 2002, Chapter VII, para 8.12.1

Nasr-7

Figure III.X.XXVII Nasr-7 Aerial bomb

Also in 1987, testing was performed on the Nasr-7 bomb to determine its suitability for use with chemical agent (Figure III.X.XXVII). Flight test results indicated that even after only 15 minutes the temperature on the bomb, due to the friction, was too great and unacceptable according to Iraqi engineering requirements.

Al Qaa Qaa-250 and Al Qaa Qaa-500 aerial bombs

Figure III.X.XXVIII Al Qaa Qaa-250 aerial bomb

In 1987, Iraq conducted a number of static and dynamic tests using both the Al Qaa Qaa-250 and Al Qaa Qaa-500 aerial bombs at Al Habaniyah airfield, with the assistance of the Al Qaa Qaa State Establishment (Figure III.X.XXVIII). As a result of these trials the bomb was found to be unacceptable and was not pursued further.

Aluminium AALD-500 aerial bombs

In 1987, four aluminium "AALD-500" type bombs were supplied to Iraq for reverse engineering, to produce its own version of this bomb. The project was not pursued by Iraq and according to Iraq no contracts were signed for this new bomb.

Indigenously produced cluster bombs

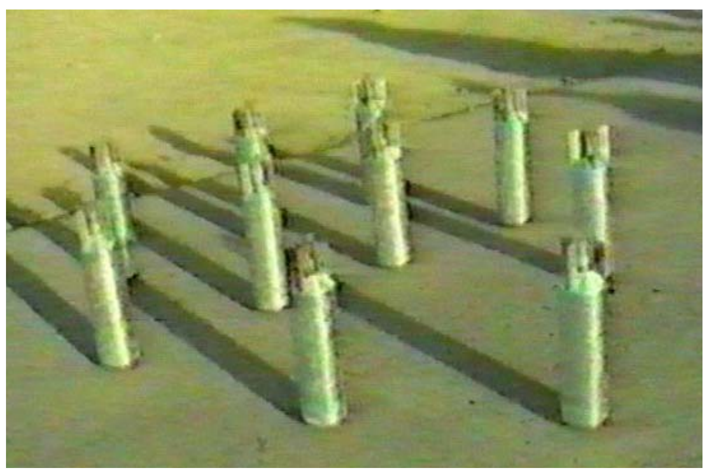
Iraq indigenously produced at least two known types of cluster bombs and some cluster warheads for rockets and missiles. Evidence of a 120kg class cluster bomb was found by UNMOVIC, at the Al Taji Munitions Depot in February of 2003.

Comment

In UNMOVIC experts' opinion, the technology that lends itself to the successful design and manufacture of conventional cluster munitions, may by virtue of its very design[21] *contribute to the efficient dissemination of chemical or biological agents.*

CB-250

Figure III.X.XXIX Sub-munitions for a cluster bomb



In July 1989, a joint research project between MSE, MIC, and Al Naoman[22] was initiated to manufacture a cluster bomb, which was a copy of CB-250, to be loaded with chemical agent sub-munitions. The sub-munitions which were manufactured from aluminum tubing similar to that used for the 122mm artillery rockets, held approximately 3.5 litres of liquid, and could be fitted with an all-ways acting fuse[23].

[21] Cluster sub-munitions are multiple point source, giving effective dissemination of chemical agent
[22] UNSCOM Doc No 904009.003
[23] UNMOVIC, Iraqi Special Weapons Guide, 122 mm SAKR30

The fuse used in the "PM-1" type anti-material sub-munitions was fitted to at least two versions of the chemical sub-munitions and after some eventual success; a number of bomblets were manufactured and arranged inside the CB-250 dispenser. Iraq stated that in the summer of 1987, flight tests were carried out with two bombs charged with 18 bomblets full of a liquid (oil). Another two bombs dropped at the Airfield 37 test range, gave negative results because they were released outside the operating parameters of the sub-munitions and bombs fuses. The tests were discontinued although the concept was not abandoned. It is clear from information contained in Iraqi documents on the production of the all-ways acting fuse[24] that one of the primary reasons for its development was for use in "CB-250" type cluster bomb to more efficiently deliver chemical agent (Figure III.X.XXX).

Figure III.X.XXX Iraqi cluster aerial bomb ("CB 250" type)

Figure III.X.XXXI A frame from a video recording of a cluster bomb experiment

During an interview [25] in 1996[26], one Iraqi researcher stated that Iraq had experimented with the use of cluster bombs for biological agents. On at least one other occasion, biological agents and cluster bombs were mentioned in statements made by Iraqi officials. The statement was later recanted: he indicated that this kind of bomb was never used or intended for being used for VX or biological agent. He was presumably talking about the use of the CB-250, fitted with the 122mm containers. According to Iraq's declarations[27] the CB-250's, one for each agent, were filled with mustard, sarin, and cyclosarin for corrosion and agent stability tests. Another possible explanation for this

[24] UNSCOM Doc No 200097
[25] UNSCOM Document No 920004 of 02 Sep 1999
[26] UNMOVIC Doc No 901010
[27] Chemical FFCD June 1996, Chapter I, para.1.14.1

statement was that Iraq was considering the use of their indigenously produced version of "CB-470" type cluster bomb.

Comment
What is clear is that Iraq did intend and in fact manufactured a number of cluster bomb sub-munitions that were designed for use with chemical agents. The nature of cluster munitions is such that once the concept if proven and tested with conventional sub-munitions, it can easily be applied to chemical or biological sub-munitions.

Spray tanks

Iraq declared that it had modified an aircraft's external fuel tank to trial the spraying of chemical agents at MSE. However, apparently the work conducted was inconclusive and was abandoned in August of 1988, at the end of the Iran Iraq war. It is unclear whether a 1990 reference by the director of MSE to the use of mustard from spray tanks was indeed just that, or whether he confused this project with the biological spray tank project, which occurred in November 1990 as he later said.

All-Ways acting fuse

In 1987, Iraq reverse engineered the "All Ways" fuse, used by the sub-munitions in "SAKR-30" type chemical rocket warhead. Iraqi copies of these fuses were fitted to 122mm sub-munitions,

Figure III.X.XXXII All-Ways acting fuse

similar to those used in the CB-250 (Figure III.X.XXXII). Iraq first experimented with an "All Ways" fuse in the first week of November 1987.

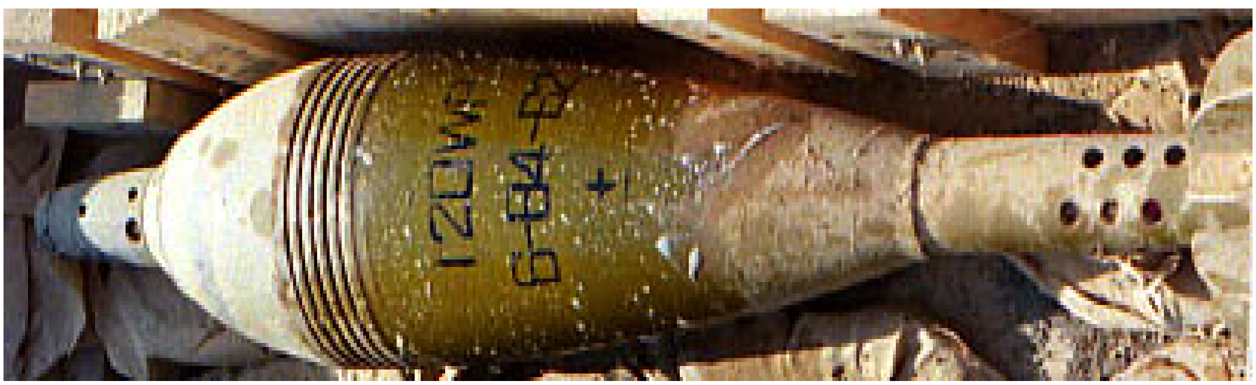
Iraq tried to indigenously produce an all-ways acting fuse at Al Qaa Qaa so as to be compatible with a range of Iraqi CBW munitions. The fuse was intended as both a primary and secondary means of initiation for munitions. According to Iraq, its plan was to have available in it's inventory a mechanical fuse, which would function regardless of orientation at impact, was sensitive enough to work on both hard and soft targets, and was able to be used in a number of different munitions. Iraq was concerned about Unexploded Ordnance (UXO) of a chemical or biological nature, and the international attention this would generate should Iraqi “special” weapons be recovered by Iran or by international organizations.

From a technical point of view, Iraq saw the development of the all-ways acting fuse, and the 122mm sub-munitions they had tested in “CB-250” type cluster bomb, as a method of increasing the efficiency of their chemical munitions.

Iraq tried to indigenously manufacture the all-ways acting fuse, for both efficiency and economic reasons. The fuse could be manufactured using locally available raw materials. It could be produced much cheaper than the version supplied. The fuse could be integrated into existing “special” munitions designs to increase efficiency of agent delivery and dispersion, and would be more reliable, and therefore less likely that there would be telltale evidence of the use of chemical weapons through the presence of UXOs.

Munitions filled with CS[28]

Figure III.X.XXXIII Munitions filled with CS



In addition to the weaponization of major CW agents, SEPP evaluated filling of different types of grenades and mortar bombs with the riot control agent CS, for use as direct fire support for attacking troops (Figure III.X.XXXIII). From 1982 until 1984, Rocket Propelled Grenades (“RPG-7” type), 82mm and 120mm mortars were successfully tested with CS. From 1984 until 1985, an unknown number of “RPG-7” type grenades, and over 1,000, 82mm, and 20,000 120mm mortars were filled with CS. “RPG-7” type grenades and 82mm mortars were indigenously produced by Iraqi companies and supplied to SEPP. Empty 120mm mortars casings were procured in 1985. According to Iraq’s declarations, a number of 120mm mortars were filled with mustard, tabun and sarin for corrosion and stability tests. There is also documentary evidence that at some stage that Iraq planned to fill these munitions with sarin, however, according to Iraq, this did not happen. In addition, a few hundred 250kg and 500kg bombs were also filled with CS.

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[28] UNSCOM Doc No 200110

Gas canisters

A test using a smoke canister containing Adamsite, CS and smoke generating chemicals was carried out at a chemical proving ground in 1988. According to Iraq's declarations the result was not encouraging. This statement is contradictory to other Iraqi documents[29] indicating that the results of trials with Adamsite were acceptable to the Special Weapons Acceptance Committee.

Dusty agents

The term "dusty agent" is used to refer to a CW agent that has been adsorbed on a finely divided solid carrier as a means to disperse a liquid agent as a dust.

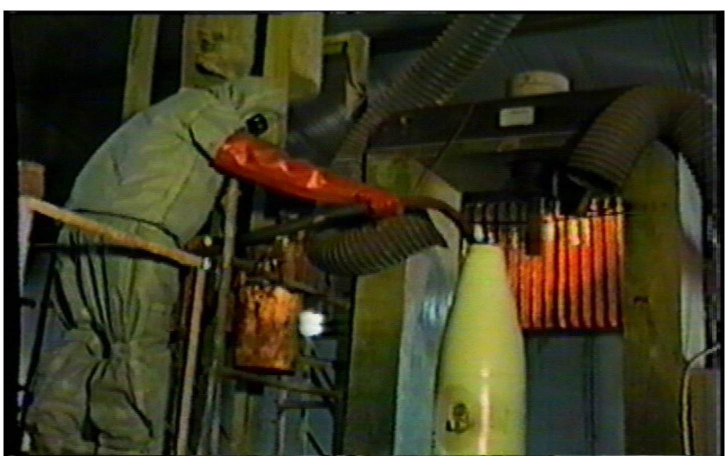
Iraq denied that it had had any interest in dusty agents. UN inspectors found a document[30] in the Haidar Farm cache titled "*Drawings for Dusty Agent Research*" which dealt with the equipment required for the production of the dust, and referred to a "*generator of the black dust*".

Comment

The "black" in Iraq's "generator of the black dust" could suggest that Iraq was studying the use of activated charcoal as the absorbent, or that the active agent was Sarin, as Iraq also used the term "black" as a code for this agent. Although Iraq was familiar with dusty agent technology and also had the necessary materials, equipment, and experience in coating solids to produce dusty agents, UNSCOM found no evidence that Iraq produced dusty agents. More likely that Iraq would have focused on more effective uses of its resources than for weaponization of dusty agents.

Filling of munitions with CW agents

Figure III.X.XXXIV A frame from a video record from a filling plant



In 1982, the filling station at SEPP, the Al Farez Plant, consisted of two dual sheds. Each shed contained an improvised filling unit, compiled by SEPP from a domestic gas cylinder filling line procured from an overseas company, and glass pipes locally manufactured at the glass workshop. From 1983 to 1985, 130mm and 155mm projectiles were filled manually using this equipment (Figure III.X.XXXIV). The volume measurement and control was crude using a visual observation of

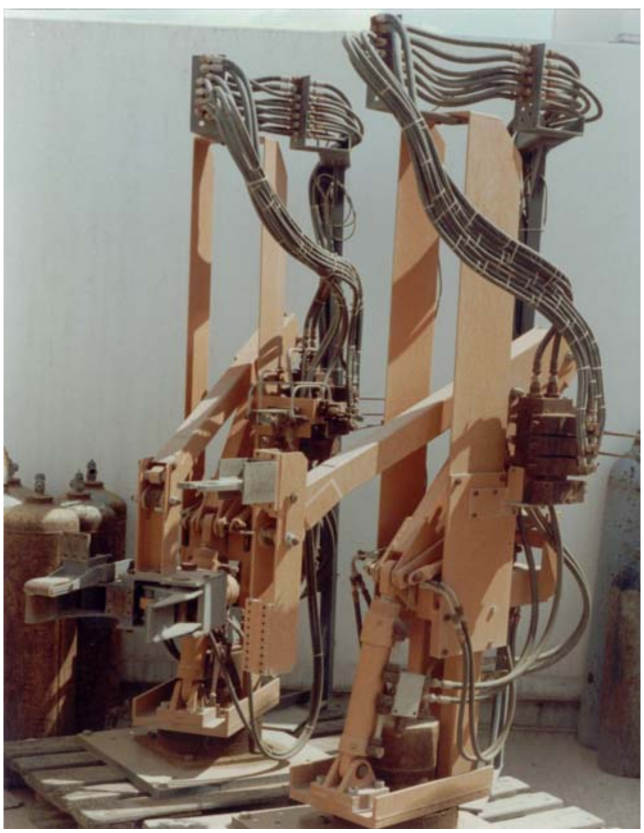
[29] UNSCOM Doc No 200095.001
[30] UNSCOM Doc No 701006

agent level through a glass tube that was fixed to the loading vessel. Munitions casings were manually placed on a conveyor and transported inside the shed. The projectiles were filled with a volumetric tank, equipped with manually operated control valves. The filling capacity was about 35 projectiles per hour.

After filling, a burster tube was inserted by hand and then mechanically pressed to seal in the agent. Prior to 1986, all aerial bombs were filled manually in the open in the vicinity of the filling station. Later, “LD-250” type bombs were stored standing upright and taken by forklift truck to the filling rig. The bombs were then manually filled with agent through the nose via an operator dressed in protective equipment and a hose. The operator would then insert the burster tube and fuse well assembly, which was then press fitted into the bomb, sealing in the agent.

This type of filling operation was later changed when Iraq modified their stocks of chemical weapons by introducing a transverse filling port, thus simplifying the process of bomb filling.

Figure III.X.XXXV Robotic equipment installed at the filling station for the filling of 122mm warheads

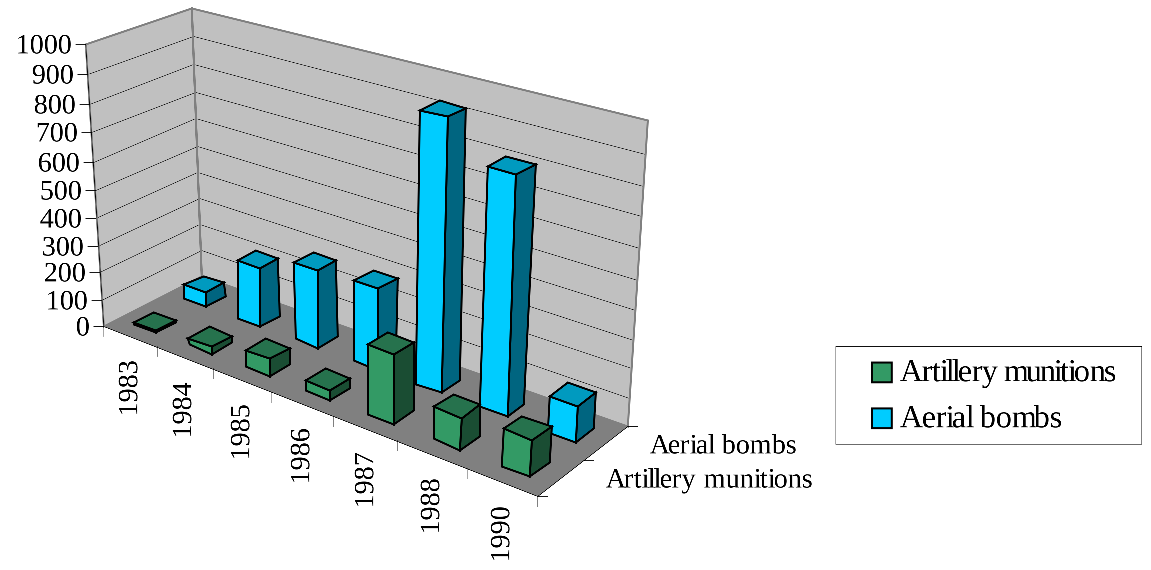


In 1985, a semiautomatic filling line was built at the filling station, using equipment procured as well as locally manufactured parts and components. The line was intended to fill and seal aerial bombs. Starting in 1986, the bombs were filled by barrel pumps and were sealed with a locally manufactured mechanical press. The unit had a capacity of twenty 250 kg or twelve 500 kg bombs per hour.

In 1986, robotic equipment was procured and installed at the filling station for the filling of 122mm warheads. Volumetric sensors were used to doze and control filling operations. By the end of 1990, there were four operational filling lines at the filling station, including dedicated filling units for aerial bombs, artillery projectiles, 122mm rockets and 120mm mortars. The sheds housing the filling units were equipped with scrubbers, air coolers and ventilation equipment.

Quantities of CW agents, in metric tonnes, weaponized by SEPP/MSE for the period from 1983 to 1990 are shown in Chart III.X.I below:

Chart III.X.I Tonnes of CW Agent in Munitions by Year, as declared by Iraq

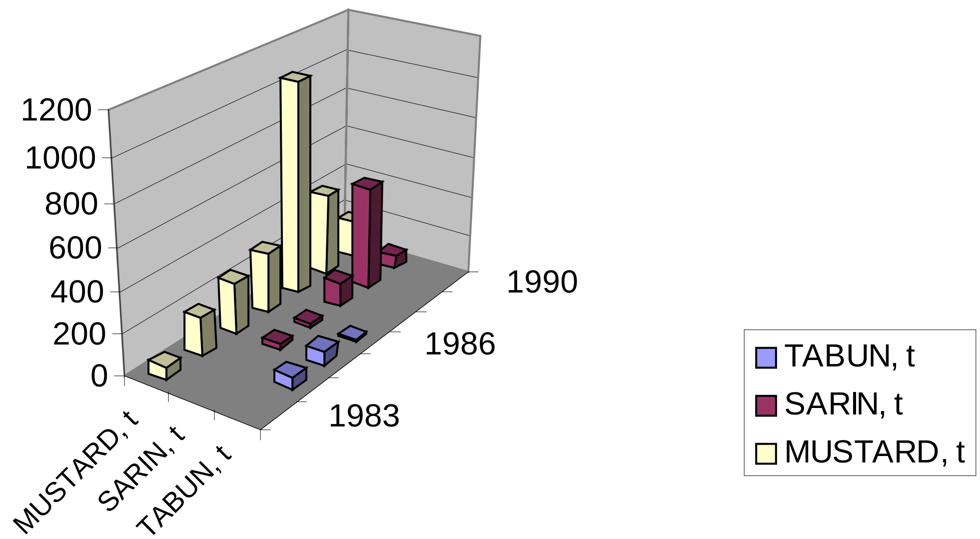


	1983	1984	1985	1986	1987	1988	1990
Artillery munitions	10	27	61	32	243	110	123
Aerial bombs	53	220	284	292	931	807	126

There was no bulk chemical agent produced or weaponised in 1989 according to Iraq's declarations. It produced an unknown number of weapons (probably small) in 1981 and 1982.

More than 80% of CW agents were filled in aerial bombs. According to Iraq, of the total of some 3,850metric tones of chemical warfare agent produced, over 3,300 tonnes of CW agents were weaponized, including some 2,400 tonnes of mustard, 140 tonnes of tabun and over 700 tonnes of sarin as shown in Chart III.X.II.

Chart III.X.II Tonnes of Agent Weaponized by Year, as declared by Iraq



	1983	1984	1985	1986	1987	1988	1990
TABUN, t		60	69	10			
SARIN, t			24	15	122	507	67
MUSTARD, t	63	187	252	299	1052	410	182

There was no bulk chemical agent produced or weaponized in 1989 according to Iraq's declarations. It produced an unknown number of weapons (probably small) in 1981 and 1982.

In the period from 1981 to 1991, Iraq weaponized some 130,000 chemical munitions. Of these, over 101,000 munitions were used in combat, according to Iraq.

Quality control at SEPP/MSE

Significant technical problems with chemical munitions were caused by corrosion and the degradation of CW agents. The degradation rate, which occurred for different agents in particular weapons depended on both the quality of agents and construction material of munitions. The major parameters of agent quality comprised their purity, combination of sub-products and by-products and volume concentrations of resulting impurities. Some by-products and sub-products of CW nerve agents, such as hydrogen fluoride, were extremely aggressive chemicals that dramatically accelerated the corrosion process.

Heavy corrosion between the carbon steel of the munitions bodies of the BR and AALD series of bombs and the CW agents, led to unacceptable agent leakage. Leakage also occurred due to mechanical damage to munitions during their transportation and handling. Multiple instances of leakage resulted from mechanical defects and poor workmanship during the production of munitions casings.

Mounting internal gas pressure in aerial bombs filled with CW agents was the result of ongoing chemical reactions involving chemical warfare agents and other reagents contained in the impurities in combination with corrosion processes. High internal pressure led to the rupture of munitions. Additionally, a specific problem occurred with the polymerization of mustard in munitions, mainly aerial bombs.

In 1985, SEPP established a Quality Control section to oversee and control the production of CW agents, their key precursors, munitions casings and components, weaponization and to monitor the quality of filled chemical munitions and bulk CW agents.

Several attempts were made to mitigate leakage of chemical munitions, these included the dozing of munitions filling operations at the filling station to prevent overloading munitions casings beyond 90% (by volume), which could contribute to increased gas pressure within the munitions.

The Quality Control section established minimal acceptance criteria for major CW agents to be weaponized by SEPP/MSE; 40% purity for tabun and sarin and 80% purity for mustard. According to records of the Quality Control section, the average purity of tabun and sarin, from 1984 to 1988 was between 45% and 50%.

Bulk and weaponized nerve agents produced at MSE although low in purity remained viable until 1992. International inspectors had reached such conclusions prior to the destruction of bulk and weaponised nerve agents, which occurred under international supervision.

Conversely, the average purity of mustard produced was above 85%. This mustard is known to have remained at average 80% purity level until 1992, when its remaining quantities were destroyed under international supervision. The purity of mustard produced and filled into 155mm artillery projectiles, remained at 95% purity level until 2003, when the last remaining munitions were destroyed under international supervision.

Chemical weapons, produced by SEPP/MSE during the Iran-Iraq war, from 1981 to 1988, were not intended for a long-term storage. Most of the chemical weapons produced during this period were deployed and consumed in the same year, therefore the low purity of CW agents generally affected only munitions remaining in storage after 1988.

After the end of the Iran-Iraq war, Iraq’s MoD outlined new operational requirements, including a capability for the long-term storage of chemical munitions as well as the need for more lethal agents. From 1989 until 1990, MSE conducted several studies, and ran production trials, to develop technology for the production of higher purity CW agents, mainly sarin and cyclosarin and experimented with a mixture of sarin and cyclosarin. In addition, Iraq continued the development of binary agents such as those described above.

Although these efforts helped slightly to improve the agent quality, they did not achieve any revolutionary breakthrough. The average purity of sarin/cyclosarin produced in 1990, according to records, was still only around 50%, and did not exceeded 60%. The purity of sarin/cyclosarin formed from the binary composition did not exceed 55%. However, a true binary concept solved, to a certain degree, a problem of stability.

System of chemical munitions and operational requirements

Standard battle scenarios prepared by Iraq's MoD envisaged both, defensive and offensive operations and thus comprised requirements for different types of chemical munitions to assure operational flexibility.
The following types and numbers of chemical munitions were required for a seven-day battle scenario, as of 1987:

Munitions type	CW fill	Caliber	Quantity of munitions
Aerial bomb	Mustard	AALD-500	1,232
Aerial bomb	Sarin	AALD-500	1,232
Rocket warhead	Sarin	122mm	8,320
Artillery projectile	Mustard	155mm	13,000

Iraq acknowledged that regular military combat units in operational theatres, using conventional munitions, were to receive and use chemical weapons if necessary, under special directives. This suggested that even if chemical munitions were stored and handled separately from conventional munitions at ammunition depots, that they could have been inadvertently issued or accounted for as conventional munitions by the user units. Iraq's ammunition marking codes were notoriously inconsistent and still remain unclear.

Storage and handling of chemical munitions

Filled munitions

SEPP/MSE was the major contractor to MoD, and was solely responsible for the provision of all chemical munitions to Iraq's armed forces. According to Iraq's declarations, interviews with Iraqi officials and documents found in Iraq, over the period from 1981 to 1991 SEPP/MSE filled and delivered to the MoD over 130,000 chemical munitions. These numbers do not include mortar bombs filled with riot-control agents.

Of the nearly130,000 munitions filled with CW agents, some 105,000 were supplied to the Iraqi armed forces during the Iran-Iraq war between 1981 and 1988. Of the 105,000 munitions, 101,000, filled with about 3,000 tonnes of CW agents, were deployed, and used in combat by Iraq over the same period. The remaining 25,000 filled chemical munitions, were delivered by MSE, to the armed forces after the Iran-Iraq war, and shortly before the 1991 Gulf War.

During the 1980s, SEPP only accumulated stocks of filled chemical munitions within the scope of specific orders from the MoD as described above. Prior to their shipment by trucks to the armed forces, temporary storage of chemical munitions occurred at reinforced concrete bunkers in the storage area at SEPP/MSE, and at dedicated storage areas controlled by SEPP, at two conventional ammunition depots, Muhammadiyat and Al Ukhaider. Chemical munitions were shipped to central and regional conventional ammunition depots and air bases. From here munitions could be issued to artillery units and Air Force regiments. After chemical munitions had been issued, SEPP/MSE maintained responsibility for the periodic technical inspection and maintenance of munitions in the possession of the armed forces units.

Defective or leaking chemical munitions were routinely recalled and handled by SEPP/MSE, resulting in the accumulation of hundreds of filled and defective munitions held at SEPP/MSE establishments. According to documents found in Iraq, some unused chemical munitions were returned to MSE in August 1988 after the end of the Iran-Iraq war.

Comment
It remains unknown whether all the remaining chemical weapons were actually collected and returned to MSE. Iraq did not provide sufficient production, deployment, and consumption records, for its chemical weapons, to verify this question.

The second large-scale chemical weapons production campaign occurred from April 1990 to January 1991. During this period MSE produced and supplied the armed forces with 25,000 chemical munitions referred to above. According to Iraq's declarations, the weapons were deployed to 17 ammunition depots, airbases and airfields throughout Iraq. The locations of these depots are provided in the supporting table and shown on the following map. There was no evidence suggesting that they were issued to field military units, with the exception of 50 chemical warheads for the Al Hussein missiles deployed to the Technical Battalion of the Surface-to-Surface Missile Corps.

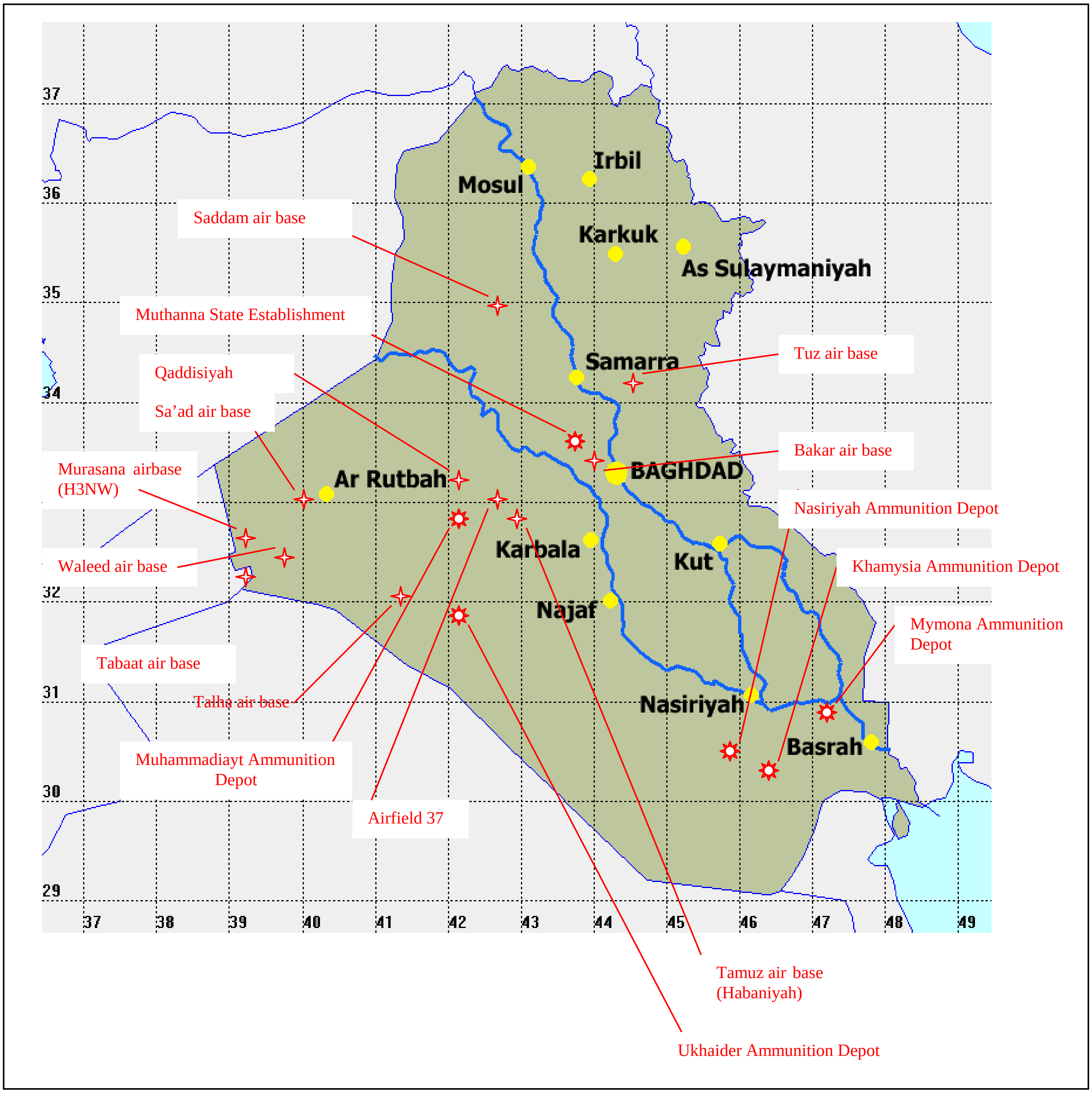
In addition to chemical munitions delivered by MSE to the Iraqi armed forces in 1990-1991, hundreds of chemical munitions remained in MSE's custody; these weapons consisted of munitions left over after the Iran-Iraq war and defective munitions not suitable for combat use. According to Iraq's declarations, most of these munitions were destroyed or damaged by the coalition through the aerial bombardment during the 1991 Gulf war.

Location of munitions filled with CW as of January 1991[31]

#	Storage name	Munitions
1.	Airfield 37	250 kg aerial bombs
		R-400 aerial bombs
2.	Bakar air base	250kg aerial bombs
		500 kg aerial bombs
3.	Murasana air base (H3 NW)	R- 400 aerial bombs
4.	Qadissiyah air base	R- 400 aerial bombs
		250 kg aerial bombs
		500 kg aerial bombs
5.	Sa'ad air base (H-2)	R- 400 aerial bombs
6.	Saddam air base	R-400 aerial bombs
		250 kg aerial bombs
		500 kg aerial bombs
7.	Tabaat air base (H3 SW)	R- 400 aerial bombs
8.	Talha air base	R- 400 aerial bombs
9.	Tamuz air base (Habaniyah)	R-400 aerial bombs
		250 kg aerial bombs
10.	Tuz air base	250 kg aerial bombs 500 kg aerial bombs
11.	Waleed air base	R- 400 aerial bombs
		250 kg aerial bombs
		500 kg aerial bombs
12.	Ukhaider ammunition depot	122mm rockets
		155mm artillery shells
13.	hamissiyah ammunition depot	122mm rockets
14.	Muhammadiyat ammunition depot	250 kg aerial bombs
		DB-2 aerial bombs
		155 mm artillery shells
15.	Mymona ammunition depot	122mm rockets
16.	Nasiriyah ammunition depot	155mm artillery shells
17.	Muthanna State Establishment	122 mm rockets
		250 kg aerial bombs
		500 kg aerial bombs
		155 mm artillery shells

[31] UNSCOM Doc No 700030, UNSCOM Doc No 700029

Figure III.X.XXXVI Location of munitions filled with CWA as of -January 1991



Empty munitions

According to Iraq's declarations, in addition to munitions filled with CW agents, 98,000 munitions were acquired or produced by SEPP/MSE, for CW purposes. These munitions remained unfilled up until 1991. Empty munitions were kept at multiple storage areas in the vicinity of MSE under its control, and at several military ammunition depots and munitions production facilities within in Iraq. The locations of these munitions are shown in the following table and on the supporting map.

Comment

SEPP/MSE was able to implement its major function and to supply a variety of chemical munitions to the armed forces. Within the constraints imposed upon it, SEPP/MSE worked to develop chemical weapons that were effective within context of their perceived threat and operating environment.

Iraq had a relatively sophisticated technical work force, however, was limited in its ability to transcend some critical technological barriers, such as issues related to design and construction of complex delivery means, including electronic fusing and control systems.

As a consequence of the Iran-Iraq war, Iraq developed methods to address the technical issues it experienced when handling chemical munitions. By storing sufficient war reserves of filled munitions for short periods only and by keeping the remaining weapons as bulk agents and empty munitions, the issue of agent degradation and corrosion were partially overcome.

Empty munitions, their raw materials and production equipment, procured by Iraq from foreign suppliers, largely contributed to the success of its weaponization efforts. An indigenous conventional munitions production capability facilitated Iraq's ability to modify and reverse engineer munitions for use with chemical agent. The transfer of foreign technology was essential for Iraq to achieve the level of indigenous production of its delivery systems

Iraq developed knowledge and experience in the modification of conventional munitions, to hold and disseminate CW agents based on the initial testing of 130mm and 155mm chemical artillery projectiles and 122mm rockets. The basic design principles used for this development was transferred to modification and reverse engineering used in all of Iraq's chemical munitions. These included a means for filling and emptying munitions with liquids, increasing explosive burster tube lengths, changing explosive charges, and addition of agent containers of various materials to prevent corrosion and reduce agent degradation.

