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Working paper on monitoring destruction of stockpiles of chemical weapons and chemical warfare agents

Introduction

A critical issue for the trust, which States will put in a future chemical weapons convention prohibiting the acquisition and retention of chemical weapons and prescribing their destruction, will no doubt be the destruction of the weapons and the possibilities the convention will provide for verifying compliance with this provision. It therefore seems useful to look particularly at these issues as soon as possible and as detailed as necessary during the negotiations. This Working Paper concentrates on verification problems in relation to the destruction of chemical munition and bulk stockpiles of chemical warfare agents. The available literature is rather extensive, see e.g. references 1-13, and cannot be fully accounted for in this preliminary analysis of the principles.

It concentrates on two types of chemical weapons (agents), mustard gas and nerve gas. Two rather different destruction procedures have been chosen and the process flows have been simplified in order to highlight particularly those points, which are of principal interest for a discussion on verifying destruction. As a basis for the models we have used the destruction of mustard gas, as described by the Netherlands and Indonesia in reference 7 and the destruction of nerve gases in the United States of America as described in reference 11. This does not mean that the Swedish delegation in any way regards these two particular methods as preferable to others. Before a future, practical application many more detailed problems will remain to be solved, and probably local conditions will have a strong influence on the choice of method and type of verification.

The local conditions will probably have a particular influence in the case of destruction of old stocks of chemical weapons, which were hidden in the earth or in the sea many years ago, after World Wars I and II. Such rediscovered stockpiles have now and then already been taken care of in different countries. See e.g. Kurata: Lessons learned from the destruction of the chemical weapons of the Japanese Imperial forces, p. 77 in reference 10. It seems necessary to have particular provisions for the purpose, when a future convention comes into force, in order to clarify ambiguities about the sources of munitions to be destroyed. Destruction of such old munition should not need to be verified. On the other hand, there seems to be no reasons against on-site verification of such activities.

The aim of a comprehensive study would be to try and identify any information about the destruction process which could be:

(1) critical to obtain assurance that the chemical weapons (agents) are actually being destroyed — with or without on-site inspection,

(2) possible to obtain in an as non-intrusive way as possible but at the same time being safeguarded against attempts to manipulate the information gathering,

(3) possible to transmit in a cheap and safe form from the monitoring instrument to a central decision-maker at another location.

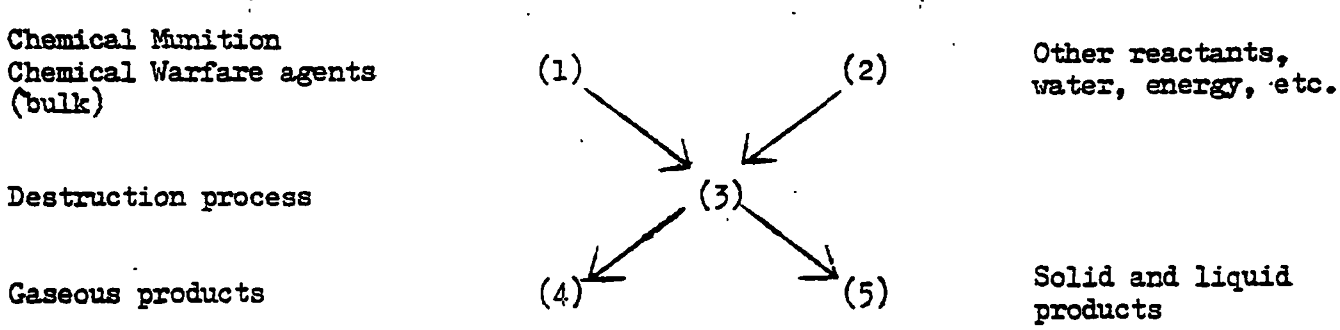
The present Working Paper constitutes a preliminary approach in this direction.

Experiences of similar problems made in other contexts, which are relevant also for the design of the verification process of a chemical weapons convention, should be utilized in this process. This is the reason for referring to the study on transmission of monitoring information from verification stations in the nuclear energy industry (RECOVER ref. 14) as one aspect in this Working Paper. See also reference 8. It is, however, clear that this system constitutes only one of the components of a verification structure. Its main initial interest may be to point to the availability of such transmission systems. The following account of the RECOVER-system therefore limits itself to a factual summary of a preliminary evaluation of the results obtained so far during the development of the system according to the draft report in reference 14.

