

Part I. Introduction

Chapter 1. An overview of chemical warfare

1.1. Chemical Agents in War

Chemical warfare aims to reduce the fighting effectiveness of the enemy. Chemical agents can incapacitate or kill and, in that sense, are like any other weapon used in war. The way they work, often described as their *mode of action*, differs from agent to agent, but all need to enter the human body to have any effect. Typically, *routes* into the body are through the skin or eyes, inhalation, and ingestion in either food or drink.

In war, chemical agents are deployed against the enemy in various ways (called *modes of delivery*). Typically, a chemical warfare agent is loaded into an aircraft bomb or an artillery shell in liquid form. When the weapon explodes the liquid agent is released as a cloud. The cloud is made up of small droplets of liquid agent, and might be inhaled by enemy troops or make contact with their skin and eyes.

A key difference between chemical warfare agents and other weapons is *persistence*. Once a bullet is fired, it either hits a target or misses. If it misses it becomes harmless. Chemical warfare agents behave differently. Droplets of liquid agent in clouds may eventually settle on surfaces and on the ground, and can remain potent for some time. Troops brushing against these surfaces or walking over contaminated ground can be exposed to the agent some time after the chemical agent was first delivered.

The length of time the agent has this residual effect is related to its *volatility*, a measure of how quickly a liquid evaporates. In war, chemical warfare agents of low volatility might be preferred, as they will persist in liquid form and contaminate ground and surfaces for a long time. But highly volatile agents are also useful. The vapour given off by volatile agents can be very dangerous and if inhaled or absorbed through the skin can incapacitate or kill. So for chemical warfare agents whose vapour is as lethal as their liquid, there is a balance to be struck between volatility and persistence. Some types of military operation, for example, a tactical assault to recover ground, might use chemical warfare agents to gain a short-lived advantage. Using a persistent agent in these operations would run the risk of exposing one's own forces to the chemical while they recapture the objective.

Protective clothing which covers the skin, respirators which filter the air inhaled and a mask to protect the eyes would render troops safe from chemical warfare agents. Protective clothing could be worn all the time by troops but this would impose handicaps. Although modern protective clothing is made of lightweight material, it is worn over normal battle-dress. Naturally, wearing an extra layer of clothes may tire troops, particularly if they are doing arduous work.

Furthermore, the clarity of speech and hearing is reduced by the combination of the respirator and mask, and peripheral vision is constrained by the eye-piece. Gloves affect dexterity and that makes the operation of weapons less speedy and accurate. In the modern age when so many military systems are controlled through computer keyboard and mouse actions, gloves can impair operations.

In short then, wearing protective gear reduces fighting effectiveness. Here is an advantage perceived in chemical warfare: either the enemy is killed or incapacitated through direct contact with chemical warfare agents, or his effectiveness is reduced by having to wear protective clothing. Even the threat of using chemical agents might suffice to persuade the enemy to wear protective clothing for long periods.

1.2. Chemical Agents in Civilian Settings

Chemical agents can be used in civilian settings to restore order, riot control agents being the most obvious example. The use of chemical agents in this context differs from the use of them in war. The aim of riot control agents is to induce temporary incapacity which allows

forces of law to intervene safely. It is not the intention to kill people. Therefore, riot control agents are chosen for their *safety margin*: this being the difference between the dose of the agent which temporarily incapacitates and the dose which kills. Typically, riot control agents have huge safety margins of many thousands.

Artillery shells and aircraft bombs are generally not used as modes of delivery for riot control agents as they can inflict injuries (from shrapnel) and can cause damage to buildings. Furthermore, shells and bombs deliver chemical agents over a wide area. In civilian settings, particularly indoors, more accurate modes of delivery are necessary, such as water cannon, aerosol sprays from cans, and plastic grenades.

Persistent agents are a disadvantage in civilian settings. For public safety and convenience, a volatile riot control agent that evaporates quickly, and whose vapour is not harmful, is an advantage.

Chapter 2. Chemical Warfare work at Porton

2.1. Defensive Work¹

Since it opened in 1916, Porton has been responsible for the development of protective clothing and medical treatments for the UK Armed Forces. Of crucial importance is that the protective clothing and medical treatments developed allow members of the Armed Forces to conduct their military tasks efficiently. Highly effective protective measures will be rejected by the UK Armed Services if they hamper military operations too much. Here, then, is the emphasis of Porton's defensive work: it is not just to protect troops from chemical attacks, but to preserve as much as possible their fighting efficiency while at the same time protecting them.

Defensive work is determined by the chemical warfare agents that UK Armed Forces might face in war. Intelligence of the offensive chemical warfare capability of potential enemies to the UK therefore plays a key role in Porton's defensive work. The path to the development and design of protective measures can be split into hazard assessment, detection, protection and treatment.

Hazard Assessment

Work here identifies the form of exposure that would be expected in war: the concentration of the chemical agents expected on the battlefield, the size and density of droplets and so on. Studies might then assess which routes into the body the agent exploits and the physiological effect of the agent on the body. The effects of the agent through each route may be studied. The way the agent works might be the same irrespective of how it enters the body. But the physiological effects may also differ slightly, as might the dose required to achieve them. In other words, the agent is more effective through some routes of entry than others.

Physiological studies may seek to determine three different dose levels of the agent: the threshold dose (the minimum dose required for the agent to have any effect on the body), the incapacitating dose (at which level soldiers might not be able to perform their military duties), and the lethal dose. Physiological studies can be conducted in the laboratory, with samples of blood and tissue, or with animals and humans. They yield important information for the development of protective measures.

- a. The routes into the body best exploited by the chemical warfare agent, which helps to determine the nature of protection required.
- b. Whether the exposure of humans to low doses is harmful, which helps determine if detection of the agent by unprotected individuals is acceptable as a cue to don protective clothing.
- c. The effect of exposure to various doses through different routes on human physiology, mental and physical performance. These studies help to identify the impact on military effectiveness and the symptoms induced.
- d. The effects of the agent on the body, which guides work into medical treatments and helps to identify biological features which make humans more or less susceptible to the effects of the agent.