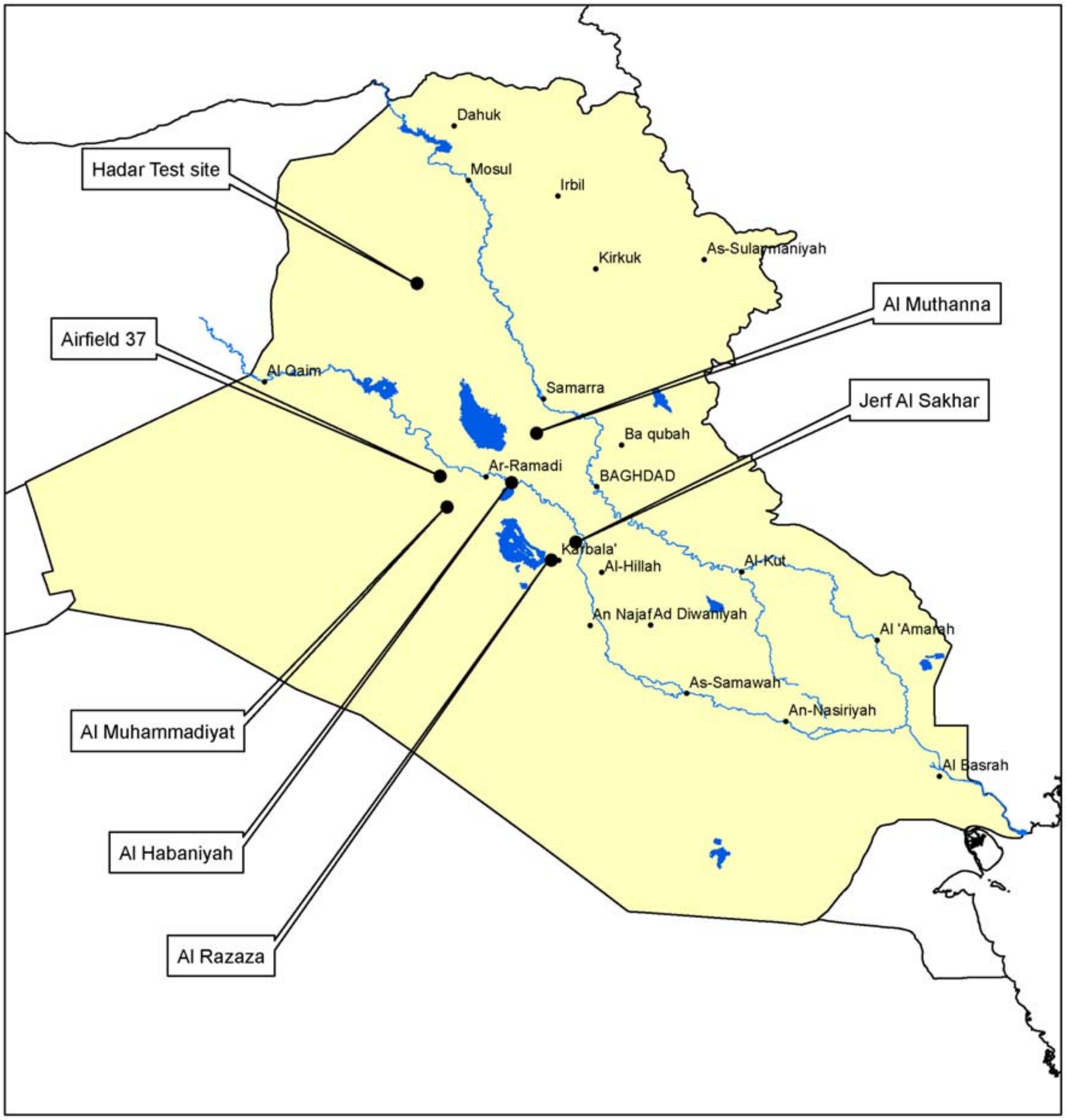
The experience of verification of Iraq's chemical munitions showed that to recognize the subtle modifications used to convert conventional munitions into chemical munitions a detailed understanding of the original munitions materials, design and manufacturing process was required. Understanding all conventional delivery means available to Iraq was essential for the recognition of Iraq's chemical weapons munitions, their distinctive parts and components.

Location of unfilled chemical munitions as of January 1991[32]

#	Storage name	Munitions
1.	Ukhaider ammunition depot	122 mm rocket motors
2.	Fallujah ammunition depot	122 mm rocket motors
3.	Haditha 1 ammunition depot	122 mm rockets
4.	Haditha 2 ammunition depot	122 mm rockets
5.	Muhammadiyat ammunition depot	122 mm rockets
		250 kg aerial bombs
		DB-2 aerial bombs
6.	Salah Al-Din ammunition depot	122 mm rockets
7.	Taji ammunition depot	155 mm artillery shells
8.	Muthanna State Establishment	122 mm rockets 250 kg aerial bombs

[32] UNSCOM Doc No 70030, UNSCOM Doc No 700029

Figure III.X.XXXVII Chemical Weapons test sites



Chemical Munitions Tests carried out within Iraq

- Bahr Al Najaf
    - 130mm Tabun (1982, 1983)
- Al Muhammadiyat
    - BR-250, BR-500 (1983, 1984, 1985)
    - BR-250 CS (1984)
    - 155mm projectiles burster strength (1984)
    - 155mm projectiles Sarin (1984)
    - 122mm Al Borak Sarin (1988)
    - AALD-250 White Phosphorous (1988)
    - 155mm Binary Sarin (1989)
- Airfield 37

Alternate names: Air field 37 Al Muhammadiyat
    - CB-250 18 bomblets (1987)
    - R-400 bombs (1990)
- Al Muthanna
    - AALD-250 White Phosphorous (1987)
    - 122mm Al Borak burster strength (1987)
    - DB-2 (1988)
    - 122mm Al Borak burster strength (1988)
    - RPG-7 (1988)
    - 122mm Firos-25 with canisters (1988)
    - All-ways acting fuse (1988)
    - 122mm agent containers for binary Sarin (1989)
    - 122mm binary Sarin (1990)
    - CB-250 and Nasr-250 binary bombs (1990)
- Al Razaza
    - 122mm SAKR-18 (1987)
    - BR-250 Sarin (1987)
- Al Habaniyah air field
    - Al Qaa Qaa-250, Al Qaa Qaa-500 (1987)
    - AALD-250 with four canisters (1988)
- Jerf Al Sakhar
    - 82mm 120 mm mortars (1982, 1984)
    - Smoke rockets (1983, 1987)
    - RPG-7 (1983)
    - 122mm Firos-25 burster strength (1985)
    - 122mm Firos-25 test fire (1985)
    - 122mm SAKR-30 colored liquid (1988)
    - 122mm Al Borak oil (1988)
    - 152mm binary Sarin (1988)
    - 152mm binary VX (unknown)
    - 152mm binary Mustard (1988)
    - 155mm ERBB binary Sarin (1988)

Overseas Tests:

- 122mm SAKR-18 and SAKR-30 (in 1984, 1985 and 1986)
- 155mm projectiles (1983)
- 122mm Firos-25 (1984)

APPENDIX: UNMOVIC FINDINGS REGARDING CHEMICAL MUNITIONS IN IRAQ

Introduction

Between 27 November 2002 and 17 March 2003, UNMOVIC conducted over 90 inspections of munitions related facilities in Iraq. During the course of these inspections a small number of either proscribed munitions, components of proscribed munitions or suspect related items were either discovered by UNMOVIC inspectors or examined as the result of declarations by Iraq.

UNMOVIC inspectors examined examples of seven types of chemical or biological munitions previously known to UNSCOM and discovered evidence of six additional types. Additionally, UNMOVIC inspectors discovered evidence of two types of cluster munitions possibly related to chemical or biological munitions that had not been noted by previous UN inspectors. Lastly, UNMOVIC inspectors examined two types of munitions that had possibly been intended for use with chemical agents but were instead loaded with high explosives.

Organization of the document

UNMOVIC's findings regarding chemical munitions examined are divided into three groups according to UNMOVIC's approximate degree of certainty regarding the purpose of the munition. These groups include the following:

- Group A: Findings Regarding Confirmed Chemical Munitions
- Group B: Findings Regarding Munitions and Components Linked to Prohibited Programmes
- Group C: Findings Regarding Munitions and Components Whose Purpose is Under Review

This document includes also comments stemming from UN and Iraqi documents revisited in the light of Iraq's declarations of 2002 and UNMOVIC findings in the period November 2002 – March 2003.

Group A. Findings Regarding Confirmed Chemical Munitions

Disposal of Mustard Filled 155mm Artillery Projectiles

Background

Artillery projectiles (the munition) were configured to disseminate their chemical agent load by various means including explosive aerosolisation; thermal aerosolisation; base ejection of bulk fills; and via the ejection of sub-munitions of various types. The most commonly encountered configuration is a projectile designed to aerosolize a load of liquid unitary agent via the detonation of an internal explosive burster.

Projectiles can either be designed specifically for use with chemical agents or they may be modifications of projectiles designed for other purposes. In some cases projectiles designed for one purpose are suitable for use with certain chemical agents without modification. For example, projectiles designed to explosively atomize smoke producing compounds are suited for use with chemical agents.

Discoveries

Four 155mm artillery projectiles were discovered at the Ukhaider Ammunition Depot during UN inspections in 1997. A further ten similar projectiles were discovered at the same facility in 1998. Four of these projectiles were opened and their contents sampled and drained during operations conducted by UNSCOM. The contents were determined to be the chemical warfare agent mustard. The remaining ten filled projectiles, along with the mustard agent from the four that had been drained, were moved to the Muthanna State Establishment for storage and proposed destruction. The proposed destruction did not take place prior to the withdrawal of UN inspectors from Iraq in late 1998.

On 4 December 2002, UNMOVIC inspectors examined the ten filled projectiles and the bottles containing the remaining mustard agent at the Muthanna site. The projectiles were all 155mm smoke projectiles intended for use with white phosphorus. These projectiles have a central explosive burster and are suitable for the dissemination of mustard without modification. The projectiles and the plastic pails containing the bottles of mustard are shown below.

Figure III.X.IA Ten 155mm mustard filled projectiles at Muthanna

Figure III.X.IIA Plastic pails containing bottles of mustard at Muthanna

Disposal Operations:

Disposal operations began on 11 February 2003 at Muthanna. All stages of the disposal were implemented by UNMOVIC's inspectors. The first projectiles were opened and sampled using the remotely controlled MONICA drilling device on 12 February. During subsequent drilling operations all the projectiles were opened and their contents sampled and analyzed. The samples taken from the shells showed that mustard produced over 15 years ago was still of high quality - 97% purity.[1]

Figure III.X.IIIA Remote drilling into amustard filled projectile with MONICA

The mustard agent was drained from all ten projectiles and subsequently destroyed by chemical neutralization with sodium hypochlorite. The empty projectiles were destroyed with explosives on 3 March 2003. The disposal operation was completed on 5 March 2003 with the final decontamination of

[1] All samples of mustard stored in the Commission's chemical laboratory were destroyed the day before withdrawal of UNMOVIC's staff from Iraq in March, 2003. No quantities of live agents were left behind in the BOMVIC's offices at the Canal hotel.

the barrels used for neutralization of the mustard.

Conclusions:

UNMOVIC identified, handled, opened, sampled, analyzed, neutralized and disposed of a small quantity (approximately 49 liters) of mustard filled into 155 mm artillery projectiles remaining from the UNSCOM period.[2]

Examination of Five Types of 122 mm Rocket Warheads[3]

Background

Several types of 122mm rocket warheads relevant to UNMOVIC's mandate were either declared to UNMOVIC by Iraq or were discovered by UNMOVIC inspectors during the course of their work. These warheads are described in the following paragraphs.

Discoveries and Analysis

122mm "Sakr 18" type chemical warheads:

During the course of inspecting the Ukhaider Ammunition Depot on 16 Jan. 2003 the inspectors discovered 12 boxes containing 122 mm "Sakr 18" type chemical warheads and motors. Eleven of the warheads were sealed in what appeared to be their original plastic protective bags and were separated from their motors. The twelfth warhead, no longer in its plastic bag, was attached to a rocket motor. This warhead was x-rayed and found to contain two plastic containers and several litres of an unknown liquid. The liquid was subsequently sampled, analyzed and assessed by UNMOVIC's laboratory to be primarily water.

Figure III.X.IVA Twelve boxes of 122mm "Sakr 18" type rockets

The warheads and motors were packed in wooden boxes that were all similar in construction and markings. Metal bands sealed most of the boxes. There was no evidence of tampering with the bands.

An example warhead and the boxes found are shown in the following photographs.

[2] UNMOVIC-03-00585-CW-NONE-1042

[3] In total, 18 chemical warheads were tagged by UNMOVIC for destruction

Figure III.X.VA Nose of "Sakr" type warhead

Figure III.X.VIA Base of "Sakr" type warhead

The boxes were painted dark green and lettered in English in yellow paint. Each box was marked as follows: In transit, L/C, Contract, shipping date, weights, box number, and the destination - Al Qaa Qaa Establishment. Both the L/C number and the contract number mentioned in Iraqi declarations concerning the acquisition of chemical munitions during the 1980's.

Figure III.X.VIIA Destination markings on Sakr type warhead boxes

An additional empty "Sakr 18" type chemical warhead (without motor) was discovered on 4 February 2003 at the Al Taji Ammunition Depot. This warhead was identical to the warheads discovered at Ukhaider with the exception that it was neither in its plastic bag nor was it in a shipping box.

122mm "Firos 25" type chemical warheads

On 20 January 2003, the Iraqi government notified UNMOVIC that four 122mm Firos 25 type chemical warheads had been found at the Al Taji Ammunition Depot. Inspectors examined these warheads on 21 January and discovered that one contained a small quantity of unidentified liquid. Samples of this liquid were extracted on 9 February and subsequently analyzed at the BOMVIC laboratory. The liquid was found to be primarily water.

Figure III.X.VIIIA 122mm "Firos 25" type chemical warheads at Al Taji

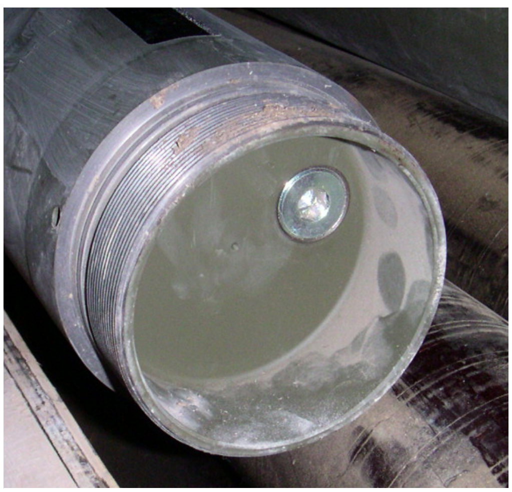


Figure III.X.IXA Base of "Firos" type warhead

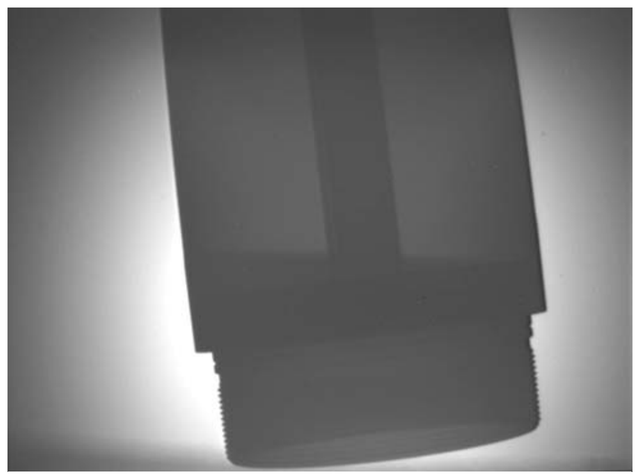


Figure III.X.XA X-ray of "Firos" type warhead showing burster tube and liquid

122 mm Al Buraq chemical warhead

During an inspection of the Al Taji Ammunition Depot on 9 Feb. 2003 an empty warhead was discovered that has been identified as a 122 mm Al Buraq. The Al Buraq is an Iraqi produced aluminum warhead designed for use with chemical agents. The warhead was damaged and not suitable for use.

Figure III.X.XIA 122 mm Al Buraq chemical warhead at Al Taji

Figure III.X.XIIA Base of Al Buraq warhead

122mm Steel Warheads Filled With TNT

During the inspection of the Al Taji Ammunition Depot on 9 February 2003, two unusual 122mm warheads were examined. The warheads were manufactured from steel and had the general profile of “Sakr 18” type chemical warhead. However, they were approximately 4-5 inches longer than “Sakr 18” type warhead. Physical examination disclosed that they had a full-length burster tube similar to what is typical for a chemical warhead. The warheads were, however, filled with what appeared to be the explosive TNT. Sampling and subsequent analysis at the BOMVIC laboratory confirmed that the filler was TNT. Photographs follow below:

Figure III.X.XIIIA 122 mm explosive filled warhead

Figure III.X.XIVA Nose of warhead showing

Figure III.X.XVA Base of warhead showing TNT filler

The Al Karama Co controlled the Al Taji bunker where the warheads were found. The Iraqi government representatives assisting the inspection were unable to provide any details concerning the origin of these warheads.

The physical characteristics of the warheads are similar to a chemical warhead. Iraq is known to have produced 122mm steel warheads for use with chemical agents. It is possible, but not established, that these warheads were initially produced for use with chemical agents but subsequently filled with TNT for unknown purposes.

Unidentified 122mm Rocket Warhead Components

An additional discovery during the inspection at the Al Taji Ammunition Depot on 9 February 2003 included the warhead nose, part of the body and a base plate of what appears to be a previously unreported type 122mm chemical rocket warhead.

The design of this warhead is, in some regards, similar to the design of the 122mm "Sakr 18" type warhead. The nose, with attached burster tube, is threaded into what appears to be the forward portion of the warhead body. The design suggests that the nose was intended to be removable which in turn suggests that the warhead was intended for use with internal agent canisters rather than be bulk filled. The tapered, rather than ogival, nose is unusual as is the heavier than typical thickness of the nose body.

Figure III.X.XVIA Nose of unknown 122mm warhead

Figure III.X.XVIIA inside view of unknown warhead

A steel base plate for a chemical rocket warhead was also discovered at Al Taji on Feb. 9th. The base plate is appropriate in diameter for a 122 mm warhead and includes both a threaded hole that appears to be a filler port and a machined recess that appears to be for a buster tube. The plate is similar, in general design, to the base plate of a 122 mm "Firos" type chemical warhead. The possible relationship between these plates (shown below) and the warhead nose assembly described above is unknown because the nose assembly was separated from the remainder of the warhead body by sawing.

Figure III.X.XVIIIA Forward side of base plate showing recess for burster tube

Figure III.X.XIXA Rear side of base plate showing possible filler

These items were discovered in the same Al Taji bunker as both "Firos" type warheads and the Al Buraq warheads described above. No further information regarding these warhead components was available.

Comment

UNMOVIC examined three types of previously known 122mm chemical rocket warheads and two other types of warheads that may have been originally intended for use with chemical agents. None of these warheads appears to incorporate technology that differs from that observed during the UNSCOM inspections. Indeed, "Sakr 18" type, "Firos 25" type and Al Buraq warheads are identical to warheads described by UNSCOM. The two remaining types of warheads, the steel TNT filled example and the unknown type found at Al Taji, were not described by UNSCOM but do not incorporate significant novel concepts. The dates of manufacture of these latter two types of warheads have not been determined but they do not appear to have been manufactured recently.[4]

Evaluation of a 2.5 Litre Cylindrical Sub-munition

Background:

The term sub-munition refers to one of the primary components in a cluster munition. A cluster bomb or cluster warhead contains multiple (typically dozens to hundreds) sub-munitions. Each sub-munition is a complete munition comprising a body, fuse, filler and other necessary components.

[4] UNMOVIC-03-00142-MD-none-1851;UNMOVIC-03-00521-MD-none-1851; UNMOVIC-03-00052-MD-none-1088
UNMOVIC-03-00158-MD-Sampling Mission –1851; UNMOVIC-03-00523-MD-011-1088;UNMOVIC-03-00153-MD-0011-1088

Cluster munitions releasing agent filled sub-munitions create multiple points of agent dispersal. This facilitates target coverage regardless of wind direction (assuming that the sub-munitions are distributed across the target). Sub-munitions are an efficient and effective means to disseminate either chemical or biological agents.

Discovery at Al Noaman:

An inspection team inspected the Al Noaman Factory in Baghdad on 2 February 2003. During the course of the inspection, a sub-munition capable of being used with either chemical or biological agents was discovered. The factory manager denied knowing what the item was and declared that it was scrap. NMD personnel initially concurred with the factory manager but ultimately acknowledged that the item might have been an experimental chemical munition. They adamantly denied that the item was intended for use with VX.

Figure III.X.XXA 2.5-litre sub-munition found at the Al Noaman Factory

The item was an aluminum cylinder 122 mm in diameter and approximately 480mm long. It has a central burster tube, a welded base plate and a four-bladed aluminum tail fins assembly threaded into the rear of the sub-munition. The forward end plate and nose assembly were missing. This munition appears identical to the 2.5 litre sub-munition example in the BOMVIC munitions collection. The item also appears identical to the munitions shown in Iraq videotapes of tests of experimental chemical or biological sub-munitions.

Figure III.X.XXIA Burster tube inside sub-munition

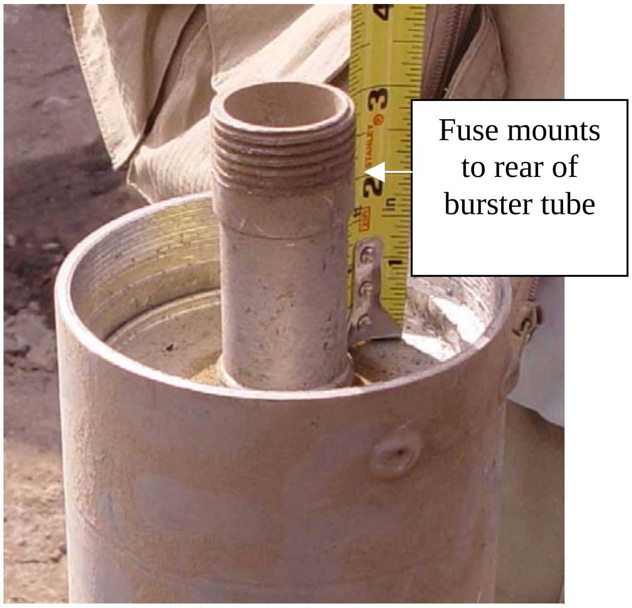


Figure III.X.XXIIA Base of the sub munition (without fins) showing rear of the burster tube

Figure III.X.XXIIIA Base of the sub-munition showing fins in place and rear of the

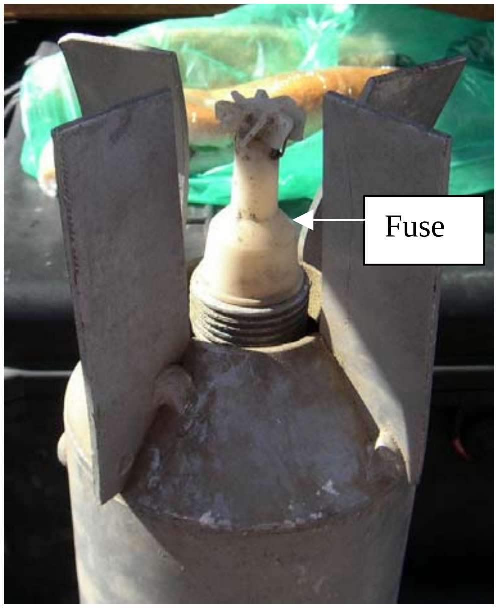


Figure III.X.XXIVA Base of the sub-munition showing position of fuse. Fuse retainer is not

Relevant data from Iraq's CW CAFCD and other documentary evidence:

Iraqi declarations in CW CAFCD Sec. 8.10.4 Aerial Bomb / CB-250

"In 1987 cluster bomb / CB-250 manufactured by Al-Noaman factory of fiber glass 18 bomblet made of (AL) by Al-Noaman factory, were modified. The bomblet are closed cylinder of 3.5 L. capacity and equipped from the rear side by an ordinary fuse for CB bomb manufactured by Al-Noaman factory as in several test were conducted for studying the possibility of using those bomblets. The first tests were to drop the bomblet from different altitudes (10,20,30m) to determine the function of bomblet."

"In view of those tests, a number of bomblets were manufactured and arranged inside the cluster bomb / CB-250. In summer of 1987 flying test was carried out for two bombs /CB-250 charged with 18 bomblet full of a liquid (oil). Another test was conducted for dropping two bombs/CB-250 on airstrip 37. The results were negative because some of the fuses did not operate due to insufficient altitude. The tests were abandoned. An idea was suggested to add another fuse as shown in…. This kind of bomb was never used or attend to be used for VX or biological agent."

UNSCOM Document No. 600324 (video)

This 1987 video shows flight tests of the CB 250 cluster bomb filled with 2.5-litre sub-munitions.

UNSCOM Documents No. 600328 and 600370 (videos)

These 1987 videos show the 2.5-litre sub-munition being dropped from cranes at Al Muthanna and Al Noaman.

Figure III.X.XXVA 2.5-liter sub-munition being loaded on crane

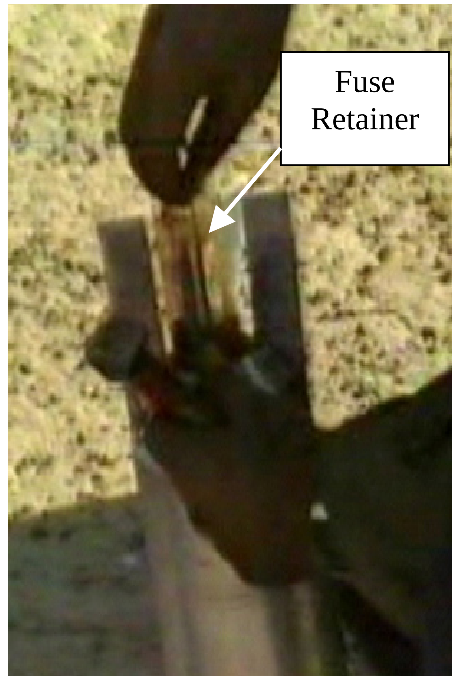


Figure III.X.XXVIA Plastic sleeve for retaining fuse being removed.

Discussions were held with Iraqi personnel at the Al Noaman Factory 2 February and 5 February 2003.

During the inspection of the Al Noaman factory several technical discussions were held concerning the items discovered including the 2.5-litre sub-munition. Several of these discussions were captured on videotape and digital voice recorders and have been transcribed.

The most relevant material from the transcriptions of these discussions is included in the analytical section of this report.

Drawings and Photographs of the 2.5-litre sub-munition recovered by UNSCOM and residing in the BOMVIC munitions collection.

The following photograph shows a munition that is essentially identical to the munition recovered at Al Noaman.

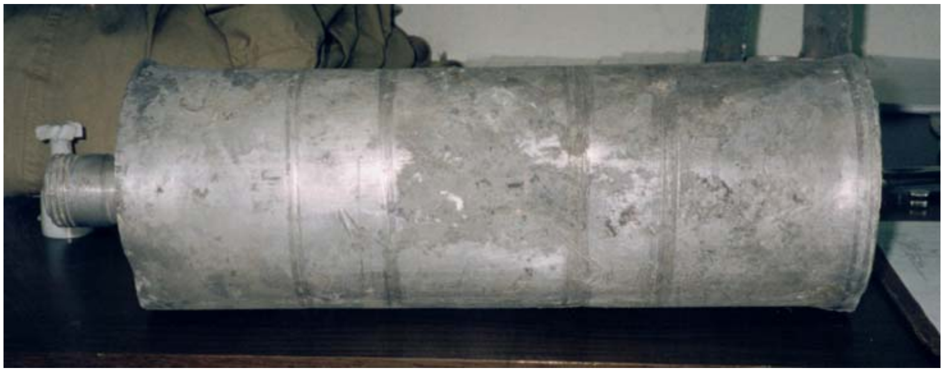


Figure III.X.XXVIIA 2.5-*litre* sub-munition in the BOMVIC

Information gathered from UNSCOM interviews and other documents. Comments made during interviews conducted by UNSCOM 17 and 140 and interviews with General Hussein Kamel in Jordan are included in the analysis section of this report. Additional information was extracted from the Muthanna State Establishment Annual Report of 1988.

Analysis

1. Is the 2.5-litre sub-munition discovered at Al Noaman and the 3.5-litre sub-munition mentioned in Iraqi declarations the same item?

The sub-munition recovered from Al Noaman is missing the forward internal closure plate. The sub-munition is otherwise identical to the completely intact example held at BOMVIC. Based on an examination of both munitions, the internal volume of the sub-munition is calculated to be slightly in excess of two litres.

If we consider only the total length of the body of the munition and its internal diameter then the volume is theoretically 3.6 litres. However, this requires that we ignore the significant loss of internal volume due to the burster tube and the recessed closure plates at both ends.

During discussion of the 2.5-litre sub-munition at Al Noaman, the Iraqi officials stated, "we expect this to hold about 3.5 litres."

Comparing the diameter to length ratio of the recovered munition to the munitions shown in Farm Document Videos suggests that they are identical. The videos record tests of what they describe as a 3.5-litre sub-munition.

The available evidence clearly suggests that the 2.5-litre sub-munition discovered at Al Noaman and the 3.5-litre sub-munition referred to in the prior FFCDs are one and the same.

2. What is the relationship between the 2.5-litre sub-munition and the CB 250 cluster bomb?

CW CAFCD refers to tests of fiberglass CB 250 cluster bombs holding 18 aluminum 3.5-litre sub-munitions.

> "In 1987 cluster bomb / CB-250 manufactured by Al-Noaman factory of fiber glass 18 bomblet made of (AL) by Al-Noaman factory, were modified. The bomblet are closed cylinder of 3.5 L. capacity…."

The Al Noaman Factory included a plant for producing fiberglass CB 250 cluster bombs. Numerous components for the CB 250 cluster bomb were found in building 27 along with the 2.5-litre sub-munition.

Al Noaman is not the only facility in Iraq that made fiberglass munitions. A label found on a cluster warhead for a 540mm rocket suggests that the Al Bahrani Company also manufactured fiberglass munitions. However, Al Noaman is the only Iraqi company known to have produced the CB 250 cluster bomb.

Videos of Iraqi dynamic tests of the CB 250 cluster bomb and the 3.5-litre sub-munition analyzed by UNMOVIC include close-up images of the recovered sub-munitions. The sub munition shown in that report appears identical to the sub-munition recovered at Al Noaman with the exception of the rounded nose that is missing from the munition discovered at Al Noaman.

It appears that the 2.5-litre sub-munition discovered at Al Noaman was intended for use with the CB 250 cluster bomb. However, it should be noted that this sub-munition is probably suitable for use with other cluster munitions including the larger CB 500 also produced by Al Noaman.

3. What agents were intended for use with this sub-munition?

The 2.5 litre sub-munition is similar to other known Iraqi chemical munitions in that it is cylindrical and has an explosive burster extending most of its length along its central axis. The agent to burster weight ratio is 14:1, that is sufficient to effectively disseminate a volatile agent such as sarin.

The CAFCD-Chemical (Sec. 8.10.4) contains the following declaration relating to the agent in sub-munitions:

> "In summer of 1987 flying test was carried out for two bombs /CB-250 charged with 18 bomblet full of a liquid (oil)…. This kind of bomb was never used or attend to be used for VX or biological agent."

Comment
The Iraqi declarations and comments to UNMOVIC inspectors were consistent in their insistence that the 2.5-litre sub-munition was intended for use with a chemical agent other than VX. However, for some unexplained reason they were unwilling or unable to give any hint of what agent that was.

Despite repeated requests to reveal the agent intended for use with this munition the Iraqis only restated the list of agents declared as being available at the time. Additionally, both in declarations and during the discussions at Al Noaman Iraq emphatically stated that neither VX nor biological agents were considered for this munition. Further, the Iraqis stated that someone else would select the agent at a later time.

Based on the Iraqi statements and the physical characteristics of the munition, sarin and cyclosarin would seem to be the most likely chemical agents for this munition.

4. What was the relationship of this sub-munition to the development and testing of 122mm chemical and biological rocket warheads?

The 2.5 litre sub-munition is very similar in several aspects of construction to the 122mm Al Buraq chemical warhead. Specifically, they share the following characteristics: both are 122mm in diameter; both are made of aluminum of similar thickness; both have an explosive burster extending most of their length along their central axis and both have similar end plates. The sub-munition bears a strong resemblance to the rear half of the Al Buraq.

The principle differences between these munitions are their length, the type of fuzing, and the presence of a fin assembly attached to the rear of the sub-munition.

The following photographs illustrate the physical similarity of the 2.5 litre sub-munition and the 122mm Al Buraq chemical warhead.

Figure III.X.XXVIIIA Front end (nose) of the 2.5-litre sub-munition

Figure III.X.XXIXA Rear end (base) of the Al Buraq warhead

The Muthanna State Establishment Annual Report for 1988[5] contains the following statement in the munitions section:

[5] UNSCOM Doc No 200097

> "It will be possible, in the future, to suppress the plastic canisters and the metallic canisters, equipping the above-mentioned rocket and the cluster bombs (special), and to rely on canisters made out of aluminum alloys only, with the same moulds used to manufacture aluminum tubes which will be used to produce special warheads made out of aluminum. "

This statement indicates MSE's intent to use the same equipment and raw materials to produce both 122mm warheads and sub-munitions.

Examination of the both the 2.5-litre sub-munition and 122mm Al Buraq warhead reveal significant similarities in construction. Additionally, Iraq admitted in their statements to UNMOVIC inspectors and state in a document from Muthanna, that both the 2.5 litre sub-munition and the 122mm aluminum warheads were produced by the same people, using the same materials and technology and, to some degree, the same components.

It is clear that substantial linkage exists between the development of the 2.5-litre sub-munition for the CB250 cluster bomb and aluminum warheads for 122mm rockets. The Iraqi statement to UNMOVIC inspectors that "There is no relationship at all…" is clearly false.

Comment

1. The 2.5 litre sub-munition discovered at Al Noaman is identical to the munitions described by Iraq as 3.5 litre sub-munitions in both discussions and prior declarations.
2. The 2.5 litre sub-munition discovered at Al Noaman was intended for use with the CB 250 cluster bomb.
3. It is not possible, with the information currently available, to conclusively determine what agents were intended for use with the 2.5 litre sub-munition. The available information suggests that sarin, cyclosarin and biological agents are credible alternatives.
4. Substantial linkage existed between the programmes to develop and produce aluminum 122mm rocket warheads and the development and production of the 2.5 litre sub-munition.

Group B. Findings Regarding Munitions and Components Linked to Prohibited Programmes

Evidence Concerning a 107mm Rocket Warhead

Background:

Iraq's military inventory included substantial quantities of short-range 107mm surface-to-surface rockets with high explosive warheads. The declaration of December 2002 mentions that Iraq considered development of a chemical warhead for this rocket.

Discovery:

On 9 February 2003, UNMOVIC team inspected the Al Taji Ammunition Depot with the intention of sampling 122mm warheads declared by Iraq the previous month. While inspecting building 31 a box was discovered that contained various machined aluminum parts that appeared to be components of chemical or biological rocket warheads.[6]

Figure III.X.XXXA Box of aluminum warhead parts discovered at Al Taji on 09/02/03

Amongst the items in the box was a single example of a machined aluminum component 106 mm in diameter. The component is generally similar in design to the base assembly of a chemical rocket warhead. The photo below shows this item:

[6] UNMOVIC-03-00153-MD-0011-1088

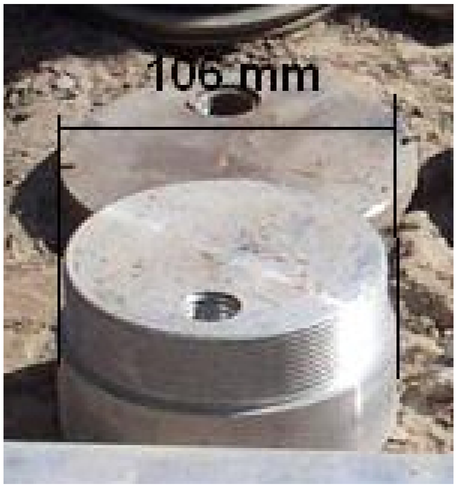


Figure III.X.XXXIA
Aluminum base plate possibly for 107 mm rocket warhead

Relevant declarations:

Chemical CAFCD (page. 7-6): Aluminum Warheads for 122 mm Rockets. “Other ideas presented by Project 144 for binary systems and not pursued further were conversion of warheads for C-24, 107 mm rockets. No prototypes were produced.”

Analysis:

The component shown above appears to be an unfinished base assembly for a rocket of approximately 107mm diameter. The similarity in basic design of this item to the base assembly for a 122mm FIROS type chemical warhead and other 122mm base plates for chemical warheads suggests that this item is indeed a component of a chemical warhead. Lending further credence to this conclusion is the Iraqi declaration regarding consideration of a chemical warhead for the 107mm rocket.

Figure III.X.XXXIIA Base plate for 107mm warhead

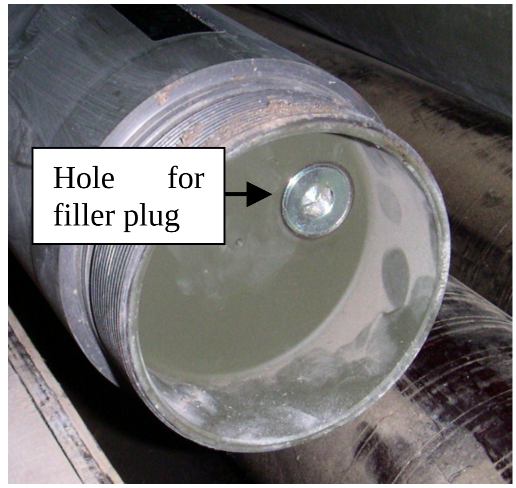


Figure III.X.XXXIIIA Base plate for 122mm "FIROS" type chemical warhead

Comment
There is insufficient evidence to draw any conclusions regarding the possible Iraqi development of a liquid filled bursting warhead for 107mm rockets. Additionally, the available evidence does not afford an adequate basis to evaluate the accuracy of Iraqi declarations regarding a chemical warhead for 107mm rockets. However, certain comments can be made including the following:

1. At some point Iraq considered the development of a liquid chemical warhead for 107mm rockets.
2. The aluminum component discovered at Al Taji appears to be an unfinished base assembly for a liquid filled bursting warhead for a 107mm rocket.
3. If this component is part of such a warhead then it appears that, in contradiction to CAFCD declarations, Iraq had, at least, begun the production of prototype warheads.
4. If this warhead was indeed intended for use with chemical or biological agents then the existence of this munition should have been declared.
5. No conclusion can be reached regarding the extent of development or the number of warheads produced.