<u>Principal aspects of destruction of chemical weapons and its verification under a chemical weapons convention</u>

The purpose of verifying the destruction of chemical weapons or bulk stockpiles of chemical warfare agents is to ensure that at least those quantities of the weapons and bulk stockpiles, which a Party has declared as being under its jurisdiction, are being destroyed, i.e. transformed into products which cannot again be converted back into chemical weapons or warfare agents.

A schematic description of a destruction process can be made in the following way:



With regard to the marked processes (1-5) the following comments can be made:

(1) The amount of agent introduced into the destruction process should be carefully monitored in order to avoid overestimates of the actual quantities destroyed and thereby eliminating the possibility of clandestine withholding of the declared stocks. This problem was addressed e.g. in reference 5. This principle requires knowledge of the chemical content of the munition and bulk stockpiles. If such knowledge cannot be obtained, continuous toxicity tests on the material introduced into the destruction process, as described in Working Paper CD/485, reference 3, are necessary. In such a case automation would not be possible and accordingly inspection personnel would have to carry out the toxicity determinations at the site of the destruction.

(2) The uni-directional flow and amount of reactants, as well as their carry-throughs into the destruction confinement have to be checked initially and also periodically by visual on-site monitoring.

(3) It may not be necessary to follow in detail the destruction process itself provided (a) that the flow direction of the process can be followed, (b) that there is no unknown in- or outflow of materials to or from the confined destruction facility, and (c) that there is only limited space within the destruction facility to stockpile products. However, from a practical point of view, some of the monitoring measures applied to follow the ongoing destruction as a chemical process might be of use, e.g. for following the direction of the flow of the process. In any case, so many parameters have to be followed during the destruction process that they should be utilized also for verification purposes.

(4) Monitoring gaseous products emitted into the atmosphere is not necessary from the disarmament point of view. Such products cannot be collected again and converted into chemical warfare agents. Monitoring of these products may however be necessary with regard to safety of workers and neighbouring population. Harmless concentrations of degradation products or of the agents themselves, which so far seems to have occurred in closed off areas of the CAMDS facility (ref. 11), can be monitored continuously and be related to other parameters following the destruction process. Thus, even such monitoring may contribute to increase the confidence in the proper performance of the destruction over the time.

(5) The solid and fluid waste products resulting from the process have to be monitored in several respects. Thus, the quantity has to be established, the toxicity — or rather absence of toxicity — has to be stated. The occurrence of typical degradation products could be followed continuously, i.e. if the destruction process gives rise to such products. The possibility for the waste products to be reconverted into chemical warfare agents has to be investigated. If economy or other factors speak for a destruction process that produces reconvertible waste products, measures must be taken to dispose of them in a way which makes reconversion uneconomical.

Some details of the described process have to be discussed further.

Under (1), two possibilities can be foreseen:

(a) the destruction is performed on the whole piece of munition of bulk container without separating the components (metallic parts, explosives and chemical warfare agent),

(b) the components are separated and destroyed by means of different processes.

(a) would require methods like (very hot) thermal destruction, destruction by means of nuclear explosions, or simply stowing away the stockpiles in inaccessible parts of the earth such as the deep ocean trenches. These methods have all met with objections in different respects, although they certainly have some technical advantages. They will thus not be discussed further in this Working Paper. The process discussed here will involve the technical process of separating the munition parts from the agents, and the bulk containers from the agent.

In both cases it is necessary to ascertain the amount of agents and its toxicity or chemical identity. Since this may in some cases be difficult or even impossible with respect to the method used for the destruction, some sort of statistical random sampling of the munition or bulk containers subject to destruction has to be applied. This would comprise:

- observation of the number of units to be destroyed,

- random sampling of the containers, the samples to be subject to measurement of volume or weight of the agent content, as well as toxicity or chemical identity to be checked against declared information.