Detection

Detecting a chemical warfare agent reliably is important to ensure that protective gear is donned only when it is needed. Large detectors may not be feasible for the field of battle where forces manoeuvre quickly and the direction and location of enemy chemical warfare

¹ This section and the next one, 2.2, discuss the types of work done at Porton over the period covered by the survey. It should not be inferred that all this work continues to this day.

attacks is unknown. Some fixed detectors might be used for long range detection. But smaller and more portable means of detection are generally required. Obviously, detection of the agent by individual troops through smell or sight might be acceptable but only if exposure to doses is safe (determined by physiological work). Other portable methods of detection might include paint or strips of material impregnated with chemicals with which the agent is known to react and cause, for example, the paint or material to change colour.

Work on detecting a chemical warfare agent can be done entirely in the laboratory and concentrates on the chemistry of the agent and how it reacts to other substances that could serve as detectors. Human studies in which volunteers are exposed to very low doses of the chemical agent might be conducted to find out if individuals can detect the agent by smell or by a combination of smell and the onset of particular symptoms.

Protection

Work here can cover two aspects:

- a. the degree of protection afforded by the normal Service dress worn by the UK Armed Forces and the design of protective gear. Research into normal battle dress might consider how well the material in the dress protects the skin from droplets of chemical agent.
- b. the design of protective gear (gloves, suits, overboots and head protection), where work may consider a range of fabrics and how effectively they protect the skin from droplets and vapour. Respirators and facelets to prevent inhalation of the agent might be developed and tested.

Work with normal battle dress and candidate fabrics for protective clothing can be conducted in the laboratory and with animals and humans. The rate at which liquid agents penetrate fabrics and battle dress can be determined in the laboratory. Samples of battle dress or candidate protective fabrics can be attached, individually or in combinations, to animals and humans. In these experiments, drops of liquid agent are placed on the sample. The protection afforded by respirators can be examined in the laboratory using mechanical devices or in human studies.

The aim of Porton's work is to develop protective gear that preserves as much as possible the fighting efficiency of members of the UK Armed Forces. Therefore, the effect of protective gear on human mental and physical performance is of great interest. Two types of studies might be carried out:

- a. Tests of candidate fabrics for protective clothing, often called *patch tests*. These tests aim to find out if fabrics can be worn next to the skin for a long time without causing irritation. These tests are important, as protective clothing may need to be worn for many hours at a time. Typically, a small piece of fabric might be placed on the skin and left for some time. Various fabrics might be tested in this way, including different mixes of rubber which might be used in respirator design.
- b. Physiological testing. The effect of wearing protective clothing on military efficiency may be investigated. Men wearing such clothing might be asked to perform various tasks. Typically, they may be asked to exercise in a certain way, and the effect of the protective clothing on heart rate, blood pressure, breathing rate and mental performance measured. Other work might investigate the clarity of speech and hearing while wearing protective clothing.

Emerging from this work and previous research on hazard assessment will be designs for protective gear which do not irritate the wearer, impair mental and physical performance only to acceptable levels and provide protection against chemical warfare agents.

Treatment

Medical treatments can be separated into those which guard against the effects of chemical warfare agent poisoning (called *prophylactics*) and treatments applied after exposure to agents (commonly called *therapy*). The form of therapy varies for each chemical warfare agent, according to the effect the agent has on constituents of the human body. Therapy differs with the route into the body exploited by an agent: for example, a chemical warfare agent falling on skin in liquid form might be treated with medicated swabs and ointments, while an agent entering the eyes could be treated with eye-drops. Therapy for individuals who have inhaled chemical warfare agent vapour or who have absorbed the agent through their skin tends to take the form of internal medicine administered in tablets or through injections.

No matter what form the prophylactics and therapy take, they must be portable and easy to administer. Field hospitals are generally located well away from the fighting on the battlefield and it may not be practicable for a soldier to leave the fighting each day for a daily dose of prophylactics. Moreover, soldiers and aircrew may suffer exposure to enemy chemical agents when they are some distance from field hospitals. Even if they are capable of making their way to the hospital after exposure, the delay in receiving therapy may prove fatal. Therefore, prophylactics and therapies are designed to be portable.

Because of this the administration of these medical treatments must be as simple as possible. Some therapies need to be self-administered when the individual is under severe stress (believing him or herself to have been exposed to a chemical agent, and perhaps being shot at) and when the individual may be suffering from physical and psychological effects of the chemical agent. Just as with protective gear, it is not sufficient for Porton merely to develop medical treatments to counteract chemical warfare agents but to design them so that they can be safely and easily used by people with no medical training under stressful conditions. Human studies can help to establish whether the designed medical treatments are easy to administer, even though these studies cannot replicate the stress of the battlefield.

So much for the form of prophylactics and therapies. Work must first establish which medical treatments are effective against a chemical warfare agent. Research to identify medical treatments can begin with laboratory work with samples of blood and human tissue; then candidate treatments can be tested with animals and humans to address the following themes.

- a. Studies of the effectiveness of treatments in alleviating the symptoms caused by exposure to a chemical agent. The effectiveness of combinations of treatments, particularly prophylactics and therapies, over several days might be studied.
- b. The effect of therapies on the body and physical and mental performance. In the stress of the battlefield, members of the UK Armed Forces may administer therapies when they have not been exposed to a chemical warfare agent. This means the dose of the therapy required to counteract an agent must be safe if it is taken by a person who has not been exposed to that agent.
- c. The effect on the body and performance of a regime of taking prophylactics over a long period. A regime may stipulate that they are taken for many days (perhaps for as long as soldiers are deployed to the theatre of operations). Ideally, prophylactics should have a limited effect on physical and mental performance.