A fuller understanding of Iraq's programme to develop warheads for 107mm rockets would require more relevant documents by and detailed interviews with relevant personnel.

Examination of a 540 mm Cluster Warhead for The Luna Rocket[7]

Background:
The Iraqi military inventory included significant quantities of 540mm Luna (FROG-7) surface-to-surface rockets. Iraq's known holdings of these rockets included only high explosive warheads. The declaration of December 2002 includes a statement regarding development of a cluster warhead for Luna for use with chemical agents.

Discovery:
On 2 and 5 February 2003, UNMOVIC inspected the Al Noaman Factory. While examining the contents of building 32 the inspectors observed two items that were generally similar in size and shape to a warhead for a large rocket. These items are shown in the photograph below.

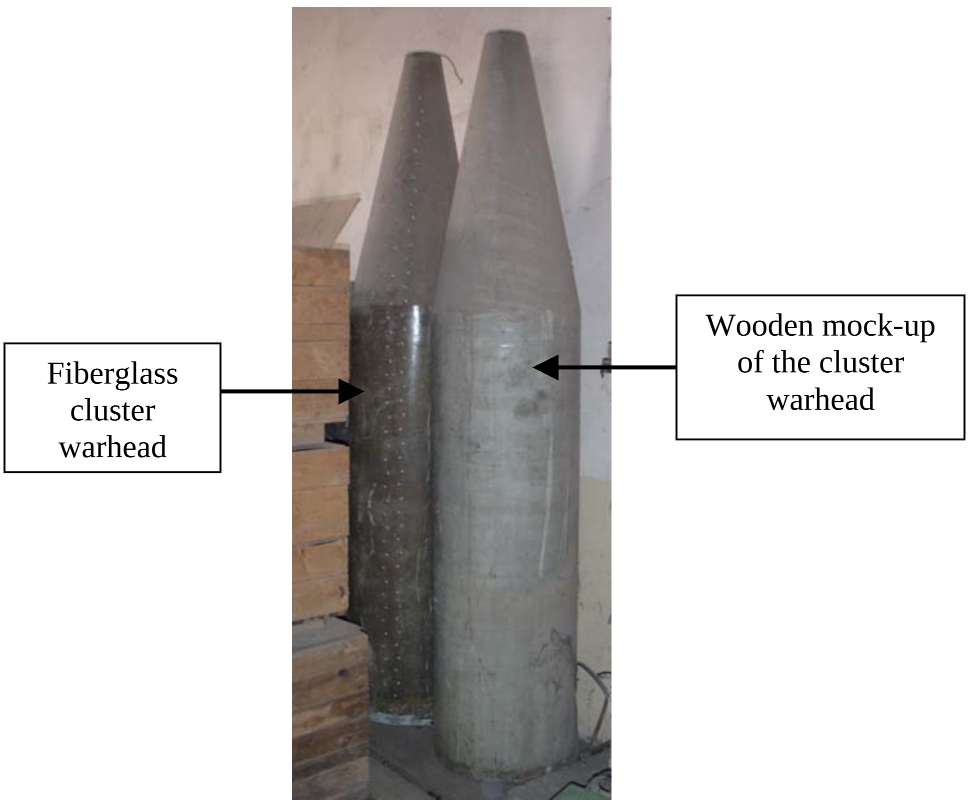


Figure III.X.XXXIVA 540mm Warheads discovered at the Al Noaman Factory

The factory staff initially stated that the items were cluster bombs for aircraft (the Al Noaman Factory formerly manufactured cluster bombs). During further discussions with NMD

[7] UNMOVIC-03-00511-BW-0091-1279; UNMOVIC-03-00596-BW-0091-1279

representatives on 5 February 2003, the inspectors were informed that the items were Laith warheads for the Luna (FROG-7) rocket and that they were intended for use with the same conventional sub-munitions used with the Ababil 50 rocket.

While similar in size and shape the two items are very different in construction. Both are approximately 2.7 metres in length and 540mm in diameter. One item is fabricated from fiberglass and steel and is apparently a cluster warhead for the Luna rocket. The other item is fabricated from wood and is apparently a full-size mock-up of the cluster warhead. Drawings and photographs of these items are shown below.

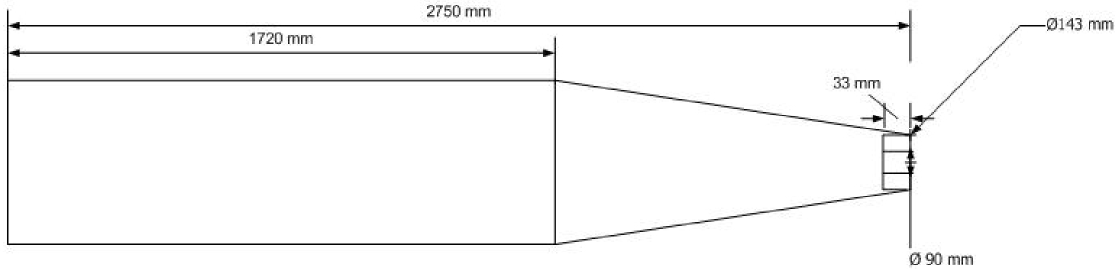


Figure III.X.XXXVA Sketch of the cluster warhead found at the Al Noaman factory

The cluster is apparently designed to open during flight by the detonation of three longitudinal lines of detonation cord embedded in the fiberglass warhead body. These lines of detonation cord were visible where they came together at the nose ring.

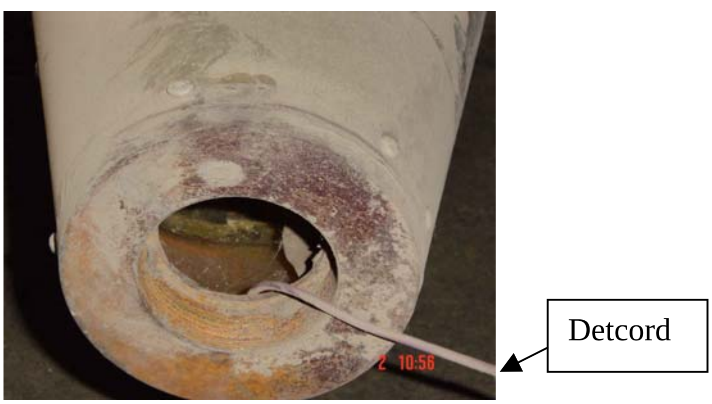


Figure III.X.XXXVIA Warhead nose ring

Figure III.X.XXXVIIA Nose section of the Laith cluster warhead

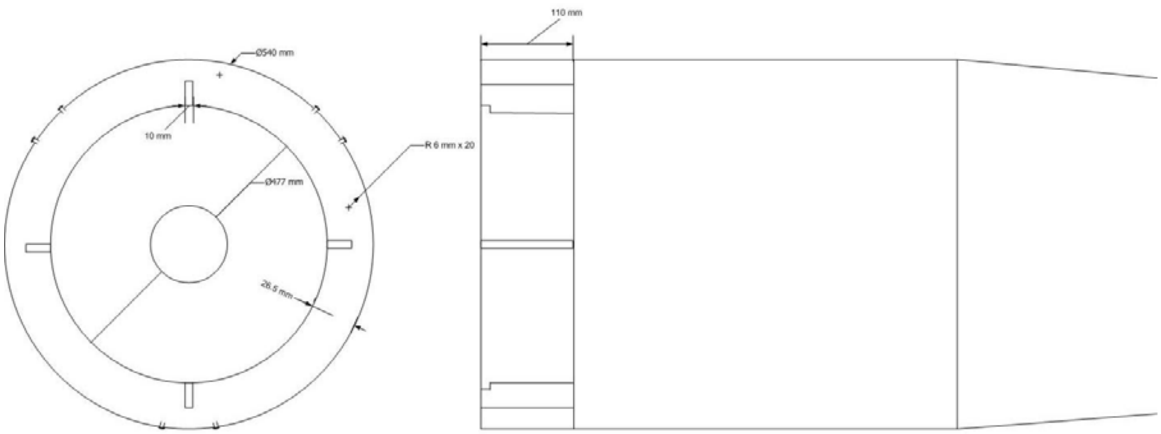


Figure III.X.XXXVIIIA Sketch of the steel ring at the rear of the Laith warhead

Figure III.X.XXXIXA Side view of steel ring

Figure III.X.XLA Rear view of steel ring

The inspectors noticed a label affixed to the steel ring at the base of the cluster warhead. The label includes the name Bahrani Plastics Materials Co. and two Baghdad phone numbers.

Figure III.X.XLIA Labels attached to the ring at the rear of the warhead

When asked about the Bahrani Plastics Materials Co. the NMD personnel stated, “it is a private company working with fiberglass.” NMD further stated that Bahrani manufactured the samples of the Laith warhead. However, NMD personnel denied knowledge of where Bahrani might be located.

Related Information from Declarations:

1. CW CAFCD Chapt. VII

    “In May 1988 Project 144 offered to design a cluster warhead for CW agents to be used on the missile Luna. A mock-up prototype was made and the Project was abandoned for lack of interest.”

2. BM CAFCD Chapt. IV

    1. Name Of The Project: Laith
    2. Missile System Involved:
        - B. Name: Luna Cluster
        - C. Dimensions: Dia. = 500mm L
        - D. Range: 68 Km
        - E. Payload: 450 Kg
        - F. Warhead: 450 Kg

Analysis:
Physical examination by inspectors and statements by Iraqi representatives during inspections at the Al Noaman Factory on 2 and 5 February 2003, confirm that the warhead discovered at the Al Noaman Factory is a cluster warhead for the Luna rocket.

Iraq has declared two projects pertaining to cluster warheads for the Luna (FROG) rocket. The first project was reportedly started in May of 1988 under Project 144[8]. This project proposed the development of a cluster warhead to be filled with chemical sub-munitions. The declaration states that a mock-up was produced but the project was abandoned. Subsequently, in June of 1988, Project 144 proposed a cluster warhead to be filled with conventional sub-munitions[9]. This warhead was known as the Laith. Iraqi representatives stated that at least two prototype warheads were produced under the Laith project before it was abandoned by the end of July 1988. Iraqi representatives denied that the Laith warhead was intended for use with either chemical or biological sub-munitions.

The cluster warhead discovered at the Al Noaman Factory is constructed in a manner generally similar (fiberglass body designed to be opened in flight by the detonation of linear strips of explosive) to the cluster bombs previously produced at the factory. This type of construction facilitates use with a variety of shapes and sizes of sub-munitions. Further, this type of construction is appropriate for both conventional sub-munitions and for sub-munitions filled with either chemical or biological agents. The warhead discovered at the Al Noaman Factory appears equally suited for use with either conventional sub-munitions or with sub-munitions filled with either chemical or biological agents.

The warhead is approximately 2.7 metres long and 0.5 metres in diameter and is constructed of fiberglass and steel. The fiberglass components are large and include precisely aligned cylindrical and conical sections. Embedded in the fiberglass section are three lengths of explosive and unique steel backing plates. At each end of the fiberglass section are precisely machined rings. The rear ring is large and has dozens of precisely located holes, grooves and other machined surfaces to facilitate mating with the fiberglass section and proper alignment and attachment to a Luna rocket motor. The forward ring, while smaller and less complicated, is nonetheless precisely made. The Iraqi representatives repeatedly stated that this warhead was conceived and fabricated in less than two months and that nothing more than the crudest sketches were prepared to guide the fabricators. The physical size of the warhead and the complexities of its design are such that it seems very improbable that the Iraqi statements are true. Despite repeated requests for these sketches, none were provided.

[8] Chemical CAFCD December 2002
[9] Ballistic Missiles CAFCD December 2002

The Iraqi declarations state that mock-ups of the proposed chemical cluster warhead were built. The declarations pertaining to the proposed conventional cluster warhead do not mention the fabrication of prototypes. Neither engineering drawings nor sketches for either warhead were provided to UNMOVIC. The Iraqi representatives stated that the warhead and the wooden mock-up discovered at the Al Noaman factory were Laith warheads for conventional sub-munitions but provided nothing to substantiate this claim. There is no apparent mechanical reason why the warheads for the two projects would have to be constructed differently. Given that the same organization, Project 144, proposed both projects and that these projects were consecutive (May through July 1988) and that no conflicting information has come to light it seems reasonable to presume that the warhead discovered at the Al Noaman Factory may have been intended for use with both projects.

The role of the Bahrani Plastic Materials Co. is unclear. The presence of their label on the fiberglass warhead and the statements by the Iraqi representatives suggest that Bahrani had some role in the fabrication of both this and possibly other warheads.

An Iraqi official present during the inspection at Al Noaman stated that there had never been any thought to using chemical or biological agent filled sub-munitions with either the warhead being examined or with any other missile. This statement is in direct contradiction to the declaration in the chemical CAFCD.

Comment

1. The cluster warhead for the Luna rocket and the wooden mock-up of this warhead discovered at the Al Noaman Factory are the warheads separately described in the chemical and missile CAFCDs.

2. This warhead may have been intended for use with both conventional and chemical or biological sub-munitions.

3. The Iraqi representative's statements denying that Iraq had ever contemplated the use of chemical or biological sub-munitions in rocket warheads are contradicted by the Iraqi declarations. Additional statements by the same representative denying that chemical or biological sub-munitions had never been considered for use with the warhead discovered at Al Noaman appear to be false.

4. The role of the Bahrani Co. in the fabrication of these warheads and other munitions could not be established and required further clarifications.

Cluster Munitions Summary[10]

Introduction:

[10] UNMOVIC-03-00615-BW-0092-1048; UNMOVIC-03-00511-BW-0091-1279; UNMOVIC-03-00596-BW-0091-1279

UNMOVIC inspectors examined various cluster munitions in Iraq. Some of these cluster munitions were produced in Iraq while others were procured abroad. Cluster munitions consist of the cluster body (outer shell of the munition), multiple sub-munitions, a fuzing mechanism and a fin assembly. Sub-munitions can be configured as cylinders, spheres, cubes or various other shapes. Sub-munitions contain either conventional (shaped explosive charges, fragmentation, or incendiary) or prohibited (chemical, biological or radiological) fillers. To some extent sub-munitions of different size, shape and filler are interchangeable in a cluster munition. It is relatively unusual to see two different types of sub-munition loaded together in one cluster munition but it is not unusual to see one type of cluster munition filled with any one of several different types of sub-munitions.

Cluster munitions are an efficient means to disseminate chemical. Iraq declared that they had tested chemical agent stimulant filled sub-munitions in a cluster bomb originally designed for anti-personnel and anti-vehicular use. Iraq also declared a proposed project to develop a chemical cluster warhead for the 540 mm Luna rocket.

"CB250" type Cluster Bomb:

A production line for these cluster bodies, along with production lines for the conventional sub-munitions, was established at the Al Noaman Factory in the mid 1980's. Al Noaman reportedly produced several thousand of these munitions.

Figure III.X.XLIIA "CB 250" type cluster bomb at the Ukhaider Ammunition Depot

Figure III.X.XLIIIA Conventional sub-munitions in the CB 250 cluster

Figure III.X.XLIVA Airburst fuse on a CB 250 cluster bomb

Figure III.X.XLVA Fiberglass bodies for CB 250 cluster bomb near the Al Nida factory

The CB 250 has a thin fiberglass body and metal tail fins. The bodies were manufactured at Al Noaman from moulds produced by Al Nida. The CB 250 incorporates three longitudinal lines of explosive to rupture the fiberglass body and free the sub-munitions. The fuse mounted in the nose of the cluster bomb body initiates these lines of explosive.

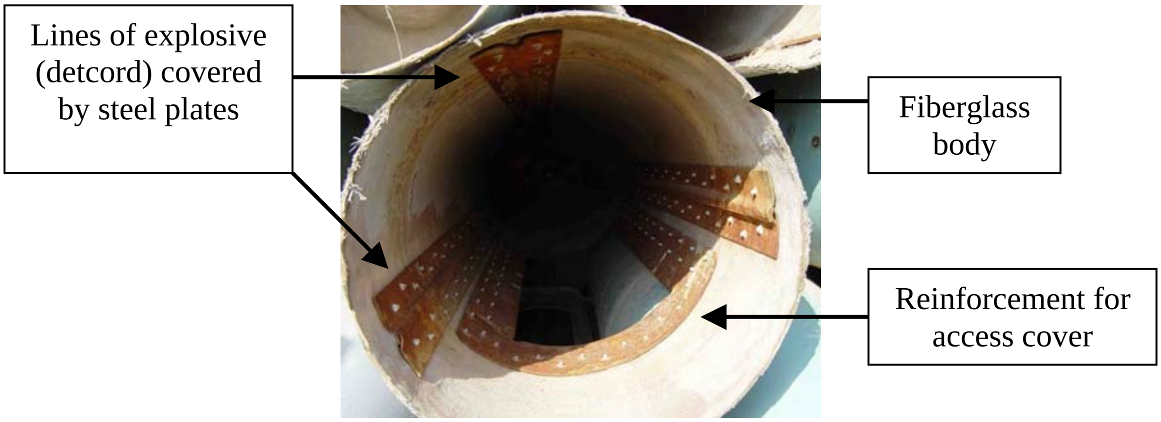


Figure III.X.XLVIA Interior of a CB 250 cluster bomb

Figure III.X.XLVIIA Moulds for CB 250 cluster bomb

"CB 500" type Cluster Bomb:
Like the CB 250, the CB 500 was produced at Al Noaman from moulds supplied by Al Nida. Al Noaman personnel said that only a small number of CB 500 bombs were produced and that the design was successful for delivery at other than high angles of attack. No evidence was offered to support of these statements.

The CB 500 is a 500 kg class bomb that incorporates a thin fiberglass body, metal fins, an airburst fuse and sub-munitions. Visually, the rounded nose and longer body length of CB 500 distinguish it from the otherwise very similar CB 250. There is also a minor difference in the design for the forward portion of the tail fins.

The CB 500 could be used with a variety of sub-munitions of various shapes, sizes and fillers.

Figure III.X.XLVIIIA CB 500 cluster bomb on display at the 1989 Baghdad military exposition

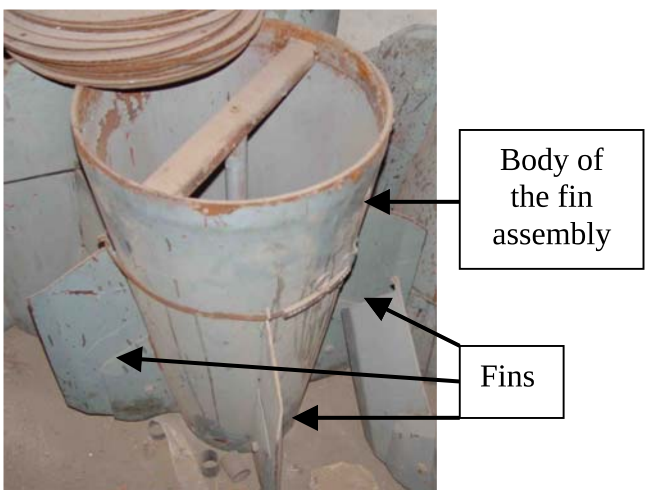


Figure III.X.XLIXA Fin assembly for the CB 500 bomb

Figure III.X.LA Moulds for CB 500

Figure III.X.LIA CB250 and CB 500 fiberglass bodies at Al Nida

Nasr 28 Cluster bomb:

Like the CB 250 and CB 500 the Nasr 28 was produced at the Al Noaman factory. Al Noaman personnel said that approximately twelve Nasr 28 cluster bombs were produced. UNMOVIC inspectors found approximately one dozen Nasr 28 cluster bombs in various stages of assembly and parts for approximately two dozen more.

Figure III.X.LIIA Partially assembled Nasr 28 cluster bombs at Al Noaman

The Nasr 28 is a 500 kg class bomb that works in a manner very different than the CB 250 and CB 500 bombs. The Nasr 28 consists of 40 short ejection chambers arrayed in rows around the circumference of the bomb body. Each ejection chamber contains one 155mm diameter spherical sub-munition. Following release from the aircraft, and a short delay, the nose fuse initiates an expelling charge. The sub-munitions are then ejected radially away from the bomb.

Figure III.X.LIIIA Nasr 28 cluster bomb showing covered and uncovered ejection

Figure III.X.LIVA Nasr 28 ejection chambers

The number of launch tube and the distinctive features of the tail fins distinguish the Nasr 28 from the very similar CB 470 bomb. The Nasr 28 is similar in size to the CB 500 cluster bomb but uses the CB 250 tail fins.

Figure III.X.LVA Nasr 28 tail fin

Figure III.X.LVIA CB 470 tail fins

Unlike the CB 250 and CB 500 cluster bombs, the Nasr 28 is not compatible with sub-munitions of different sizes and shapes. To function reliably, the Nasr 28 design requires sub-munitions to be spherical and 155mm in diameter.

Figure III.X.LVIIA Nasr 28 cluster bomb with 155mm diameter spherical

200 mm Cluster Warhead:

Evidence of a 200 mm diameter cluster warhead was discovered on 3 Feb. 2003 at the Al Noaman Factory storage area owned by the Al Nida State Enterprise. Iraqi personnel declared that a fuse discovered in building 27 at the Al Noaman factory was part of the sub-munition intended for this warhead. An intact warhead has not been found and no drawings were made available.

Figure III.X.LVIIIA Moulds for fiberglass munitions in an Al Noaman storage area

540 mm Cluster Warhead:

A cluster warhead for the Luna (FROG-7) rocket was examined at the Al Noaman Factory on 2 and 5 Feb. 2003. Except for its much thicker body, the warhead is constructed in a manner similar to the CB 250 and CB 500 cluster bombs. Based on an analysis of Iraqi declarations, the warhead was intended for use with both chemical and conventional sub-munitions. There is no indication that the warhead was mass-produced.

Summary:

Five distinct types of Iraqi produced cluster munitions were examined by UNMOVIC. Iraq declared interest in using the CB 250 cluster bomb and 540mm cluster warhead for the Luna rocket with chemical agent filled sub-munitions. Iraqi statements suggest that chemical fillers may have been considered or tried in a sub-munition for the Nasr 28 cluster bomb. All of these munitions are suitable for use with either chemical or biological agents.

Group C. Findings Regarding Munitions and Components Whose Purpose is Under Review

UNMOVIC inspectors discovered munitions and munition components that are not described in Iraq's declarations of December 2002, although they have characteristics consistent with chemical or biological munitions. It was not possible to clarify the actual purpose of these items prior to the withdrawal if inspectors.

Examination of a 81mm Rocket Warhead[11]

Background:

Iraq produced the 81mm "Medusa" type rocket. Initially intended for use as a air-to-ground munition for helicopters, the Iraqi's used 81mm rocket as a ground-to-ground munition.

Discovery:

On 28 December 2002, UNMOVIC inspected the Air Munitions Test Site near Hadre. During the course of this inspection numerous fragments of munitions were discovered. One of these fragments appears to be the base assembly of a rocket warhead of approximately 81mm diameter. This fragment includes what appears to be a filler plug similar to what has been observed on other chemical or biological warheads. Samples taken for analysis did not indicate the presence of either chemical or biological agents. Photographs of this fragment are shown below.

[11] UNMOVIC-03-00153-MD-0011-1088; UNMOVIC-02-00029-MD-0008-1195

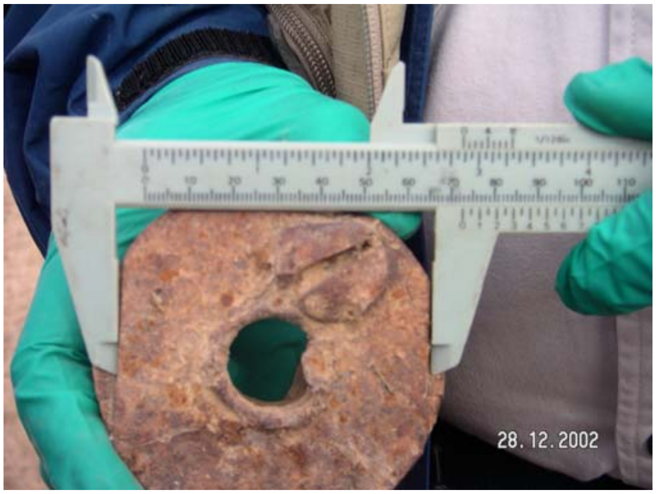


Figure III.X.LIXA Rear face of a possible base assembly for 81 mm rocket warhead found at Hadre. Note hole for burster tube.

Figure III.X.LXA Forward face of the Hadre fragment

On 9 February 2003 UNMOVIC’ team visited the Al Taji Ammunition Depot with the intention of sampling warheads previously declared by Iraq. While inspecting building 31 a box was discovered that contained various machined aluminum parts that appeared to be components of chemical or biological rocket warheads. Other related parts were discovered elsewhere in the bunker. Following careful inspection of all recovered parts it was discovered that some of these fit together to form a 81mm rocket warhead. The following photographs illustrate what was found.

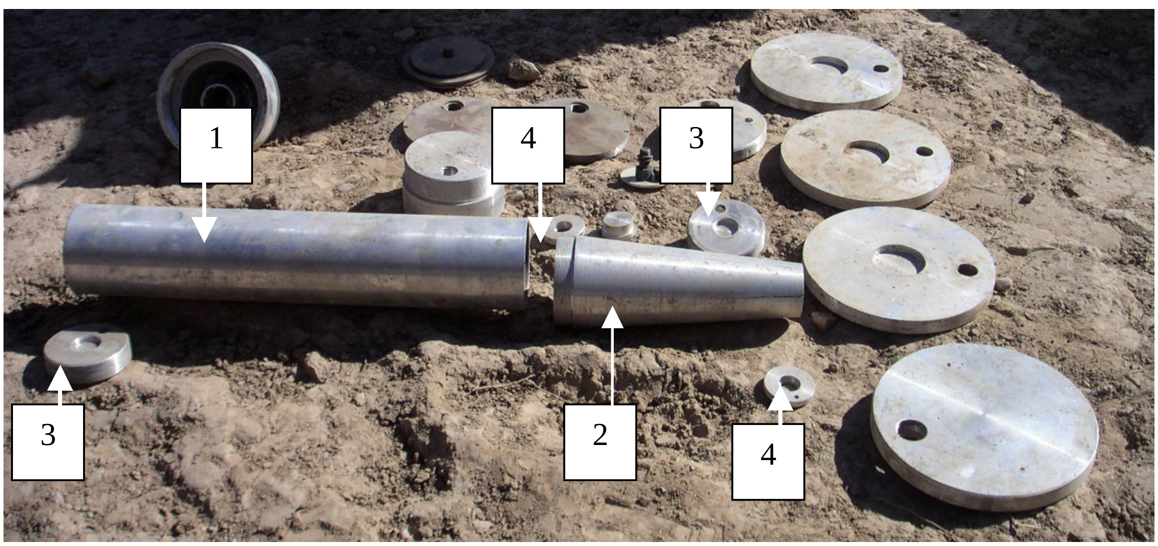


Figure III.X.LXIA Parts for 81 mm rocket warhead found at Al Taji
1 = rear body, 2 = forward body, 3 = base plug, 4 = forward internal burster support

Figure III.X.LXIIA Base assembly of 81 mm warhead. Note- base plug is not fully in place

Figure III.X.LXIIIA Opposite view of base showing burster tube recess.

Relevant declarations:
No declarations pertaining to 81mm rockets were provided in the CAFCD 2002

Analysis:
81mm rockets with conventional warheads have been observed in Iraqi ammunition depots.

Examination of the various parts suggests that at least two types of warheads had been evaluated – one made of steel and one made of aluminum. The presence of a burster tube recess in the aluminum example and the central hole in the steel example suggest that both warheads were intended for use with a central explosive burster. The hole through the center of the steel base assembly also suggests that it may have been intended for use with canisters to contain the agent whereas the blind hole in the center of the aluminum base assembly suggests that it was intended for bulk fill.

Comment
Sufficient evidence was discovered to conclude that Iraq had explored liquid filled bursting warheads for 81mm rockets. However, the available evidence does not afford an adequate understanding of either the scope or scale of these developments.

1. At some point Iraq initiated development of a liquid filled bursting warhead for 81mm rockets.
2. At least two warheads were in development for this rocket including a steel warhead and an aluminum warhead that where somewhat different in design.
3. These warheads appear to have been useable either with smoke agents, toxic chemicals or biological agents.
4. If either of these warheads were indeed intended for use with chemical or biological agents then the existence of these munitions should have been declared.
5. No conclusion can be reached regarding the extent of development or the number of warheads produced.

Evidence of 200 mm Rocket Warheads[12]

Discoveries:

On 3 February 2003, UNMOVIC inspected a storage area adjacent to the Al Nida State Company. This area is used by the Al Noaman Factory for the storage of scrap and components of past projects. During the course of this inspection the team discovered a mould that Iraq eventually admitted was for the production of the fiberglass body of a warhead for a 200mm diameter surface-to-surface rocket. A photograph of cross section of this mould is shown below:

Figure III.X.LXIVA Fuse for sub-munitions found at the Al Noaman Factory

Figure III.X.LXVA Cross section of the warhead mould found at Al Nida

On 5 February 2003, the UNMOVIC team returned to the Al Noaman Factory to conduct a detailed inspection of the contents of buildings 27 and 32. These buildings house the remains of prior work on cluster bombs, sub-munitions and missile warheads. During the course of this inspection the team discovered a unique sub-munition fuse.

[12] UNMOVIC-03-00615-BW-0092-1048; UNMOVIC-03-00153-MD-0011-1088; UNMOVIC-03-00596-BW-0091-1279

On 9 February 2003, the UNMOVIC team visited the Al Taji Ammunition Depot with the intention of sampling warheads previously declared by Iraq. While inspecting building 31, a box containing what appeared to be various parts for chemical or biological rocket warheads was discovered. Following careful inspection of all recovered parts they discovered that some of the parts appeared to be components for a chemical or biological rocket warhead of approximately 200mm diameter. The following photograph illustrates what was found.

Figure III.X.LXVIA Warhead parts found at Al Taji

Iraqi declarations, statements and admissions:

No mention of a 200mm diameter rocket has been found in the CAFCD.

Regarding the mould –
When the warhead mould was discovered at Al Nida on 3 February, the representative from the Al Noaman Factory stated that it was for a cluster bomb to be dropped from an aircraft. Additionally, he maintained that it was a notional item conceived by a junior engineer and that it was not further developed or produced. A senior representative from NMD's missile team was summoned when the inspectors challenged these assertions. After initially backing up the explanation offered by the Al Noaman representative he acknowledged that the mould might be for a rocket warhead.

During a meeting at Al Noaman on 5 February with representative from NMD, the Al Noaman Factory, former employees and others, the Iraqi side acknowledged that the mould was for a rocket warhead. They stated that the rocket was under development in the early 1980's and was subsequently superseded by the Ababil 50 in the mid-1980s. Additionally, they stated that a small number of warheads and the associated sub-munitions were produced and tested but that all work had ceased with the acceptance of the Ababil 50.

Regarding the fuse –
Following protracted discussions on 5 February the Iraqi's stated that the fuse was part of a unique sub-munition intended for the 200mm cluster warhead that would be produced by the moulds UNMOVIC had found on 3 February They stated that the sub-munition associated with this fuse was similar to the sub-munition used with the Ababil 50 rocket. Despite requests, the inspectors were neither shown one of these sub-munitions nor were drawings presented. When asked, the Iraq absolutely denied that this sub-munition was ever intended for use with either chemical or biological agents.

Regarding the parts found at the Al Taji Ammunition Depot –
Both the base commander and the NMD representatives stated that they had no information regarding the box of warhead parts found in building 31.

Analysis:

Based on the physical evidence collected and the Iraqi statements it can be concluded that at some point in time a 200mm diameter rocket was being developed by Iraq. The exact time frame of this development work is, however, uncertain. During the discussions on 5 February, Iraq stated: (1) work began on the 200mm rocket in 1983, (2) development of this warhead preceded work on the Ababil 50 and (3) all work on this warhead stopped with the introduction of the Ababil 50. These statements appear to be in contradiction with Iraqi declarations that state that the agreement with a foreign country concerning the Ababil 50 was signed in 1980.

Based on the characteristics of the warhead mould and the Iraqi statements, it is safe to conclude that it is intended to produce a cluster warhead. However, there is considerable uncertainty regarding its functioning. The design of the mould includes no obvious provision for the customary fuse in the nose of the warhead. Possibly, the fuse is located in the base, a feature that is both unusual in small diameter warheads and one that cannot be verified without access either to complete drawings or an actual warhead. The mould is designed such that the warhead apparently has a removable panel a short distance behind the nose. This is also an unusual feature in a small diameter rocket warhead and needs further explanation.

Little is known about the sub-munition intended for use with this warhead other than the Iraqi statement that it was a conventional explosive design. The Iraqi claim that the sub-munition is similar to the one used in the Ababil 50 is suspect. First, the sub-munition for the Ababil 50 is compact, effective and may have already been in production in Iraq by 1983. Second, the substitution of the fuse discovered on 5 February would almost double the length of the Ababil 50 sub-munition without adding to its effectiveness.

The fuse that was found on 5 February is an apparent modification of the fuse used with the 122mm diameter chemical/biological sub-munitions in 1987 cluster bomb tests. The following photographs offer a comparison of these fuses.

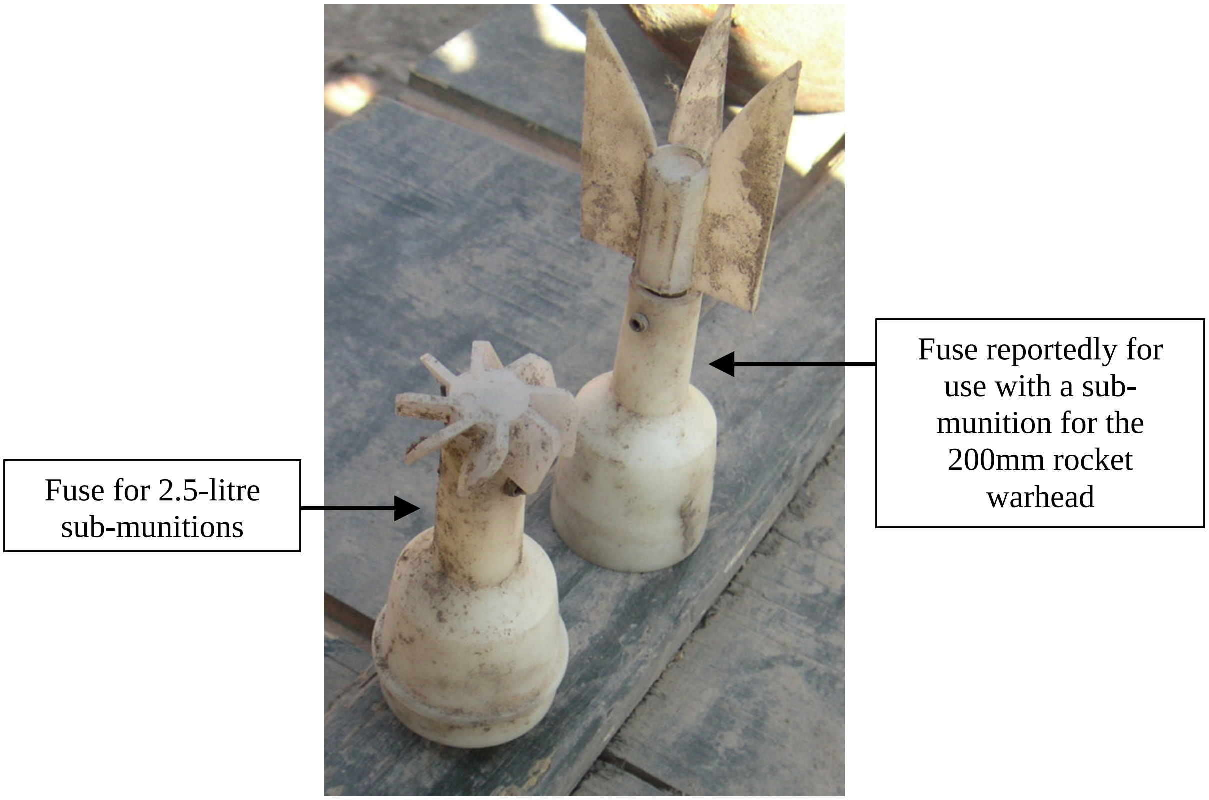


Figure III.X.LXVIIA Comparison of fuses found at the Al Noaman factory

The large aluminum base plates in the box of parts found at Al Taji on 9 February are 183mm in diameter. This diameter is approximately what would be expected for a base plate designed to screw into the rear of a warhead of approximately 200mm in diameter. However, it is very unlikely that these base plates are intended for use with the warhead produced from the mould described above. The design of the base plates incorporates both a recess suitable for a burster tube and a threaded hole essentially identical in both size and placement to the screw plugs found in other well-documented chemical warheads. These features are strong evidence that these base plates are components of a warhead equipped with a central explosive burster and intended for filling with either unitary liquid chemical, biological or smoke agents. Additionally, the absence of any observable provision for a base fuse suggests that the warhead associated with these parts incorporates a nose fuse. These points are illustrated in the following photographs.

