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MEDICAL RESEARCH COMMITTEE.

REPORTS

OF THE

CHEMICAL WARFARE MEDICAL COMMITTEE.

No. 18.—REPORT ON THE MEDICAL ASPECT OF THE PRODUCTION OF MUSTARD GAS.

January, 1919.

In January, 1918, the Director-General, Army Medical Service with the concurrence of the Controller of the Chemical Warfare Department, Ministry of Munitions, appointed a special Committee to prepare reports, based upon information received from all sources at the Chemical Warfare Department, for submission to him with a view to their distribution to those concerned, to make suggestions for further co-ordinated medical investigations that may seem desirable, and to advise him generally in respect of the scientific medical aspects of Chemical Warfare. Present constitution of Committee :—

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REPORTS ALREADY ISSUED.

No. 1. Notes on the Pathology and Treatment of the Effects of Pulmonary Irritant Gases. (*March*, 1918.)

No. 2. The Histological Effects produced by Gas Poisoning and their Significance. (*April*, 1918.)

No. 3. The Symptoms and Treatment of the late Effects of Gas Poisoning. (*April*, 1918.)

No. 4. Polycythæmia after Gas Poisoning and the Effect of Oxygen Administration in the Treatment of Chronic Cases. (*April*, 1918.)

No. 5. The Reflex Restriction of Respiration after Gas Poisoning. (*April*, 1918.)

No. 6. Investigations into the Reaction of the Blood after Gas Poisoning, and the Results of the Administration of Saline and other Substances. The Effects of Bleeding and of the Injection of Calcium Chloride. (*April*, 1918.)

No. 7. Changes observed in the Heart and Circulation and the general After-Effects of Irritant Gas Poisoning. (*April*, 1918.)

No. 8. Reports on Fatal Cases of Poisoning. (i) Ethyl iodoacetate.

No. 9. Tissue Changes in Animals produced by Pulmonary Irritant Gases. (*September*, 1918.)

No. 10. The Administration of Oxygen in Irritant Gas Poisoning. (*October*, 1918.)

No. 11. Investigations of Chronic Cases of Gas Poisoning. (*October*, 1918.)

No. 12. Treatment of Patients suffering from "Effort Syndrome" by continuous inhalation of Oxygen. (*October*, 1918.)

No. 13. Bleeding after Poisoning by Pulmonary Irritant Gases, with Appendices. (*November*, 1918.)

No. 14. The Delayed Effects of Phosgene in Rabbits, with special Reference to the Influence of Muscular Contraction. (*November*, 1918.)

No. 15. The Later Effects of Irritant Gas Poisoning. (*November*, 1918.)

No. 16. Report on the Length of Stay in Hospital in the United Kingdom, and the Disposal of Gas Casualties. (*November*, 1918.)

No. 17. Report on Cases of Poisoning by "Mustard Gas" (Dichlorethyl Sulphide), with special Reference to Histological Changes and to Alterations in the Leucocyte Count. (*December*, 1918.)

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REPORT ON THE MEDICAL ASPECT OF THE PRODUCTION OF MUSTARD GAS.

By Frank Shufflebotham.

CONTENTS.

Mustard gas is a solution of dichlor-diethyl sulphide in carbon tetrachloride, the solution containing between 20 per cent. and 30 per cent. of the latter body.

I.—Physical and Chemical Properties of Dichlor-Diethyl Sulphide.

Dichlor-diethyl sulphide, when pure, is a colourless oil which becomes pale yellow on exposure to light. It freezes at between 11° and 12° C., but the crude oil previous to distillation freezes at 7·5° C. The boiling point of this oil at 750 mm. pressure is about 216° C. and the specific gravity at 10° C. is 1·27.

This body is only slightly soluble in water, but if agitated with water it hydrolyses, giving non-toxic decomposition products. It is soluble in alcohol, carbon tetrachloride, chloroform and ether, and it is very volatile in steam. It is slightly soluble in paraffin and vaseline and freely soluble in animal and vegetable oils and fats. This

body is slowly decomposed by alkaline solutions such as sodium bicarbonate, but rapidly destroyed by chloride of lime, chlorine and to a less extent by potassium permanganate.

II.—Physical and Chemical Properties of Mustard Gas.