2.2. Offensive work

At various times during its history, Porton has searched for new chemical warfare agents. New chemical compounds which might be used as chemical warfare agents can be produced

in the laboratory (this is often called *synthesis*). Alternatively, Porton might receive samples of compounds from academia and from pharmaceutical companies. Subsequent steps determine if the new compound has practical potential. Each step forms a test; if the compound fails any of the tests it is rejected.

Is the compound 'better' than existing agents? 'Better' might mean 'more toxic', 'faster acting', 'longer lasting' or 'safer' depending on why a new agent is being sought. The comparison between the new compound and existing agents of the same type might be made through chemical analysis in the laboratory or in experiments with tissues and animals. Sometimes, the comparison may require human studies.

Can the compound be delivered satisfactorily? This test is related to ways in which the compound is delivered. Some compounds, even though they may be 'better' than existing agents, can be destroyed or damaged by heat and therefore unsuitable for delivery by aircraft bombs and artillery shells. Others may not be very soluble and might be unsuitable, say, for use in riot control devices such as water cannon.

Is the compound stable when stored? Weapons used by the military are generally not produced only when they are needed. Weapons are stockpiled, often being stored for many years. The new compound must retain its effectiveness during storage.

If the new compound passes these tests, subsequent research might cover similar ground to defensive work. In particular, physiological studies might be carried out to determine dose levels. Studies might be conducted with human volunteers to establish the threshold and incapacitating doses.

2.3. Chemical warfare studies involving volunteers

The different types of chemical warfare studies involving volunteers conducted at Porton in the period covered by the survey might be discerned from the previous two sections. They are summarised in Table 2.1. Virtually all the human studies conducted at Porton over this period fall into one of these categories. Some of the studies did not involve volunteers being exposed to chemical warfare agents.

Subsequent parts of this report describe in detail those studies in which volunteers were exposed to chemical warfare agents or to prophylactics and therapies for chemical warfare agent poisoning (shown in bold in Table 2.1.). The survey thus ignores important studies such as tests of the effect on performance of wearing protective clothing and patch tests of candidate materials for protective clothing. Many thousands of volunteers took part in these types of test, so their exclusion may be regarded as a shortcoming, but the survey is focused on those studies involving chemical warfare agents and those which tested treatments aimed at countering the effects of chemical warfare agents.

During the period covered by the survey Porton conducted work which involved volunteers but was not related to chemical warfare. Porton developed smokes of different colours that were used by Royal Navy ships for signalling. Smokes to screen ships and tanks from the enemy were also developed. Much work was conducted on protecting UK Armed Forces from insects, typically locusts and mosquitoes, in foreign countries. Insecticides were adapted and different ways of impregnating garments to repel insects were tested. These studies, and others similarly unrelated to chemical warfare, are not covered in great detail; an outline of them is given at Annex A.

Type of Study	Comment
1. Determination of threshold dose	Typically, the type of symptoms and effects produced by the threshold dose were studied. Some of these studies were comparative: does agent A produce effects at doses lower than agent B, for example.
2. Determination of incapacitating dose	Studies to identify the doses required to hamper performance and to render soldiers incapable of effective action. Many studies saw volunteers attempting physical and mental tasks before and after being dosed with the agent to assess the effect on performance. Some studies assessed the impact of the dose on the ability to complete military tasks (such as rifle shooting) in field trials
3. Relationship between dose and symptoms	Studies sought to find out if there was a clear relationship between doses and the symptoms induced. The results might be used by medical staff in the field to decide the extent of poisoning from the nature of the symptoms. Results might be used to estimate lethal dose levels from the effects induced by much smaller doses.
4. Detection of agent by sense or onset of symptoms	Volunteers were exposed to low doses of CW agent, either in the chamber or in field trials, to find out if they could detect the agent by their senses (typically, by smell) or by symptoms (for example, a runny nose or some effect on vision).
5. Protection: normal service dress	In some studies volunteers tested the protection of normal service clothing impregnated with material to protect the wearer from chemical agent vapour. Sometimes, normal clothing was dusted with protective powders and tested in human studies.
6. Protection: patch tests	CW agents were not used in these studies. Patches of material would be fixed to a part of the body (arm, shoulder, chest) and left there for some days to find out if they caused irritation
7. Protection: penetration of protective clothing	Studies to assess if fabrics being considered for protective clothing protected the wearer from liquid agents. Usually, pieces of fabric (perhaps in layers) were attached to a volunteer's arm and drops of liquid placed on the fabric. The arm was inspected for any effects of the liquid.
8. Protection: leakage of respirators	Studies to find out if respirators, properly fitted, were effective in protecting the wearer from CW agents. Many of these studies involved a chemical warfare agent whose effects were known so that any leakage could be detected. Some studies used harmless substances instead of CW agents. The substances might be detectable inside the respirator or on the exhaled breath of volunteers after the study was complete.
9. Protection: effect of wearing protective clothing	CW agents were not used in these studies. Studies might determine the physiological effect (pulse rate, temperature, respiration rate and so on), performance (speech clarity and hearing) or the effect on work rate (as measured by exercising on a treadmill, for example). Some studies involved volunteers attempting military tasks in field trials.
10. Skin decontamination	Typically a drop of liquid chemical warfare agent would be placed on the skin (normally the arm) and different ways of decontamination would be assessed: swabs and ointments being used to remove the liquid.
11. Treatment of eye effects	Different types of eye-drops were assessed in alleviating the symptoms after the eye had been exposed to either chemical agent vapour or liquid.
12. Treatment of poisoning	The effectiveness of treatments in alleviating or preventing the symptoms induced by chemical warfare agent poisoning. Studies typically exposed volunteers to a CW agent, and then monitored the onset and duration of symptoms with various treatments. The treatments here were either tablets (taken as prophylactics) or injections (taken after exposure).
13. Treatments: physiological effects	CW agents were not used in these studies, which sought to assess the effect of the treatments. Volunteers would take the treatments, without being exposed to any agent, and the physiological effects (pulse, blood pressure etc.) monitored. Some of these studies explored the effect of treatments on physical and mental performance, and on some real world tasks (such as car driving).
14. Treatments: ease of use	CW agents were not used in these studies. Some studies considered how easy it was for Servicemen to administer therapies by injection. Others looked at the size and shape of tablets and how easy they were to take when wearing protective clothing.