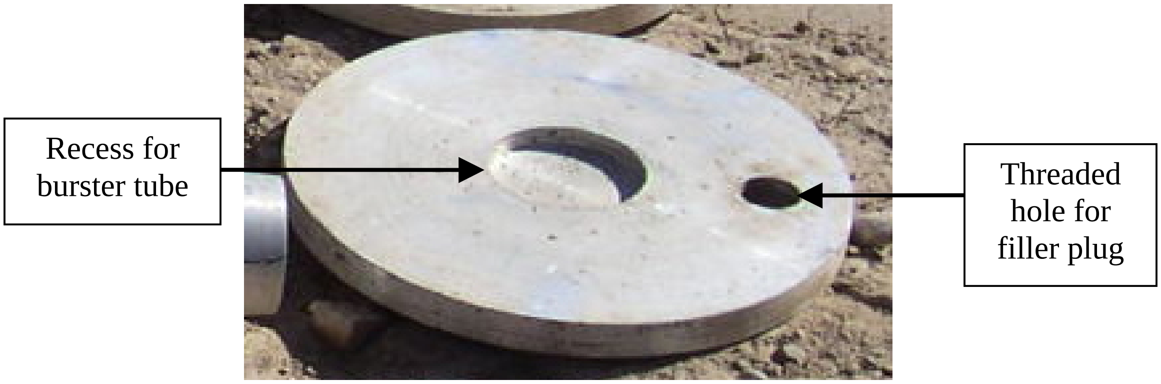


Figure III.X.LXVIIIA Rear face of base plate found at the Al Taji Ammunition Depot

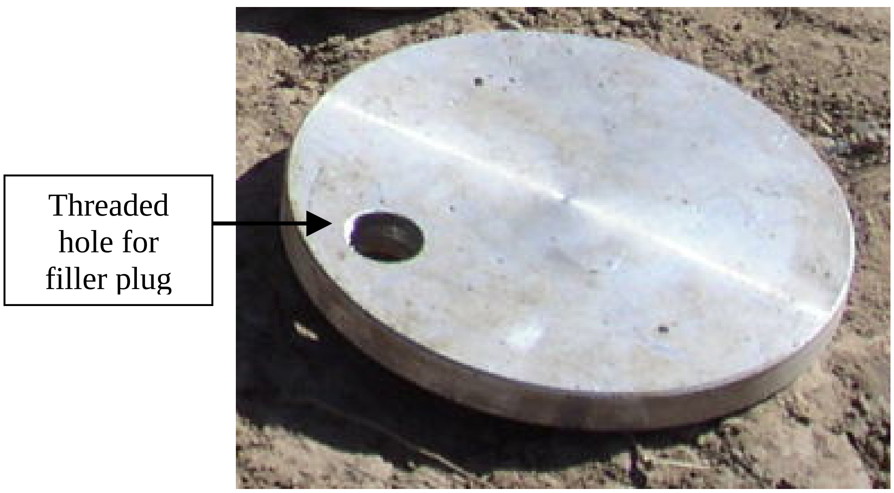


Figure III.X.LXIXA Front face of base plate found at the Al Taji Ammunition Depot

Comment

There is insufficient evidence to support definite conclusions regarding Iraq's development of 200mm rockets and warheads. However, the limited evidence allows the following comments can be made.

1. Iraq initiated development of a 200mm rocket system at some point in the 1980's
2. At least two warheads were in development for this rocket including a cluster warhead and a bulk liquid warhead intended to be filled with either chemical, biological or smoke agents
3. The cluster warhead may have been intended for use with chemical or biological sub-munitions.

These preliminary conclusions must be validated via document analyses when available and *further interviews with the relevant Iraqi personnel.*

Examination of 155mm Spherical Spray Sub-munitions[13]

Background:

Previously observed Iraqi chemical munitions create airborne clouds of agent either by explosive aerosolisation or by hydraulic or pneumatic spray. Aerosol clouds can also be created by other means including thermal aerosolisation. This technique involves rapidly raising the temperature of the agent to the point where it either boils or sublimates. Subsequent condensation of the agent in the air results in an aerosol of small diameter droplets.

Discovery:

During the period 2-5 February 2003 UNMOVIC conducted a series of inspections focused on the development of cluster munitions by the Al Noaman Factory. On 3 February 2003 the same team inspected an Al Noaman Factory storage site owned by the Al Nida State Enterprise.

During each of these inspections the team observed spherical sub-munitions (bomblets) and cluster bombs designed to use these munitions. Factory personnel informed the inspectors that the cluster bombs were reversed engineered "CB 470" type cluster bomb. The copy produced by Al Noaman is known as the NASR 28. A photograph of this cluster bomb follows:

Figure III.X.LXXA NASR 28 cluster bomb at the Al Noaman Factory

[13] UNMOVIC-03-00511-BW-0091-1279; UNMOVIC-03-00615-BW-0092-1048; UNMOVIC-03-00596-BW-0091-1279

The NASR 28 is designed to contain and eject spherical sub-munitions from a series of short tubes arranged in rows along its body. One sub-munition is contained in each tube. These tubes are loaded with a sub-munition and then covered with a metal plate held in place with small tabs. Apparently several versions of the NASR 28 were developed. The inspectors noted versions with between 33 and 40 ejection tubes. While the CB 470 used a pyrotechnic charge to eject the sub-munition, the ejection mechanism used with the NASR 28 is not clear. Photographs showing the relationship between the sub-munition and the ejection tubes are shown below.

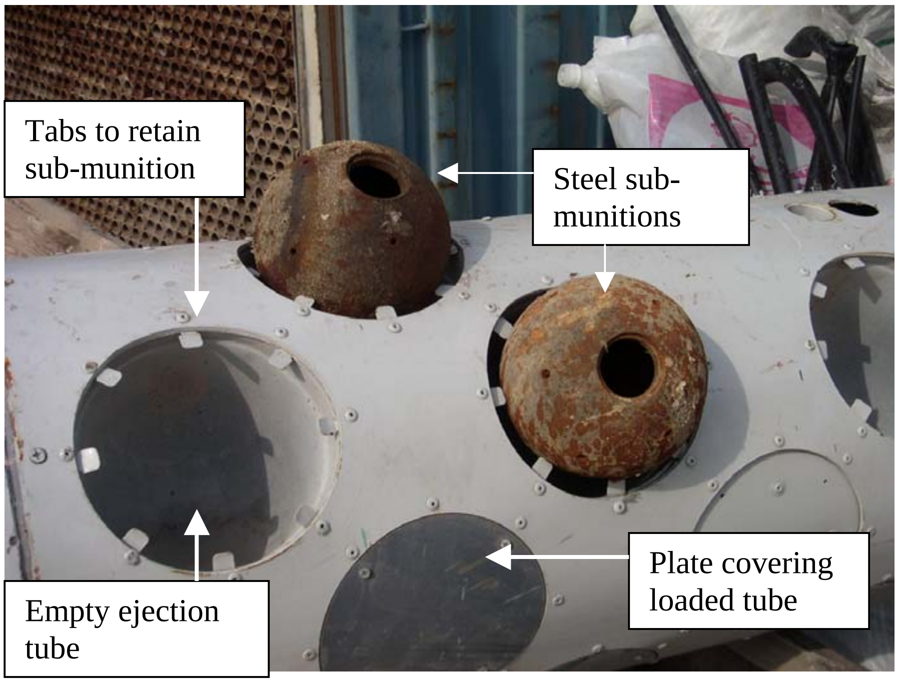


Figure III.X.LXXIA Arrangement of sub-munitions and ejection tubes in the NASR 28 cluster bomb

Inspectors discovered two types of sub-munitions intended for use with the NASR 28 cluster bomb. One type was a 135mm steel sphere covered with a 10 mm thick coating of rubber giving it a total diameter of 155mm. Examples of this type (the rubber sphere) were discovered filled with either wax, sand or possibly explosives. Only one type of fuse was observed with these sub-munitions and it was apparently designed to initiate on impact then detonate the sub-munition after a very short delay. The Al Noaman Factory personnel stated that the rubber sphere was a conventional high explosive munition and that the rubber covering was intended to facilitate it bouncing (2-3 metres) in the air prior to detonation. A photograph of the rubber-covered sub-munitions follows:

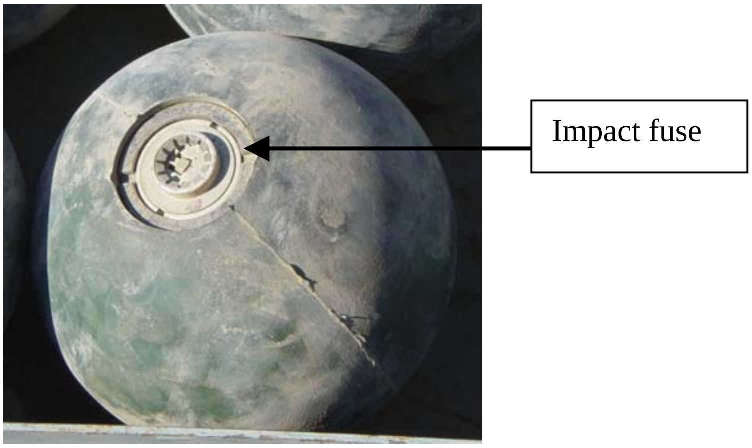


Figure III.X.LXXIIA Rubber covered sub-munition at Al Noaman

The second type of sub-munition discovered was a 155mm steel sphere. These sub-munitions (the steel sub-munitions) were not covered with rubber but did incorporate a pattern of small holes drilled in the body. The Al Noaman Factory personnel stated that these particular sub-munitions were designed to spray smoke rather than explode. They further explained that the steel sub-munitions had been produced to aid the development of the rubber-covered sub-munitions by allowing technical personnel to observe the spraying of the smoke when the steel sub-munitions bounced in the air and thereby judge the height to which the rubber-covered sub-munitions bounced. A photograph of the steel sub-munition follows:

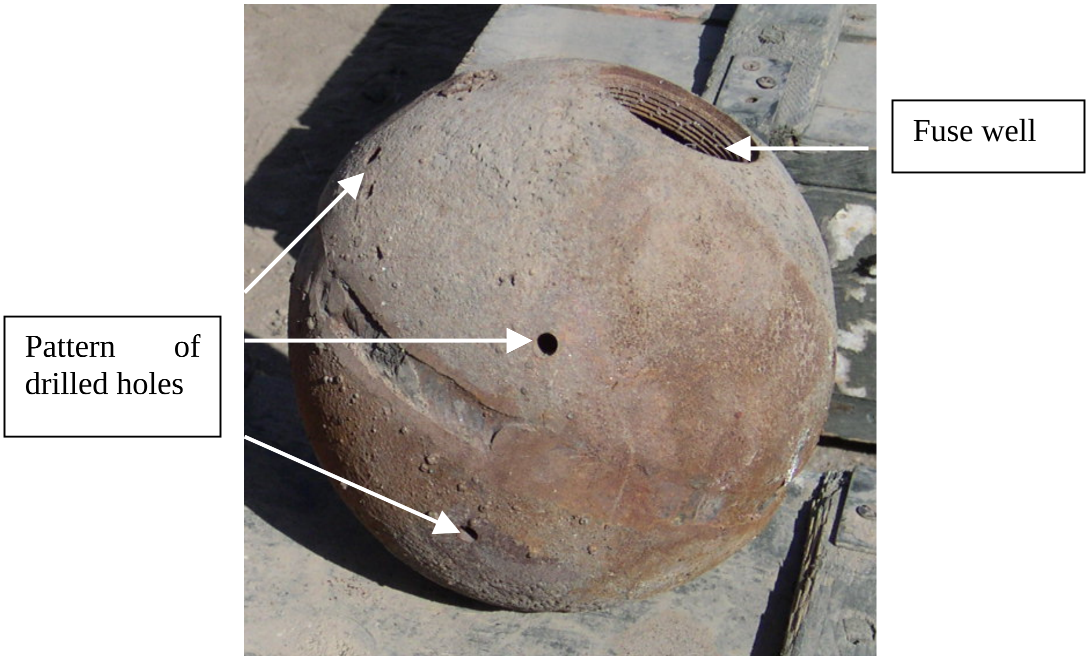


Figure III.X.LXXIIIA 155 mm steel sub-munition at Al Noaman

When asked to elaborate on the spraying of smoke the Al Noaman Factory personnel stated that white phosphorus was the smoke agent spray from this munition. They remained consistent in their claim even when inspectors pointed out that white phosphorus was not a liquid and therefore could not be sprayed in the manner described.

The Al Noaman Factory personnel were also asked to help the inspectors understand why Iraqi engineers believed that a 155mm diameter steel sphere would accurately simulate the physical behavior (bounce) of a 135mm rubber-covered sphere. The Iraqi side offered no explanation. A comparison of the two munitions is shown below:

Figure III.X.LXXIVA Comparison of spherical sub-munitions

Relevant Declarations:

No declarations refer to either spray sub-munitions, steel sub-munitions or to the NASR 28 cluster bomb.

Analysis:

1. The first question to be answered relates to the plausibility of the Iraqi explanation of the purpose of the 155 mm steel sub-munition. The Iraqi's claimed that this munition was designed to (a) spray (b) smoke from the (c) pattern of holes in order to facilitate (d) measurement of the (e) height of bounce of the rubber-covered sub-munition. An examination of each of the numbered points follows.

(a). The Al Noaman Factory representatives were very clear in their claim that the steel sub-munition was designed to spray smoke from the holes. These holes are several millimetres in diameter and therefore are much more likely to create a narrow stream of agent rather than a spray.

In order to eject agent via the holes there must be a source of either hydraulic or pneumatic pressure. Detonation of the explosive booster attached to the fuse is likely to rupture the welded steel sphere rather than acting as a source of pressurizing gas. It is therefore unlikely that the components shown to UNMOVIC inspectors could produce the effect Iraq claimed.

(b). When asked about the specific smoke composition used with this munition the Al Noaman personnel agreed that it was white phosphorus. White phosphorus is a very dense gel used almost exclusively in bursting smoke munitions. It is very difficult to image how a dense gel could be sprayed from this munition. The only other smoke compound that Iraq is known to use is hexachlorethane, a solid. The principal liquid-smoke agents, smoke generating fog oil (SGF) and titanium tetrachloride have not been observed in Iraq.

(c). Each 155 mm steel sub-munition has four holes both above and below its equatorial junction. Each set of holes is approximately equally, but not precisely, spaced around the circumference of its respective hemisphere. The diameter of the holes was consistent for an individual sub-munition but varied between sub-munitions. Hole diameters ranged from approximately three to six millimeters and appeared to have been drilled. The range of hole diameters observed suggests that experiments had been performed to determine optimum hole diameter for whatever effect was being sought.

(d). The Al Noaman personnel said that the steel sub-munition was intended to initiate spraying of smoke at the uppermost point of its bounce. Furthermore, the ejection of smoke at this moment would allow observers to thereby judge the height of bounce and, by inference, the height at which the rubber-covered sub-munition would detonate.

There are at least two problems with this claim. First, no matter what the orientation of the sub-munition is at the moment that spray is initiated, half of the holes will point downwards. If the munition does indeed create a spray then the size of the "ball" of smoke produced is likely to completely obscure the height at which it occurred. Second, white phosphorus produces a very hot smoke that rises very rapidly. This characteristic produces the well-known vertical column effect that would yet further complicate any effort to visually discern relative minor differences in the height of functioning. Bear in mind that Iraq believed the height of bounce for the rubber-covered sub-munition to be only 2-3 metres.

(e). It seems highly unlikely that the height of bounce of an explosive filled rubber-covered 135 mm diameter steel sphere will be the same as a white phosphorus filled 155 mm diameter steel sphere that has no rubber covering.

2. If the 155 mm steel sphere was not actually intended to spray white phosphorus as claimed then what was its purpose?

Drilling a number of holes in the body of a munition is a technique used to distinguish a practice or dummy munition. It is, therefore, possible that the steel sub-munitions are meant merely to roughly simulate the rubber-covered sub-munitions for some unexplained purpose. While this explanation is attractive for its simplicity the Iraqi representatives denied it. Instead they specifically stated the sub-munitions were meant to spray smoke. Additionally, rubber-covered sub-munitions filled with sand or wax (practice or dummy munitions) were observed and none had holes.

Alternatively, the steel sub-munition could be intended to spray something other than smoke. One obvious choice would be thermally stable low volatility toxic agents such as mustard or VX. Munitions designed to disseminate mustard in this manner are mentioned in Volume II of the SIPRI report entitled Problem of Chemical and Biological Warfare, which Iraq has declared as consulting as a technical reference.

The 155 mm steel sub-munition could function adequately well to generate a thermal aerosol of either mustard or VX if two conditions exist. First, there must be source of heat that burn hot enough and long enough to boil a significant percentage of the liquid contents of the sub-munition. Replacing the explosive booster attached to the bottom of the fuse with a comparable sized pyrotechnic charge is likely to meet this requirement. Second, the holes must be adequately plugged to both contain the agent during storage and transportation and to allow substantial pressure to build up as the agent begins to boil. Suitable plugs could be made from plastics, sheet metal or, perhaps, even wax. Although neither suitable pyrotechnic charges nor plugs were observed during the inspection, neither was being sought at the time and therefore may have gone unnoticed.

Comment

1. Based on the unequivocal statements by Iraqi officials, it is almost certain that the steel sub-munition was intended to spray something.
2. Iraqi statements regarding the spraying of white phosphorus for the purpose claimed are completely unsupported by the available evidence and the experience of the inspectors.

3. The most likely, but not only, explanation of the purpose of the 155 mm steel sub-munitions is the intent to disseminate either mustard or VX via thermal aerosolization.
4. The existence of a programme to thermally aerosolize low volatility agents and the existence of these munitions should have been declared.

Evidence of an Unidentified Sub-munition[14]

Background:

The previously described 2.5 *litre* sub-munition is suitable for use with chemical agents. This is due to both to its volume and high agent to burster weight ratio. A smaller sub-munition with a lower agent to burster weight ratio would be more efficient for biological agents. Statements by Iraqi technical personnel clearly indicate that they were aware of this deficiency in the 2.5 *litre* sub-munition.

Discoveries:

During the inspection of the Al Noaman Factory on 5 February 2003, the inspectors examined an unusual fuse. The fuse is a modification of the standard fuse produced by Al Noaman for use with the CB 250 sub-munition. The modified fuse has four long fins rather than the approximately eight short vanes used with the original fuse. Additionally, the long fins are not canted as are the short vanes. Canting the fins causes either the fins or the entire munition to rotate during flight. This feature is commonly used to arm fuses in the air following release from a cluster bomb.

Figure III.X.LXXVA Fuse for an unknown sub-munition found at the Al Noaman Factory

Declarations:

[14] UNMOVIC-03-00511-BW-0091-1279; UNMOVIC-03-00596-BW-0091-1279

During an inspection of building 27 the Al Noaman Factory on 2 Feb. 2003 an Iraqi official stated that the 2.5 litre sub-munition that was being discussed was too large for use with biological agents and held too much explosive. He gestured with his hands while describing a “much smaller” sub-munition for use with biological agents. When asked if he was declaring the existence of another sub-munition he responded that he was not.

During discussions at the Al Noaman Factory on 5 February 2003, the Iraqi engineer responsible for the development of this fuse and the related sub-munition stated that the sub-munition was conventional but was unable to describe its size, weight or other characteristics. The engineer indicated that the sub-munition was intended for use with the 200 mm rocket warhead described in a previous section of this report.

Haidar Farm Documents #. 600328 and 600370 (videos): - These 1987 videos show the 2.5-*litre* sub-munition and a smaller object being dropped from cranes at Al Muthanna and Al Noaman. The following pictures are from these videos.

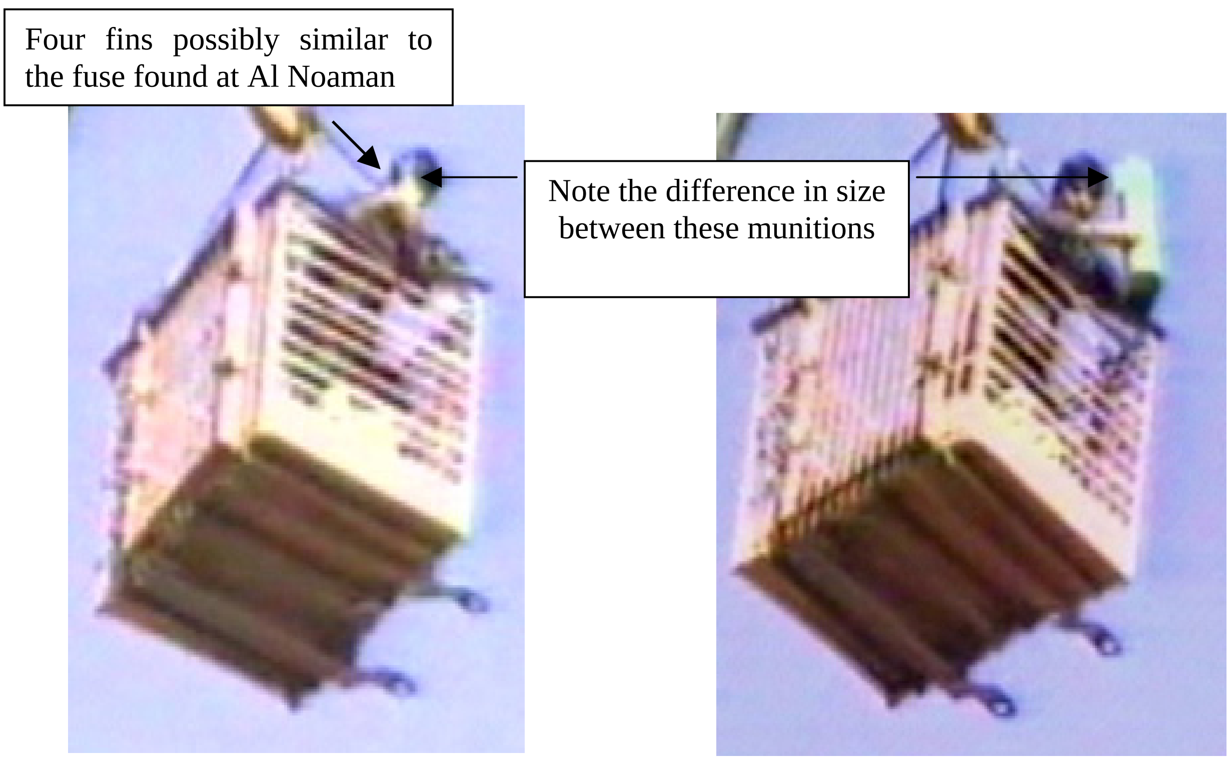


Figure III.X.LXXVIA Drop test with unidentified small sub-munition (left photograph) and with 2.5 litre sub-munition (right photograph)

During the discussions at Al Noaman on 5 February 2003 the inspectors asked the Iraqi representatives about the small munition that was observed on the videotape of the 1987-drop tests. The engineer shown in that video was present at this meeting. He stated that there was no small munition, only the 2.5 litre sub-munitions. When pressed on this point the engineer eventually said that there could have been a smaller sub-munition.

Analysis:

Based on their statements, Iraqi technical personnel were clearly aware of the deficiencies of the 2.5 litre sub-munition for use with biological agents. One Iraqi technical expert specifically stated that a small sub-munition would be more efficient for use with biological agents.

The Iraqi representatives were unable to provide even the simplest description of the sub-munition intended for use with the fuse discovered at Al Noaman on 5 February 2003. The fins on that fuse bear some similarity to the fins on the small sub-munition.

The engineer who conducted the drop tests of the munitions was present for the discussions at Al Noaman on 5 February 2003 even though UNMOVIC had not specifically asked that he attend. When asked about the small sub-munitions the video shows him dropping, he denied that any such munition was tested that day.

The Iraqi representatives stated that the fuse was intended for use with a conventional sub-munition for the 200mm rocket warhead that Iraq had declared just days before. However, they provided no evidence to substantiate their statements.

Comment

1. It appears that Iraq was, in 1987, developing a small sub-munition. That this munition was drop tested during the tests of the 2.5 litre chemical sub-munition suggests, but does not prove, that the small sub-munition may be related to either a chemical or, more probably, a biological munitions programme.
2. The fuse found at Al Noaman may be related to this unidentified small sub-munition.
3. The delivery system for the small sub-munition remains unclear

CHAPTER III.XI

DESTRUCTION OF CHEMICAL WEAPONS AND RELATED ITEMS UNDER UN SUPERVISION

First steps

Resolution 687 (1991) was adopted on 3 April 1991. Three days later Iraq accepted the resolution[1]. On 18 April 1991[2], in accordance with paragraph 9 (a) of resolution 687 (1991), Iraq submitted a declaration of the locations, amounts and types of items relating to its chemical weapons. In a letter of April 18 the Iraqi Government also accepted the arrangement of an immediate on-site inspection of the sort described in paragraph 9 (b) of resolution 687(1991).

The first Iraqi declaration was very brief (one page and half). Iraq acknowledged a CW stockpile of about 550 tonnes of CW agent, including about 350 tonnes in bulk form and about 200 tonnes in weapons, mainly in aerial bombs and artillery. The agents declared were mustard, sarin and tabun. The Iraqis declared that their chemical weapons were stored at their Samarra CW complex (Muthanna) and at six airfield sites. No ground forces sites were included.

The initial declaration was assessed by the permanent members of the Security Council[3] and declared as falling short of requirements. Some Council members were concerned that Iraq had under-declared the number of sites associated with CW, the details of activities at the named sites and the types and quantities of weapons and agents in its possession.

UN Data Declaration Requirements were established in a letter of 16 April 1991 from the Department for Disarmament Affairs of United Nations[4] to the Permanent Mission of Iraq to the UN. According to these requirements Iraq was required to declare:

A. Names, location and condition of each facility engaged in research, development, production (including precursor production), filling, test and evaluation, and storage of CW agents or weapons.
B. Names, location and organizational affiliation of the commander of each unit with CW munitions; managers, scientists, and engineers at each CW agent or

[1] A letter dated 6 April 1991 from the Minister for Foreign Affairs of the Republic of Iraq to Secretary General and to the President of the Security Council.
[2] A letter dated 18 April 1991 from the Minister for Foreign Affairs of the Republic of Iraq.
[3] UK Assessment of Initial Iraqi Declaration, 23-Apr-91; US Assessment of Initial Iraqi Declaration, 6-May-91.
[4] The Secretary-General in discharging his mandate under section C of the resolution was being assisted by the Department for Disarmament Affairs.

precursor production facility, munitions-filling facility, and research, development, test and evaluation site.

C. Location and condition of CW munitions, to include all components (by type of agent mixture, type of weapon and quantity), line drawings, description of explosive and propellant system used, quantity of agent per weapon, weapon/agent marking systems and storage configuration).
D. Location and condition of current and past bulk storage sites and the quantity and condition of agent currently in bulk storage (by type, quantity and form).
E. Other than at the facilities listed above, the location and condition of research and development, production and filling, and test and evaluation equipment. This included facilities with reactor vessels larger than 5 litres used for chemical warfare purposes (including associated processing and separation equipment) and chemical reactors made of high nickel (greater than 30%) alloys.
F. Technical data on all chemical agents developed, produced or weaponized by Iraq, including the chemical name, CAS number, physical characteristics and any special additives.
G. Location and quantity of unfilled munitions capable of being filled with chemical agents.
H. The storage configuration of the stockpile by location, agent type and munitions or bulk.
I. Location and characteristics of facilities for CW destruction, if any.

The Chemical and Biological Warfare (CBW) Working Group held its first meeting in New York from 6 to 17 May 1991[5]. At the outset it agreed that it would be guided by the ongoing work in the Conference on Disarmament (CD) in Geneva and in particular by the contents of the most recent version of the text of the draft Convention being negotiated by the CD's Ad Hoc Committee on Chemical Weapons (CD Document CD/1046 of 18 January 1991)- also known as the Rolling Text. It would also be guided by the results of the 1986 Review Conference of the Biological Weapons Convention and the confidence building measures and information and data exchange mechanisms established by the 1987 Ad Hoc meeting of Scientific and Technical Experts.

The main task of the group was to develop conceptual solutions for the implementation of paragraph 9 of Security Council resolution 687 for Iraq's chemical and biological capabilities. It subdivided its work into three broad categories:

- Verification of Iraq's declarations of its chemical and biological capabilities,
- Inspection of those capabilities,
- Destruction of those capabilities

After intensive discussions of the details given in the declaration by Iraq of its chemical weapons and related capabilities, the CBW Working Group decided to recommend the

[5] CBW Working Group Report for the Period 7-13 May 1991; CBW Working Group Record of Discussion from 13-17 May 1991.

dispatch of a letter to Iraq requesting more information. The Working Group stated that declarations of the amount of agents and number of sites given were inadequate and that it would be necessary to conduct on-site inspections at undeclared sites in Iraq. The final decision as to which sites would be inspected should be made after the reply of the Iraqi government and the receipt of information to be supplied by other governments. Iraq affirmed its willingness to cooperate and, by its own efforts voluntarily to destroy or render harmless the weapons[6] in a way that “would achieve the desired objective under the supervision and to the satisfaction of United Nations experts”.

The Government of Iraq also affirmed that it was prepared to discuss this subject with United Nations experts in order to confirm the destruction plan formulated by its technicians and to establish the plan's exact details by carrying out practical tests. Iraq expected the UN experts to determine what additional measures and resources would be required and expressed its opinion that participating in this way would reduce the cost of destruction and the period of time required for implementation of the destruction plan. Iraq also expected that these measures would reduce the dangers arising for the United Nations inspection teams during the destruction process, especially at a time of extremely hot and dusty local weather conditions.

There was also a continued exchange of communications between the Special Commission and the Government of Iraq with a view to obtaining additional information and clarifications[7]. Iraq's declared holdings of chemical weapons have grown with each successive letter on this subject. [8,9]

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[6] Letter Dated 9 June 1991 from the Charge d'Affaires A.I. of the Permanent Mission of Iraq to the United Nations Addressed to the Secretary-General, S/22682.

[7] Letter of the Permanent Representative of Iraq to the United Nations to the Secretary-General of United Nations of 18 April 1991; Letters of Executive Chairman of the Special Commission the Permanent Representative of Iraq to the United Nations of 30 April 1991, 14 May 1991; A letter signed by the Minister of Industry & Military Industrialization addressed to the Iraqi Foreign Ministry giving information concerning mass destruction weapons in connection with SC Res. 687, May 16, 1991.

[8] In the letter of 16 May, in addition to those munitions listed in the 18 April declaration, Iraq also listed 20,000 CS-filled 120mm mortar bombs, 12,634 mustard-filled 155mm artillery shells and a substantial quantity (approximately 75,000) of unfilled CW munitions, including 24,000 unfilled mortar bombs. Two hundred sarin-filled DB-2 aerial bombs listed in the 18 April declaration as being located at Muthanna were stated in the 16 May letter to be at Muhammadiyat. The letter of 20 July recorded a further “growth” in the Iraqi stockpile. The number of mustard-filled AALD-500 aerial bombs has grown from 140 in the declaration of 18 April and the 16 May letter to 675 in the 20 July letter. Two categories of filled mortar munitions listed: 120mm and 80mm.

[9] Iraqi Declarations of their Chemical Weapons Stocks, 26 July 1991.

It was necessary for the Commission to work out the technical modalities with a view to ensuring the complete and safe handling of chemical weapons and related items for their subsequent destruction, removal or rendering harmless. It was also necessary for the Commission to identify and evaluate safe destruction techniques that could be made operable within stringent time frames taking into account the paramount importance of maintaining acceptable safety standards for the disposal teams and for the local population given the resources available.

There was no prior international experience, although some state-possessors had begun destruction operations of CW stockpiles. Since the expertise needed was not found among the members of the existing CBW Working Group, a special destruction advisory panel had to be established under the aegis of the CW coordinator[10].

The Executive Chairman of UNSCOM approached the governments of Canada, Russia, the UK and the US and asked if they could provide specialists experienced in the chemical weapons field. The countries agreed to provide experts in this field, and these experts (five in total), a representative from the World Health Organization (WHO) and an independent expert in combustion engineering formed a Chemical Weapons Destruction Advisory Panel (DAP) [11].

The function of the CW DAP was to consider possible approaches for the destruction of Iraq's chemical weapons and chemical weapons facilities and make recommendations to the Executive Chairman of the UN Commission. In particular, it had to advise him on destruction methods, sources of destruction equipment and personnel, standards for safety and environmental protection and feasible schedules.

The first task of the DAP[12] was to assess the magnitude of the problem, to select the safe destruction methods and then to plan and supervise the implementation of the destruction operations. In order to do this, all the available options for the destruction of Iraq’s CW stockpiles were reviewed. The question of who would undertake the actual destruction operation was still open. The possible options included the involvement of member states, commercial companies and Iraq itself. A general policy on what items were to be destroyed, removed or rendered harmless, what sequence of the destruction operations had to be established and respective responsibilities had to be assigned to the sides responsible for destruction. The Flow Chart III.XI.I below prepared by the DAP reflects the general outline of the destruction operations and associated activities.

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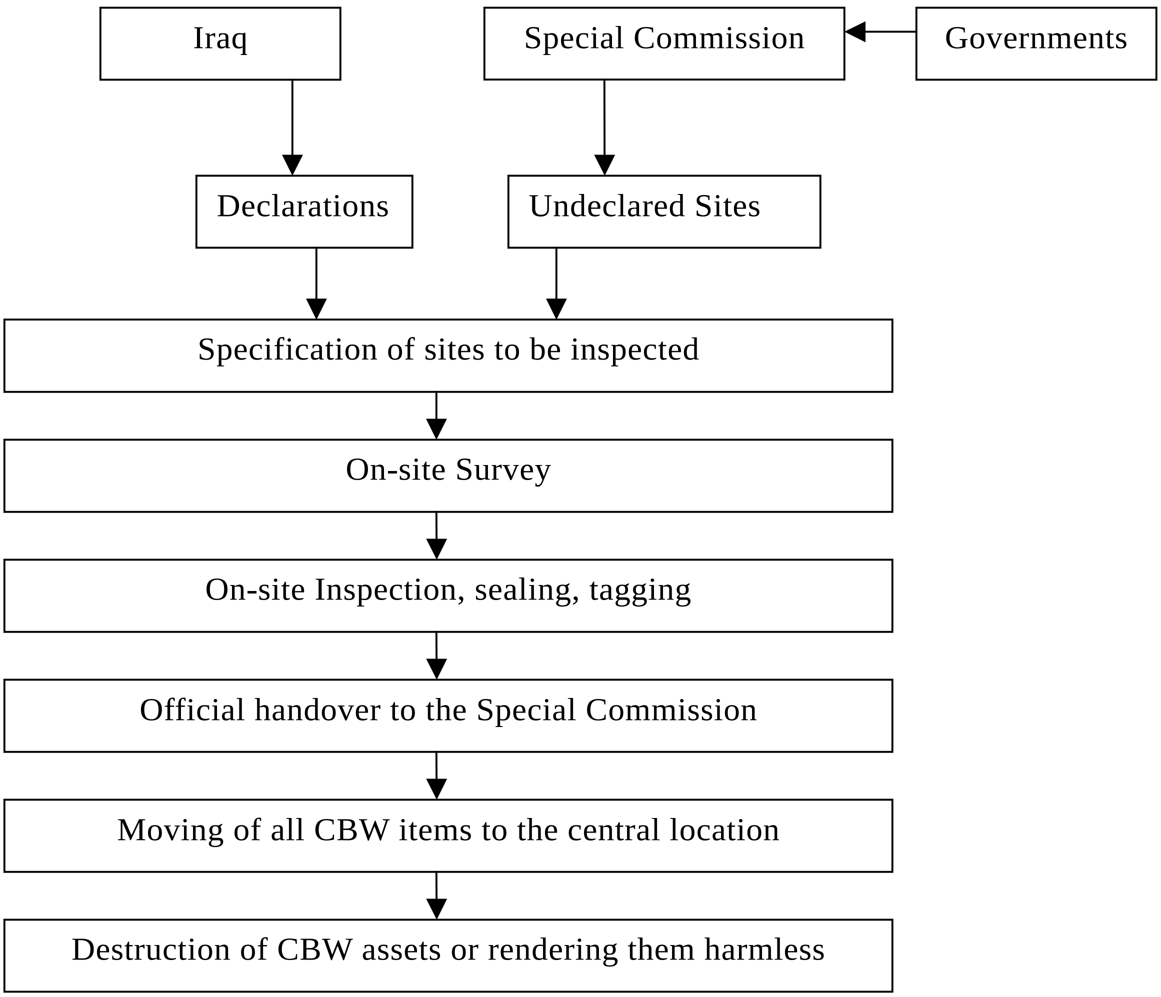
[10] Special Commission Advisory Board on CW Destruction, 30 May, 1991.