Such a random sampling with accompanying measurements may technically be difficult to perform. However, a detection probability (to find out whether serious cheating occurs, i.e. efforts to try and withhold more than 10 per cent of existing stockpiles) of 75-90 per cent seems to be sufficient for a deterring effect against cheating. That would imply that for a lot of 100,000 pieces of munition, only 13 randomly chosen pieces need to be checked. However, this approach would also require monitoring of the flow of the agent into the destruction facility. Some of these problems have already been discussed in different connections, see e.g. reference 10.

Description of two models for destruction of chemical weapons and chemical warfare agents

Both nerve gases and mustard gas can be destroyed by means of chemical reactions or by incineration. These methods are used in the two models described below.

The destruction processes for the two agents are described by means of two simplified flow charts. The aim is to display the flow of material and to identify possible check-points for verification purposes. See Figures 1 and 2.

I. Model for destruction of nerve gases

The model is based on the United States facility for destruction of nerve gases in Utah, United States of America (Chemical Agent Munitions Disposal System, CAMDS, Tooele Army Depot, Utah, see ref. 11).

At one part of the facility munition is taken apart. The agent (GB or VX) is collected and pumped to storage tanks, and from there to the reaction vessels. In these the agents are destroyed by hydrolysis (GB) or acid chlorinolysis (VX) respectively. The reaction mixtures are evaporated and the residuing salt mixtures transported to separate deposit areas (see Flow chart 1).

The separated explosives are burnt in a furnace.

The remainder of the munition and the bulk containers are heated in another furnace, whereby residues of the agents are destroyed thermally.

For verification purposes, the most important parts are the pipelines leading from the storage tanks to the reaction vessels. They are marked by an (X) in the chart. Types and quantities of agents can be measured and registered at these points. Data resulting from them could conceivably be compared with figures concerning the amounts used of the reactants, sodium hydroxide, hydrochloric acid and chlorine, which are added as marked by (T) in the chart. Finally, the amounts of salt residues can be measured and their contents of methyl-phosphonates be determined.

It should be pointed out here, that the actual CAMDS facility in Utah does not seem to be constructed with regard to verification purposes for the actual processes. Thus, that particular facility in its present form can only serve as a model for verifying destruction by on-site inspection.

Taking into account the details described above, it is obvious that the process could easily be monitored by continuously attending verification personnel — in addition to the processing personnel. However, given the possible restriction that such personnel can attend only occasionally or only when specifically called for, the question arises which of the available data can be selected as particularly important for assessing the progress of the process. Given the choice, how can the data be acquired and distributed in a safe way? For the present model, the following suggestions can be made:

Random samples for checking the type of agent might be taken from the items to be processed. This can be done by means of an automated process. The type of agent might be checked by gas chromatography, if the agent is known. The amount of agent might e.g. be registered as the volume of agent filling the storage tank, from which the agent is then pumped into the destruction process. Also samples for confirming the presence of the agent in the storage tank can be taken, and, by the same means, the presence of the agent in the pipeline. The flow of the agent might be followed by a flowmeter in the pipeline.

As mentioned above, the salt residues can be monitored, probably in batches.

All data could then be correlated to each other as a final check.

It is, of course, conceivable that all these arrangements could be circumvented. They certainly would be of no use if they were installed without any outside checks of the facilities. The verification authority would have to inspect their installation and function, and also periodically and randomly the performance of the destruction process. At such occasions, the process could be checked at the facility and comparisons be made with the data provided through the monitoring instruments. In this way one would also obtain a "signature" for the process, which might serve as a basis for evaluating incoming data to the verification authority during periods when no inspection personnel was present at the facility.

Such an approach might serve to obtain a reasonably high degree of probability that the destruction is really carried through.

The presented discussion on destruction of nerve gas munition is far from complete. It is only intended to serve as a basis for discussion. It should be observed that the suggested model presupposes several forms of on-site inspection, but it is also to a large extent non-intrusive. Data, resulting from the measurements can e.g. be distributed internationally, and every party to a convention can investigate and evaluate them, as long as confidence prevails that the data are authentic.