Mustard gas is a colourless fluid which becomes pale yellow on exposure to light, and it has a pungent odour variously described as resembling oil of mustard or garlic. The vapour has a penetrating nature and will pass through ordinary clothing, rubber and even leather, and it is almost impossible to remove this body from them except by prolonged boiling, which, of course, in the case of leather articles it is impossible to carry out.

III.—Physiological and Pathological Effects of Mustard Gas.

Both these bodies produce practically the same effect upon the human system, and their effects for all practical purposes may be considered the same.

The vapours of dichlor-diethyl sulphide and mustard gas produce no immediate physiological or pathological changes, but after a few hours the skin becomes severely inflamed, and inflammation of the eyes and the mucous membrane of the air passages ensues. The parts of the skin which are most commonly and certainly most severely affected are the exposed surfaces and those where there is increased perspiration: the skin over the genitals, between the buttocks, and the thighs are invariably involved.

Inflammation of the skin may be of varying degrees from simple erythema or discoloration, as if the skin had been painted with a solution of silver nitrate, to severe destruction of all the skin tissues, resembling in the latter case the lesions produced by scalds. The photographs (*vide* plates following page 8) show the distribution of the skin lesions in a series of typical cases.

The contact of these bodies in a liquid state with the skin is similar in effect to that of the vapour, but more intense in action.

In a typical case of poisoning by these bodies conjunctivitis is most intense, and œdema of the eyelids is pronounced. Iritis and corneal ulcers with subsequent opacities have been recorded.

The inhalation of vapours of dichlor-diethyl sulphide and mustard gas produce inflammatory changes upon the mucous membrane of the respiratory passages from the nose downwards, and copious expectoration is one of the principal features. In severe cases there may be acute inflammation of the windpipe and bronchi with actual necrosis of the mucous membrane, while in other cases bronchitis and broncho-pneumonia may supervene. In the latter class of case secondary infection is often set up.

As a result of respiratory trouble following poisoning by mustard gas, fibrosis of the lung may be set up and an X-ray examination of the chest should be made in every chronic case so as to estimate the amount of fibrosis produced.

Aphonia may be a prominent symptom with or without laryngitis. In the latter case it may be functional in nature.

The effect of inhalation of these bodies on the pulse rate is to increase it in a large number of cases, and sometimes the frequency of the pulse rate exceeds 170 per minute. The blood pressure in the majority of cases of poisoning by mustard gas is sub-normal. A very frequent symptom of mustard gas poisoning is an accentuated second sound in the mitral area, a symptom which may be of great diagnostic value.

Microscopic examination of the blood reveals an unusual number of blood platelets, but otherwise practically no abnormalities.

Associated with the inhalation of these toxic vapours we may find acute pain in the gullet and in the stomach with nausea and vomiting. The vomiting may persist for weeks after the other symptoms have disappeared. Gastric and intestinal symptoms follow when food or drinks which are contaminated with this lethal body liquid or gas are taken. In addition to pains in the gullet, stomach and small intestines, nausea and vomiting, there may be diarrhœa with or without blood in the stools.

Albuminuria of two or three days' duration has been found in the majority of cases which arise among workpeople employed in the manufacture of mustard gas, but casts are not frequently found. In severe cases the albuminuria may persist for some weeks.

Headaches are a common symptom associated with mustard gas poisoning. They may be general in character or specially localized to the frontal region when there may be tenderness over the frontal sinus. Intercostal neuralgia of a persistent nature is frequently recorded.

Clinically, the majority of cases of poisoning by mustard gas may be classified into three types :—

(1) Those in which the main symptoms are those of inflammation of the skin, conjunctivitis and perhaps pharyngitis.

(2) In this class, in addition to the above named symptoms there are laryngitis, aphonia and bronchitis of a simple type. For a few days the temperature may be raised to 101° F. or 102° F., and the pulse rate is increased.

(3) These cases are of the septic type of broncho-pneumonia or bronchitis and are much more serious in character than the two preceding types.

IV.—Chronic Poisoning by Mustard Gas.

Chronic poisoning may be set up as a result of prolonged exposure to minute traces of mustard gas vapours, and among workmen employed in the production of these bodies one finds symptoms which cannot be dissociated from the nature of their employment.

These symptoms, generally speaking, are of the following types :—

(1) *Digestive disorders* with loss of appetite, chronic indigestion associated with pains in the stomach and bowels, nausea and vomiting, and one often finds that the action of the

bowels is most irregular. At times, diarrhœa is present followed by a period of constipation. In some cases bleeding from the bowel has been noticed.