[11] Report by the Executive Chairman of the Special Commission, established by the Secretary-General pursuant to paragraph 9 (b) (i) of Security Council resolution 687 (1991), UN doc No S/23165, 21 Oct 1991, para. 21.

[12] The DAP met for the first time in New York 24-28 June 1991. It subsequently met at regular intervals to review the progress of the destruction programme and to provide further technical advice as appropriate.

Chart III.XI.I Flow chart of on-site activities



The analysis of difficulties and constraints

Environmental constraints

Whichever disposal method or methods were to be adopted, the results had to be achieved with a high standard of environmental safety. In difficult and hazardous operations, setting environmental emission standards at realistic and scientifically justifiable levels was essential.

The added difficulty was that the environmental standards varied widely between different countries and there was often little common ground. For example, under United States environmental legislation, CW agents were proscribed substances and their emission to the environment was forbidden. The European approach was somewhat different. Although standards still varied between individual states, the environmental standards were based on two principles: *Best Available Techniques Not Entailing Excessive Cost* and the *Best Practical Environmental Option*. In the case of hazardous materials, the regulations required the potential human and environmental impact to be identified, the risk to be assessed and appropriate action taken to reduce this risk to the minimum practical level.

CW destruction methods evaluation by DAP

In general, the DAP selection approach for the destruction methods was based on following criteria: such methods should be simple, safe and easy from the point of their technological implementation. The following methods were evaluated by the experts of DAP as possible methods of destruction for CW agents and their precursors in Iraq:

Open pit burning

Open pit burning could be used for the disposal of mustard. This process, however, results in the releases into the atmosphere of large amounts of acid combustion products together with quantities of partial combustion products and often some quantities of unburned toxic agent. This method of disposal therefore was only to be adopted as a last option when no other safe methods existed or was possible to apply.

Chemical degradation

An option widely acceptable was chemical degradation, which is the elimination or reduction to an insignificant level of the “highly toxic CW agents” by transforming them into other chemicals. For example sarin is rapidly hydrolysed by the treatment with a 10% to 20% aqueous solution of sodium or potassium hydroxide. The hydrolysis rate of tabun and cyclosarin is markedly slower, due to their lower solubility, but the addition of ethanol to the decontaminant eliminates this problem. Mustard can also be hydrolysed satisfactorily using aqueous/alcoholic solutions of sodium or potassium hydroxide. A 10%-20% chlorine bleach solution was known to be equally effective.

Once the agent degraded, there remained the problem of the disposal of the degradation products. Possible solutions to this problem included incineration or concentration followed by land burial.

The organic content of the hydrolysate can be further degraded by high temperature incineration. However, the very low calorific value and high salt content of the material make this a demanding and expensive solution. Also the problem of disposing of the inorganic salts recovered from the incinerators effluent gas cleaning plant would remain. Since the potential hazard from this material was considered to be low, this somewhat drastic treatment was deemed unnecessary.

The option adopted was concentration followed by land burial. In this approach the products of hydrolysis would be first placed in an open-air evaporation lagoon and the liquid phase would be evaporated. The residual salts would then be collected and buried in a properly constructed landfill capable of preventing any leakage. Given the high ambient temperature in Iraq this was an attractive option. It was safe, cheap, energy efficient and environmentally acceptable when carried out correctly.

Incineration

The majority of CW agents are flammable and have reasonable calorific values.[13] Therefore, they can be destroyed by incineration. Although non-flammable, even sarin can be satisfactorily destroyed by this method. It had already been demonstrated by that time that in properly designed and operated plants a complete disposal[14] of these agents could be achieved.

There had been sufficient experience with direct, high temperature incineration of stocks of mustard in other countries. No problems were experienced with the process and the procedure was environmentally acceptable. It was expected that the provision of an incineration plant in Iraq should not pose major technical problem since it could be constructed from commercially available components. It was therefore decided to opt for incineration as the method of destroying Iraq's stocks of mustard.

It is an equally effective method of destroying G agents, but their higher volatility and greater inhalation toxicity makes the operation more difficult. The problem is not in the actual incineration step, but rather in the handling and feeding of the waste to the furnaces and the protection of the operating staff. Even the best commercial hazardous waste incinerators available at that time provided only a limited degree of containment.

The capability to design incineration plants with the necessary level of containment for the safe handling of nerve agents was very limited in case of Iraq. Plants of this type, by their very nature, require advanced and complex technology. Thus, incineration for nerve agents was not optimum disposal solution.

It was obvious to the UN Special Commission that destroying CW agents and related materials and their associated production and storage facilities was going to be both technologically difficult and hazardous. And although it would be possible to apply

[13] The notable exception being sarin.
[14] 99,9999%.

certain general principles to the overall destruction programme, the actual destruction of each category of CW related materials and its associated facilities would need to be tackled on a case by case basis.

Evaluation of Munitions disposal options

It was clear to the DAP that the major problems were not likely to arise with the final destruction step, but would rest instead with the transportation and preparation of the munitions for destruction. These problems might differ in severity for each of the different categories of material filled into munition and type of munitions.

The destruction of the bulk stocks of agents at their storage locations is less complicated, in comparison with the destruction of CW munitions and CW production facilities. The principal problem in this situation is the provision of the appropriate level of containment and protection for the operators undertaking the work. Protection procedures were well established by those countries, which produced such weapons, including Iraq. Also, Iraq had the well-trained necessary expertise in the area of chemical weapons.

However, in the view of the DAP the transfer of the bulk stocks to a centralized location for destruction would involve problems connected with the safe transportation. It would be necessary to have appropriate packaging, determine acceptable routes of transportation and draw up emergency procedures to deal with any incidents that might arise.

CW munitions without an explosive or propellant component could be treated in a manner similar to bulk agent storage containers, and therefore would not pose any significant additional problem. The situation with Iraq's CW munitions, which contained explosives or propellants would be, however, entirely different. Destruction of these items in a safe manner posed a major problem resulting from environmental constrains and explosive associated hazards. The historical solution to this problem - deep sea dumping – was rejected by the DAP. Instead, two other approaches were considered. One involved the separation of the explosive component from the CW material and then the separate destruction of each element by an appropriate safe method. The other approach was to develop a process capable of safely handling the combined hazard.

The first option was used in other countries for the disposal of occasionally found old chemical munitions. Munitions were placed in a specially designed chemical containment facility, either drilled or cut open remotely, and the CW content then removed by personnel wearing full individual protective equipment. The CW material recovered was either treated chemically or incinerated in a high integrity incineration plant designed for the purpose. The explosive component was destroyed by open burning and the decontaminated metal components buried in a secure landfill.

The technique proved to be safe, relatively cheap and no major problems had been experienced with it. However, it was slow and the disposal throughput was fairly low. Where large numbers of similar munitions were involved, the throughput could be greatly improved by the use of automation. The process needed to be designed in such a manner that an accidental explosion would not present any risk to the staff involved. .

Concerning the second approach a cryogenic fracture process was considered as an option. In this process, the complete munitions should be cooled in liquid nitrogen, to make them brittle, and then mechanically fractured into small pieces. These pieces supposed to undergo a further treatment at a high integrity incineration plant. The system should be designed to provide complete chemical and explosive containment. Plants of this type would require sophisticated technology and engineering. They would involve a lengthy design, construction and commissioning period and would be expensive. The DAP decided not to opt for such a method.

Production Plant, Filling and Storage Facilities Dismantling

In order to decontaminate the associated CW production plant and equipment once the bulk of the agent was removed, a detailed knowledge of the plant's functioning and configuration would be required. Any potential points where remaining toxic liquid might be trapped or held up had to be identified.

The first step would be to drain the facility down and remove as much of the CW agent as possible. The plant process lines would be then completely filled with a 10-20% sodium hydroxide solution to complete the neutralization of the equipment and left to stand for a lengthy period of several weeks. On removal, the sodium hydroxide solution would be checked for the presence of any anti-cholinesterase activity and disposed of accordingly. However, the plant, now free of gross contamination, might still contain traces of agent. For example gaskets, seals as well as building construction materials (such as concrete and tiles) might still be contaminated with the traces of agents.

In the view of the DAP, dismantlement of the plant should start at the top and gradually worked down, piece-by-piece. All joints would need to be broken; gaskets removed and potentially contaminated surfaces exposed. Where practicable the individual plant items would be submerged in decontaminant. The decontaminated components could then be buried in a secure landfill. An additional problem was associated with the fact that many of such facilities were severely damaged during 1991 bombardment by Coalition forces.

Selection of destruction location

In general, the decision concerning whether to destroy the CW munitions and materials at their storage locations or move them to one or two centrally located destruction facilities depended on at least three factors. Firstly the condition and the services available at the respective CW storage sites, secondly, the difficulties associated with moving the CW safely across the country and finally, the destruction method selected.

For example, all incineration plants need ready access to significant amounts of power, fuel and water (if wet scrubbers are used) and require a high level of maintenance support. The situation with incineration plants suitable for handling CW materials is even more complicated.

After considering all aspects of the problem and based on the results of the initial evaluation inspections of Iraq's pre-1991 remaining CW stockpiles, it was decided by the DAP to centralize the destruction operation at a single site and to transport all munitions deemed safe to be moved to this location. It was decided to conduct the destruction operation at the Muthanna CW production site. All the bulk stocks of chemical agent and most of the precursor chemicals were already at the site. In addition, although damaged by 1991 bombardment, much of the necessary infrastructure for the destruction operation was present.

Working personnel requirements

A risk assessment of the effect of destruction activities on the people involved[15] was made. The following general rule was adopted: where protection from exposure would be necessary this would be achieved by primary containment and the use of engineering controls as well as by the use of personal protective equipment.

The need for routine atmospheric monitoring for the presence of toxic substances and routine medical surveillance of staff was also recognized. For the task to be carried out successfully, with the minimum risk to the operators and the surrounding population, the staff involved required knowledge of the hazards and adequate training. Emergency procedures were drawn up and later, their effectiveness regularly tested.

A workforce, teams of engineers and craftsmen with the experience and training necessary to undertake the destruction of CW related materials and facilities, was required. Experience in this field was largely limited to those countries that had CW production knowledge, including Iraq. In addition a wide range of other skills was

[15] This would include both normal and abnormal operating conditions.

required. These included chemists, safety personnel, occupational hygienists, analysts, medical staff, maintenance personnel and ventilation engineers.

Other considerations

Taking into account the complexity, difficulties and constraints associated with the destruction process, any practical arrangements had to be preceded by an on-site evaluation of each facility or storage locations. This was carried out by UNSCOM teams made up of scientists and engineers with hands-on experience of CBW materials.

With the acceptance of Iraq's request[16] to undertake the operation using its own process equipment and personnel, the major logistical problem associated with transporting such equipment and international technical personnel to Iraq was removed. Another consequence of this was that the destruction techniques had to be a reliable solution within Iraq's existing capabilities.

Detailed discussions were therefore held between the UNSCOM experts and their Iraqi counterparts to establish whether the Iraqi proposal to handle large-scale destruction operations was feasible. As a result of these discussions it was agreed that Iraq would construct the facilities required for the destruction of its CW stockpiles and operate them under UNSCOM supervision and direction[17]. The decision to have the destruction centralized at MSE ensured that the major safety and environmental hazards would be limited to one site, and therefore more easily controlled[18].

During the MSE site evaluation, inspectors noted a high level of hazards as a result of both bombardment and the past chemical weapons programme. The first UNSCOM inspection team reported from Muthanna in 1991[19] "chemicals at Muthanna are stored in many places, indoors and outside, in containers and weapons, many of which are leaking. It constitutes significant safety hazard". Lots of barrels of chemicals and weapons including 250kg and 500kg aerial bombs were dispersed all over the MSE territory. Taking care of these poorly secured munitions represented one of the first tasks to be carried out by UN inspectors.

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[16] Iraqi Letter No 212 to the SG concerning voluntary destruction of weapons; Iraqi letter proposing chemical and missile destruction plans 19 May 1991.
[17] UNSCOM 09/CW-2, August 1991, Para 4.7; Iraqi letter No 1-7-333, The Approval of UNCOM to Iraq's use of Pilot Site No 2, Aug 22 1991; Executive Summary of Fact-finding Mission to Iraq 11-14 August on CW Destruction, 1991; Cost of Destruction of Iraq's CBW; Destruction of Iraqi CW Agents and Munitions Potential Options.
[18] Environmental Protection during UNSCOM chemical agent destruction operations, May 1 1992
[19] UNSCOM 02/CW-1, June 1991.

General destruction policy

In October 1991, UNSCOM established a general policy[20] on destruction[21], removal[22] or rendering harmless of Iraq's CW[23]. The policy included following:

1. All weapons and weapons systems (whether fully functional or not) including all their related subsystems and components were to be destroyed.

2. Equipment and materials:
    a. Equipment or material specially designed or used for prohibited under SCR 687 activities were be destroyed (or removed from Iraq if destruction would not be practically possible);
    b. Dual purpose, multi-purpose or general purpose equipment or materials
        i. that were exclusively or primarily used (or intended to be used) in prohibited activities or activities related to prohibited items shall be destroyed (or removed from Iraq if destruction is not practically possible);
        ii. that were only in part used (or intended to be used) in prohibited activities related to prohibited items shall be destroyed unless the special Commission upon specific written request from Iraq authorizes their use as an exception in activities not prohibited by resolution 687 (1991).
3. Buildings
    a. Buildings that have distinctive features making them specifically suitable for prohibited activities related to prohibited items shall be destroyed (if it is not practically possible to destroy the building, its distinctive features shall be destroyed);
    b. Standard buildings shall be destroyed unless the Special Commission upon specific written request from Iraq authorizes their use as an exception in activities not prohibited by resolution 687 (1991)

The criteria for the release of equipment, materials and building from destruction were not precisely spelled out, which later resulted in arbitrary decisions on whether or not an item might be released.

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[20] Guidelines For The Destruction, Removal or Rendering Harmless of Prohibited Items Under Resolution 687 (1991).
[21] "Destruction" meant physical demolition of an item; (for chemical it was appropriate chemical transformation).
[22] "The removal" meant moving an item outside Iraq.
[23] "Rendering harmless" meant modification of an item to such a degree that it no longer possesses specific features that rendered it capable of use by Iraq in prohibited activities or readily amenable to re-conversion.

Comment
The decisions made by the Commission with regard to release of some process equipment from MSE for commercial activities in 1994 were later changed. It became apparent that Iraq falsely declared the purpose of the equipment installed, for example at the Dhia plant (VX facility). This equipment used for and intended for production of VX was declared as pesticide formulation equipment. Later, in 1997 UNSCOM destroyed this VX related equipment as well as other equipment previously removed from MSE (in total 200 pieces).

Destruction Operations

After the destruction plan was drafted and UNSCOM discussed with the United Nations Environmental Programme destruction methods selected,[24] Iraq was instructed to start collecting chemical filled and unfilled munitions and other related items and materials from various locations and bringing them to the Muthanna site. Only munitions and chemicals representing immediate health and environmental hazards and assessed as too unsafe to transport were destroyed by Iraq under UNSCOM supervision at sites where they had been located[25].

In the autumn of 1991 Iraq destroyed the first batch of unfilled chemical munitions under UNSCOM supervision[26]. By the summer of 1992, most of Iraq's chemical weapons stockpiles were already accumulated at Muthanna. The construction of two main destruction plants was also underway[27]. The direct destruction activities under UN supervision started in September 1991.[28] Unfilled chemical weapons munitions, 122 millimetre rocket warheads and dies used for making bombs were destroyed. But large-scale destruction began in June 1992 when a special Chemical Destruction Group (CDG) was formed. During the period from June 1992 to June 1994 Iraq, under the supervision of UNSCOM's CDG, destroyed thousands of tonnes of warfare agents and

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[24] A letter of 4 May 1992 to the Executive Director of United Nations Environmental Programme, Environmental Protection during the Special Commission Chemical Destruction Operations; Communication of Environmental Protection during CDG destruction operations in Iraq of 15 May 1992.
[25] Second report of the Executive Chairman of the Special Commission, established by the Secretary-General pursuant to paragraph 9 (b) (i) of Security Council resolution 687 (1991), UN Doc No S/23269, 4 Dec 1991, Para. 19; Fact Finding Mission Regarding CW Destruction In Iraq, August 1991; UNSCOM 20/CW-6 paras 23 and 141d.
[26] UNSCOM 12/CW-04 August 1991.
[27] Third report by the Executive Chairman of the Special Commission, established by the Secretary-General pursuant to paragraph 9 (b) (i) of Security Council resolution 687 (1991), UN Doc No S/24108, June 1992, para. 13.
[28] UNSCOM 12/CW-04 August 1991.

their precursors along with tens of thousands of chemical munitions[29]. This destruction included 22,000 filled and over 16,000 unfilled chemical munitions, 690 tonnes of CW agents (both bulk and weaponized), more than 3,000 tonnes of precursor chemicals and over 100 major items of CW production equipment.

The last destruction activities under UN supervision occurred in February 2003, when UNMOVIC disposed of small quantities of 155mm artillery shells and the mustard they contained.[30]

Below is a summary of all UN missions related to the destruction of CW related items, a description of the methods used and material balance of items destroyed.

Destruction related missions

UNSCOM 2 (9-14 June 1991)[31]

The first chemical weapons related inspection was a survey of the Al Muthanna State Establishment. One important task of the survey team was to evaluate the hazards as well as to make a preliminary assessment of the site and of Iraqi declarations as a necessary preliminary step to a subsequent full, detailed and safe inspection of the site. Personal safety issues were considered to be a priority during this survey because of the unknown nature, magnitude and extent of hazards. The site had been heavily bombed during 1991 and it was expected that the site would be in a very hazardous condition, not only because of the presence of damaged and leaking chemical weapons munitions and bulk chemical weapons agents stored there but also due to unexploded ordnance and construction hazards. .

Other tasks of this survey team included:

- a general description of the Al Muthanna State Establishment;
- a detailed description of specific areas (identifying any that would require particular attention during the subsequent inspections) ;
- identification of any particular problems likely to be encountered during the subsequent inspections
- any indicators of undeclared activities relevant to Security Council resolution 687 (1991) ;
- any factors relevant to the use of the site for the destruction of chemical weapons; and a brief description of the Iraqi chemical weapons munitions present .

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[29] Executive Summary Report – Chemical Destruction No. 3 (CD3), 1994.
[30] Thirteenth quarterly report of the Executive Chairman of the United Nations Monitoring, Verification and Inspection Commission in accordance with paragraph 12 of Security Council resolution 1284 (1999), May 2003, S/2003/580.
[31] UNSCOM 02/CW-01 June 1991.

The following were the principal outcomes of the inspection:
(a) None of the information gathered was significantly at variance with the Iraqi declaration of 1991;
(b) No evidence was found at this site for non-chemical weapons activities relevant to Security Council resolution 687 (1991);
(c) The site was in a highly dangerous condition;
(d) The site would provide a suitable location for the centralized destruction of Iraq's chemical weapons agents and munitions, but the technical details regarding the destruction of those items, particularly the involvement of Iraqi personnel, remained to be fully defined.

UNSCOM 9 (15-22 August 1991)[32]

The second chemical weapons inspection consisted of one day at each of three chemical production sites in the Al Fallujah area, two days inspecting the pilot plants at Al Muthanna and one day inspecting the declared storage site at Tammuz (Al Taqqadum) Air Base at Habaniyah. Discussions with Iraqi officials during the inspection clarified previous ambiguities about the Al Muthanna State Establishment.

The inspections of the Al Fallujah sites in general confirmed the Iraqi declarations. The site Fallujah 1 had never been completed and had therefore not been used for the production of chemical weapons-related items. According to Iraq, plans for the large-scale production of other materials such as PCl_3, $POCl_3$, $SOCl_2$ and other precursors at Fallujah 2 were not realized. Fallujah 3 had never been used for the production of chemical weapons agent precursors; instead it had been used for the formulation of pesticides, the active ingredients being imported. Some commercially available chemical weapons precursor chemicals were found at this site. Bombing during 1991 extensively damaged all three sites.

The Iraqi authorities stated that chemical weapons agents were neither produced nor stored at any of these sites. The team found no evidence, which contradicted this statement.

The inspections of the pilot plants at Al Muthanna revealed that one had been destroyed by bombardment, but two others were still in relatively undamaged condition. These two pilot plants were inspected in detail and UN inspectors concluded that they could, as proposed by Iraq, be adapted for use as a pilot-scale facility to develop a method for the destruction of the Iraqi nerve agents based on caustic hydrolysis. The team recommended that Iraq be given permission to carry out the necessary modifications and the relevant process development.

[32] UNSCOM 09/CW-02 August 1991.

In the course of the inspection of the Tammuz (Al Taqqadum) Air Base at Habaniyah, 200 aerial bombs were counted and recorded. Analysis of air samples from two of these bombs, selected at random, confirmed that they contained mustard agent. These findings were consistent with the Iraqi declaration that 200 mustard-filled aerial bombs were stored at this site.

UNSCOM 11 (31 August - 9 September 1991)[33]

The third chemical weapons inspection visited declared sites at Dujayl, Al Bakr Air Base and the auxiliary Al Mutassim Aerodrome, the Proving Ground at Al Fallujah and undeclared sites designated by the Special Commission at Al Fallujah General Headquarters and Al Taji. In the depot at Al Fallujah General Headquarters, which had not been declared as containing any chemical weapons items, UN inspectors found chemical protective equipment and related material as well as a variety of grenades containing the riot control agent CS but no other chemical filled munitions.

The team examined the 30 chemical-filled ballistic missile warheads declared by Iraq and found by UNSCOM some 30 kilometres from the location notified to the Special Commission. Iraq had informed the Special Commission that 14 of the warheads were of the so-called binary type filled only with a mixture of isopropanol and cyclohexanol, the organophosphorous component (MPF) required to produce the nerve agent was to be added immediately prior to use. The resulting agent would have been a mixture of the nerve agents GB and GF. Fifty-six plastic containers filled with MPF were also found; these bore evidence of extensive leakage. Iraq stated that the other 16 warheads were filled with a mixture of nerve agents GB and GF. Analysis of samples taken from they binary warheads, one of the nerve agent filled warheads and MPF container, by laboratories outside Iraq confirmed Iraqi declarations. Iraq was instructed by the team to transport the warheads to Al Muthanna for disposal.

At Al Bakr Air Base 25 type 250 gauge aerial bombs and 135 type 500 aerial bombs filled with mustard agent had been declared by Iraq. These were found at Al Mutassim Aerodrome, an airfield auxiliary to the Al Bakr Air Base, situated about 30 kilometres to the north of the Base. They had evidently developed internal pressure since four had already burst spontaneously and mustard agent vapour was detected at the site, necessitating the use of full individual protective equipment when working close to the bombs or downwind of them. Samples were taken from four of the bombs, which were then resealed. Iraq was instructed to transport the bombs to Al Muthanna subject to strict safety precautions and after venting the excess pressure.

The site of Al Taji was a large military installation, which had been declared in connection with ballistic missiles but not for chemical weapons. UN inspectors

[33] UNSCOM 11/CW-03 August1991.

observed approximately 6,000 empty aluminium containers intended for filling with nerve agent and insertion into 122mm rocket warheads.

At the Al Fallujah Proving Ground, Iraq had declared the storage of 6,394 mustard-filled 155mm artillery shells. They were stored in the open and appeared to be in good condition. Analysis of samples taken from four of the shells confirmed the presence of mustard agent. In discussions with Iraqi officials contradictory statements were made regarding the marking of chemical munitions. Iraqi officials also failed to respond satisfactorily to requests for information on Iraq's past chemical weapons programme, particularly as regarding foreign suppliers of munitions, equipment and precursor chemicals.

UNSCOM 12[34] (31 August -5 September 1991)

The fourth chemical weapons inspection (UNSCOM 12) had two primary tasks. The first was to direct the destruction, by Iraqi personnel, of all unfilled chemical weapons munitions currently at Al Muthanna. The second was to reconnoitre, select and show to Iraqi officials the locations at Al Muthanna where bulk agents, chemical munitions and intermediate precursor and other chemical weapons-related chemicals would be collected and the locations where future destruction operations would be carried out.

The destruction operations were successful. A total of 8,157 unfilled chemical weapons munitions, consisting of six different varieties of bombs, 155mm artillery shells and 122mm rocket warheads were destroyed either by crushing with a bulldozer or cutting with an oxyacetylene torch. Subsequently, parts of chemical munitions and 3,672 122mm rocket warheads were destroyed. Dies used for making bombs remained to be destroyed.

During the inspection two incidents took place, which reminded the team that Al Muthanna was an extremely hazardous site and that the recovery and destruction of Iraq's chemical weapons munitions (and agents) would be a protracted and dangerous undertaking.

During this destruction work, a supposedly unfilled 122mm rocket warhead burst and a nearby Iraqi worker was exposed to nerve agent. Owing to the prompt action of a member of the inspection team the casualty was very quickly taken to the site hospital where he received appropriate and timely treatment from Iraqi medical personnel. He recovered over a period of a few days. A separate incident occurred in the case of the 30 chemical-filled ballistic warheads removed to Al Muthanna from Dujayl in two separate shipments. In the first shipment, 14 warheads stated by the Iraqis to be filled with the mixture of alcohols, and considered relatively harmless, were moved. Ten were opened, found to contain the alcohols and were drained preparatory to destruction. At this point

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[34] UNSCOM 12/CW-04 August 1991.

the senior Iraqi official present said that the remaining four were filled with the nerve agent sarin. Apparently these warheads had been moved during the night prior to dispatch to Al Muthanna and the sarin-filled warheads had been confused with alcohol-filled ones.

According to the inspection report "Iraq has declared 6,120 sarin-filled 122mm rocket warheads and their attendant motors. They are stored in the open but have not been counted nor have their contents been verified. They present a significant hazard both from the point of leakage of sarin and instability of the rocket propellant. In order to improve safety the Iraqis were directed to move the warheads to the designated storage area; the rocket motors were to be separated and moved to another storage area separate from the warheads. They will remain in these locations until both warheads and motors have been separately counted and verified. A suitable storage location at Al Muthanna for chemical weapons agents and munitions was identified and the Iraqi officials briefed and given detailed maps of the area. Four possible destruction sites at MSE were identified."

UNSCOM 17[35] (7 October - 8 November 1991)

The purpose of the fifth chemical weapons inspection (team of over 50 persons) was to conduct a detailed and full survey of Al Muthanna in preparation for the destruction phase. The team compiled a comprehensive and detailed inventory of the site, including facilities, munitions, agents, agent condition, precursors and intermediates. Among the salient findings were the discovery of small quantities of the nerve agents' sec.butyl sarin, n-butyl sarin and ethyl sarin, although Iraq has disputed the identification of the latter two agents. While the quantities found were of no direct military significance, the relevance of the finding lies in the fact that Iraq clearly had carried out research on nerve agents other than those previously declared.

Although the mustard agent at Al Muthanna was generally of good quality (typically 90 per cent), the nerve agents were found to have undergone extensive degradation and the agent content was very low, generally below 10 per cent and in some cases below the one per cent level.

In general, the findings of the inspection at Al Muthanna were in substantial agreement with Iraq's declaration. In the case of the 122mm rockets however, a precise and full count was not possible due to hazards associated with the very dangerous condition of the rockets and the fact that the bunker which contained some 2,500 sarin filled rockets was partly damaged by 1991 bombardment (it contained an unexploded bomb inside).

[35] UNSCOM 17/CW-05 September 1991.

According to inspectors, an explosive demolition would be the safest method of the destruction of the rockets since opening and draining operations would be particularly hazardous.

Technical visit by UNSCOM (11 to 15 November 1991)

A four-person mission visited Iraq for detailed technical discussions with their Iraqi counterparts on several issues related to the destruction of chemical weapons and agents, with particular emphasis on the direct involvement of Iraq in this process and on safety aspects. Issues discussed and on which the Special Commission team made recommendations included the Iraqi design for a mustard agent incinerator, the destruction of nerve agents by caustic hydrolysis, and the opening munitions and draining agent out of munitions. .

The discussions on the destruction of chemical weapons and agents resulted in a considerable improvement in technical understanding by both sides, including issues of the potential hazards involved in some operations and the technologies potentially available for implementing the various destruction processes.

UNSCOM 20[36] (22 October - 2 November 1991)

The sixth chemical weapons inspection team was tasked to inspect the declared storage sites, which were not visited previously, including some that are widely separated geographically.

In order to complete its tasks in the time allocated, United Nations helicopters were used. The chemical weapons munitions were verified, counted and recorded. Where it was safe to transport the munitions to Al Muthanna, the necessary instructions were given to Iraqi personnel. At Al Tuz, Khamissiyah and Muhammadiyat sites numbers of munitions were discovered, including 122mm rockets, which were considered to be too unsafe to move to MSE and for which a drilling and draining operation would be very dangerous as well. A recommendation was made that these items should be destroyed *in-situ* by explosive demolition. In a few cases, due to extensive destruction by coalition bombing, it was not possible to observe and count all munitions; when the damage had been less extensive the number and types of munitions observed were well correlated with the Iraqi declarations (at this point of time Iraq did not disclosed yet its large-scale unilateral destruction activities with the bulk agents, precursors and munitions and refused to discuss in any form the number of munitions consumed during Iran-Iraq war, which affected the UNSCOM ability to verify the material balance for munitions).

[36] UNSCOM 20/CW-06, October 1991.

UNSCOM 21[37] (18 November - 1 December 1991)

A combined chemical and biological weapons inspection team revisited Salman Pak, and a number of sites designated by the Special Commission as being of potential chemical weapons and/or biological weapons interest; some 13 sites were inspected. In the course of the inspection a small sub-team was dispatched to Al Muthanna to witness an Iraqi experiment with a stimulant D4 (precursor of tabun) to test the use of the modified pilot plant for exploratory work on the destruction of nerve agents by caustic hydrolysis.

At the Mosul Sugar Factory, almost 100 items of metal working machinery from the bomb workshop and general workshop at Muthanna were discovered. This machinery had been used for the manufacture of 250 and 500 gauge bombs. These items were marked and catalogued and the Iraqi officials were requested in writing to return all the items to Muthanna for further destruction.

UNSCOM 26[38] (27 January - 5 February 1992)

The 10 sites inspected had either been declared by Iraq or were designated for inspection by the Executive Chairman. The inspection team was also able to verify the return to Al-Muthanna site of the bomb-making equipment from Mosul and to observe preparations for and completion of one experimental test run of nerve agent hydrolysis at the pilot plant. Changes to the experimental conditions and procedures were requested by the team, largely on safety grounds, but also including some technical aspects. The team concluded after the test run that additional test runs would be required to establish and prove satisfactory operating conditions and procedures.

UNSCOM 29[39] (21 February to 24 March 1992)

The team directed, controlled and observed the destruction of the 122mm rockets at the Khamissiyah site (this site was damaged by 1991 bombardment) by Iraq's personnel and provided technical expertise and equipment (including explosive ordnance destruction expertise, decontamination and medical cover, atmospheric sampling and agent monitoring equipment) as necessary. These rockets were not transportable due to their hazardous status and therefore the decision was made to destroy them at the area of their location. Owing to a combination of technical problems, the work experienced initial delays; in addition more rockets were present than expected and further rockets were discovered, buried on the site, some of which were recovered and destroyed during the operation.

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[37] UNSCOM 21/CBW-1, November 1991.
[38] UNSCOM 26/CW-07, January 1992.
[39] UNSCOM 29/ CD-1, April 1992.

A total of 463 rockets (389 filled, 36 partially filled and 38 unfilled) were destroyed, approximating to 2.5 tonnes of agent (a GB/GF mixture). Safety and environmental concerns were of paramount importance throughout the whole operation, and the Special Commission's requirements were strictly observed. A system for atmospheric monitoring was established with two linear arrays, at 200 metres and 1,800 metres, downwind of the destruction area. No evidence of any significant atmospheric contamination by the nerve agent was obtained.

UNSCOM 32[40] (5 to 13 April 1992)

The team assessed progress and the need to provide expert technical guidance related to preparations for the destruction of CW agents at Muthanna. The team noticed considerable progress with the construction of the mustard agent incinerator and estimated that the work was approximately 70 per cent complete. The major elements were in place but further work, including modifications required by the team, was necessary before commissioning could be considered.

The experimental work on nerve agent hydrolysis carried out to date, together with the four experiments directed and observed by the team, demonstrated the feasibility of the process. Consistent achievement of the destruction limits set by the Special Commission had yet to be convincingly demonstrated owing to the need to check the analytical procedures. In the team's opinion further experimental runs were required to fully define operating parameters once the effectiveness of the analytical procedures, based on gas liquid chromatography, had been proven. The construction of the large-scale nerve agent hydrolysis plant progressed well but further work and modifications requested by the team as a result of their inspection were required.

The team also conducted following activities:

- selected areas at Al Muthanna where the ballistic-missile chemicals[41] could be safely stored to await destruction there;
- discussed with Iraq possible means of destruction and also safe transportation of chemicals to Muthanna;
- identified a suitable building for use as an operations room, offices, medical room and other facilities at Al Muthanna for UN inspectors supervising the destruction operations at MSE

[40] UNSCOM 32/ CD 2, April 1992.
[41] Just prior to UNSCOM 32's departure for Iraq, the Special Commission decided that ballistic-missile-related chemicals (ammonium perchlorate, hexamethylene diisocyanate, tolylene diiaocyanate, and aluminium powder - all used in the production of solid rocket propellant) should be transferred from their existing locations to the Al-Muthanna site for controlled destruction there.

- inspected a roller mounted cradle with a fitted remotely operated electric drill, developed by Iraq for the remote drilling of potentially hazardous 155mm shells, and agreed that it would be safe and effective but would be time consuming and labour-intensive.

UNSCOM 35[42] (15 to 29 April 1992)

This team visited 14 sites to verify, to the extent possible at that time, Iraq's declarations relating to CW items unilaterally destroyed by Iraq during July 1991. Additionally, the team carried out a no-notice inspection of a suspected documentation centre. The team also visited the previous headquarters of the Technical Research Centre. No activity of relevance to the Security Council resolution 687 (1991) was observed.

UNSCOM 38[43] (CDG) 18 June 1992- 16 June 1994

A dedicated UNSCOM team, the Chemical Destruction Group (CDG) was deployed in Iraq at MSE to supervise and monitor destruction operations carried out by Iraq, including regular environmental monitoring during the period 1992-1994. When CDG begun its operations some fact-finding missions and destruction operations related to CW had already been performed by Iraq under UNSCOM supervision (see above).

The work at Muthanna site was conducted in cooperation with Iraq. The CDG established and refined destruction techniques in coordination with the members of Destruction Advisory Panel. The Iraqi side, under the CDG supervision, then implemented all destruction operations. The CDG's developed operational procedures that covered physical destruction operations and chemical reconnaissance. It also provided decontamination and medical support to Iraqi personnel. Over 100 experts from 25 countries served with the Group during the period of its work in Iraq. Owing to the dangerous nature of the work and the hazard inherent in the destruction area, utmost attention was given to minimizing the health and environmental impacts of the destruction of CW and their components. The group personnel suffered no serious injures during destruction operations. The final sampling and analysis conducted by UNSCOM upon the completion of the destruction showed that no significant chemical weapons related environmental hazards existed at the Muthanna State Establishment.

The CDG utilized a number of techniques to achieve its mandate. Mustard agent and other flammable precursors were destroyed in an incinerator designed and built by Iraq from items of equipment procured and used in the past by Iraq's CW programme. This incinerator at MSE was commissioned by UNSCOM. While the incinerator was

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[42] UNSCOM 35/CW-08 April 1992.
[43] UNSCOM 38/ CDG, Executive Summary Report.

operated by Iraq, the CDG monitored its operation and monitored the exhaust products. The CDG developed and implemented detailed medical support procedures.

The nerve agents sarin, cyclosarin and tabun and their precursors D4 and MPF were hydrolysed using a converted former Iraqi sarin production plant. The facility was converted from production to destruction activities by Iraq under UNSCOM's guidance and supervision.

Destruction on an ad hoc basic through explosive venting and simultaneous burning was implemented for chemical munitions damaged during the 1991 Gulf War. These munitions represented immediate health and environmental hazards and for safety considerations could not be transported to the designated destruction plants at Iraq’s former chemical weapons complex.

In order to fulfil its mandate, the CDG borrowed and purchased a large amount of specialized equipment. Nearly all of the materials needed to effect the destruction of the Iraqi chemical weapons had to be imported. The CDG benefited greatly from the UNSCOM helicopter and fixed wing aircraft capabilities. Helicopter support was used for transport from Baghdad to Muthanna and other operating areas, for site surveys and was on hand for Medical Evacuation support.

All hazardous waste resulting from the destruction of CW was safely sealed at several structures and areas of the Muthanna State Establishment with reinforced concrete and brick walls covered with earth. These included two bunkers, one of which was damaged by aerial bombardments in 1991 and contained 122mm artillery rockets and munitions remnants that had been filled with the nerve agent sarin. To maintain security and safety, in a signed protocol with UNSCOM, Iraq undertook to inspect the sealed structures at least once a month to ensure that the seals were intact and warning signs had not been removed, damaged or defaced for as long as SC resolution 715 (1991) remained in force.