Table 2.1. Types of chemical warfare studies involving volunteers

Chapter 3. Chemical warfare compounds used in human studies 1939-1989

3.1. Overview of chemical warfare compounds

The chemical warfare compounds used in human studies at Porton in the period 1939 to 1989 are shown in Figure 3.1.

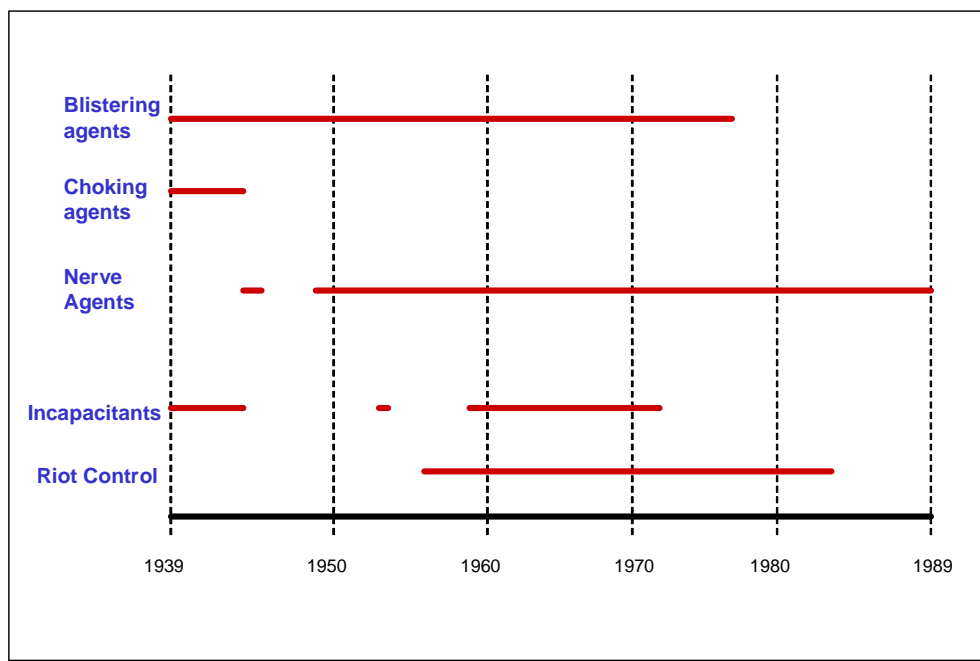


Figure 3.1. Chemical Warfare compounds used in human studies

The compounds can be separated into classes, as shown in Figure 3.1.

Blistering Agents Blistering agents are known as *vesicants*. They burn or blister either through contact with the skin in liquid form, or through inhalation of vapour. Mustard gas, known as *H*, and Lewisite, known as *L*, are examples. Both were developed before 1939.

Choking Agents Choking agents cause damage to the lungs, usually through inhalation. They can cause injury through contact with the skin. Phosgene and Chlorine are examples of choking agents and were developed before 1939.

Nerve Agents These attack the body's nervous system, interrupting (among other things) the function of relaxing muscles. They are effective through various routes into the body: inhalation of vapour, absorption of vapour through the skin and eyes, and absorption of liquid on skin and eyes. Nerve gases were first developed by Germany during World War II; Tabun (or *GA*), and Sarin (*GB*) are examples of these.

Incapacitating Agents These are agents which are not intended to kill but to render the enemy incapable of effective military action. They can be split into psychological agents, which affect mental processes and perception, and physical agents, which upset some physical attribute such as muscle control or body temperature. This split is often not clear: some psychological agents have physical effects (and vice versa). *LSD*, one derivative of lysergic acid, is an example of a psychological incapacitating agent. *Oripavines*, similar to morphine in effect, are an example of physical

incapacitating agents. Older incapacitating agents, discovered before 1939 include *sternutators* which incapacitate by inducing a sneezing fit.

Riot control agents These agents are, strictly, physical incapacitating agents but this survey treats them separately to incapacitating agents because they are designed for use in civilian settings. When the search for a new riot control agent began in the 1950s, sternutators were briefly considered but "tear gases" (called *lachrymators*), such as CS, are more common. Lachrymators and sternutators were studied in World War II but the interest in them arose from the possibility of use in war.

3.2. Routes of Administration

The routes into the human body exploited by these agents were replicated in studies involving volunteers. Some other routes of administration were also used, partly for scientific clarity. An explanation of them might be useful.

'Inhalation' Obviously, breathing in a chemical warfare compound. Many experiments involved breathing in vapour. Some involved agents being administered through cigarettes or nasal sprays.

'Percutaneous' Literally 'through the skin', and used to refer to the absorption through the skin of chemical agent vapour, or the penetration through skin of liquid drops of chemical agents.

'Ophthalmic' The effect of vapour or drops of chemical agent on the eyes.

'Subcutaneous' Literally 'under the skin'. Some experiments at Porton administered chemical warfare agents directly into the tissue beneath the skin by injection. This route of administration replicates the entry of a chemical agent into an open wound, which may happen on the battlefield. It also serves a scientific purpose because it can be very difficult to measure the proportion of a drop of liquid placed on the skin that is absorbed, as opposed to the proportion that evaporates. Scientific explorations are more accurate if the agent is introduced directly beneath the skin.