(2) *Nervous troubles* are frequently found among workpeople who have been employed in mustard gas processes for a considerable time, and the principal symptoms under this heading are general lassitude; mental depression, or in some cases increased mental excitement; weakness of memory, headaches, especially after the day's work; while in serious cases mental excitement and muscular cramps (especially affecting the lower limbs) with convulsive symptoms have been noticed. In such cases, the prognosis is grave.

(3) *Eye troubles.*—Photophobia (dread of light), chronic conjunctivitis and chronic spasms of the eye-lids are commonly found in mustard gas workers, and in one factory which I have recently visited in France every worker engaged in one filling shed appeared to be suffering from these symptoms.

(4) *Kidneys.*—Albuminuria is not only found among cases of acute mustard gas poisoning, but may also be present in those who show no acute symptoms, and should it persist after removal from work it must be regarded with gravity.

(5) *General conditions.*—Apart from the foregoing types of disorder, which may be set up by the prolonged inhalation of small quantities of either dichlor-diethyl sulphide or mustard gas, there is in many cases found a deterioration in the general health of those so exposed; loss of weight, anæmia, inaptitude for work and constant drowsiness are among the commonest symptoms.

V.—Post-mortem Changes.

The post-mortem changes presented in fatal cases are mainly found in the respiratory tract. From the larynx down to the smallest bronchial tubes we generally find intense inflammation of the mucous membrane with a thick yellowish-white false membrane, on the removal of which there is a red granulating surface which may be in some cases covered with small patches of ulceration. As a rule there is no œdema of the lungs, but in fatal cases which take place soon after exposure to the poisonous vapours, there may be found in the lungs patches of emphysema alternating with collapse, as well as patches showing minute hæmorrhages. In later cases there will be areas of consolidation, and should the case be an infected one pus will be found to exude from the lung on section.

The mucous membrane of the stomach generally shows petechial hæmorrhages which may be also found in the duodenum.

According to the official report of the French Government on Poisoning by Poison Gas, the small intestine is very often found to be œdematous and congested, but the great intestine is only rarely affected.

The liver, kidneys and spleen may be enlarged to some extent and show congestion.

VI.—General Remarks on Medical Symptoms.

It will thus be seen that the effects of poisoning by the vapours or liquids of dichlor-diethyl sulphide and mustard gas are not only local and due to irritation, but in acute cases, and in those where the inhalation has been prolonged to minute quantities, these bodies have a definite toxic effect upon the human subject, but it must be realised that the vast majority of cases of poisoning only show symptoms of inflammation of the skin, eyes and upper respiratory passages, which arise some hours after exposure to the gas.

One attack of mustard gas poisoning increases the susceptibility to fumes of this body.

VII.—Prevention of Mustard Gas Poisoning.

The prevention of poisoning among work-people who are employed in the manufacture and filling of mustard gas, depends upon many factors which are fully dealt with in the French reports. Briefly summarised they are as follows :—

1. *Workshops.*—The workshops in which mustard gas is manufactured or filled, or the buildings in which this product is stored, should be as isolated as possible, and it has been proved from the experience gained in France, that the structural arrangements should be large and airy and similar to aeroplane hangars, and the floors should be impermeable and capable of being easily washed and drained. The use of wood and absorbent materials in construction should be avoided, as such articles might be a source of great danger.

It is absolutely necessary for all the machinery which is required for the manufacture of filling of mustard gas to be as perfect as possible, so that the escape of fumes from faulty joints, valves or other parts of the machinery is reduced to a minimum. In the filling sheds it is most necessary that there should be no dripping of liquid during the process of filling.

The physical properties of mustard gas are the determining factor in deciding the method of ventilating the workshops, and it is absolutely necessary to employ an exhaust down draught. Without an efficient ventilating plant the workpeople cannot be kept in a healthy condition, and many casualties will occur.

It is highly important that the factories and sheds should be kept in a thorough state of cleanliness. The floors, walls and surroundings should be frequently disinfected by chloride of lime followed, in the case of the floors, by the free use of boiling water.

2. *Individual Protection.*—Up to the present time it has been found impossible to produce mustard gas by mechanical processes, without protective measures being necessary to preserve the health of the workpeople.