II. Model for destruction of mustard gas

The model is based on the method described in CD/270, 31 March 1982 (ref. 7). The method was utilized for destruction of about 45 tons of Mustard Agent at Batujajar, West-Java, Indonesia, during 1979.

The mustard agent was stockpiled in storage tanks from which it was pumped into a furnace, the temperature of which was kept at a suitable level by means of oil burning. The gaseous waste products from the incineration were let out through a smoke-stack, without separation of toxic products like sulphur-dioxide or hydrogenchloride. See Flow chart 2.

With respect to the verification of this process, two factors should be pointed out:

It was a question of destruction of only about 45 tons of agent, not several thousands of tons.

Although being the result of careful design, the facility was extremely simple and was built at the site of the stockpile. It was also easily removed from the site after completion of the destruction, which lasted only a couple of months.

These two factors both facilitate and make difficult a verification of the destruction.

Again, inspection on site during the time of destruction, perhaps with the aid of some very simple identification methods, would constitute a reliable and cheap verification.

On the other hand, if some form of remote monitoring of the kind discussed above for nerve gas destruction, had to be applied, such an elaborate set up would probably not be economical. Also only one point is actually useful for monitoring devices, i.e. the pipeline between the storage tank and the furnace, where a flowmeter and a device for identification of the agent might be situated. However, only one such device could easily be tampered with, and might thus not be reliable. The only correlation would be against the volume of the storage tank. This volume must be measured on the site and its content verified. An independent level indicator might verify that the content disappears at the same rate and at the same time as the flowmeters in the pipelines show during the process.

Some assistance might also result from correlating the oil burning rate and the emission data for e.g. sulphurdioxide, such data being evidence of the ongoing process. Still, the small size of the facility seems to be an important argument against remote verification, since possible evasive measures might more easily be undertaken. This same conclusion was drawn by the authors of the Working Paper CD/270, albeit without giving any particular reasons for that opinion.

One should also remember that the mustard gas is not as toxic as the nerve gases. Confinement and safety precautions thus may not need to be equally stringent. It would be more difficult to instal monitoring equipment and at the same time secure their independent function. Perhaps a fool-proof instrument can be developed that can at least monitor the flow and the type of agent in the pipeline, and disseminate its results to a remote verification authority.

The situation would perhaps be more similar to the nerve gas destruction if also munitions and not only bulk stockpiles had to be taken care of. If should be noted that the CAMDS facility can handle also the destruction of mustard agent munitions.

<u>Comments on RECOVER as a basis for a discussion on its possible application in the verification of a chemical weapons convention</u>

The following comments refer to a draft evaluation of the experimental RECOVER system (ref. 14) and are made in order to stimulate the discussion on the possible application of RECOVER in the verification of a chemical weapons convention. The following issues are considered:

- For what particular purposes has RECOVER been found reasonably well applicable?

- What restrictions influence the cost-benefit of the system?

- What amount of information can the system handle?

- What seems to be the present state of development of the system?

RECOVER was developed as a secure system for remote verification of the status of containment and surveillance instruments employed at different types of nuclear facilities. Those considered were light-water reactors, pressurized heavy-water power reactors, fast critical facilities, mixed-oxide fuel fabrication plants, spent-fuel reprocessing plants, centrifuge enrichment plants and inactive stores of plutonium or highly enriched uranium.

It was found that RECOVER could be beneficial and cost-effective in the safeguarding of pressurized heavy-water power reactors, fast critical facilities and inactive stores of plutonium or highly enriched uranium. In all these cases RECOVER could reduce the inspection frequencies by at least a factor 2, which would result in a net saving of the order of $100,000 per year and facility. In the case of plutonium or high enriched uranium storage facilities the conditions for this would be (1) the store is relatively inactive, which means that nuclear material is neither added to, nor removed from the store more often than once per month, (2) maintenance on the store can by synchronized with the inspections, and (3) false alarms and failures resulting in a loss of continuity of knowledge for a time long enough for the removal of a significant quantity of nuclear material do not occur more frequently than roughly once every two months.

In all other of the above-mentioned facilities RECOVER was found not to be cost-effective. The main negative factor is the necessity for inspectors to be present frequently to verify material flows, regardless of whether RECOVER is employed or not.