'Intravenous' (IV). Here the chemical warfare agent is administered directly into a vein. On the battlefield this route is very unlikely to occur but the reason IV administration is sometimes used is to establish much more precisely the link between dosage and symptoms. The proportion of an agent entering the body which subsequently reaches the blood is difficult to measure and will vary according to many factors. IV application yields more accurate scientific results.

'Intramuscular (IM)' The application directly into muscles through injection. This route is also unlikely to be encountered in the battlefield but is sometimes used for the same reasons as IV and subcutaneous applications. Some chemical warfare therapies are designed to be injected IM in the field.

'Ingestion' Chemical warfare agents might contaminate food and water supplies, even though this is not the primary intention of using the agent. Other agents might intentionally be introduced into water supplies. In human studies at Porton, some agents were administered in drinks (generally of water, sometimes fruit juice). Ingestion through eating food was not used. Instead, for some psychological incapacitating agents, ingestion took the form of a tablet administered orally.

3.3. Measurement of Doses

Doses of chemical agents are measured using a standard nomenclature. Exposures to chemical agent vapour are often measured according to the concentration of the vapour to

air, usually measured as milligrams (mg) per cubic metre, and the period of the exposure, usually measured in minutes. Therefore exposures of vapour are measured as:

Ct where C is the concentration, mg/m^3 , and t is the period of exposure, min.

A standard measure of the lethal exposure level of chemical agent vapour is $L(Ct)50$. This is a measure of the exposure expected to kill 50% of a particular species. It is normally quoted for the species concerned: rabbits, guinea pigs, man etc. The important point here is the statistical nature of the effects of chemical warfare agents. $L(Ct)50$ is commonly referred to as the 'lethal dose', even though half the individuals of the species exposed to it would be expected to survive.

Although $L(Ct)50$ is a single number it represents a multiple of the concentration and the length of the exposure. So, this measurement can represent a variety of concentrations and exposure times. Therefore, it is usual to specify the exposure time, t, when $L(Ct)50$ is mentioned.

Exposures to liquid drops of chemical warfare agent entering the body through the skin or eyes, and exposures by ingestion, are normally referred to by the amount of agent, usually milligrams (mg) or micrograms (μg), to body weight, usually kilograms. The lethal dose is normally referred to as 'LD50'. LD50 is easier to interpret than $L(Ct)50$ because it does not represent a multiple. It is usual to stipulate the species and the route with citations of LD50.

Chapter 4. The direction and oversight of chemical warfare work at Porton Down.

4.1. UK chemical warfare policy

The previous chapters have outlined the nature of chemical warfare work carried out at Porton during the period covered by the survey, which was conducted against the background of chemical warfare policy established by the UK Government. Staff at Porton did not decide themselves what work they should do.

4.1.1 Background: 1915 to 1945

In April 1915, during World War I, Germany used chlorine gas against the Allies. The Allies sought to defend themselves against future attacks and to develop the means to retaliate. By September 1915 the UK started to produce chemical weapons and protective equipment. An offensive capability, based around the Army and the Ministry of Munitions' organisations and committees, was *de facto* government policy. The Geneva Protocol was produced in 1925. It prohibited the 'first use' of chemical weapons in war, but retaliation in kind was permitted. The UK ratified the protocol in 1930.

Between the wars, government policy was to continue to develop the means to defend against chemical warfare attacks. In the 1930s, Italy employed 'poison gas' in attacks in Ethiopia and, from 1936, Germany was openly and actively re-arming with modern weapons. The government's highest-ranking defence body, the Committee of Imperial Defence, was prompted to increase chemical warfare research, in part to create a viable retaliatory offensive capability.

The outbreak of World War II saw the UK intensify efforts on chemical warfare. Much work was conducted into developing protective equipment, such as respirators and clothing impregnated with substances to shield the wearer from the effects of gas, and on ointments for treating gas burns. Considerable stocks were created of agents and munitions charged with agents. This activity was conducted under the authority of the War Cabinet, with routine matters being handled by the inter-service Chemical Warfare Committee (CWC). After the war, the CWC agreed in early 1946 that a six month supply of CW agents and charged munitions should be retained and that a capability to produce agents should be maintained at about 30% of the war-time level [1]. That recommendation was agreed by the Defence Committee on 3 July 1946.

4.1.2 Nerve agents: 1945 to 1956

Work at Porton on the captured German artillery shells containing the nerve agent GA (Tabun) revealed that the G agents were far more potent than others worked on so far. Further, there were clear indications in October 1945 [2] that the Soviet Union had captured the German plants which produced GA and another of the nerve agents, GB (Sarin), and had moved them with their personnel to the USSR. UK policy in this period was to develop the means of defence against attacks with nerve agents and to develop nerve gas weapons.

Offensive policy was agreed by the Defence Committee in 1946 "requiring the Services during the next 5-10 years to be in a position to wage chemical warfare from the outset of hostilities" [3]. The aspiration in 1947 was to develop a prototype nerve gas bomb by the end of 1949 [4]. It was recognised that mustard and phosgene weapons would be used until nerve gas weapons became available [5].

There was much work to do to develop nerve gas weapons: each of the G series had to be assessed for effect and ease of delivery, so that one could be chosen for weapons. In May 1951, it was decided that GB would be the agent used in UK offensive chemical weapons and would be produced on a large scale [6] in Cornwall [7]. Prototype GB munitions were tested in tropical climates in Nigeria in 1951 and 1952 [5, 8].

Notwithstanding these offensive efforts, defensive research into improving physical protection (respirators and clothing) and developing therapy was deemed more important in 1950 [9]. Moreover, the concern was not just to defend the UK Armed Services; civil defence against nerve agent attack had also been given a high priority. In 1948, the government decided to produce 50 million civilian respirators by 1957, with new designs, originating from Porton, to be available for testing in 1949 [10]. In 1951, the Home Office placed an order for 15 million of the new civilian respirators [6] and by the end of the year some were issued for fitting trials with school children and adults at Civil Defence schools and other representative groups of the population [11].