Experience both in France and England points to the fact that the following provisions are necessary :—

(A).—*On the part of the Employers.*

(1) The employers should provide all workers with suitable clothing (including headgear and gloves), which should be kept in a clean condition at the factory and should on no account be taken home; they should be responsible for the washing of this clothing.

(2) Sufficient cloakroom accommodation, lavatories and latrines should be provided, and there should be an ample supply of liquid soap, brushes and clean towels.

(3) Bathrooms should be provided so that all workpeople may have a hot bath daily after leaving work, and the walls of the bathroom should be lined with glazed bricks.

(4) In every workshop and filling shed there should be provided—

(*a*) A sufficient supply of boxes containing—

(i) Finely divided sawdust,

(ii) A mixture of three parts of dry bleaching powder and one part of fuller's earth.

(*b*) Ample washing accommodation so that the workers may wash with soap and hot water when necessary.

(5) Attendants should be appointed so as to assist the workpeople when necessary and to see that the regulations are strictly carried out.

(B).—*On the part of the Employees.*—All workers must :—

(1) Change into the clothing provided by the management before beginning work.

(2) Never Eat During Working Hours and only eat when overalls and gloves have been removed and hands washed in the presence of the first-aid attendant, using the special soap provided.

(3) Never Touch Eyes, Face, Ears, or Parts Concerned in Bodily Needs Without Previously Washing Hands with the Liquid Soap Provided.

(4) Observe Carefully when pouring fluids whether the splashing occurs. If the Splash Falls on Wearing Apparel or Boots, at once Change the Article. (It is advisable for the removal of the clothing to be effected by an attendant and not by the wearer.)

(5) On no account continue to wear the affected garment. The affected article should be given to the bathroom attendant for treatment.

(6) If splashes occur on bare skin, or soak through any garment, at once rub the affected part with sawdust, afterwards with the mixture of dry bleaching powder and fuller's earth, then wash off with special soap and water. The affected part should then be suitably dressed in the ambulance station.

Fig. 1.—Discoloration of skin over the genitals, inner part of thigh, knees and inner aspect of elbows. The skin looks as if it had been painted with a solution of silver nitrate. There is slight blistering over the right knee and right thigh.

Fig. 2.—Discoloration of the skin over the back, buttocks, thighs and behind the knee-joints. Blistering is seen in places.

Fig. 3.—Discoloration of the skin over the neck, chest and arms with blistering.

Fig. 4.—Extensive blistering of the skin over the buttocks and arms.

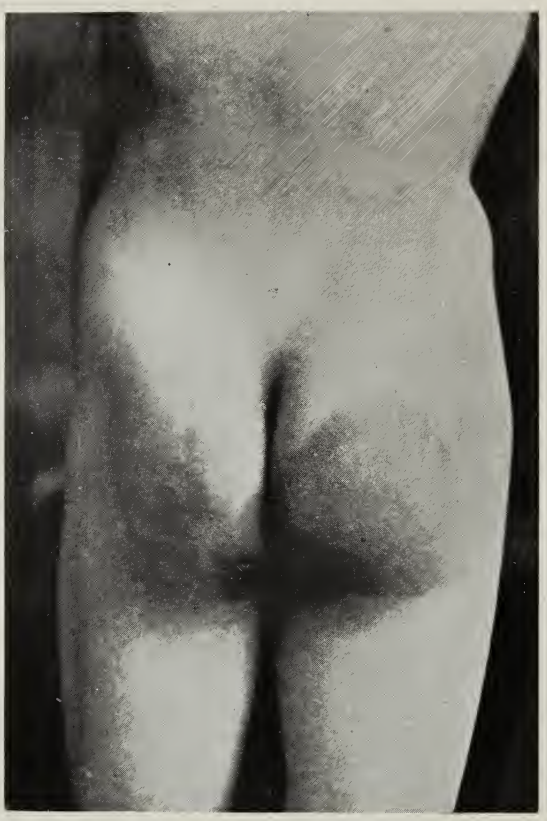

Fig. 5.—Discoloration of the skin over the buttocks and thighs.

Fig. 6.—Eczematous ulceration of the skin over the hands and wrists.

(7) Report immediately to the plant superintendent any such occurrences; also report at once to the medical officer anything unusual in eyes, throat or on surface of the body in general.