Comment
Iraq’s UN-supervised destruction of chemical weapons shows the importance of long-term continuity in the site security and safety arrangements and hazardous materials disposal.

UNSCOM 39[44] (26 June - 10 July 1992)

This team conducted inspection activities at declared and undeclared Iraqi sites, essentially in the search of documentation concerning Iraq's proscribed weapons activities. The team also surveyed and recorded reconstruction activity at the Fallujah

[44] UNSCOM 39/CBW-2 June 1992.

sites. In addition, it supervised the destruction of the majority of the chemical bomb-making equipment at MSE.

UNSCOM 44[45] (21 - 29 September 1992)

The aim of this mission was to verify the location and quantity of chemical munitions and agents awaiting destruction and hence to assess whether Iraq had implemented in full the Commission's instructions to move all identified agents and munitions to the central destruction facility at the Muthanna State Establishment. With the exception of the mortar rounds at Fallujah and whatever remained in the damaged and unsafe bunkers at Muhammadiyat and Khamissiyah, this was found to be the case. A full survey of the agents and munitions at Muthanna was carried out and a comprehensive inventory, which formed the baseline for destruction activities 1992-1994, was drawn up.

UNSCOM 47[46] (06-14 Dec 1992)

Through a series of inspections of undeclared sites that were primarily CW-related and through interviews with Iraqi personnel, the team sought information to fill gaps and clarify ambiguities in Iraq's declarations of its programmes relating to both chemical weapons (CW) and biological weapons (BW).

UNSCOM 55[47] (6 - 18 April 1993)

A number of potentially chemical weapons-related sites were visited, including the Fallujah sites. A Chief Inspector handed over to the Iraqi side a letter requiring the removal of certain items of equipment used in the PCl_3/$POCl_3$ production plant at Fallujah to Muthanna for destruction under the Special Commission supervision. These items had been procured by Iraq specifically for the production of chemical weapons precursors and as part of Iraq's chemical weapons programme. Consequently, the Commission decided that the whole PCl3/POCl3 plant needed to be dismantled. .

UNSCOM 67[48] (1 to 11 February 1994)

The team inspected sites at which dual-purpose chemical production equipment was located, inventoried all the equipment at the sites visited and tagged approximately 240 pieces of dual-use chemical production equipment procured under the auspices of Iraq’s chemical warfare programme. It also assessed how and when the Chemical Destruction Group at al Muthanna should terminate its operations there.

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[45] UNSCOM 44/CW-08, September 1993.
[46] UNSCOM 47/CBW-3, December 1992.
[47] UNSCOM 55/CW-10, April 1993.
[48] UNSCOM 67/CW-13, February 1994.

UNSCOM 76[49] (31 May to 12 June 1994).

The aim of the inspection was to take environmental samples and to analyse them in real time at Muthanna in order to provide data on the state of the Muthanna site at the time of handover to Iraq.

UNSCOM 77[50] (8 to 14 June 1994)

The results of the analysis of environmental samples taken by UNSCOM 76 were incorporated into the Muthanna handover protocol[51]. UNSCOM 77 conducted a final inspection and found no presence of the traces of toxic compounds in environmental samples and transferred responsibility for the Muthanna site back to the Iraqi authorities.

UNSCOM 153[52] (2-17 May 1997) and UNSCOM 195[53] (1 - 4 July 1997)

The missions contributed to unravelling the history of the Muthanna State Establishment in terms of CW production plants and equipment used for CW purposes. Only under pressure from the Commission did Iraq admit that 48 pieces of the equipment released from destruction under UN supervision had actually been used in Iraq's VX- activities. A comprehensive description of CW production activities at MSE and their chronology was established by inspectors, including the detailed inventory of specifically designed and standard process equipment involved or intended for production of CW agents and their precursors.

UNSCOM 196[54] (29 Sep - 09 Oct 1997)

The team was tasked to supervise the destruction of process equipment, analytical equipment and glassware admitted by Iraq to have been procured for its CW programme. On the first day of the mission part of the analytical equipment and the fragile graphite elements of the heat exchangers were destroyed. Conventional gas welding equipment used for cutting proved to be unsatisfactory because the rate of progress was very slow. Even when, on the second day, two plasma cutters and an extra crane were provided, the amount of cutting required destroying the large, jacketed

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[49] UNSCOM 76/CW-17, May 1994.
[50] UNSCOM 77/CW-18, June 1994.
[51] In order to ensure accurate transfer of results and full coordination, UNSCOM 77 and 76 inspections overlapped by three days. On 14 June 1994, the Chemical Destruction Group (UNSCOM 38) and UNSCOM77/CW-18 left Iraq, and the Chemical Destruction Group was disbanded.
[52] UNSCOM 153/CW-31, May 1997.
[53] UNSCOM 195/CW-38, July 1997.
[54] UNSCOM 196/CW-18, September 1997.

reactor vessels meant that the aim of the mission could not be achieved in time. Therefore UN inspectors decided that filling the vessels with concrete would be an acceptable destruction technique and quicker method of destruction, although some cutting of the vessel was still required. A second advantage was that this method did not require the burning of tank residues and therefore the amount of toxic fumes coming out from equipment was minimized.

The concrete trial was carried out on the third day of inspection, and proved satisfactory. Unfortunately, the poor state of the tyres on the cement mixer meant that only two reactors could be destroyed with one load of concrete ($3m^3$). The remaining analytical equipment and the glassware were destroyed with no difficulty on the fourth day of the mission.

In the final three days, the Iraqis managed to destroy all of the equipment at Fallujah 2, Muthanna and Ibn AI Beytar. The team's active approach, with the many detailed suggestions and advice offered to Iraqi personnel, combined with the expertise of the Iraqi site engineers lead to the successful conclusion of the mission

Chemical Group, CG-11[55] (1-9 Sep 1997)

CG-11 (chemical residential monitoring group) was tasked to support the mission of UNSCOM 196 in the phase of the preparations for the equipment destruction by supervising the dismantling of equipment designated for the destruction and during the destruction operation itself. It also discussed the procedure for the destruction of isopropanol (precursor for sarin) and diisopropyl amine (precursor for VX) transferred by Iraq in 1991 from MSE, with Iraqi representatives and supervised the destruction process of these precursors at the Dawrah Oil Refinery.

Mustard filled 155-mm artillery shells

Under UNMOVIC supervision, Iraq destroyed mustard filled 155mm shells remaining in Iraq. The shells found in 1997, were stored at a declared location at the former Muthanna State Establishment[56]. In total, there were 14 shells, containing approximately 49 litres of agent — four of them had been earlier emptied and sampled by UNSCOM[57]. The agent was destroyed at the site in February 2003 by chemical reaction and the empty shells destroyed with explosives. Samples taken from the shells

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[55] CG-11, CW precursor destruction reports September 1997.
[56] Declarable changes for the site covered by monitoring in the chemical field since 16 December 1998 para 35.3 (Iraq's Semi-Annual Declarations Jul. 1998-Jul.2002), Iraq's Chemical CAFCD December 2002, Addendum, UNMOVIC-02-00007-CW-0008 December 2002;
[57] UNSCOM 229/CW-45, March 1998 UNSCOM 210/CW-48 May 1998.

showed that mustard gas produced over 15 years earlier was still of high quality — up to 97 % purity.

Thiodiglycol

A small quantity of thiodiglycol (500ml) was also destroyed under UNMOVIC supervision in January 2003. That prohibited mustard precursor was found at the Al Basil Jadiriyah complex along with some other dual-use chemicals (also of laboratory quantity) by the chemical inspection team[58]. According to the Iraqi site representatives, the chemical had been left over by a previous occupant of the site — the Scientific Research Centre — and had not been used by the Al Basil complex for any purpose. The entire quantity of the chemical was destroyed on-site by chemical reaction and combustion[59]. Inspection activities following the finding did not reveal evidence of any research being done at the site regarding the chemical agent mustard or the precursor itself[60].

[58] UNMOVIC Site Inspection Report 5 Jan 2003, UNMOVIC-03-00172-CW.
[59] UNMOVIC, 19 Jan 2003, UNMOVIC-03-00400-CW.
[60] UNMOVIC Site Inspection Report, 24 Jan 2003, UNMOVIC-03-00472-CW.

122mm artillery rockets

Figure III.XI.I Examination of an artillery rocket warhead by an UNMOVIC inspector

An UNMOVIC inspection team found 12 undeclared 122mm chemical warheads and motors at the Al Ukhaider ammunition depot (11 of them were unfilled and 1 filled with water)[61]. Iraq notified the Commission on 20 January 2003 that four more warheads had been found at the Al Taji ammunition depot (Figure III.XI.I)[62]. In February 2003, another UNMOVIC team discovered an additional two undeclared 122mm chemical warheads at the same depot (one of the six warheads discovered at the Al Taji depot was filled with liquid that was subsequently identified as water)[63]. In total, 18 chemical

[61] UNMOVIC Site Inspection Report, 16 Jan 2003, UNMOVIC-03-00142-MD.
[62] UNMOVIC Site Inspection Report, 21 Jan 2003, UNMOVIC-03-00052-MD.
[63] UNMOVIC Site Inspection Report, 9 Feb 2003, UNMOVIC-03-00153-MD; Sample Analysis Report No MD101, 9 Feb 2003.

warheads were tagged by UMOVIC for destruction. The destruction did not take place due to the withdrawal of UNMOVIC from Iraq.

In its submission of the backlog of semi-annual monitoring declarations in October 2002, Iraq declared that it had repaired and transferred one piece of process equipment, previously destroyed in 1997 at MSE, from the MSE storage area to the phenol factory of Fallujah II. It further declared that five other items of production equipment from the former Al Muthanna weapons plants had been recovered, repaired and installed in a production plant of Al Qaa Qaa[64]. In its declaration of 7 December 2002, Iraq had declared that an additional piece of destroyed equipment (a heat exchanger) had been installed in the chlorine factory of Fallujah II[65]. Following technical discussions on 9 February 2003, Iraq submitted a letter to UNMOVIC explaining the use of previously destroyed equipment in Fallujah II and declared that a third piece of previously destroyed equipment (a pump) had been repaired and then installed at the phenol factory[66]. UNMOVIC conducted inspections to verify the declarations and clarify the issue. Those three pieces of equipment at Al Fallujah II and five pieces of equipment at Al Qaa Qaa were to be destroyed under UNMOVIC supervision. However, that destruction was not carried out prior to the withdrawal of the inspectors.

[64] Declarable changes for the site covered by monitoring in the chemical field since 16 December 1998 (Iraq's Semi-Annual Declarations Jul. 1998-Jul.2002;
[65] Chemical CAFCD December 2002 Part II.
[66] Repaired chemical processing equipment destroyed under UNSCOM supervision, 9 Feb 2003.

Destruction methods[67]

Destruction of Bulk Agent

Hydrolysis Plant Operation

Alkaline hydrolysis (around 15 to 20% solution of aqueous sodium hydroxide) was selected for the destruction of nerve agents and their precursors after a number of pilot-scale tests. The batch hydrolysis plant was made by conversion of the former sarin production plant (former P-7 plant), which was not severely damaged during 1991 bombardment. This facility was converted from a production to a large-scale destruction facility by Iraq under UNSCOM supervision (Hydrolysis plant – Figures III.XI.II and III). The final plant design was agreed with Iraq in April 1992 and it was commissioned by UNSCOM in September 1992. The plant commenced its first test run in September 1992. The destruction of agents began in October 1992. The nerve agents tabun, sarin/cyclosarin and their precursors D4, MPF were destroyed there.

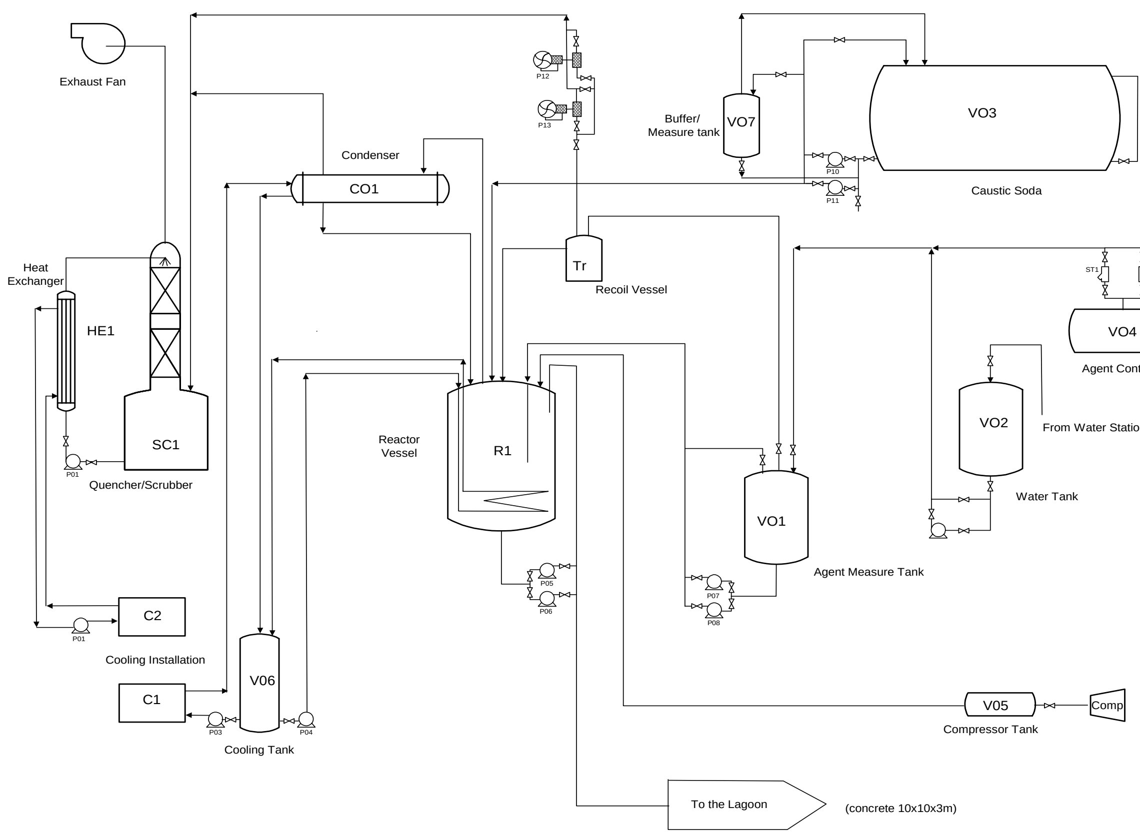
[67] Approved Destruction Activities for Precursor Chemicals, 8 March 1993; Chief Inspector's Report, CD Commissioning Team, 31 Mar 1993; Destruction of Chemicals Remaining at Muthanna, Jan 6 1994; Cees Wolterbeek, "Destruction of Iraqi Chemical Munition, UNSCOM-38/Chemical Destruction Group", in Proceeding 5th International Symposium Protection Against Chemical and Biological Warfare Agents : Supplement Stockholm, Sweden, 11-16 June 1995; R. G. Manley. "UNSCOM's experience with chemical warfare agents and munitions in Iraq", in The Challenge of Old Chemical Weapons and Toxic Armament Wastes, T. Stock and K. Lohs (Eds.), pp. 241–252, Stockholm International Peace Research Institute, Oxford University Press (1997).

Figure III.XI.II General view of the hydrolysis plant

Figure III.XI.III Closer look at the furnace for the destruction of vapours from the hydrolysis plant (visible also on the left hand side of the previous photograph)

The plant was situated in a bunker and was divided into a control room maintained under slightly positive pressure and a reactor room, a fully contained area maintained under negative pressure. On the control panel there were all electrical switches for all pumps and machinery inside the reactor room. Through a large Plexiglas window the reactor room could be observed. A diagram of the hydrolysis plant is shown in Figure III.XI.IV.

Figure III.XI.IV. Hydrolysis plant flow diagram (only main elements shown)



The control room and the plant area were continuously monitored for the presence of vapours of toxic agents. The destruction process was as follows: A storage tank (V04), for the agent being destroyed, was brought in and placed in an earth berm in the plant area[68]. A Teflon pipe was placed inside the tank and two electrical vacuum pumps (P12, P13), located on the roof, were used to create vacuum necessary to empty the agent

[68] The bulk agent GB/GF was mostly stored in two-tonne containers (sometimes in one-tonne containers). D4 was stored in 200 litre barrels.

storage containers through the Teflon pipes. The agent was transferred to a 750 litre agent measure tank (V01), located in the reactor room. A level, on the outside of the agent storage tank, would indicate the amount of agent inside. After the transfer of the agent into the V0l tank was completed, two dosing pumps (P08, P08) transported the agent from the V01 tank into the $3m^3$ reactor (R1). Caustic soda was fed into this reactor by gravity from an external storage tank (V03) causing neutralisation through hydrolysis.

To absorb the heat generated during the destruction process a cooling system was used. Nevertheless the high temperatures (80-90°C) inside the reactor caused the agent to boil. A reflux cooler returned the vapours to the reactor vessel and cooled the exhaust gases. The exhaust gases proceeded to the scrubber and then were released into the atmosphere.

The completeness of the reaction was checked in the laboratory. If laboratory analysis determined that excess caustic was less than 3% more caustic was added to the reactor. The valve at the bottom of the reactor was opened and the mixture flowed into two circulation pumps (P05, P06). The circulation pumps in turn pumped the mixture to the two-way directional valve. The valve was turned so the mixture would flow back into the reactor. This would also ensure better mixing. In cases, when the laboratory results of greater than 3% of caustic soda were obtained, the same procedure would be followed. At the point where the agent concentration fell below the detection limit of 1ppm, the reaction mixture was transferred to a holding tank. After a final analytical check the directional valve was turned so that the generated waste would travel to an open concrete-lined reservoir (lagoon) located outside the plant, where it was allowed to evaporate naturally into the air.

After water evaporated a residue in the form of a salt stone mixture remained. Once all destruction of chemicals had been completed the salt stone was covered with 20cm of soil and then 10cm of concrete as a cap. With the exception of tabun waste, all hydrolysis mixtures went to the lagoon. Tabun hydrolysis wastes (containing large amounts of sodium cyanides) were collected in separate steel tanks and then transported to the bunkers area and sealed there.

Operating Parameters

mixture for reactor	2500 litres of 15-20% caustic soda aqueous solution per 250-300 litres of agent (per batch)
pH	12 - 14 (dosing pumps were switched off, when pH was less than 12)
excess caustic	Greater than 3%
temperature	80° C – the dosing was stopped, 90° C - the cooling system was turned on

Comment
The method was found to be expedient and cost effective. The containment within the reaction unit was a problem. Due to the high caustic content, some leaks developed. Valves and flanges required drip pans underneath them. All valves were manual. An individual would have to wear full IPE to change flows and to conduct sampling. Operators entered and exited the contained area through a decontamination area.

Incinerator

General Remarks

Mustard, its main precursor TDG and some other flammable materials (such as morpholine, phenol, dichlorphenol, trichlorphenol and pyridine) were destroyed by incineration.

No suitable plant existed at Al Muthanna for the incineration, and therefore it was decided to design and construct such an incinerator. UNSCOM and Iraqi experts agreed on the final design of the plant in November 1991. The construction of the plant began at Al Muthanna in January 1992 at the former munitions filling area. Construction continued throughout 1992 with UNSCOM providing advice and assistance. Iraqi personnel under the direction of UNSCOM commissioned the plant in November 1992.[69] (Figure III.XI.V, VI and VII). In total, nine months were spent by Iraq to complete plant construction and commissioning.

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[69] *Executive Summary Report – Chemical Destruction No. 3 (CD3),* August 1994, Para 8,; *Executive Summary of Fact-finding Mission to Iraq on CW Destruction*, August 1991; *Nerve Agent Hydrolysis--Pilot Plant Process Assessment*, Annex B to CD2/MUT/01, March 1992,; *Commissioning of Mustard Agent Incineration Plant,* 26 March 1992,; Report of the CW Destruction Advisory Panel of the UNSCOM for the period 18-22 January 1993;

Figure III.XI.V View of the incinerator

Figure III.XI.VI Furnace of the incinerator

Figure III.XI.VII Lagoon area of the incinerator

Incinerator Operations

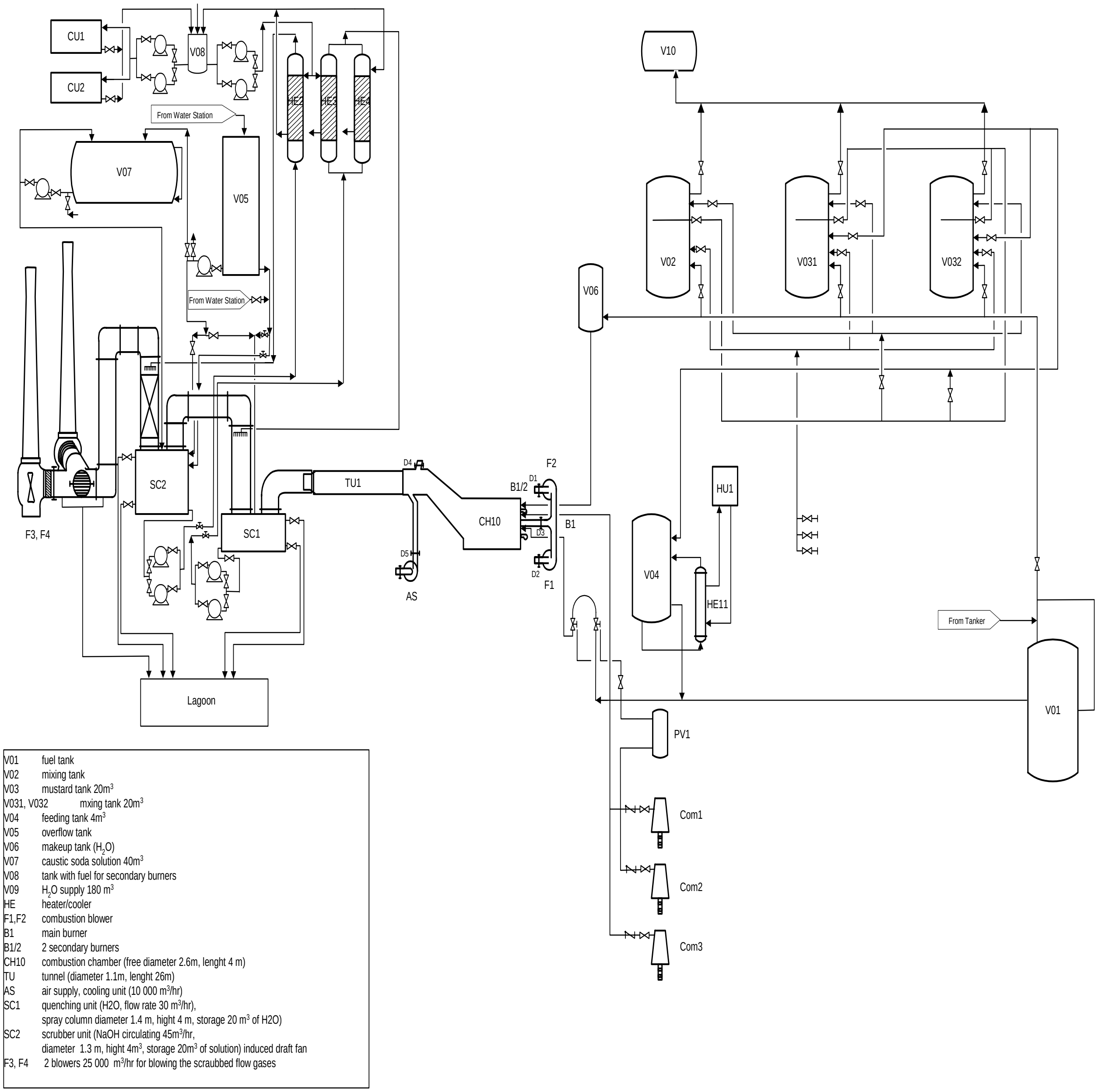
The plant was composed of three major parts: the tank farm and mixing area, the furnace area and the pollution abatement system. Mustard was transferred to one of the bulk storage tanks in the tank farm area and mixed with fuel oil and a petroleum fraction containing benzene and toluene (V04 – see the process flow diagram below). The purpose of this was to prevent the mustard from solidifying in the tanks and feed lines when the ambient temperature fell below 14°C, and to provide a uniform feed stock to the burners. Pilot scale tests had shown that the mustard would not readily dissolve in the fuel oil and a co-solvent was necessary to produce a homogeneous solution for feeding to the burner guns. The petroleum fraction used was a by-product from Iraq's oil industry and thus readily available. The optimum mixture was found to be 12 parts mustard, 2 parts petroleum fraction and 1 part fuel oil[70]. Two circulation pumps agitated this mixture. During the winter months this mixture was pumped through a heating system to keep the mustard from freezing[71].

A diagram of the incineration process is shown in Figure III.XI.VIII.

[70] After mixing, the tank contained 6 m^3 mustard agent, 1 m^3 fuel oil, and 0.5 m^3 Benzene-Toluene. The mixture was measured by volume and monitored by a gauge on the outside of the tank. The incinerator was originally designed to use a 50/50 % mustard- Fuel Oil mixture but the first experiments showed that it was impossible to obtain a one-phase mixture (solution). The separated phases of the mixture caused irregular burning.

[71] Due to additives, the Iraqi mustard was still fluid around 0°C

Figure III.XI.VIII Incinerator flow diagram (only major elements shown)



A standard brick-lined furnace (CH10), constructed in a trench cut in the desert floor, was brought up to temperature by operating the main burner gun and secondary burner gun on fuel oil from V01. Once the temperature reached 1000°C the main burner was switched to the mustard gas petroleum fraction/fuel oil mixture. The mustard/fuel mixture would feed into the combustion chamber by gravity. However, the pipe, leading into the combustion chamber, had another pipe over it. It was through this pipe that forced air flowed through creating a sort of jet spray into the combustion chamber.

The combustion efficiency of the plant was monitored by means of an emission-monitoring system, which continuously measured and recorded the levels of excess oxygen, carbon monoxide and carbon dioxide in the exhaust gases.

The furnace conditions

Combustion Chamber Temperature	1000–1200°C
Excess oxygen levels	8–14 %
Carbon monoxide level	20–50 ppm
Flow rate mixture of the mustard gas/fuel mixture.	450 kg/hr
Average destruction rate per day	1500 kg

Exhaust

The hot exhaust gases from the furnace were diluted by the injection of ambient air and cooled by passing them through a conventional water quench tower (SC1). The majority of the hydrogen chloride formed in the combustion process was removed. Then the gases would travel to the scrubber/atomizer (SC2) to be sprayed with a 5–10 per cent sodium hydroxide solution. This removed the remaining hydrogen chloride and most of the sulphur dioxide. The cleaned gases then passed through the induction fan before being finally discharged to the atmosphere via a high smokestack.

The waste liquids from both the quench tower and the packed scrubbing tower were collected in an underground storage tank. Any overflow was piped to a large lagoon where the bulk of the water evaporated. The lagoon was lined along the bottom, with limestone. Thereby, any materials leaching into the ground would not harm any underground water table. At the end of the operation the residual salts were recovered and disposed of in an appropriate manner.

The target emission standards for the incineration plant at Al Muthanna[72]

Emission	Stack concentration limit (mg/m^3)
SO2 (80% removal efficiency)	500
HCl (90% removal efficiency)	100
Particulates	180
Carbon monoxide	100
Mustard gas	0.03

The Destruction Advisory Panel established the target emission standards for the plant outlined in the table above. These values could realistically be achieved and were appropriate for emissions from a plant at a remote desert site according to DAP evaluation. When plant became operational all of these emission targets were readily achieved with the exception of that set for sulphur dioxide. At the maximum throughput of the plant, this limit could not be met owing to the lower than anticipated efficiency of the packed scrubbing tower. It therefore proved necessary to reduce the mustard feed rate to the furnace to nearer 300 kg/hr, thereby reducing the load on the packed scrubber and improving the sulphur dioxide removal efficiency. Like all incinerators the plant suffered a number of maintenance related problems. However, it continued to operate and when the incineration of the mustard was finished by Iraq in 1994 approximately 400 tonnes of mustard had been destroyed.

Bulk storage containers with mustard

One tonne containers

Containers of mustard, that could not be manually opened, were opened or vented in the "Pit Area" by established EOD procedures. Containers were then transported, by truck, to the incinerator area. All containers were measured for content using the dipstick method and recorded. In the incinerator area a truck, with a vacuum pump and mounted storage tank, connected three (3) mustard storage containers together. This connection was done using a series of pipes interconnecting the containers. The pump was turned on and the mustard was transferred to the storage tank by vacuum. Once this procedure was complete the truck would drive to the Storage Tank, V04, and fill the tank.

Containers of mustard, that could be manually opened, were drained by vacuum into a truck with a mounted storage tank. The truck would then go to the tank V04 and fill it up.

[72] Report of the Destruction Advisory Panel of the United Nations Special Commission on Iraq for the period 24–28 June 1991 (June 1991).

Destruction of munitions

Transportation and removal of the agent

The transportation of the chemical munitions from the various depots in Iraq to Al Muthanna, had to be done in a safe manner. Prior to being moved, each munition was checked to ensure that it was free from explosives. Leaking munitions were sealed using a variety of techniques, and then checked to confirm that they were no longer hazardous.

The munitions were placed in specially designed racks and packed into International Standards Organisation (ISO) transport containers, which had been modified to ensure that they were both liquid and vapour-tight. A deep layer of absorbent material was placed on the floor of each container. As an additional precaution refrigerated containers were used for the munitions containing mustard. Such method allowed to transport mustard, which solidifies at 14°C, in a solid form. A small number of munitions, judged to be too hazardous condition to be moved, were set aside for on-site disposal at a later date.

UNSCOM supervised all transport operations conducted by Iraq. Each shipment was accompanied by sufficient security, monitoring, decontamination and medical personnel and equipment that would allow personnel involved to deal with all possible incidents. Shipments were carefully monitored during the transfer process to ensure that any leaks would be promptly detected and appropriate action taken. Routes were planned, as far as possible, to avoid populated areas in Iraq. On arrival at Al Muthanna the munitions were placed in storage in a remote area of the site. Using these procedures all of the munitions that could be moved were safely transferred to Al Muthanna without incident.

The removal of the chemical agent from the munitions for its subsequent disposal constituted the most difficult step in the destruction of chemical weapons. At Al Muthanna the operation was further hampered by the absence of a suitable operational containment facility. As a result the draining operation had to be undertaken by Iraqi personnel working in full protective clothing. This, together with the high summer temperatures in the desert and the need to implement individual draining techniques for each type of munitions, resulted in a long and difficult operation.

Aerial Bombs

For the aerial bombs[73] filled with mustard a specially designed vacuum transfer system was used when possible to suck the liquid mustard out of the bombs (Figure III.XI.IX). If the filling plug could not be removed, appropriately sized holes were drilled in the

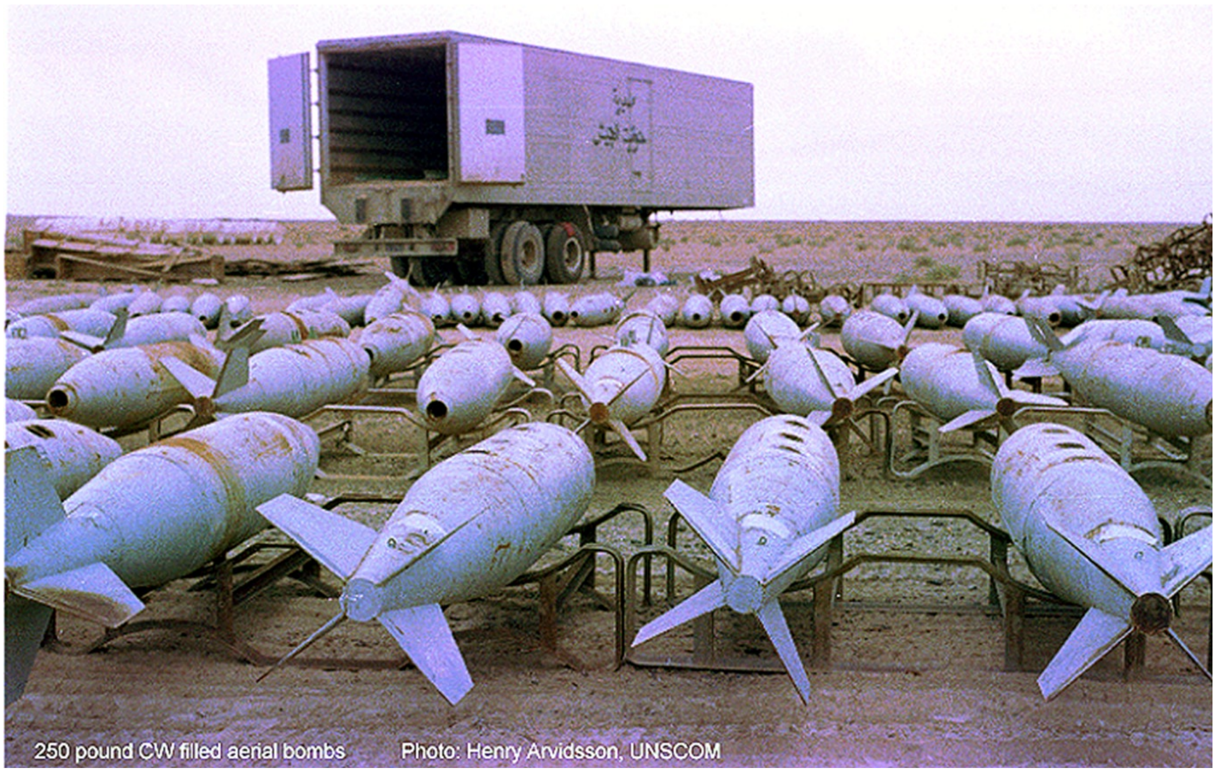
[73] 120 litres (500 gauge) and 60 litres (250 gauge)

casing of the bomb using a remotely operated drill or two small shaped explosive charges. In the later case mustard-filled bombs without fuses and detonators were placed in the pits area and two small shaped explosive charges were attached to the external surface of each bomb and detonated. The holes made by the charges were then plugged and the bombs transported to the incinerator area where a vacuum transfer system removed the chemical agent and transferred it into a storage tank from where it was fed into the incinerator. The emptied bombs were taken back to the pit area.

Figure III.XI.IX Installation used for empting the storage containers and aerial bombs and for transportation of the agent to incinerator.

After removing mustard, a varying quantity of viscous tar, consisting primarily of polymerised mustard with about 7 per cent entrained mustard remained in each munition. The drained bomb cases were therefore filled with a 20 per cent solution of sodium hydroxide in isopropanol and left for several hours. An explosive charge was then placed on the bomb casing and detonated remotely. The explosion ruptured the casing and ignited the isopropanol. When the destroyed bomb casings had burnt out each was carefully checked to ensure that no trace of mustard remained. The technique worked well and several thousand bombs were successfully processed in this manner.

Figure III.XI.X CW aerial bombs



Some amounts of corroded or leaking 250kg and 500 kg aerial bombs filled with mustard, which could not be opened manually and were too hazardous to open using the shaped charge method above, were opened by explosion at the pit area, in a container with fuel. The explosion also ignited the fuel oil and benzene simultaneously burning the agent.

Al Hussein missile warheads

Figure III.XI.XI Destruction of an Al Hussein missile warhead

It was not possible to remove the filler plugs of the Al Hussein missile warheads (Figure III.XI.XI). Various techniques were considered for opening these warheads, and the technique finally used was to blow a small hole in the nose of each warhead using a 'shaped' charge. The contents were then removed using the vacuum transfer system developed for the aerial bombs. Any residual agent was neutralized by filling the warhead with alcoholic caustic soda. Once neutralization process inside warheads was completed and no traces of contamination left, the warheads were destroyed by mechanical means.

Mustard -filled 155mm artillery shells

The mustard filled 155mm artillery shells[74] posed a particularly difficult problem as they had no filler plugs and the thick-walled cases were not easy to drill. Owing to the presence of hydrogen gas and other gaseous degradation products of mustard in many

[74] Iraq used 155mm carbon steel artillery shells M-110 with a total weight 41kg and a payload of about 4.5kg (or about 3.5 litres) of mustard.

of the rounds, there was not only considerable internal pressure but also a high risk of ignition during the drilling operations.

Figure III.XI.XII Sampling of 155mm artillery mustard rounds

Besides wearing out the drill bit every three or four shells, the method also proved unacceptably slow with an average opening rate of less than one shell a day.

In order to increase the effectiveness of the opening operation the following method was used: Firstly, the shipping plug and explosives from the buster tubes were removed. About 50 shells were placed in an iron transport pallet; nose up, to prevent them from falling during the procedure. For each shell a small charge, consisting of knot at the end of detonation cord covered with 15g ball of explosive C-4 (PE4A) was lowered into tube. The explosive charge was just enough to rupture the burster tube and its positioning was such that when it was fired the explosive force cut the burster tube just below the point where it joined the neck of the shell. The rounds were wired up and opened in batches of 200 (Figure III.XI.XII).