It should be pointed out that interest on the capital costs of RECOVER equipment has been neglected in the evaluation. Taking this into account would substantially increase the costs of the system and reduce the net savings.

The RECOVER system consists of four major components; a monitoring unit (MU), an on-site multiplexer (OSM), a portable verification unit (PVU), and a resident verification unit (RVU). The MU (of which there might be several) would be attached to a containment and surveillance device. This device or sensor could be a film camera, a fibre-optics seal, or any of a host of other devices that are capable of being monitored electronically.

The MU would register the status of various parameters, monitor its own status, store the information, and, on demand, transmit it to the OSM. Present design for the MU allows for the storage of up to eight bits of information. The MU updates itself approximately 100 times per second.

The OSM interrogates all MU's attached to it, stores data on their status, and, on demand, transmits the data to the RVU over the international telephone system. It also monitors and stores data on its own status and on tampering attempts. Today up to 30 MU's may be attached to it and its storage capacity is 2,000 characters. The frequency at which it interrogates the MU's may vary, but every hour or half hour would be typical.

The PVU is a portable device with a keyboard and a display that enables the inspector to provide the MU's and the OSM with the proper values of certain parameters. On command it can display the current status and operating parameters of the OSM and its MU's, as well as its own operating parameters. One PVU can service up to eight OSM's.

The RVU is a microprocessor-based device attached to the telephone system. It interrogates the OSM's, receives the coded transmissions, decodes them, stores them, detects whether any predefined "alert" status exists, and activates audio-visual alarms in response to such alerts. The information stored may be displayed on a colour-graphics screen or printed out as hard copy. The frequency at which the RVU interrogates an OSM will vary between once per day to once per week, depending on the sensitivity of the site. At present, the RVU is capable of monitoring 40 devices (MU's plus OSM's). However, changes have been proposed that would enable it to sustain a network of 100-500 facilities.

Conclusions

The present preliminary analysis allows the following tentative conclusions with regard to the verification of destruction of chemical weapons:

1. On-site inspection would be necessary at least during the construction of a destruction facility, in order to assure the confinement of the facility with respect to out- and in-lets to the destruction space.

2. Occasional on-site inspections would be necessary during the destruction period in order to check the process followed in situ by means of monitoring equipment providing data for transmission to a distant receiver.

3. Destruction at small and technologically simple destruction facilities processing a limited amount of chemical weapons may have to be followed continually by on-site inspection.

4. There might exist possibilities to monitor particular events during the destruction process and correlate monitoring data with each other to give a reliable picture of the ongoing process also when transmitted to a distant location. As mentioned under paragraph 2 checks have to be made occasionally on site in order to sustain the reliability of the monitoring.

5. Some further technical work may still have to be performed in order to develop suitable tamper-proof monitoring equipment.

6. The type of information that may have to be transmitted from the destruction site to a distant verification authority may range from television pictures and chromatograms to simple numerical information.

7. The experience with RECOVER makes it probable that such information can be transmitted safely over unlimited distances. However, these experiences also show that the need for on-site inspection may differ for different processes, and thereby influence the cost benefit of the transmission system. A corresponding situation would probably apply to the verification of destruction of stockpiles of chemical weapons, as evident from paragraphs 1-3 above.

8. It is necessary and seems possible to work out the technical solutions, which still do not exist, on the assumption that the destruction of chemical weapons would have to be followed and registered in an unambiguous way, irrespective of whether the verification will be carried out finally by national or by international verification authorities.