(8) After finishing work and before leaving the plant, remove gloves, then overalls, then rub the hands first of all in the sawdust, afterwards with the mixture of dry bleaching powder and fuller's earth, then wash the hands with the special soap provided, in the presence of the first-aid attendant, afterwards have a bath with special soap and change into their own clothes.

(9) Use solely the lavatory specially allocated to the plant.

General Remarks on Foregoing Precautions.—It is not yet definitely decided which is the most suitable material for the factory clothing. Oiled cloth or oilskin has been suggested as the best fabric, but there is the objection on the part of the workpeople to performing their duties in clothes made of this material on account of the excessive heat produced when working in such clothes. It is not claimed that these materials are proof against fumes of mustard gas, and should the material not render complete immunity, the excessive perspiration produced as a result of working in clothing made of such material would predispose the workers to skin trouble.

Dr. Audistere's report dealing with the question of clothing, gloves, boots, etc., describes in great detail all the points connected with this subject not only with the different forms of material to be used, but also with the method of keeping the clothes free from contamination by mustard gas in liquid or gaseous form. The disinfection of clothing when accidentally infected, as well as after work, is a matter of great importance. Clothing made of material such as calico or linen is best disinfected by soaking in a large quantity of water containing 5 per cent. of powdered carbonate of lime for an hour, at a temperature of about 85° C. The articles of clothing or gloves made of rubber before being immersed in the hot water should first of all be brushed over with dry chloride of lime, and oilcloth garments should only be brushed with dry chloride of lime and subsequently washed in cold water.

As a matter of practice in France, I find that the men employed in the manufacture of mustard gas simply wear a calico overall, and those employed in filling shellings wear a waterproof apron but neither goggles nor gloves.

It has been found that the application of dry bleaching powder to the skin causes irritation and eczematous ulceration in many cases, but the preliminary rubbing with fine sawdust and the dilution of the bleaching powder with fuller's earth prevent such skin troubles.

VIII.—Detection of Mustard Gas in Small Quantities.

It is of great importance to be able to detect small traces of mustard gas in the atmosphere, in clothing and other objects, and by means of chemical tests it is possible to detect the presence of traces of this body.

Colonel Raper of the Anti-Gas Department regards the platino-iodide detector for mustard gas as the most satisfactory reagent. The sodium salt is used for this purpose, and it is made as follows :—

1 cc. aqueous	5 per cent. platinum chloride.
5·3 cc. aqueous	Sodium iodide.

These solutions should be mixed and made up to 60 cc. with distilled water. This solution contains double the quantity of sodium iodide required to convert the platino-chloride present into Na_2Pt_6.

Detection by Test Paper.—Filter paper is dipped into the above solution and used wet (excess of moisture removed by drawing it between the fingers); it turns from pink to blue in presence of mustard gas vapour.

It gives a reaction with 1/1,000,000 of mustard gas vapour, and should be useful for detecting leaks of vapour from pipes, valves, etc., or for determining whether splashes on various utensils or on the ground consist of mustard gas.

Since the reaction is due to the liberation of iodine from the platino-iodide and its subsequent reaction with the starch present (starch solution is added when the reagent is used in liquid form), the possible presence of chlorine in the air of factories, due to the decomposition of bleaching powder, may cause a difficulty as traces of chlorine would also give the reaction.

Another test, devised by M. Grinard, depends upon the action of the solution of hydriodic acid upon the solution of mustard gas in water. The test is carried out in the following way :—

(1) Wash in 100 cc. of water about 50 gr. of the suspected matter and filter several times till a clear solution is obtained.
(2) To 4 cc. of this solution add 1 cc. of hydriodic acid solution—33 per cent.
(3) Heat to 60° and cool.
(4) A cloudiness already produced in the hot state when the concentration of mustard gas is sufficient, appears on cooling in water when the concentration is 0·05 gr. per litre, representing $\frac{1}{4}$ milligramme of the sample tested.

This test is suitable for testing soil, clothing, etc., and not for traces of mustard gas in the atmosphere.

IX.—Destruction of Mustard Gas when Spread on the Ground.

The French regulations which deal fully with this subject should be carried out to the letter. Dry bleaching powder is the most effective destructive agent of mustard gas, and about 10 gr. are required to completely destroy 1 gr. of this body.