A siphon hose from a mobile vacuum transfer system was then lowered into ruptured tube and the agent was removed and taken for destruction in the incinerator. To destroy the polymerized agent residue remaining in the emptied shell cases they were filled with alcoholic caustic soda and, after soaking for a period of time, were burnt out. The number of shells opened by the buster tube method was gradually increased from 30 to several hundred per day. The maximum amount opened in a single day was 1000. The main limit to destruction by this method was the thermal decontamination process requiring usually more than one burning.

The shells from which the shipping plug could not be removed were destroyed using 20 kg of explosive for each. The projectiles were completely encapsulated with explosives to ensure complete thermal treatment of the chemical agent filling. Then the munitions were submerged in a container with benzene and fuel oil to ensure agent residue was burned (Figure III.XI.XIII).[75].

In December 1993, after the destruction of bulk mustard was finished, more than 2000 munitions were found.[76]

The CDG decided to fill all the emptied but still contaminated shells with mixture of caustic soda and alcohol and place them into Bunker #41 of the MSE bunker area. The CDG did not issue a separate destruction certificate for the munitions placed into Bunker #41.

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[75] The destruction of 155mm shells filled with mustard was preformed in the Pits area.

[76] On 17 February 1994 UNSCOM 38/CDG reported that they started sweeping the destruction area again and they found a lot of “forgotten” munitions. However, the number and condition of munitions were not mentioned. In the end of March 1994, the Iraqi personnel flattened out some sand hills in the Graveyard and the “Old chemical pits” area and at that time the CDG reported about 1800 munitions were found in different conditions: 250 sealed with shipping plug, 778 without shipping plug but still containing mustard, 204 clean, and about 600 had to be investigated.

Figure III.XI.XIII 155 mustard-filled projectiles prepared for opening (rupturing buster tube)

Artillery Rockets

The disposal of the 122mm nerve agent rockets posed a particularly difficult problem (Figures III.XI.XIV to XVI). Owing to internal pressure created by degradation products of sarin and sarin-type agents many of the filler plugs in the internal plastic agent containers had been ejected and agent was therefore leaking into the metal rocket cases, which were not fully sealed. In addition, a significant number of the rockets were fitted with solid fuel motors. Without the use of a purpose-built, fully contained plant, the risks from attempting to open these rockets and drain the contents were considered to be extreme and unacceptable. Constructing a remotely operated plant would have required many months and the use of technology that was not available in Iraq. During this period the rockets would have continued to release agent to the environment at an ever-increasing rate. An alternative solution had to be found.

Figure III.XI.XIV Preparation of 122mm sarin-filled artillery rockets for transportation

Figure III.XI.XV Preparation of 122mm sarin-filled artillery rockets for destruction

The process developed and adopted, consisted of explosive venting and simultaneous burning.

The rockets, 20 at a time, were placed on top of containers with diesel fuel in the bottom of a deep pit. Each rocket was wired with three small explosive charges—one to disable the solid fuel motor and one to rupture each of the two agent containers. An igniter charge was also placed in the fuel container. When preparations were complete helicopter reconnaissance was carried out to ensure that the area up to six km downwind was clear. Immediately thereafter the explosive charges on the rockets were fired and a fraction of a second later the fuel ignited. The resulting fuel–air explosion generated a high-temperature fireball and the agent released from the rockets underwent instantaneous thermal degradation to simple non-toxic molecules.[77]

[77] Environmental Protection during UNSCOM chemical agent destruction operations, Letter to UNEP, Geneva, April 1992.

When it was possible to disassemble the rocket into a warhead and a rocket motor and then to separate the propellant from the motor tube, the rocket cases were destroyed by burning. The separated warheads were then placed across containers filled with oil. Liner charges were used to open munitions and a small thermite charge to ignite the fuel mixture in pits, as described above. If it was not possible to disassemble the motor, the complete motor was put under a massive concrete block and ignited with a remote firing device. During trials of this method downwind sampling arrays were erected at 100m and 200m intervals. Although agent vapour was detected in some of these samples the levels were low[78]. Burnt out rocket cases and soil samples from the pits were also checked for residual contamination. No significant contamination was found.

There were some exceptions to the general procedure. For example, the 122mm rockets, formerly filled with sarin and stored in a bunker #13 at MSE bunker area damaged by aerial bombardment during the 1991 Gulf War, were considered as destroyed. According to Iraq, this bunker was filled with about 2,500 rockets. And since the access to the rockets was not safe and presented a considerable health hazard, the CDG did not attempt to recover or account them[79]. Instead Iraqi personnel sealed the hole remaining at the bunker top by filling the inner bunker space with the soil through that hole to the top level of the bunker and sealing it with concrete. All entrances to the bunker were sealed with over one metre thick reinforced concrete walls and the bunker was a subject to UN monitoring after completion of destruction operations in 1994. Some precursor chemicals were also placed in this bunker. Another bunker[80] in the same area of Muthanna (bunker #41) was used to entomb parts from disassembled destruction equipment, storage containers and other materials that could not be thoroughly decontaminated. The bunker was also sealed. Procedures for sealing these bunkers and other structures containing toxic wastes were agreed between the Government of Iraq and UNSCOM (Figure III.XI.XXVII).

During the final sweep of Muthanna at the end of destruction operations a 122mm rocket warhead with unknown liquid content was discovered in the area of the old bomb making facility. This item was transferred to the accumulation area and destroyed using a large excess of explosives. No chemical contamination was detected right after the destruction operation.

Comment
The sophisticated drilling technologies, such as diamond drilling or cutters using a fine water jet, were not available in Iraq. Accordingly the CDG had to design destruction methods that were fast, effective, safe and environmentally clean. The CW stockpile of leaking and corroded munitions often with charged buster tubes with irremovable explosives necessitated a rigid solution to the destruction problem. The CDG always

[78] The agent concentration was in the order of 10-4 mg/m^3, which is the level to which unprotected workers can be exposed for up to 8 hours per day.
[79] Hand-Over Protocol For Al-Muthanna State.
[80] Iraqi number of the bunker was 6, UNSCOM referred to it as bunker 41.

required opening munitions mechanically. When it could not be done, it would use shaped charges with a minimal amount of explosives to open the munitions for subsequent draining. Unstable and cracked munitions were opened in the place of their location, to minimize any additional contamination of the environment. Clouds from explosive venting were analysed to assess whether contamination occurred. No cases of dangerous releases of the agent into the air were registered. Before initiating an explosion, reconnaissance of the surroundings by a helicopter was standard practice. Personnel in charge of the destruction process always monitored the environment and wore full individual protective equipment. A medical team and EOD personnel were always on site, and a rigid clean/dirty line policy was enforced. After finishing the entire destruction process and cleaning operations, an environmental survey of Muthanna was conducted. No contamination was detected in about 200 randomly taken samples.

Unfilled Munitions

Most of the unfilled munitions and related equipment were mechanically destroyed using a welding torch and/or a bulldozer. Sometimes to destroy equipment explosive charges were also used (Figures III.XI.XVI and XVII).

Figure III.XI.XVI Destroyed empty aerial DB-2 bomb

Figure III.XI.XVII Bomb empty cases being destroyed

Destruction of CW agent precursors and missiles program related chemicals

In addition to the destruction of chemical warfare agents, the Commission was also responsible for the destruction of the chemicals used in their production including precursors, catalysts and solvents, as well as some chemicals used in the missiles programme. Large quantities of these precursor chemicals were present at both Al Muthanna and Al Fallujah. Among these chemicals were large quantities (about 3000 tonnes) of highly reactive compounds. The storage containers with precursors were highly corroded and, in many cases, leaking. It was thus necessary to adopt a disposal method, which minimized the need to handle or transport these containers, primarily 200-litre drums.

Incineration

The stocks of combustible organic precursors such as thiodiglycol, isopropanol and the like were destroyed by incineration once destruction of the mustard stocks had been completed.

Neutralization and Entombment

The precursor chemicals of an acidic nature (such as HF and $SOCl_2$) were neutralized in a number of large lagoons constructed closely to each of the storage sites (Figures III.XI.XVIII to XX). Each lagoon was filled with a mixture of crushed limestone and water. Wherever practical, the contents of each container were piped to the bottom of the lagoon where they reacted with the limestone–water mixture to form a nontoxic, relatively insoluble calcium salt. When it was deemed too dangerous to handle a container manually it was picked up by a crane and lowered into the lagoon and, if not already leaking, the container was ruptured with a mechanical prod. Once the operation had been completed the lagoons were allowed to evaporate to dryness under the desert sun. Eventually the dried salts were permanently sealed in concrete.

Figure III.XI.XVIII Semi-underground storage tank used for neutralization and entombment

Figure III.XI.XIX Thionyl chloride lagoon during neutralization operation

Figure III.XI.XX Thionyl chloride lagoon sealed with concrete after neutralization operations

Open air burning

Flammable chemicals (such as chlorobenzaldehyde and di-isopropylamine) were destroyed by open-air burning using halves of 200 litre barrels cut crosswise. White phosphorous was destroyed in specially built ground pits (Figure III.XI.XXI). Usually about seven white phosphorus barrels were simultaneously opened by explosion and the hypergolic reaction of WP with air moisture led to self-ignition and vigorous burning (Figure III.XI.XXII).

Figure III.XI.XXI White phosphorous destruction site

Figure III.XI.XXII Explosive destruction of white phosphorous

Entombment

Some of the wastes resulting from the destruction process along with some chemicals and contaminated equipment were entombed into bunkers and lagoons of the bunker storage area. This is discussed in more detail later in this section.

Spreading over the land

Since ammonium perchlorate, a missile propellant component, had ingredients that were useful as a fertiliser, it was sprayed over the ground with the density accepted in agriculture for ammonium mineral fertilisers. The spraying was done at the accumulation area of MSE (left side from the main road) about 10 x 4 metres for each barrel, and once sprayed the ammonium perchlorate was soaked several times with water until all salt was dissolved. Then the affected soil was harrowed carefully to ensure that the fertiliser penetrated and was spread throughout the soil (Figure III.XI.XXIII).

Figure III.XI.XXIII Destruction of ammonium perchlorate

The solutions adopted for the destruction of chemicals were as follows:

DF	hydrolysis
D4	hydrolysis
Thiodiglycol	incineration
Morpholine	incineration
Phenol	incineration
2,4 Dichlorophenol	incineration
Trichlorophenol	incineration
Sodium cyanide	entomb
Potassium cyanide	entomb
Chlorobenzaldehyde	fresh air burning
Diisopropylamine	fresh air burning, burning at refinery
Ethylenechlorohydride	fresh air burning
Dimethylaminehydrochloride	hydrolysis
As2O3	entomb
AsCl3	entomb
Thionylchloride	hydrolysis
Monoethyleneglycol	fresh air burning
KF.HF	entomb
NaF	entomb
KI	entomb
CH3 I	hydrolysis
Triethanolamine	fresh air burning
AlCl3	hydrolysis
Mandelic acid	fresh air burning
Malononitrile	fresh air burning
Pyridine	incineration
Chloracetic acid	fresh air burning
Malathion	fresh air burning
Dichlorobenzene	fresh air burning
Dichloroethane	fresh air burning

Propanol-2	fresh air burning
Hydrogen sulphide	fresh air burning
2-Diethylamino-ethanethiol-hydrochloride	fresh air burning
Toluene	fresh air burning
CH2Cl2	evaporation
3-Hydroxymethylpiperidine	fresh air burning
Thiokolpolysulphide	fresh air burning
Dimethylamine	hydrolysis
Glycolic acid	fresh air burning
HF	neutralization
Na Monochloracetate	entomb
Methanol	fresh air burning
PCl3	hydrolysis
POCl3	hydrolysis
White Phosphorous	explosive
Ethanol	fresh air burning
Isopropanol	incineration

Destruction of production facilities and related equipment

Figure III.XI.XXIV Preparatory work for the destruction of a building

Destruction of production facilities was the major remaining task in UNSCOM's chemical weapon destruction operations (Figure III.XI.XXIV). With the exception of the old sarin production facility, used for the destruction of the nerve agent stocks, and two pilot plants all other former CW production facilities, the laboratories at Al Muthanna and the precursor production plants were severely damaged during the 1991Gulf War and were no longer able to be operated. However, in order to fulfill its mandate UNSCOM was required to ensure that all process equipment, which was considered critical to the production of chemical agent, was also destroyed. Given the condition of the plants and laboratories this was a difficult and hazardous task.

Figure III.XI.XXV
Preparatory work for the destruction of a building

First, the critical components of the process lines had to be identified and a decision taken as to whether they could be recovered and destroyed or whether they had to be destroyed *in situ* (Figures III.XI.XXV and XXVI). In the latter case the preferred method of component destruction was explosive demolition using appropriately placed, shaped cutting charges. Where components could be recovered they were first decontaminated and then destroyed either by mechanical deformation, cutting into sections or, in the case of some tanks and reactors, by filling with concrete.

Upon completion of its work, the hydrolysis plant was first decontaminated and then destroyed to prevent its possible re-conversion to a CW production plant. Iraq was permitted to retain some dual-purpose items of the chemical plant which could not be clearly identified with its CW programme. However, each item was permanently tagged and was to be subject to regular ongoing monitoring by UN inspectors.

Figure III.XI.XXVI A tank destroyed by cutting out a hole

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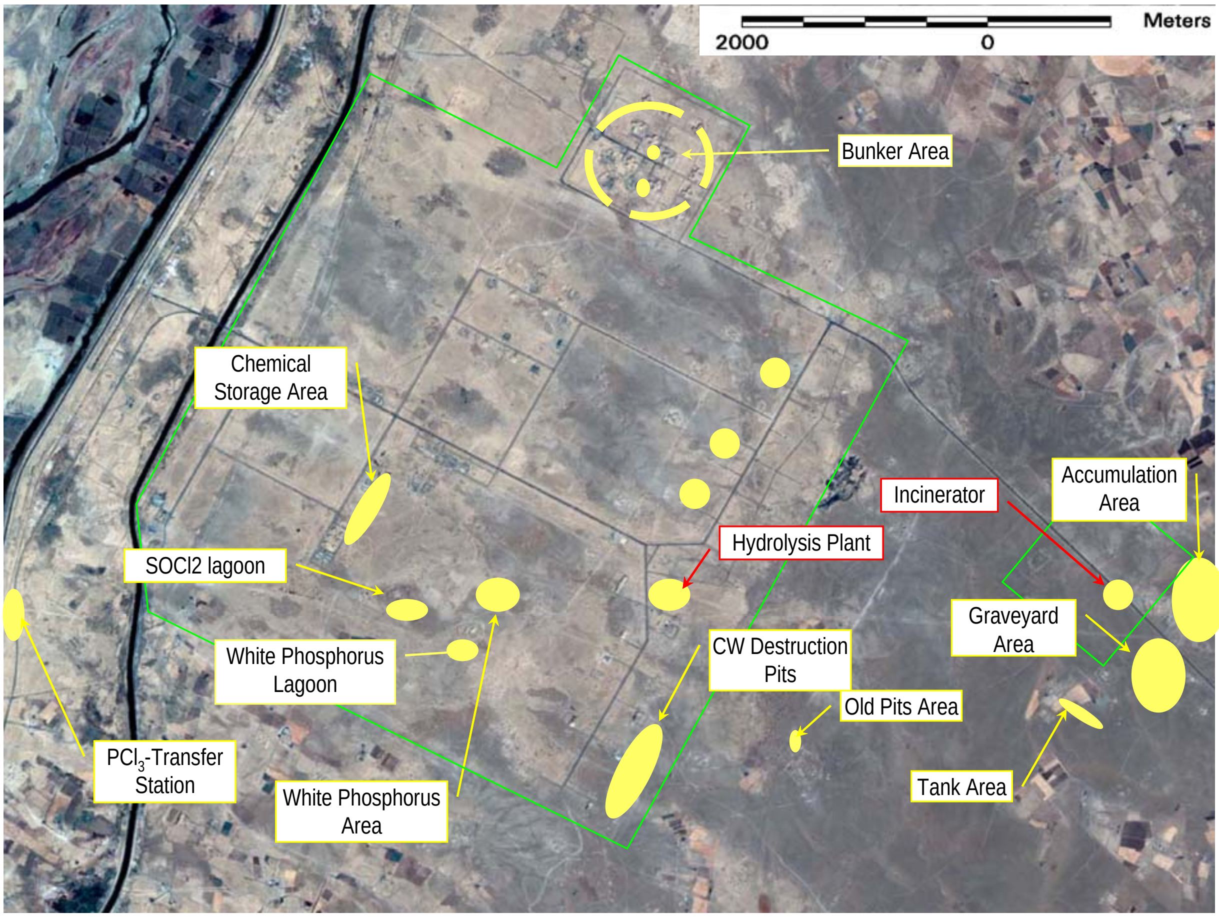
Figure III.XI.XXVII Sealed entrance of a bunker

In addition to the two Muthanna bunkers both known to have contained chemical munitions and agent residues, there were a number of other structures and locations previously used in the destruction operations. They included 26 large underground concrete water reservoirs (lagoons), three pilot production plants, and a number of pits and landfills where chemicals and wastes from the destruction process were entombed or dumped. Figure III.XI.XXVIII shows the destruction sites at Muthanna.

Destruction location at Muthanna

Figure III.XI.XXVIII the destruction sites at Muthanna.



The usual route of munitions or a container filled with an agent was the following. All items were collected and sorted out at the secured accumulation area. From there they were transported to CW destruction pits – in reality there were two separate places next to each other, one for mustard-filled munitions and containers, the second - for nerve agents (Figures III.XI.XXIX and XXX).

They were opened with a small charge of explosives (due to corroded or blocked valves). Depending on the content, the storage container or the bomb was transported to the Incinerator or Hydrolysis Plant for emptying and destruction. The agent was decanted to a tank, and the empty container was transported to the Graveyard for decontamination and destruction. Some storage containers with residues of solidified agent were moved to the Bunker Area, filled with a mixture of caustic soda and alcohol and finally put inside the bunker.

Some precursors were neutralized in lagoons called Thionyl Chloride and White Phosphor lagoons. White Phosphorous previously stored there was destroyed in a nearby area by explosion. The majority of lagoons were located in the Bunker Area (22 lagoons).
There are some more locations marked on the above map. These are:

- the Chemical Storage Area where most of precursors were stored.
- the Old Pits Area – used at the beginning of destruction operation for emptying and destruction of munitions, later abandoned.
- the Tank area – where bulk storage containers were buried.
- the Phosphorus-Trichloride-Transfer Station – with a number of big storage tanks of that chemical.

Figure III.XI.XXIX View of destruction pits

Figure III.XI.XXX Indication of a sealed destruction location (lagoon)

Completion of CDG activities and the Handover Protocol

The final phase of the CW destruction operation was completed in May 1994. At that time UNSCOM conducted a final sweep of the entire Al Muthanna site to identify and dispose of any item that might have escaped earlier notice. All areas of the site where destruction operations had been undertaken were cleaned up, checked to ensure that they were free from contamination and, to the extent possible, restored to their original condition. Two inspections were then conducted in May and June 1994: first, to undertake an environmental survey of the site, and second, to document the status of the site prior to its reversion to Iraqi control.

Finally, on 13 June 1994, a Handover Protocol[81] was signed which included an obligation on Iraq to control and protect the integrity of the site. The whole protocol contains 183 pages including eight pages of main text. It documents:

- the activities of the Chemical Destruction Group
- the state of the site at the time of close out
- Iraq's continuing obligations and

[81] UNSCOM Hand-Over Protocol For Al-Muthanna State.

- the hand over of control of the site to Iraq.

It was clearly defined in the Protocol, which locations had been used for the destruction operations – by name and geographical coordinates and depicted on an attached diagram. Those locations were also divided into three groups depending on the threat posed by the hazardous materials remaining there. The first group contained locations where munitions, large quantities of wastes and some precursor chemicals were entombed. It included Bunker 13 and 41.

The second group comprised sites where the destruction processes was carried out while three sealed underground pilot plants (one of them contained an inhalation chamber) constituted the third group.

Provisions of the Hand-Over Protocol[82]

The Hand-Over Protocol of 1994 ended UNSCOM's direct control of the Muthanna site, which it had had while destruction operations were in progress. However, UNSCOM included in the Protocol special requirements concerning safety and security in the Bunker Area. This included:

1. So long as SC resolution 715 (1991) is in force, Iraq shall notify UNSCOM, and receive permission prior to opening or entering the following sealed structures: bunkers 13 & 41, lagoons in bunker area, hydrolysis plant lagoon, and white phosphorus lagoon. However, no such request was made.
2. Iraq shall immediately inform the UN Commission in the event a bunker seal is damaged.
3. Repairs to the seals shall be made as soon as possible; however, UNSCOM reserves the right to postpone the repair until an inspection is performed; - In this regard no seal damage was ever reported or observed during UNSCOM/UNMOVIC presence in Iraq.
4. The protocol provides instruction on how the bunker 13 should be re-entered if needed.
5. Iraq shall maintain warning signs in the areas that are known to contain hazardous materials.
6. These areas should be inspected by Iraq at least once per month to ensure that the warning signs are in place and legible and the seals are intact. Regarding this point Iraq in fact did more than required, especially in the period up to 1998 when there was a permanent guard presence. According to Iraq, in 1999 that permanent guard was withdrawn but Iraqi personnel were still present on a daily basis.

[82] UNSCOM Hand-Over Protocol For Al-Muthanna State.

7. In the event that a sign has been removed or damaged, Iraq shall replace or repair the sign; Iraq shall maintain warning signs in the areas that could potentially contain hazardous materials;
8. Any actions taken by Iraq in these areas should be undertaken with appropriate caution;
9. All tagged production equipment remaining at Muthanna may not be moved without prior notification by Iraq and confirmation of receipt of notification by the UN Commission.
10. Other requirements specified by UNSCOM included the maintenance of rooms for use by UNSCOM, maintaining a telephone line there and a helicopter-landing site in an adjacent area.

After the Protocol was signed, control over the Muthanna site was return to Iraq but UNSCOM teams regularly inspected the site. Under SC resolution 715 and the OMV Plan, Muthanna was regularly declared as a site previously involved in chemical weapons activities. The disabled tagged chemical production equipment was also stored there. UNSCOM monitored the equipment and the sealed structures.

A second reason for visiting the site frequently was the presence of two air samplers installed by inspectors, one next to the Bunker Area and the second close to the chemical storage area (Figure III.XI.XXXI). Those samplers required maintenance and the changing of their sampling tubes every 24 days. During those inspections, the integrity of the bunkers and other sealed structures were checked. After UNSCOM was withdrawn, Iraq kept guarding the site. In 1999, the UNSCOM samplers were dismantled by Iraq and removed.[83]

[83] “Declarable Changes for the sites covered by monitoring in the Chemical Field since December 16, 1998 (July 2002)” document submitted during Vienna Height Level Talks, October 2002.

Figure III.XI.XXXI Air samplers installed at Muthanna site (automatic, driven by a solar panel)

Long-term environmental implication

Until the start of the 2003 war, Iraq fulfilled most of its obligations under the Handover Protocol and the Special Commission monitored it. When UNMOVIC inspected Muthanna in November 2002[84], a small team of Iraqi personnel was present at the site and all sealed structures were found intact. The last UNMOVIC inspection team was at Muthanna on 14 March 2003[85].

After 14 March 2003 the situation changed. Iraqi Survey Group Report[86] stated that all sealed structures at the site had been breached and some equipment and materials were

[84] UNMOVIC-02-00007-CW December 2002.
[85] UNMOVIC Daily Report, 14 Mar 2003.
[86] ISG Report, October 2004.

removed. There was also information that the bunkers tested positive for the presence of chemical warfare agents[87].

In 2005, based on satellite imaginary analysis, UNMOVIC noticed[88] that some agricultural activity had started inside the perimeter of the former Muthanna State Establishment, some as close as 500 metres from the bunkers. In February 2006 UNMOVIC further reported to the Security Council on the developing security and safety conditions at MSE with regard to increased agricultural activity. UNMOVIC is unaware of whether any measures to reseal broken structures with hazardous materials were undertaken at the MSE.

In the period September-October of 2006 UNMOVIC provided Iraq upon its request with CD-ROMs containing large number of destruction certificates issued by the UNSCOM during the period 1991-1997, the MSE handover protocol and 54 documents regarding unresolved disarmament issues. These documents were requested by Iraq in view of its plans to accede to the Convention on the Prohibition of Chemical weapons.

The history of bunkers 13 and 41

On 8 February 1991, during the Gulf War, bunker#13 was damaged by aerial bombardment. According to Iraqi declarations, 2,500 122mm artillery rockets were stored inside the bunker at the time of the bombing.[89] During the aerial bombardment of 1991, the roof of bunker #13 was hit by a bomb.

The bunker #13 and bunker #41 were selected for entombing of materials resulted from the 1992-1994 destruction operations at MSE, because they were very solid structures, located in an isolated from population area and they could also be easily sealed. Entombing all the hazardous items in these bunkers combined with long-term monitoring was considered a reliable and safe way of rendering them harmless both by the DAP and the CDG.

Bunker #13 and # 41 were closed by sealing all entrances before the end of CDG mission. Each seal consisted of two brick walls with a 5cm layer of tar between them. Then a third brick wall at a distance of one metre from the second wall was built and the space between them was filled with reinforced concrete. Altogether, such a seal was over 1.5 m thick. The hole in the roof of the bunker #13 was also sealed with reinforced concrete.

[87] When military type detectors are used for the survey they might indicate the presence of CW agents when only degradation products are present.
[88] UNMOVIC's 23rd Report to the Security Council, 29 November 2004.
[89] Letter from Iraq of 16 April 1998.

Some detailed information on the materials remaining at the two sealed bunkers is presented below, as well as issues stemming from an evaluation of the current situation at the site.

Bunker contents

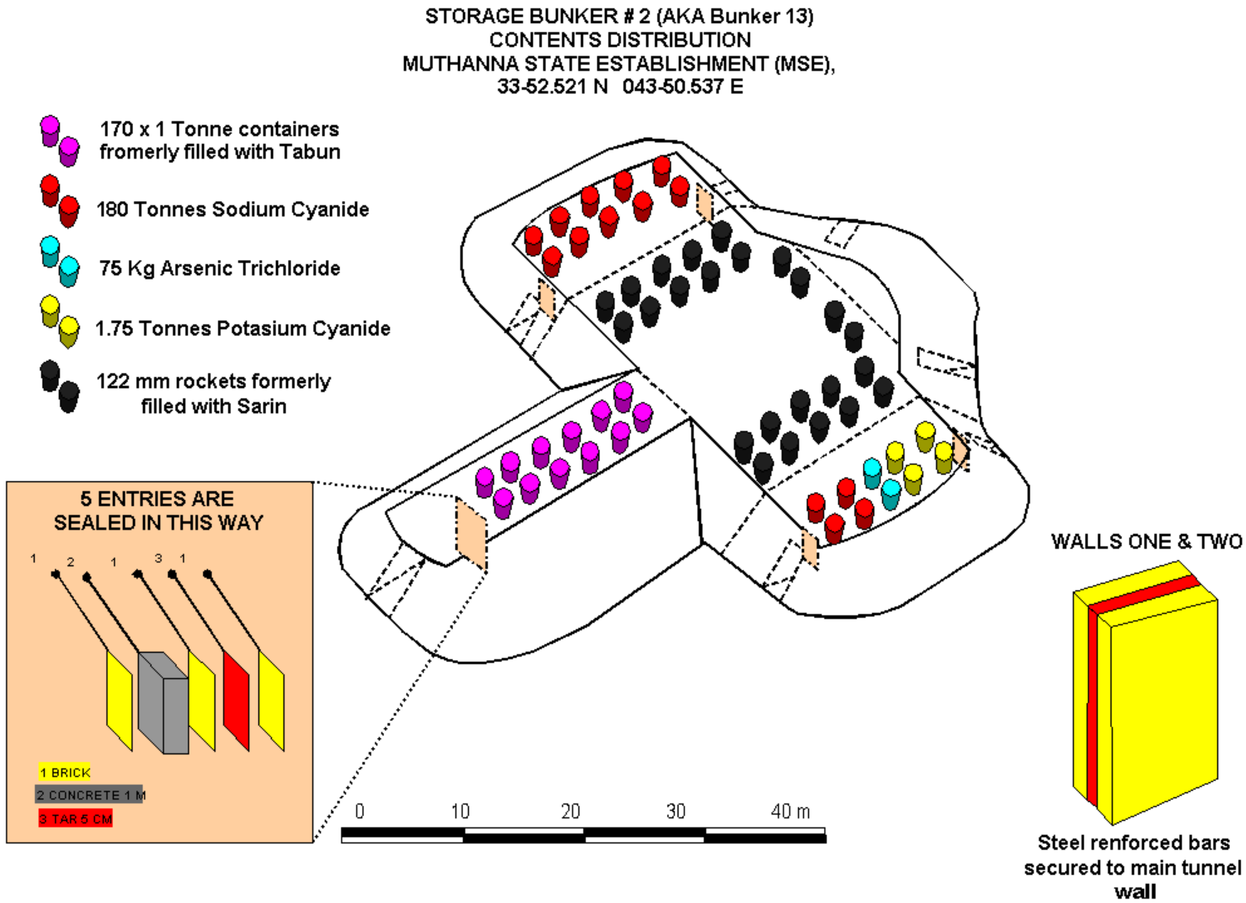
Based on the information available, both from Iraqi sources and CDG documentation, the following items were recorded as present in the two sealed bunkers as of March 2003:

Bunker # 13

- 2,500 122mm chemical rockets (as declared by Iraq – but not verified) filled with the chemical nerve agent sarin stored in wooden boxes, partially destroyed or damaged by bombing during the Gulf War.

- About 180 tonnes of sodium cyanide, a very toxic chemical and a precursor for the warfare agent tabun, was brought to MSE from another location in Iraq where it had been stored. Due to the poor condition of the packages in which it had been held, it was placed in the bunker mostly as loose salt.

- about 200 tonnes of cyanides, procured by MSE in the past for tabun production, stored as salt in cardboard boxes.
- 75 kg of arsenic trichloride, a precursor in the synthesis of blister warfare agents.
- 170 one-tonne containers previously used for tabun storage. Due to difficulties in emptying them fully, (because of crystallized salts) they were filled with caustic soda and left for gradual decomposition of the agent residue.


STORAGE BUNKER # 2 (AKA Bunker 13)
CONTENTS DISTRIBUTION
MUTHANNA STATE ESTABLISHMENT (MSE),
33-52.521 N 043-50.537 E
170 x 1 Tonne containers fromerly filled with Tabun
180 Tonnes Sodium Cyanide
75 Kg Arsenic Trichloride
1.75 Tonnes Potasium Cyanide
122 mm rockets formerly filled with Sarin
5 ENTRIES ARE SEALED IN THIS WAY
1
2
1
3
1
1 BRICK
2 CONCRETE 1 M
3 TAR 5 CM
0
10
20
30
40 m
WALLS ONE & TWO
Steel renforced bars secured to main tunnel wall

<u>Bunker 41</u>

- 2,000 empty 155mm artillery shells contaminated with mustard. These 155mm shells were found by inspectors in a dumpsite at Muthanna during a survey of the site after the completion of the CW destruction operation. Despite efforts by the CDG, complete agent decomposition was not achieved. For this reason those shells were sealed inside the bunker.

- 605 one-tonne mustard containers with residues of polymerised agent were placed to the main chamber of the bunker. They were filled with a solution of caustic soda and alcohol to allow the degradation process to continue over time.

- Equipment from the incinerator. After the unit was dismantled, all the contaminated pumps, pipes, valves, heat exchanger and tanks were partly cleaned by burning, and stored in the bunker, as their thorough decontamination was impossible. Some 200 litre barrels after chemical agents or other toxic chemicals were also moved into bunker # 41.

- **Construction material scrap.** Heavily contaminated bricks, concrete slabs and soil from the destruction sites (incinerator, CW pits), were crushed, partly decontaminated by splashing with fuel and burning and then sealed in the bunker.

The main entrance to the bunker # 41 was completely filled to the top with bricks, shells and soil. The D4 (tabun precursor) barrel leakage had caused serious contamination of the bunker.

Comment
A. agents and chemicals

Bunker 13

UNMOVIC has neither a comprehensive record of the exact number or condition of munitions stored in the bunker and associated quantities of sarin and sarin-type agents. The last estimated inventory was done by UNSCOM in 1994[90]*. According to Iraqi declarations, the storage bunker in question contained different types of 122mm chemical rockets filled with sarin with various kinds of internal compartments for the warfare agent.*

[90] Annex B to CDG Situation report 171, March 1994.

Sarin

According to Iraq's declarations and documentary evidence, sarin produced and filled into munitions was of poor quality and not suitable for long-term storage. The agent would have been loaded into polymer-based containers inside the munitions, which would not have contributed to the degradation of the agent. On the other hand, those rockets that were filled directly with agent into their metal housings without internal containers would have reacted with the metal and degraded substantially. To the extent of UNMOVIC's current knowledge regarding Iraq's sarin production, the agent stored with or without internal containers would largely be degraded after years of storage under the conditions existing there. This conclusion is reinforced by the fact that no sarin-filled munitions discovered by UNSCOM were ever found to contain high purity agent.

Tabun

The tabun filled containers previously used for storage were all treated with decontamination solution prior to being placed in the bunker, and can therefore be assumed to no longer contain agent. The residue of this decontamination would contain cyanides, which would still be a hazard.

Cyanide salts

Sodium and potassium cyanide salts were placed in bunker #13 as loose salts and in cardboard boxes. While these are not chemical warfare agents per se, they are inherently blood toxins, and should be treated as hazardous materials. The level of danger posed by these chemicals cannot be ruled out until the area is investigated through detailed sampling and analysis.

Chemicals containing Arsenic

The arsenic compounds contained in the bunker are not per se chemical warfare agents. However, these chemicals do constitute a major toxicological hazard since all degradation products of these chemicals are hazardous.

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[91] Nineteenth Quarterly Report of UNMOVIC, UN Doc No S/2004/129.
[92] Comprehensive Report of the Special Advisor to the DCI on Iraq’s WMD, 30 Sep 2004, Vol. III, page 78.
[93] Twenty-Third Quarterly Report of UNMOVIC, UN Doc No S/2005/742.

Bunker 41

Mustard

The mustard contaminated 155mm artillery shells; agent containers and chemical equipment in the bunker do not constitute a CW proliferation issue. However there might still be some residue of polymerised mustard in the containers, even if they had been filled with a decontamination solution of caustic soda and alcohol. Such residues of polymerised mustard, although no longer useful as chemical warfare agent due to solidification, remain highly toxic.

B. Munitions and explosives

Bunker 13

Given the status of this bunker as described above, it was not possible to identify type and number of 122mm rockets stored there. There might also be a number of other types of munitions located within this facility. The munitions inside the bunker may be both filled and unfilled, armed or unarmed, in good condition or deteriorated, and may be unsafe to move.

It cannot be confirmed whether these 122mm rockets were all or partially fitted with their respective rocket motors, nor whether they still contain their explosive burster assemblies, and fuses. It is possible that these munitions still pose a significant safety hazard because of the explosive propellant in the motors. The effects of aging and the unstable nature of the explosive compounds used in the munitions systems, requires that caution be exercised when dealing with the bunker's contents.

Bunker #13 rockets were not included in the inventory of 122mm filled sarin rockets destroyed under UNSCOM supervision. They were declared by Iraq as "Destroyed in Gulf War" In a worst-case scenario there could be nearly 50 tonnes of double based propellant and 15,000 litres of chemical nerve agent

Bunker 41

About 2,000 artillery shells emptied during destruction operations and stored in the bunker had been treated according to the destruction procedures before being placed inside. This included breaking of their burster tubes, chemical destruction of the agent inside the shell and then burning the shells to enhance agent decomposition. By these actions they became unusable as chemical munitions but still constitute a health hazard.

UNMOVIC has had no physical access to the Muthanna site after it was withdrawn from Iraq in March 2003. However UNMOVIC was also to survey the site status, to some extent, by using commercially available imagery. Thus, in 2004 it was noted that chemical production equipment rendered harmless and tagged by UNSCOM was removed from MSE to an unknown destination as the sheds in which they were stored were completely dismantled[91]. UNMOVIC was concerned when in its September 2004 report, the ISG[92] noted that all sealed structures at Muthanna had been breached and that some equipment & materials had been removed; bunkers tested positive for chemical agents.

Information (imagery and open-source media reporting) available to UNMOVIC indicated that as of 2005 agricultural activities were carried out in the close vicinity of the bunker area Current state of the site (as of June, 2007) is not known. In its December 2005 report[93] to the Security Council UNMOVIC noted that agricultural activities were taking place within the perimeter of the site and in an area 500 m from the bunkers with hazardous content.