Fig. 1

Simplified flow chart for destruction of nerve gas munition at CAMDS, USA

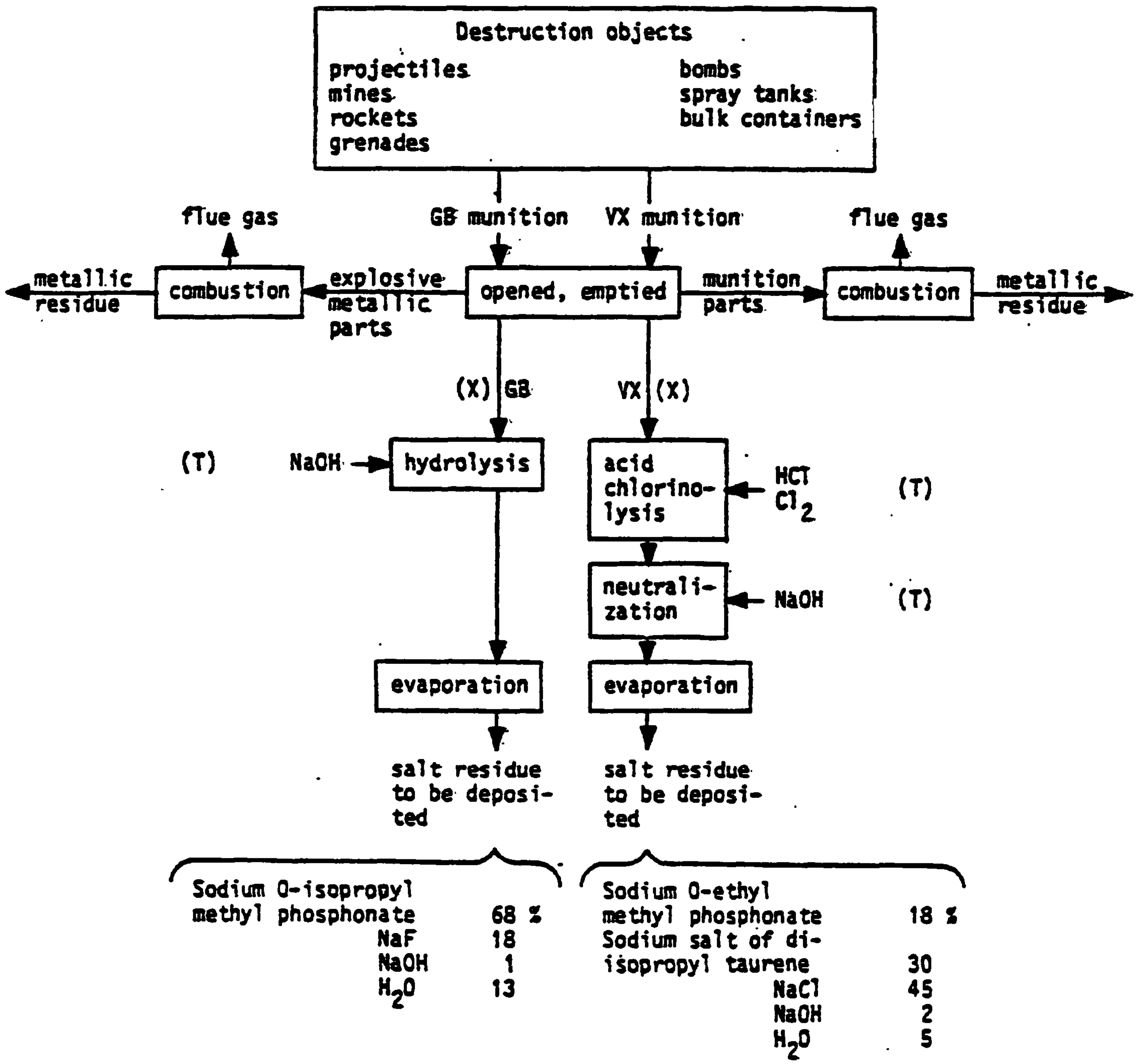
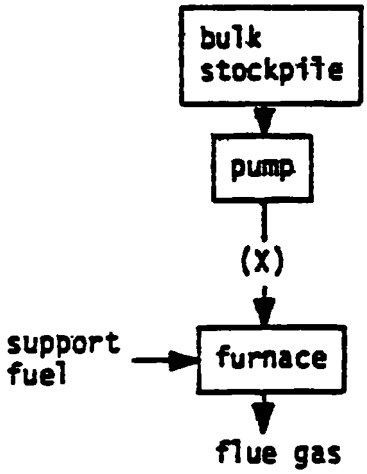


Fig. 2

Simplified flow chart for destruction of mustard gas in Batujajar



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