When quantities of bleaching powder and mustard gas are mixed together a lively reaction takes place and chloruretted vapours are given off with great heat. These vapours may cause irritation of the mucous membrane of the respiratory passages with cough, expectoration, etc., and the symptoms are similar to those of chlorine poisoning.

The regulations drawn up by the French authorities may be summarised thus :—

(1) Men working in the neighbourhood must immediately separate themselves from one another.
(2) They must not throw dry bleaching powder on the ground which is contaminated.
(3) Two or three men furnished with gas masks and protective clothing (*i.e.*, gloves, boots, aprons) will mechanically drag over the infected ground wood sawdust in a receptacle limiting the operation as far as possible to the polluted area.
(4) This sawdust steeped with mustard gas will be mixed closely and slowly with dry bleaching powder. The contents of this receptacle will then be buried in the ground.
(5) Spread dry bleaching powder on that area of the ground which has been polluted by the mustard gas.

X.—Protective Ointments.

Many researches have been carried out with the object of endeavouring to find a protective ointment to be applied to the skin of those liable to be exposed to mustard gas in either a liquid or gaseous form, and the report of Captain Ball of the Anti-Gas Department deals with the protective influence of an ointment of vaseline and dry bleaching powder (10 per cent.). The conclusions arrived at are as follows :—

(1) Vaseline ointment containing 10 per cent. of bleaching powder gives good protection against mustard gas vapour, and is much superior to the other ointments that have been tried.
(2) It has little irritative action on the skin, but care would have to be exercised in applying it over large areas and on sensitive persons, as it can produce itching and redness.
(3) Rubbed on the skin immediately after exposure to mustard gas vapour it diminishes the subsequent effects.
(4) The protective effect diminishes apparently rather rapidly with increase of time after application ; 24 hours after application a protective effect could no longer be detected.

The report of Captain Nicolet of the United States Chemical Warfare Service Laboratory gives a summary of the researches on ointments for the protection of the skin against mustard gas. In this report there is a description of the tests which have been made on various ointments, including :—

(1) Zinc stearate ;
(2) Bleaching powder ;
(3) Calcium oxide, linseed oil and lanolin ; and
(4) Magnesium oxide with linseed oil, cocoanut oil and paraffin.

It is claimed that various glyceride oils increase from three to six times the length of time required for the production of a given burn by mustard gas vapour, but that the presence of zinc soaps in such oils has little or no direct effect on their protective value.

We thus see that the value of protective ointments is not yet established, but I would suggest that the medical officers attached to the factories and filling stations make trials of the various suggested remedies, with a view of throwing further light on this subject.

XI.—Incapacity for Work.

The average duration of incapacity for work among workpeople employed in the production of mustard gas who have incurred illness in the course of their employment, and who have received prompt and efficient treatment, is about six weeks, but in cases where septic trouble affects either the skin or the lungs the period of incapacity is longer.

Mild cases may only incapacitate for work for a few days, and if treatment is carried out promptly after exposure to the fumes the trouble may be of a slight nature.

Up to date in the factories of this country there have only been two fatalities through mustard gas poisoning, and the majority of the casualties have not been of a dangerous character.

In France I was told that in the manufacture of mustard gas the casualties amounted to 30 per cent. per month, while in the filling sheds the casualties were only 5 per cent. per month.

The period for work among chronic cases of poisoning cannot yet be estimated because our knowledge on this subject is not yet complete, and the same can be said for the ultimate conditions of after-effects of mustard gas poisoning. It is not yet thoroughly established whether the nervous symptoms associated with poisoning are functional or organic, or whether the kidney trouble when it arises may not in some cases be permanent.

Radiographic examinations of the chest of cases where lung symptoms have predominated show in some instances fibrotic thickening of the lung, particularly around the bronchi. All these points require further investigation before it is possible to estimate the amount of incapacity for work produced by these changes.

Under this heading it is important to remember the susceptibility of some people to mustard gas fumes, especially after they have once been gassed, and it may be necessary for them to change their occupation on recovery from the poisoning.

XII.—Conditions of Labour.

In France, only male labour is employed in the production of mustard gas, and this labour is recruited from :—

(1) The army, Grade 1 men being transferred to the factories for this purpose and granted all the privileges of soldiers in the field.

(2) Moors from Morocco and Algeria.
(3) Chinese from Cochin China.

Female labour is not engaged, as this kind of work is regarded to be unsuited for women and girls.