Several issues remain over the current status of bunkers 13 and 41 stemming from disarmament, security and safety concerns:

- *There is no verifiable evidence regarding the contents of bunker #13 prior to its bombardment, or the number, types and composition of the stockpiled sarin-filled munitions declared by Iraq as destroyed during the bombardment in 1991.*
- *The 122mm rockets stored in bunker #13 are designed to be chemical warfare agent delivery systems and pose a proliferation risk. Since the state of their destruction by the bombardment has not been possible to verify, it may be that some if not many of the rockets inside the bunker remained intact.*
- *The levels of degradation of the sarin filled in the munitions cannot be established without exploring the bunker and taking samples from intact warheads.*
- *Bunker #13 contains hundreds of artillery rocket motors with propellant and an unknown quantity of burster charges and fuses that in combination with the possible presence of sarin makes physical exploration of the bunker very dangerous.*
- *About 200 tonnes of cyanides and arsenic containing compounds entombed in bunker #13 may pose an environmental threat. The remnants of munitions hardware and bulk containers with the residues of polymerized mustard left after the destruction operations and entombed in the bunker #41 may pose a similar threat to human health if handled improperly.*

The presence of thousands of tonnes of various chemical compounds, resulting from destruction operations, buried in the underground structures concentrated at the bunker area make the land unsuitable for agricultural activities without preliminary evaluation. Due to the unknown state of any leakage of chemicals emanating from the bunkers or the effect on the water table or hydrological condition of the site, a safe distance for agricultural activities cannot be defined.

APPENDIX I TO CHAPTER III.XI

Iraq's Chemical Weapons Accounting by the UN Commission

Introduction

In its 1996 Chemical FFCD Iraq revealed a much broader scope of its CW programme. Numbers and quantities of the CW were verified by UNSCOM to the extent possible and a material balance prepared, including the status of verification and remaining uncertainties. All results were presented by UNSCOM in January 1999, in a report submitted to the President of the Security Council and published as UN document S/1999/94 (also known as the Butler Report). That report was analyzed by UNMOVIC along with other Commission's findings, assessments and original Iraqi documents after it took over the responsibility from UNSCOM. The respective issues were included into the Draft Work Programme on Unresolved Disarmament Issues of March 2003.

The Material Balance

Iraq declared overall holdings of more than 200,000 unfilled and filled special munitions (those produced and procured for CW and BW purposes) during the entire period of the implementation of its CW programme. Special munitions included aerial bombs, artillery shells, rockets for multiple launching systems and missile warheads. According to Iraq, about half of the declared total holdings, filled with CW agents, were consumed or disposed of in the period of the Iran-Iraq war, up until August 1988.

With respect to the munitions, which existed in Iraq as of January 1991, Iraq declared 127,941 filled and unfilled special munitions. These munitions were declared by Iraq and were accounted for by the Commission as follows:

a) 56,281 munitions [22,263 filled munitions and 34,018 unfilled munitions] declared by Iraq as having remained after the 1991 Gulf war:

- 40,048 munitions were destroyed under UNSCOM supervision [these comprised 21,825 filled munitions and 18,223 unfilled munitions],
- 16,263 munitions were not destroyed, but nevertheless accounted for by UN inspectors. These include 15,616 unfilled munitions, which were converted by Iraq for conventional weapons purposes in 1993-1994. These also include 438 filled munitions destroyed, according to Iraq, during a fire accident.

b) 41,998 munitions [5,498 filled munitions and 36,500 unfilled munitions] declared by Iraq as having been destroyed during the 1991 Gulf war:

> The Commission has accepted the destruction of about 34,000 munitions on the basis of multiple sources, including physical evidence and documents provided by Iraq. However, it was not possible to achieve a numerical accounting of destroyed munitions due to the damage of the

CW storage facilities, where these munitions had been stored during the Gulf war, the destruction of about 2,000 unfilled munitions remain uncertain and 550 filled munitions remain unaccounted.

c) 29,662 munitions [854 filled munitions and 28,808 unfilled munitions] declared by Iraq as having been destroyed unilaterally:

The destruction of about 13,660 munitions, both filled and unfilled, has been accepted by the Commission on the basis of multiple sources, including physical evidence and documents provided by Iraq. However, it has not been possible to make a numerical accounting of these munitions due to destruction method used by Iraq (demolition). Accounting for 15,900 unfilled munitions which, according to Iraq, had been melted, has not been possible.

The material balance of 127,941 unfilled and filled special munitions declared by Iraq remaining as of January 1991 is provided in Table I

Table I The material balance of special munitions remaining as of January 1991

Iraq's Declarations[i]		Accounting Status[1]
Munition Type (fill)*	Quantity	
1. Munitions declared by Iraq as remaining After the 1991 Gulf war		
250 gauge aerial bombs (mustard)	1,243	1,233 aerial bombs were accounted for by UNSCOM. They were destroyed by Iraq under UNSCOM supervision during 1992 and 1993.
250 gauge aerial bombs (Unfilled)	8,122	1) 7,627 aerial bombs were accounted for by UNSCOM. They were destroyed by Iraq under UNSCOM supervision during 1991 and 1993. 2) About 500 aerial bombs have not been found. According to Iraq, 500 aerial bombs were delivered damaged by a foreign supplier.
500 gauge aerial bombs (mustard)	1,426	1) 980 aerial bombs were accounted for by UNSCOM. They were destroyed by Iraq under UNSCOM supervision in 1992-1993.

[1] UN Doc No S/1999/94 p. 77-78

		2) Remnants of several hundred destroyed aerial bombs from 438 bombs declared by Iraq as destroyed in a fire accident in 1988, were seen by UNSCOM.
500 gauge aerial bombs (unfilled)	422	1) 331 aerial bombs were accounted for by UNSCOM and destroyed by Iraq under UNSCOM supervision. 2) Some 100 aerial bombs have not been found. According to Iraq, 100 aerial bombs were delivered damaged by a supplier.
R-400 aerial bombs (binary components of sarin)	337	1) 337 aerial bombs were accounted for by UNSCOM. 336 bombs were destroyed by Iraq under UNSCOM supervision in 1992. 2) One bomb was removed for analysis outside Iraq by UNSCOM[2]. 3) Evidence of a few R-400 bombs produced by Iraq for BW purposes has been found among 337 CW bombs declared by Iraq[ii].
R-400 aerial bombs (unfilled)	58	58 aerial bombs were accounted for by UNSCOM and destroyed by Iraq under UNSCOM supervision.
DB-2 aerial bombs (unfilled)	1,203	1,203 aerial bombs were accounted for by UNSCOM. They were destroyed by Iraq under UNSCOM supervision during 1992 and 1993.
122mm rockets (sarin)	6,610	6,454 rockets were accounted for by UNSCOM. They were destroyed by Iraq under UNSCOM supervision during 1992 and 1993.
122mm rockets (unfilled)	6,880	7,305 rockets were accounted for by UNSCOM and destroyed by Iraq under UNSCOM supervision.
155mm artillery shells (mustard)	13,000	12,792[3] shells were accounted for by UNSCOM. They were destroyed by

[2] UNSCOM 12/CW-04 September 1991 Annex 8
[3] The number does not include 14 artillery rounds destroyed by UNMOVIC

		Iraq under UNSCOM supervision in the period 1992-1994.
155mm artillery shells (unfilled)	16,950	1) 1,700 shells were accounted for by UNSCOM and destroyed by Iraq under UNSCOM supervision. 2) In 1998, Iraq presented documents on the conversion of 15,616 shells to conventional munitions. Of these, 1,779 converted shells were accounted for by UNSCOM.
Special missile warheads (sarin/binary components of sarin)	30	1) All 30 warheads were accounted for by UNSCOM. 2) Of those, 29 warheads were destroyed by Iraq under UNSCOM supervision during 1992 and 1993, and 3) One warhead was removed for analysis outside Iraq by UNSCOM.
Sub total of munitions remaining after the 1991 Gulf war	56,281	
2. Munitions declared by Iraq as destroyed during the 1991 Gulf war		
500 gauge aerial bombs (CS)	116	1) No remnants of destroyed bombs have been found. 2) In 1995, documentary evidence was provided by Iraq that 116 bombs filled with CS had been stored at a facility destroyed during the Gulf war.
R-400 aerial bombs (binary components of sarin)	160	1) In 1992, remnants of bombs consistent with the declared quantity of bombs were seen by UNSCOM. 2) The circumstances of destruction have not been fully clarified.
DB-2 aerial bomb (sarin)	12[4]	1) In 1991, remnants of up to 50 bombs were seen by UNSCOM[5].

[4] UNSCOM Doc No 70029 - Chemical FFCD November 1995 Annex 3
[5] UNSCOM 20/CW-06 October 1991 paras. 94-96

		2) In 1996, documentary evidence was found by UNSCOM that DB-2 bombs had also been filled with mustard (which was not declared). In 1997, Iraq stated that only a few bombs were filled with mustard for trials[iii].
122mm rockets (sarin)	4,660	1) In 1991, two locations were seen by UNSCOM where rockets had been destroyed. Evidence of many destroyed rockets was found. 2) In the period 1991-1998, remnants of about 4,000 rockets were recovered and accounted for by UNSCOM.
122mm rockets (unfilled)	36,500	1) Completely destroyed hangars where rockets had been stored were seen by UNSCOM. Evidence of many destroyed rockets was found. Accounting for the remnants was not possible due to the extent of the destruction. 2) In 1995, documentary evidence was provided by Iraq that 36,500 rockets had been stored at a facility destroyed during the Gulf war.
155mm artillery shells (mustard)	550	1) No evidence has been found of 550 shells declared by Iraq as having been lost shortly after the Gulf war. 2) In July 1998, Iraq provided a progress report on its ongoing internal investigation.
Sub total of munitions destroyed during the 1991 Gulf war 1	41,998	
3. Munitions declared by Iraq as destroyed unilaterally		
250 gauge aerial bombs (CS)	125	Remnants of bombs consistent with the declared quantity were seen by UNSCOM.
250 gauge aerial bombs (unfilled)	2,000	1) Remnants of 1,400 destroyed bombs were accounted for by

		UNSCOM. 2) UNSCOM was presented with ingots declared to be from the melting of 600 bombs. The material presented could not be assessed as adequate for proper verification.
R-400 aerial bombs (binary components of sarin)	527	1) Remnants of bombs consistent with the declared quantity were seen by UNSCOM. 2) Iraq presented supporting documents on the destruction of 527 bombs.
R-400 aerial bombs (biological warfare agents)	157	1) In the period 1992 to 2003, remnants of around 130 bombs were accounted for by the UN inspectors (Details in Chapter V). 2) Supporting documents on the destruction were presented by Iraq (without reference to the type of agents filled into them).
R-400 aerial bombs (unfilled)	308	1) No evidence was presented of 117 bombs declared by Iraq as having been melted. 2) No evidence was presented of 191 melted bombs declared as defective.
122mm rockets (unfilled)	26,500	1) Remnants of 11,500 rockets destroyed through demolition were seen by UNSCOM. Accounting was not possible due to the state of destruction. 2) UNSCOM was presented with ingots declared to be from the melting of 15,000 rockets. The material presented could not be assessed as adequate for proper verification.
Special missile warheads (binary components of sarin / biological warfare agents)	45[6]	1) In the period from 1992 to 1998, remnants of 43-45 special warheads were recovered and accounted for by UNSCOM.

[6] UNSCOM 31 March 1992; Iraq's Chemical FFCR 1992 Annex 24

		2) In the period from 1997 to 1998, remnants of 3 additional warheads declared as special training warheads were recovered. 3) In 1998, degradation products of CW agent VX were found on some of the remnants of special warheads. 4) Supporting documents were provided by Iraq on the overall accounting for special warheads and on the unilateral destruction of 45 warheads.
Sub total of munitions destroyed unilaterally	29,662	

Bulk CW Agents[7]

Iraq declared the overall production of some 3,850[8] tonnes of CW agents during the entire period of the implementation of its CW programme. According to Iraq's declarations, mustard, tabun and sarin were produced in large quantities. Not withstanding the admitted production of 3.9 tonnes of VX, Iraq states that attempts to produce VX had failed.

According to Iraq, of the declared total quantity of 3,859 tonnes of CW agents produced, some 3,300 tonnes of agents were weaponized. Iraq declared that about 80% of the weaponized CW agents were consumed in the period from 1982 to 1988. In addition, some 130 tonnes of non-weaponized CW agents were claimed to have been discarded by Iraq in the 1980s.

Iraq declared that 412.5 tonnes of bulk CW agents available in Iraq as of January 1991. These have been accounted for as follows:

> 411 tonnes of bulk CW agents were destroyed under UNSCOM supervision,
>
> 1.5 tonnes of CW agent VX were discarded unilaterally by Iraq and remain unaccounted for.

The material balance of 412.5 tonnes of bulk CW agents remaining in Iraq as of January 1991 is provided in Table II.

[7] Chemical CAFCD December 2002, Chapter XI, Table VIII
[8] Calculated based on data in Chemical CAFCD December 2002 Table VIII

Table II

Iraq's Declaration		
Bulk CW Agent (storage form)	Quantity (tonnes)	
Mustard (20m^3 / 1m^3 containers)	295	295 tonnes of mustard were destroyed by Iraq under UNSCOM supervision.
Sarin and its mixtures (2m^3 containers)	76	76 tonnes of sarin were destroyed by Iraq under UNSCOM supervision.
Tabun (2m^3 containers)	40	40 tonnes of tabun were destroyed by Iraq under UNSCOM supervision.
VX (1m^3 containers)	1.5	1) According to Iraq, 1.5 tonnes of VX were discarded unilaterally by dumping on the ground. 2) Traces of one VX-degradation product and a chemical known as a VX-stabilizer were found in the samples taken from the VX dump sites and remnants of special warheads. 3) A quantified assessment is not possible.
Total	412,5	

Iraq also destroyed under UNSCOM supervision, about 300 tonnes of agents retrieved from munitions or destroyed without emptying them. The quantities of agents were established based on calculations of the average payloads of the munitions and their quantity. Moreover, quantities of agents produced represent crude quantities. Therefore, the quantities of agents produced and their subsequent disposition do not precisely balance.

Material Balance of key CW Precursor Chemicals

Iraq declared that some 20,150 tonnes of key precursor chemicals had been produced by Iraq and procured from abroad for the production of CW agents during the entire period of the implementation of its CW programme.

According to Iraq, of the declared total quantity of over 20,000 tonnes of key precursors, 14,500 tonnes were used either for the production of CW agents or for the production of other key precursors for these CW agents. The rest, 5,650 tonnes, was not used in the production of CW agents.

Iraq declared that 3,915 tonnes of key precursors remained in Iraq as of January 1991. According to Iraq, the discrepancy between calculated quantities of precursors left over from the production of CW agents (5,650 tonnes) and quantities of precursors declared by Iraq as remaining in January 1991 (3,915 tonnes) could have occurred due to the lack of sufficient information and full records on the actual delivery by former suppliers, on the consumption of precursors in the production of CW agents, and on the losses of key precursors, including through unsuitable storage, spillage and leakage.

The 3,915 tonnes of key precursors remaining in January 1991 have been accounted for as follows:

- 2,850 tonnes were accounted for by UNSCOM. Of these, 2,610 tonnes of key precursors were destroyed under UNSCOM supervision,
- 823 tonnes were declared by Iraq as having been destroyed during the Gulf war. The Commission was able to confirm qualitatively the destruction of these precursors. It was not possible to make a quantitative verification,
- 242 tonnes were declared by Iraq as having been destroyed unilaterally in the summer of 1991. These include all precursors for the production of VX. The declared destruction of these 242 tonnes of key precursors was only partly accounted for.

The material balance of 3,915 tonnes of key precursors declared by Iraq remaining as of January 1991 is provided in Table III[9].

[9] UN Doc No S/1999/94, Table 3; Chemical CAFCD December 2002 Part I, Chapter XI, Table VII

Table III The material balance of key precursors remaining as of January 1991

	Key Precursor (related CW agents)	Quantity of key Precursor left over from the Production of CW Agents in tonnes (calculated quantity)* *	Iraq's Declarations (In tonnes)		Key Precursors physically remaining in Iraq and destroyed under UNSCOM Supervision
			Quantity of key Precursor destroyed during the Gulf war in 1991	Quantity of key Precursor destroyed unilaterally by Iraq in summer 1991	
1	2	3	4	5	6
1	D4* (tabun)	166	none	None	166 tonnes were destroyed under UNSCOM supervision.
2	$POCl_3$** (tabun)	477[10]	none	None	576 tonnes were destroyed under UNSCOM supervision.
3	Dimethylamino-hydrochloride (tabun)	295	30 1) Evidence of destruction was seen by UNSCOM. 2) Accounting was not possible due to the state of destruction.	None	272 tonnes were destroyed under UNSCOM supervision.

[10] In the Chemical FFCD June 1996Iraq declared the import of 946 tonnes of $POCl_3$ and quoted a number of letters of credit (LCs) in support (Chemical CAFCD December 2002, Part I, Chapter IIIA, item 7). Iraq declared that, of the 946 tonnes, 469 tonnes of $POCl_3$ had been processed into the CW agent tabun[10].

4	Sodium cyanide ** (tabun)	371	none	None	180 tonnes were destroyed (entombed) under UNSCOM supervision.
5	Thiodiglycol* (mustard)	377	120 1) Evidence of destruction was seen by UNSCOM. 2) Accounting was not possible due to the state of destruction.	None	188 tonnes were destroyed under UNSCOM supervision.
6	Thionylchloride* ** (mustard, GB, GF and VX)	none	100 1) Evidence of destruction was seen by UNSCOM. 2) Accounting was not possible due to the state of destruction.	None	282 tonnes were destroyed under UNSCOM supervision.
7	PCl_3 ** (mustard, GB, GF and VX)	2,422	none	None	650 tonnes were destroyed under UNSCOM supervision.
8	MPF* (GB, GF)	67	9 1) Evidence of destruction was seen by UNSCOM. 2) Accounting	30 1) Evidence of destruction was seen by UNSCOM. 2) Accounting	20 tonnes were destroyed under UNSCOM supervision.

			was not possible due to the state of destruction.	was not possible due to the state of destruction.	
9	HF ** (GB, GF)	181	none	None	1) 11 tonnes were destroyed under UNSCOM supervision. 2) About 200 tonnes were released by UNSCOM for civilian use. 60 tonnes thereof have already been consumed and 140 tonnes remain under UNSCOM monitoring.
10	Isopropanol ** (GB)	465	none	None	445 tonnes were destroyed under UNSCOM supervision.
11	Cyclohexanol (GF)	120	105 1) Evidence of destruction was seen by UNSCOM. 2) Accounting was not possible due to the state of destruction.	None	Tens of tonnes were consumed by Iraq in the 1990s for civilian purposes under UNSCOM supervision.

12	P_2S_5 (VX)	242	85 1) Evidence of destruction was seen by UNSCOM. 2) 168 empty barrels (200L) from P2S5 sufficient for 34 tonnes were accounted for by UNSCOM.	157 1) Evidence of destruction was seen by UNSCOM. 2) 153 tonnes were accounted for by UNSCOM.	none
13	Diisopropyl amine (VX)	210	174 1) Evidence of destruction was seen by UNSCOM 2) Accounting was not possible due to the state of destruction.	None	22 tonnes were destroyed under UNSCOM supervision.
14	Chloroethanol (VX)	202	200 1) Evidence of destruction was seen by UNSCOM 2) Accounting was not possible due to the state of destruction.	None	2 tonnes were destroyed under UNSCOM supervision.
15	"Iraqi" Choline* (VX)	55[1]	none	55[1] 1) UNSCOM took samples from the dump	none

				site. 2) Degradation products of choline were found in the samples. 2) Accounting was not possible due to the state of destruction.	
16	Sub total	5,650[2]	823	242	2,810

1 - Quantities of key precursors declared by Iraq in 1995 as having been destroyed unilaterally in 1991.

2 - Only key precursors that Iraq declared as remaining as of January 1991 are included in the column. The following key precursors, according to Iraq, were fully consumed prior to 1991: DMMP, MPC, TMP, MPS, and they are not included in the table.

* - Key precursors, which Iraq was able to produce indigenously in varying quantities (including DMMP, MPC, MPS and TMP)

** - According to Iraq, discrepancies in rows # 2,4,6,7,9, 10 between calculated quantities of precursors left over from the production of CW agents (column 3) and quantities of precursors presented by Iraq (column 6) could have occurred due to the lack of sufficient information and/or proper record keeping on their part:
a) on the actual delivery of precursors by foreign suppliers,
b) on the actual consumption of precursors in the production of CW agents, and
c) on the losses of key precursors, including through unsuitable storage, spillage and leakage.

Accounting for Iraq's CW programme was not an easy task for many reasons. Quantification of chemical agents and chemical munitions both acquired and used or destroyed, was one of the most challenging tasks due to the large amounts and numbers involved, time that had past and lack of documentary evidence. Nevertheless, UN inspectors pursued the objective for years, especially in cases where it was important for accounting for the programme as a whole. For example it accumulate a large archive of data related to procurement of items and materials from abroad, including letters from respective governments. Uncertainties however remained. The key ones have been addressed in the 2003 Draft Work Programme on Unresolved Disarmament Issues as Key Remaining Disarmament Tasks.

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[i] Chemical FFCD June 1996, Chapter XI; Chemical CAFCD December 2002, Chapter XI, page 11-19, 11-20,11-21 Ref.: 2/1/C/1012; some values were calculated based on values declared by Iraq;
[ii] UNSCOM 238 April 1998
[iii] UN Doc No S/1999/94 p 78 and UNSCOM Doc No 129134.001

APPENDIX II To CHAPTER III.XI

Comments on CW destruction operation conducted under UNSCOM supervision in Iraq

Summary

The supervision of Iraq's destruction of its chemical weapons stockpiles was one of the main achievements of the UN verification agency. It was the first CW destruction operation supervised by an international organization. Using the best expertise available internationally and applying optimal operating procedures, UN inspectors were able to ensure that this dangerous operation was conducted as rapidly and as safely as possible.

Due to the dangerous nature of the work and the hazards inherent in the destruction area, utmost attention was given to minimizing the health and environmental impacts of the destruction of chemical weapons and their components. The operation provided lots of lessons learned by experts who took part in it. Some of them were later utilized in the preparation of the text of the Chemical Weapons Convention and its Verification Annex. Below are selected comments and lessons presented in the way as they were drawn by UNSCOM and CDG staff members, during and after the destruction operation was completed, supported with other views stemming from a later assessment of Iraq's CW programme from disarmament viewpoint.

Destruction Advisory Panel

The Destruction Advisory Panel (DAP) was established to provide scientific advice to UNSCOM and acted as its highest "chemical destruction authority". This panel represented the highest scientific expertise and was working closely with the CDG. DAP recommendations established the basis of CDG rules and guidelines. The panel met on a regular basis to discuss on-going technical matters arising from destruction operations and their reports documented the status of activities and their recommendations.

DAP decisions had a direct impact on CDG work, including destruction procedures and technological issues. Sometimes, however, the communications path of information from the CDG to New York and then to DAP members at their home countries was time consuming and not all DAP members could take part in that process and respond in time.

Comment
It was recommended by the CDG that an advisory panel be maintained but that it is framed in the role of scientific advisor and monitor, rather than a real time decision maker. Decision making authority needed to be delegated to experts from the Commission headquarters, to keep the lines of communications short and to coordinate efforts of all sides involved.

Standard Operating Procedures

CDG standard operating procedures (SOPs) were not finished when the destruction process started, despite the fact that much of the inspection and engineering/technical data were accumulated by the Commission. Because of this the CDG had to work simultaneously on destruction operations and on the development of standard procedures. It was a huge challenge for the group and provided a number of lessons. An example of this is as follows:

Ammunition destruction at Khamissiyah was the one of most difficult operation implemented by Iraq under CDG supervision. Because the site was heavily damaged during the war the CDG had little knowledge of the type and technical condition of the munitions. This created a significant risk factor for the destruction operation. The primary risks during these operations were caused by corroded ammunition and unexploded ordinance scattered all over the working areas. The *in situ* destruction was the only solution to this issue.

Comment
Appropriate and effective SOPs have key importance in the complicated task of CW destruction at sites like Khamissiyah. It is important that SOPs developed before activities in the field commence are updated with any additional data based on the experience gained by the inspectors once the destruction operations have begun. SOPs for each type of chemical munition, process equipment, CW agent and precursor material to be destroyed should be outlined in the inspection manual and should include technical, safety and verification aspects. It should be written in clear language understandable by both members of the inspection team and by national personnel involved in destruction activities.

CDG Training

The CDG was comprised of appropriately qualified specialists designated by supporting countries. The vast majority of inspectors had the necessary technical knowledge and experience, but because of different techniques and standards employed by different countries the inspectors often had different technical approaches to handling of chemical agents and munitions. These differences were unified through comprehensive and extensive training and exercises conducted by UNSCOM instructors prior the deployment of inspectors to the working areas. However, it was not always possible to carry out such training to the extent required due to time constrains.

Comment
As much pre-deployment training time as possible is needed. Especially in multi-national inspection teams there is a need for everyone to clearly understand universal standards and basic requirements to be implemented during the destruction operations. Adequate pre-deployment preparations and planning usually results in better-organized operations in the field. Time in the field should be reserved for specific adaptation to the conditions and circumstances of the operation.

Standard operational procedures and training modalities are required for inspection and other equipment operated by inspectors. Also personal health and safety procedures, first aid procedures, medical evacuation procedures, monitoring procedures, and knowledge of English language are required. Advanced training courses devoted to the specific topics such as sampling and analysis techniques, EOD related training, evaluation of data received via cameras, etc. for selected roster personnel are highly advisable.

Safety and Security of CDG Operations

Safety procedures

The CDG developed and maintained strict safety standards during its destruction operations. These standards were developed taking into account the situation in Iraq and necessary safety precautionary measures were taken. Only because of these thorough and carefully developed safety procedures, were accidents avoided during destruction operations.

A regular programme of practical training exercises and briefings was crucial for the continued safety of team members and a highly developed sense of safe behavior and operation was fundamental to the overall safety approach. Development of each inspector's sense of responsibility for safe conduct of destruction operations was an on-going educational task throughout the UNSCOM operation.

As the Iraqi authorities did not submit any official accident reports, the Commission could not confirm the safety record for Iraqi workers. The CDG however noted the discrepancy between the lower level of Iraqi safety standards and the strict UNSCOM standards. Additionally, Iraqi practices led directly to a higher level of risk and could cause incidents and accidents and therefore could not be adopted by UNSCOM. Harmonization of these standards was a necessary step, which often caused operational delays.

Comment
A common code of safety for UN staff and host country personnel during destruction operations of toxic or hazardous materials is a must – only then, acceptable safety standards can be established with regard to both operational and humanitarian aspects. Such requirements should be agreed before destruction activities begin.

Operational Security during destruction

The type of destruction activity, which occurred under UN supervision and the circumstances surrounding this were unique to Iraq. However, obtained experience suggested that the destruction group of UNSCOM needed to have a secure room on the premises of the destruction site (MSE) for storage of sensitive materials and secure communications means, specifically an encrypted phone and fax for the chief inspector. Also, the integrity of the destruction area and materials needed to be continuously supervised.

Comment
Secure operations rooms need to be organized and permanently occupied while the destruction inspection team is operating in the field. The task must be assigned to the UN staff rather than to the host country personnel. If necessary, the entire operational area may need to be placed under an organization control of inspectors for the duration of the operation. Such control would minimize the risk of the uncontrolled removal of chemicals, munitions, and equipment during off-duty periods.

Medical support

The CDG operated under strict medical control throughout its mission. Medical standards were carefully maintained and supported by high safety standards.

The CDG operated with its own medical sub-team consisting of a doctor and two other medics. The medical sub-team provided support to CDG by attaching personnel to CW destruction operations at Muthanna and other operational sites. CDG found that this organizational structure and relationship met operational requirements.

CDG required also significant helicopter support throughout their mission for transportation of inspectors and equipment to the working areas. This requirement was not simply one of convenience, but also of medical necessity (recovery of personnel after work under extreme conditions, if necessary, should be time effective). Ground transport from Baghdad to the Muthanna site took up to four hours each day.

Comment
There should be no compromise for safety. In case of situations, when other inspection activities are given higher priority and require intense medical support, destruction operations should be suspended. It is considered that good coordination between inspectors, headquarter planners and CDG/Medical teams may help avoiding such a problem. In general, a permanent medic and ambulance, in addition to the medical assistance provided by the host country, should support any CDG group or activity. Additional medics could be added as needed. A flexible medical support organization is required for field destruction activities.

Precursor Destruction Operations

Precursors were destroyed under CDG supervision in the following ways: controlled hydrolysis/neutralization, open air burning, incineration and entombment into underground or semi-underground structures followed by sealing with concrete. The most complicated precursor destruction operations included such chemicals as PCl_3, $POCl_3$, $SOCl_2$, and HF. They also constituted the most bulky part of chemicals destroyed by the CDG.

On several occasions Iraq requested the Commission to spare some precursors for the utilization them in commercial activities. UNSCOM accepted some of those requests, for example some quantities of dual-use chemicals isopropanol and diisopropylamine (DIPA) procured for CW programme were initially released to the Modern Paint Industry facility. However, a few years later those chemicals were also destroyed by Iraq under UNSCOM supervision.

Comment
Strict requirements and methods for accounting for those chemicals during destruction operations need to be in place.

Material Balance and Destruction Certificates

A precise inventory of items and materials destroyed under CDG supervision proved to be of key importance in the accounting for the material balance within the disarmament process. There was no obligation for a total inventory resulting from the UN SC resolutions. The resolutions stated that “all” chemical weapons and stocks of agents and related subsystems and components were to be declared to the Commission and destroyed. Thus destruction *per se* was the key task for UNSCOM inspectors and for CDG members after its formation and not the recording of the inventory or the methodology for destruction. The material balance issue became increasingly important only after it had become clear that Iraq’s declarations and subsequently quantities of weapons and materials being subject to production, unilateral destruction and procurement were not correct. In practice, Iraq did not always request destruction certificates from UNSCOM immediately after the destruction activity took place but sometimes requested them *“post factum”*. As a result, such certificates might have contained less precise data.

Situation Reports (Sitreps) sent by the CDG to NYHQ proved to be the most valuable and reliable source of information regarding the destruction work. The format and structure of these Sitreps was not immediately obvious – it was a process from which some lessons could be learned. Such reports should be structured to ensure clarity and completeness.

Comment
Any destruction operations must have adequate measurement equipment. When precise measurement and quantification is not possible, any Destruction Certificate should

reflect this uncertainty. A computer database would greatly simplify the record keeping process but should be supported with hardcopy certificates verified and signed by both inspectors and host government. Failure to keep accurate, defendable, destruction records risks political interventions and disagreements.

Situation reports should not only contain the report of the day's activities but also, requests, recommendations and destruction certificates. Including all such data in the Sitreps would reduce the number of reference documents and lower the risk of unintentional errors.

Sitreps should be sent according to requirements. Periodical crosschecking in the form of a summary report exchanged between the field team, HQ and, to some extent with the host country is advisable. This summary report should contain experiences and recommendations as well as data on total actions to date.

Equipment and Logistics

The matter of financing of UNSCOM's operations became a question of great concern. Funding for the personnel, equipment and logistics was not assured until Iraq accepted Security Council adopted resolution 986 (1995) in mid-1996.

Equipment

Equipment needed for the destruction process ordered early in the operation, did not arrive in the country in a timely way. In addition, Iraq was not able to provide all the items required. As a result, the CDG often lacked appropriate equipment or had to make ad hoc arrangements with respect to certain items, for example, emission detectors and analytical equipment.

Comment
Some steps considered as necessary in light of the CDG experience are:
a. Determine and define equipment needs prior to the initiation of the operation.
b. Do not rely entirely on the technical or material support of the host country, and prepare back-up plans.
c. Enact formal agreements between the host and implementing agency covering as many operational aspects as possible as far in advance as possible.

The UNSCOM logistical system was not always effective for the purposes of the CDG. Since its inception, the CDG often had to wait for equipment because the mission's operational concept was not clearly defined but developed during the course of operations. Logistical support remained a problem for CDG throughout the mission. It was caused partly by the fact that UNSCOM and CDG relied on countries' voluntary contributions rather than on a planned systematic procurement based on its own allocated resources.

Comment
The over-all logistic concept should be well defined and based on the special requirements and aims of the mission.

Getting material assistance from supporting governments can prove very time consuming. Therefore, the requirements of the task must be carefully determined and communicated to supporting governments well in advance of operational implementation.

UNSCOM experts suggested that any future destruction operations, similar to the one carried out in Iraq, should first determine which nations are willing and able to contribute material support to the operation. Then, the types of equipment needed for the task along with their advantages and disadvantages must be identified. A list of "minimum basic equipment" for the operation needs to be created and this should be followed by a selection of the best type of equipment in each area. Selected equipment, particularly the basic equipment, should be provided in significant quantities, or even over stocked, at the beginning of the operation. A logistic reserve of six months is highly recommended.

UNMOVIC logistic supply with inspection equipment was based on UN procurement procedures. Supporting countries provided some small amounts of inspection equipment, for example, decontamination equipment, because sometimes the UN procurement process was time consuming.

Comment
Any verification and disarmament mission must be supplied with necessary equipment and materials before deployment. It takes time to build the necessary stockpiles of such equipment and the costs associated with this are a necessary part of the operation. If there are time constraints on a destruction mission all alternatives that do not compromise safety or efficiency of the operations should be evaluated.

Transport of Hazardous Goods

UNSCOM transported samples collected in Iraq by both commercial and military aircraft, the latter of which were supplied by member states. Samples were shipped according to International Aircraft Transportation Authority (IATA) regulations. For some special materials national clearances were also required. These national requirements were often time consuming, necessitate special packing materials, and required that chemicals and samples were described in great detail.

UNMOVIC trained many of its HQ staff in this regard. IATA certified most team leaders.

Comment
Commercial means of transportation should be used when applicable. Teams should plan well ahead for the transport of non-routine materials and make alternative plans. IATA regulations are also fully appropriate for military aircraft. Transportation of samples of hazardous or toxic materials using military aircraft offered by contributing countries is an option especially when if there are strict time constraints. Chief inspectors and if

possible the logistics officer responsible for the transport of all goods, including hazardous goods should be trained on IATA regulations.

Remarks on Selection and Qualification of Personnel

The selection of personnel for a field destruction operation should be based on a criteria catalogue of skills and abilities. This catalog should be developed before the operation commences. UNSCOM relied on the personnel supplied by contributing countries. Over 100 experts from some 25 countries served with the CDG during the period of its work in Iraq. Iraq also had experienced personnel in the CW area.

The two key concepts developed by CDG for staffing the field operation are overlap and contract time. CDG found that an overlap of four weeks for HQ personnel was important for maintaining continuity of procedure and knowledge of technical status of operations. For non-HQ personnel, including decontamination/reconnaissance and medics, two-week overlap was sufficient.

The second important factor is service time. The minimum contract time for key personnel including chief inspectors should be six months. For other team members three months was found to be a good minimum time. CDG aimed at a six month average and even an extension to nine months whenever possible. Contract durations of less time do not allow for the personnel in question to operate at an effective pace. Some CDG members were being replaced just when they were becoming most effective. The maximum service time is a function of the task and operational conditions.

Comment
Once the task is identified the headquarters (HQ) group for destruction operations should be designated and they should conduct or participate in, the initial exploratory mission to the operating area. The HQ element could then define the expert requirements for the mission taking into account the specific living conditions in country as they can have a significant impact of operational performance. In staffing the team, planners should take note of character profiles, field conditions, supply and economic conditions. These points need to be specified and adjusted based on the condition in the host country.

UNSCOM experience in Iraq showed that experts with practical leadership experience were well qualified to supervise destruction operations. Areas like EOD and analytical activities required highly specialized personnel.

Environmental Aspects

General Remarks

Muthanna State Establishment, the main destruction site for Iraq's chemical weapons was used for years as the location for their production facilities. Since environmental protection was not a high priority for Iraq, much of the area was contaminated for many years prior to the CDG supervised destruction operation. In addition, the 1991 bombardment of the site damaged many production units and storage containers and filled munitions were scattered all over the site. As a consequence, significant quantities of agents and other chemicals leaked to the ground. The situation was presented by UNSCOM to UNEP. Destruction methods applied during the whole process were optimal from environmental safety point of view.

When the destruction operations were completed, UNSCOM conducted a survey to establish whether locations and structures used for destruction purposes were free from contamination by chemical warfare agents and other toxic chemicals. Analyses of 335 samples, collected from 22 locations within MSE associated with destruction activities, were negative (less than 1ppm level). In the Hand-Over Protocol, UNSCOM warned of the future risk and hazards associated with this location because of the areas with sealed structures (lagoons and bunkers). The responsibility for other locations at the MSE as a whole, including other sources and types of contaminations was the responsibility of Iraq.

Comment

In order to assure the highest possible level of environmental protection, the destruction group must be provided with basic environmental control reference documents and guidance including a data collection framework concerning pollution and emission limits. This framework should be developed by the advisory panel and based on international standards. It may be necessary to adopt international standards in the operating region.

The task of environmental monitoring should be assigned to an analytical specialized team.

Equipment for the monitoring of emissions must be in place. This equipment must be present for test runs and the trial phases of the destruction process. Monitoring of air, water and soil samples need to be a permanent aspect of any destruction operation. The protocols for documenting the on-going environmental impact of a destruction operation are politically important and need to be worked out well in advance.