As work at Porton progressed, it was decided in the spring of 1951 that the effects and treatment of nerve gases should be published widely for the benefit of General Practitioners [12]. A symposium was held in London in 1951, where medical consultants heard evidence from Porton's work and discussed the first aid treatments recommended [11, 13]. A pamphlet on the chief characteristics of nerve gases and notes on first aid treatment was produced and published in the British Medical Journal and the Lancet on 9 August 1952 [14].

From 1954, financial pressure saw the defence budget being scrutinised for savings. As a result, the UK abandoned the means of large scale nerve gas production and the development of nerve gas weapons [15]. To save more money it was decided to dispose of stocks of mustard gas weapons and the reserve of mustard gas [16]. These decisions were agreed in July 1956 [17]. The Services withdrew their requirements for nerve agent weapons [18].

4.1.3 Nerve agents: 1956 onwards

From this point on, the UK has not developed or possessed offensive chemical weapons. Riot control agents and devices, using CS and CR, were developed from 1956 in response to government requirements but these are viewed in a different way to other chemical warfare agents. UK policy has been to develop the means of defending against chemical warfare attacks. Work on protection and treatment against attacks with nerve agents continues to the present day.

In 1956, the discovery of a new and more potent type of nerve agent, the V series, prompted this defensive work to be expanded. In 1958, "positive information" was to hand that the Soviet Union had had a V agent production capability since late 1956 and chemical weapons had recently been moved to East Germany [19]. Intelligence reported in 1959 and 1960 [20, 21] that the Soviet Union had mastered the production of G agents on an industrial scale and V agent production could be underway. UK interest in V agents was to develop therapy and defensive measures [22].

4.1.4 Incapacitating agents: 1958 to 1972

In 1960, the Defence Research Policy Committee (DRPC) was asked by the Chiefs of Staff (COS) to review developments across the whole chemical warfare field since 1958. The COS received the DRPC paper at the end of 1962. The paper explained that it was probable that the Soviet Union was interested in developing an offensive capability using incapacitating agents. The DRPC recommended that the UK increase its effort on research into incapacitating agents. The paper also opened the question of whether the UK should investigate incapacitants as offensive agents [23]:

chemical warfare with incapacitating agents would "probably not be open to the same political objections [as the use of lethal agents] and increasing research and development up to full weapon production was therefore favoured".

The COS had approved the recommendations of the paper by February 1963 [24] and sought Ministerial authority for the research programme recommended by the report. Subsequently, the Cabinet's Defence Committee agreed in 1963 to reacquire an offensive chemical warfare capability, based on lethal and incapacitating agents [25]. The government changed in 1964. Continued ministerial endorsement for the 1963 decision to acquire an offensive capability

was sought in 1965 [26] and in 1967 [27]. Financial pressures on the defence budget mounted again in the mid to late 1960s and by 1970 attempts to seek a re-endorsement of the 1963 decision were abandoned. The policy to acquire an offensive capability was, by default, abandoned. No offensive weapons were developed or acquired as a result of the 1963 policy decision.

Incapacitating agents were investigated in human studies at Porton into the early 1970s. Up until around 1967 the interest in them was provoked by the need to assess their potential, either as possible threats or as candidates for UK offensive agents. The need to assess them as threats ran on beyond the demise, in 1970, of the policy to acquire an offensive capability. 'Iron Curtain' countries were known in 1966 to be interested in LSD [28] and the UK Services feared that these countries might use incapacitating agents to attack airfields [29]. In 1969 glycollates and oripavines were considered to be threats to the UK and some of the incapacitants assessed in the Porton programme are still regarded as threats today.

4.2. The direction of Porton work

Throughout its history, Porton's work has been carried out in response to the requirements of the UK Armed Forces. Those requirements are formulated and passed to Porton by the headquarters to which it reports.

In 1917, a Chemical Warfare Headquarters was set up in London to direct Porton's work. This control was exerted from 1919 by the Chemical Warfare Department at the War Office. The War Office was the Army's ministry. The other two Services had their own departments: the Admiralty and Air Ministry. Porton remained subordinate to the War Office until 1939. Between the wars, the organisation within the War Office controlling Porton's work was given various names: from 1930 it was called the Chemical Defence Research Department (CDRD).

From 1920, the programme of research and development in chemical warfare was regularly specified by the Services through the War Office. Annual reports were produced to review progress and regular meetings were held with War Office staff to decide priorities for Porton work.

In 1939, control of Porton was moved from the War Office to the Ministry of Supply. In part, this transfer mirrored the urgent requirement to develop chemical warfare weapons for all three of the UK Armed Services. World War II work was directed by the CDRD partly through the Chemical Board, which featured many prominent scientists from academia, and partly by liaison with the chemical warfare staffs of each of the Armed Services. A sub-set of the Chemical Board, known as the Informal Chemical Board, met frequently during World War II; sometimes weekly. Progress reports were produced by Porton, which were used by the Informal and full Chemical Board and the staff of CDRD to determine priorities for future work.

After World War II, the committees which reviewed and advised on chemical warfare work at Porton changed. The committees set up in the immediate post-war years remained in being with few changes until the end of the survey period, 1989. Their proceedings are an important part of the survey and are cited regularly, so an explanation of their function and members might be useful.

Figure 4.1 shows the hierarchy of committees formed in the immediate post-war years. The Scientific Advisory Council (SAC) was (and still is) the most senior scientific defence committee. It was intended to give Ministers independent advice on the progress and direction of all scientific research conducted in the name of defence. Members were drawn from outside government: typically, academics served on the SAC. The SAC shown in Figure 4.1 was part of the Ministry of Supply (later, the Ministry of Defence would have a SAC, and still has).