In this country, however, both male and female labour are employed, women and girls being engaged largely in shell filling. The male labour, speaking generally, is of low medical category owing to the fact that all available Grade 1 men have been drafted into the army. Under these circumstances it is not surprising that casualties are larger in numbers than they should be owing to the increased susceptibility of workmen due to some pre-existing defect, although an attempt has been made to exclude persons suffering from certain diseases on account of their predisposition to gas poisoning. It has been found from experience that persons suffering from the following diseases should not be given employment at factories and filling stations where mustard gas is manufactured or handled on account of their being medically unfit for this kind of work. The list of diseases referred to is as follows :—

(1) Chronic lung diseases :—
  (*a*) Bronchitis.
  (*b*) Emphysema.
  (*c*) Spasmodic asthma.
  (*d*) Tuberculosis.
  (*e*) Fibroid lung.
(2) Valvular disease of the heart.
(3) General arterio-sclerosis (advanced cases).
(4) Exophthalmic goitre.
(5) Chronic indigestion, especially when associated with defective teeth.
(6) Bright's disease.
(7) Chronic gas poisoning cases (invalided from the army).

In the case of women, those who are expectant mothers and those who are nursing their infants should be prohibited from this class of work.

Hours of Labour.—Workpeople employed in mustard gas production work 44 hours a week (five days of eight hours each and a half day of four hours). Suitable rest times are allowed, and it has been recommended, on the strength of the experience gained in France, that after working six days, the workpeople should have two days' leave. In this way it is hoped to improve the general physique of the workpeople and to make them less susceptible to poisoning by mustard gas fumes.

XIII.—Medical Arrangements.

At all factories and filling stations where mustard gas is produced it is essential that there should be complete medical arrangements, not only for the purpose of treating accidental cases of poisoning which may arise but also for the proper medical supervision of workpeople engaged in these processes.

A properly equipped ambulance station should be provided, and at large factories a small hospital should be fitted up, so that patients can be treated in the most efficient way without delay. These arrangements necessarily involve the employment of one or more medical officers and a staff of nurses.

The duties of the medical officer will not only consist in attending cases of accidents or poisoning which may arise, but in addition he should make a fortnightly examination of each of the workpeople to ascertain whether the employment has any deleterious effect upon their health. If the health of the workpeople be slightly impaired on account of their employment, it may be necessary to suspend them from duty for a few weeks, although they may not be completely incapacitated. During this time they should be paid full wages, and before returning to duty should be re-examined by the medical officer. Workpeople who are specially susceptible to mustard gas poisoning should be given an occupation in whch they are less exposed to the fumes, and it may be advisable in more serious cases to send them to rest homes to recoup.

XIV.—Treatment.

Treatment of poisoning by mustard gas depends entirely upon the severity of the symptoms. If the trouble is caused by a splash of the liquid upon the clothes or boots, great care must be exercised by the attendant in the removal of the clothing, so that such attendant may not be poisoned by the fumes which may be given off from it, and it is equally important that the clothing should be suitably treated so that the poison can be destroyed. At the Gas Hospital in Paris, clothing of every kind is treated by super-heated steam for several hours, but up to the present there is no means for satisfactorily dealing with boots or other leather articles which have come in contact with the liquid.

While all cases can be classified from the point of view of treatment in the same way as they can be clinically, a further classification is necessary as to whether they are to be regarded as hospital cases or as out-patient cases. In all cases, however, at the outset of the treatment, the eyes should be douched and a very hot soapy bath given.

Eye symptoms are best treated by repeated douching with a warm solution of sodium bicarbonate, or better still by the use of an automatic spray of a 10 per cent. solution of bicarbonate of soda worked by steam from the exhaust pipe at a pressure of 3 kilos. For painful condition of the eyes, one application of a 5 per cent. solution of cocaine may be used with good results, and adrenaline is also recommended to relieve congestion.

Splashes on the cornea giving rise to ulceration are best treated by abundant washings with potassium permanganate (1—4,000) and by the use of an ointment containing either potassium permanganate or methylene blue.

Inflammatory conditions of the larynx and pharynx should be treated by means of sprays, and the automatic spray of bicarbonate

of soda mentioned above in the treatment of conjunctivitis gives a great deal of relief. For painful conditions, a spray containing menthol, cocaine and eucalyptol may alleviate the trouble. The French authorities recommend a laryngeal injection of 1–2 cc. of *huile gomenolée* to be given daily, and in suffocative cases this oil is given by a needle through the crico-thyroid membrane.

The skin lesions are treated first of all by washing with soap and very hot water, and the subsequent treatment depends upon the degree of destruction of the tissues. In severe cases washing with a 4 per cent. solution of potassium permanganate solution is advised, to be followed by the application of such an ointment as ambrine. Captain Roberts, who has had a large experience in treatment of burns caused by mustard gas, is of the opinion that ambrine is the best preparation we have at our disposal, and he attributes the adverse reports given of ambrine to the fact that before the application of the ambrine the skin has not been rendered sufficiently aseptic. The same failure would arise in the application of any oleaginous body if sufficient care were not taken with the skin. Other ointments have been recommended by different authorities, and picric acid has been regarded with great favour by some of the French authorities. In many cases of erythema a dusting powder may be all that is required.

The serious cases are kept in bed with hot water bottles, and when any lung symptoms supervene, oxygen should be administered by the Haldane oxygen apparatus. Venesection and the infusion of saline solution may be efficacious in cases where there is embarrassment in breathing or in the action of the right side of the heart, and in cases of collapse a hyperdermic injection of pituitrin may be of the greatest value.

In acute cases of mustard gas poisoning it is possible that some fumes may be swallowed with the saliva and enter the stomach, causing acute inflammation of the stomach and duodenum. To prevent serious complications arising of this kind it has been suggested that repeated large doses of alkali be given, either by mouth or by a tube with a view of minimizing the corrosive action of the mustard gas upon the mucous membranes of the stomach and duodenum.

With regard to other complications—whether of the heart, stomach, intestines, kidneys or other organs which may be affected as a result of mustard gas poisoning—the treatment is entirely symptomatic.

Headaches are treated with phenacetin and caffein or aspirin, and pain over the frontal sinus which may produce insomnia is relieved by the application of a little cocaine ointment to the nasal mucous membrane.

With regard to the treatment of functional disorders resulting from mustard gas poisoning, general tonic treatment is essential in each case.

Photophobia is treated by cold douching and by discarding shades and smoked glasses. Aphonia yields to one or two applications of the Faradic current to the larynx. Intractable vomiting of a functional nature is treated by the stomach tube, while the chronic cough of a hoarse and brassy type, without any expectoration, disappears under general tonic treatment.

Chronic cases with symptoms of dyspnœa, cough, irregular action of the heart, with or without dilatation, as well as those with general nervous or digestive disturbance, show material improvement under the continuous oxygen treatment as carried out at Cambridge and Stoke-on-Trent.

XV.—Conclusion.

The points which arise in consideration of the manufacture of mustard gas which affects the health of the workpeople are as follows :—

(1) The extent to which this body has a general toxic effect upon the human system should be decided, and for this purpose elaborate and periodic medical examinations are being made at the factories where mustard gas is produced, for the purpose of determining to what extent the inhalation of small quantities has upon the various organs of the human system.

I suggest that research be made with regard to blood changes and abnormalities in the urine which may be associated with working of these processes.

(2) For the prevention of eye trouble it is suggested that the use of the automatic spray of steam and bicarbonate of soda has a protective influence upon the eye against the irritating action of mustard gas fumes, but this point can only be confirmed by experimental work which is being carried out on a large scale at the factories where mustard gas is manufactured.

(3) The question of the detection of minute quantities of mustard gas in the atmosphere is one that is not outside the experimental stage, and I hope that further work will be done in this direction so as to obtain a specific test to detect the presence of mustard gas in the atmosphere in harmful or lethal concentrations.

(4) It has not yet been determined why there is a period of incubation between the time of exposure to mustard gas fumes and the outset of the symptoms, and I would suggest that research be instituted with a view to ascertaining the explanation of this phenomenon; as a solution of this problem may lead to the discovery of efficient measures of protection.

(5) The question of individual susceptibility is one upon which medical research is required, and a test has been suggested which will assist in determining whether a person is or is not susceptible to the effects of mustard gas fumes.

(6) It cannot be too clearly understood that, in the production of mustard gas, efficient ventilation of the workshops and filling sheds is the keystone to the health of workpeople being maintained at a high standard.

December 12th, 1918.