The first change after World War II was the setting up of the Chemical Defence Advisory Board (CDAB) in 1946 [30]. CDAB took over the job of the wartime Chemical Board; its terms

of reference being to review and advise on chemical warfare research. It continued the tradition of the Chemical Board in that some members were prominent scientists from academia and industry. When CDAB was first established, eight members (about half of the membership) were from universities or university hospitals [31]. CDAB was not merely a scientific body. Representatives from the Services sat on the board, thus ensuring that Service requirements for chemical warfare work were addressed.

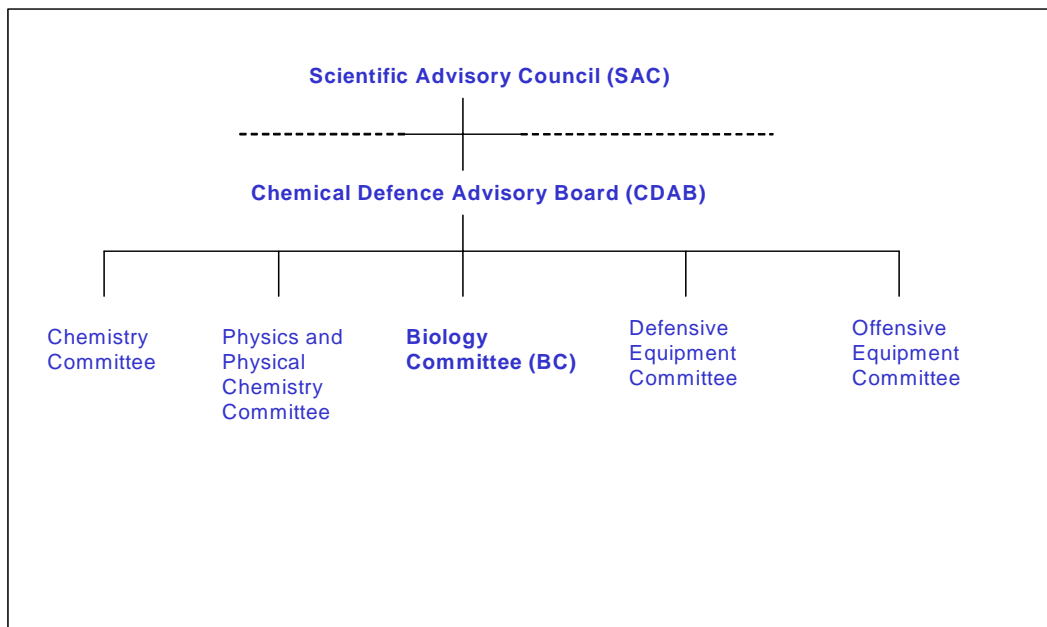


Figure 4.1. Chemical Warfare Committee Structure: 1946-1965

CDAB set up five committees to deal with different aspects of chemical warfare research. They are shown in Figure 4.1. Each was to have six independent scientific members, again about half the membership. The function of all these committees was to review and direct specific elements of chemical warfare research. Some dealt largely with pure science (the Chemistry and Physics/Physical Chemistry committees), while others concentrated more on the development of equipment, either weapons or means to protect against enemy chemical warfare attacks. The most important of them for the survey is the Biology Committee (BC).

The BC first met in 1947 [32]. It took on the responsibilities of the old Physiological and Medical Sub-committees of the Chemical Board, and considered physiological work at Porton, whether it involved tissues, animals or human volunteers. It also advised on basic biological issues, such as the mode of action of chemical warfare compounds. Independent members from university hospitals and other universities served on the BC.

These committees stayed much the same throughout the period covered by the survey. The CDAB became the Chemical and Biological Defence Advisory Board (CBDAB) in 1978. Other modifications were made in 1965 and 1980 which will be explained in the next section.

The committees normally met twice a year and the CDAB produced annual reports for the SAC. The committees were aware of the requirements of the Services for chemical warfare work and of the policy towards chemical warfare, and directed the work within this framework: advising on new avenues to explore, considering the implication of results from previous work, and so on.

After the Second World War, Porton continued to produce annual reports of progress for the Services and HQ, as well as for the CDAB and its committees. From the mid-1970s onwards,

Porton also produced annual papers describing the work proposed for the forthcoming year. These intentions were reviewed by the Services and HQ before the year began. Later, in the 1980s, when the Services started managing the budgets for research conducted at defence establishments like Porton, this arrangement continued. Annual meetings were held between Porton and its Service 'customers' to ensure that the work was focused on Service needs.

4.3. Oversight of studies with volunteers at Porton

The CDAB and the BC were not set up specifically to advise on studies with volunteers conducted at Porton. They monitored the entire direction of chemical warfare work. However, from time to time, the two committees offered advice to Porton on human studies, particularly the academic members who may have organised, or knew of, human studies conducted in university hospitals. Advice was often given by the CDAB and the BC on aspects of safety: for example, the initial doses to be used in tests with volunteers, or medical conditions that ought to rule out individuals from particular studies. Nonetheless, neither the CDAB nor the BC was charged with the responsibility of approving the type of human studies conducted at Porton.

Nevertheless, approval for studies with volunteers was sought by Porton fairly regularly. Because these studies involved Service volunteers, approval was sought from the Services. As Porton was subordinate to the War Office between the wars, the Army Council ruled on proposals from Porton to conduct human tests. For example, in 1922 the Army Council approved human tests with mustard gas [33], stipulating that animal experiments to determine the toxicity of mustard should be carried out beforehand. The Army Council also approved tests carried out between 1922 and 1932 in which volunteers were exposed to liquid mustard to test various decontamination procedures [34, 35]. The Army Council refused permission for Porton to conduct tests in which volunteers would have inhaled small amounts of toxic smoke in 1932 [36, 37]. The "occasional use" of volunteers in exposures to sternutators was approved in 1940 [36]. In World War II, requests for permission to conduct human studies with mustard gas were made to the Inter-Services Committee on Chemical Warfare [38].

In the 1950s and 1960s Ministers became involved in the approval of the type of human studies conducted at Porton. Nerve gas studies with volunteers were suspended by the Minister of Supply in 1953 [39] and the conditions under which they resumed in 1954 were subject to ministerial approval [40]. Proposals from Porton to conduct new types of studies with nerve agents were considered by Ministers from 1957 to 1962. One of the proposals was rejected in 1962; the other proposal was devolved to the BC in 1963 [42]. These accounts will be elaborated in later chapters.

In the 1960s, the oversight of human studies changed. Instead of being concerned with gaining approval for particular series of studies, consideration started to be given to approving every human study and the conditions under which it was carried out. Porton started this change in 1963 when the Committee for the Safety of Human Experiments (COSHE) was set up. COSHE members were drawn solely from departments at Porton. Its function was to approve proposals for human studies and to establish rules for safety.

A further move in the direction of approving every study occurred in 1965, when the Applied Biology Committee (ABC) was formed. It was prompted by an ethical disagreement at Porton, which arose during the work with incapacitating agents. The ABC was the first committee with members outside government which was set up to advise Porton specifically on the safety and ethics of human studies [43]. Indeed, the ABC was given the responsibility for approving the human studies which Porton proposed to perform. In practice from 1965, proposals for human studies were first discussed at COSHE and, if they passed examination there, the proposal was put to the ABC.

The ABC also inherited some duties from the BC: providing advice on medicine, physiology and psychology. The BC remained after the ABC was formed but concentrated on basic

biological problems. Figure 4.2 shows how the committee structure looked from 1965 until 1980².

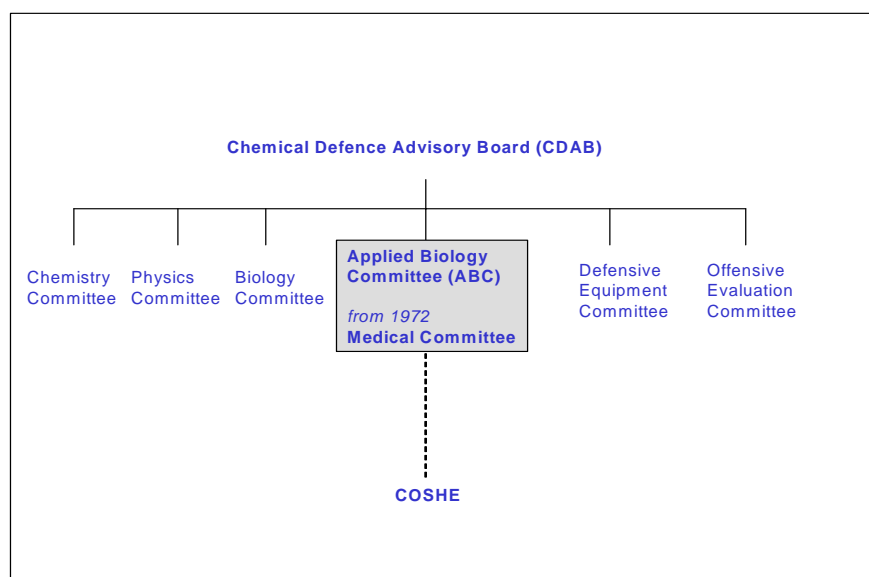


Figure 4.2. CDAB Committee Structure: 1965 - 1980

Figure 4.2. shows a new body, the Medical Committee. In August 1969, CS gas was used for the first time in the UK, in Londonderry, to disperse rioters. The Home Office set up an enquiry into the medical effects of CS on civilians. Sir Harold Himsworth and his colleagues conducted the enquiry. One of its recommendations [44] was that studies of the effects of riot control agents should adopt an approach similar to that used when developing a new medicine.

The Himsworth group was dissolved in 1971 after the enquiry reports were published. That left no independent body to advise the MOD on the safety of riot control agents and devices, and rather left hanging in the air the recommendation for a different approach to riot control studies. To fill these gaps, the Medical Committee was established in 1972 [45]. It took over the responsibilities of the ABC, which was disbanded, as well as Himsworth's role in advising the MOD on the safety of riot control agents and the devices used to deliver them.

The MC was made up of government members and independent members, typically professors and doctors from academia. It was established at the outset that the independent members of the MC had the right to hold "closed meetings" (without the government members) in which they could discuss and decide the adequacy of Porton's work. Indeed, this right was exercised frequently: for the first time in 1973, when the independent members considered the medical aspects of using a riot control agent in a water cannon [46].

Further changes were made to the CDAB committee structure in the 1980s [47]. CDAB was re-named as the Chemical and Biological Defence Board and had only three subordinate bodies. The BC and Chemistry Committee were replaced by the Life Sciences Committee. The Medical Committee continued. The Physical Sciences committee was set up.

The final committee to be mentioned is the Independent Ethics Sub-Committee (IESC), set up in 1987 by the MC [48]. Since it was set up in 1972 the MC was consulted by COSHE about approvals for human studies, in the same way that the ABC had been consulted. But the MC felt that a committee external to Porton should review and approve every single proposal for human studies, this being regarded as more in line with the guidelines on human studies

² Despite its change in name in 1978, and later in 1980, the CDAB is referred to throughout the survey by its original name.

issued by the Royal College of Physicians in the autumn of 1986 [49]. Accordingly, the IESC was established with members outside Porton.

In summary, the work at Porton, since it was opened in 1916, has been directed according to the needs of the Armed Services. Approval for the work conducted at Porton with volunteers was obtained for types of human studies up to the 1960s. Thereafter, it became usual to seek approval for every human study. From the mid-1960s this approval was sought from a committee with members outside Porton. Many references will be seen in the later chapters of the survey to the committees described in this chapter.

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