LECTURES ON THE SANITATION OF INDUSTRIES AND OCCUPATIONS.

WORKERS IN MERCURY, PHOSPHORUS, AND SULPHUR.

By T. EUSTACE HILL, M.B., C.M., B.Sc., &c.,

Medical Officer of Health for the County of Durham.

(Member.)

One of a course of five lectures on the Sanitation of Industries and Occupations.

Read November 15th, 1894.

I felt much honoured on being asked to deliver one of the lectures on the Sanitation of Industries which the Council of the Sanitary Institute, whose chief aim has always been the improvement of the Public Health and the advancement of sanitary science, has arranged during this month. The reduction in the general death-rate of this country, and consequently the diminution of sickness and suffering, which has rewarded the efforts that have been made for the better housing of the people and the improvement of the general condition of our towns and villages, has been so marked that popular interest in sanitation is now thoroughly aroused, and though I feel that the subject of to-night's lecture might have been entrusted to someone more able and experienced than myself, I have no doubt that the object of the Council of the Institute will be successful, and especially appreciated by sanitary inspectors, on whom recent legislation has transferred part of the work formerly performed by special factory inspectors.

The first part of my lecture has reference to the metal *mercury*, and to the health of those employed in industries where either the metal or its compounds is used. Mercury is not found either in the free state or in combination in this country, in fact, it is but rarely found in nature in an uncombined state, and then usually in the form of an amalgam with gold and silver. The sulphide of mercury (cinnabar), however, occurs in considerable quantities in Spain and elsewhere, and the metal can readily be extracted by simply roasting the ore, either alone or mixed with lime or iron filings, when metallic mercury is given off and is easily condensed. The preparation and purification of mercury on a commercial scale is entirely carried on abroad, the metal being imported into this country in an almost pure state. The processes usually employed appear to be very dangerous to the workers, who are said to suffer severely from mercurial poisoning.

Mercury has several properties which are peculiar to itself. It is the only metal which is liquid at all temperatures, but one of its chief characteristics, from an industrial point of view, is that it volatilizes or gives off vapours at ordinary temperatures which are readily absorbed by persons working in mercury, though they may not even handle the metal, and frequently give rise to mercurial poisoning. As an example of this, and as showing how readily mercury is absorbed into the human system, Dr. Taylor, in his excellent work on poisons, records an instance where a ship was laden with metallic mercury and during the voyage the bags in which the mercury was contained burst, so that the metal became scattered throughout the vessel, with the result that all the crew soon suffered from an aggravated form of mercurial poisoning.

Another peculiar property of mercury, and on which its application in several industries depends, is the readiness with which it forms alloys or amalgams with other metals. It is on account of this property that mercury is used in large quantities abroad for the extraction of gold and silver from their ores.

In this country the persons working in mercury or its compounds, and therefore exposed to the dangers of mercurial poisoning, are *water gilders, silverers or mirror makers, barometer makers, a class of bronzers, furriers and felt hat makers.*

In the process of *water gilding* the mercury is used for depositing gold on metallic surfaces. The metal to be gilt is first carefully cleansed, and then brushed over with a solution of nitrate of mercury, after which it is covered with a layer of the amalgam of gold and mercury. Heat is then applied to drive off the latter, and the gold is left deposited and only requires to be burnished. Throughout the process, both during the application of the amalgam, but especially during the driving off of the mercury, the workers are much exposed to the vapours of that metal. As far as possible the work is done in special chambers, from which the workman is separated by a glass sash, a small opening only being left at the bottom of the sash to allow of the hands being introduced for the necessary manipulation; but even with these and other precautions, the majority of those employed in the work are said to suffer sooner or later from mercurial poisoning to a greater or less extent. Where large articles have to be gilt, the work cannot be done in glazed chambers, and is usually performed in the open shop, when the danger to the workmen is much increased. The process of water gilding has of late years very greatly been replaced by electroplating, though it is still considered preferable for gilding certain articles, such as sword handles, as there is an impression that mercurial gilding is more permanent than that deposited by the electrolytic process.

The silvering of mirrors, which was at one time the most important industry in which mercury was employed, is now fortunately very largely superseded by a much improved and harmless process by which metallic silver is deposited on the glass from a tartrate of the metal. The mercurial method of silvering is however still employed to some extent, especially for the production of articles sold at a low price, and is effected by carefully flattening out a sheet of tinfoil on the silvering stone and then covering it with mercury. The sheet of glass to be silvered is then slid over the tinfoil so that a portion of the mercury intervenes regularly between the tinfoil and the glass. The excess of mercury which is used in the process runs off the table into vessels suitably arranged, and is afterwards strained and made fit for further use. Dr. George Whitley, who in 1863 reported on the liability of workers in mercury to mercurial poisoning, stated that in the early days of the process mercurialism among the silverers was extremely common, but at the period of his enquiry, owing to the larger size of the workshops and their better ventilation, its prevalence had much decreased, though mild cases were even then by no means uncommon, especially among young men when first commencing to work at the process. Dr. Whitley also stated that silvering on a small scale was carried on in London by persons, chiefly Italians and Jews, at their own homes and that they probably suffered severely from exposure to mercury fumes, but I have not been able to ascertain whether the work is carried on under similar conditions at the present day.

Barometer and philosophical instrument makers appear to suffer very rarely from mercury poisoning. The work is generally carried on in well-ventilated shops, and the quantity of mercury dealt with is comparitively small. The chief danger arising from the work appears to be from the bursting of the tubes in which the metal is heated, but this is not of frequent occurrence, and the exposure to its vapour is even then not continuous. If the workmen are temperate and cleanly in their habits the liability to mercury poisoning in this particular industry is extremely small.

There is a form of *bronzing* by which a metallic appearance is given to plaster figures by rubbing them with an amalgam of mercury, tin, and bismuth and then varnishing them. Persons engaged in this work are said not uncommonly to suffer from mercurial poisoning in a marked degree.

Another class of operatives liable to mercury poisoning are felt-hat makers and skin and fur dressers. In this industry either acid nitrate of mercury or a mixture of that salt with the perchloride (corrosive sublimate) and arsenious acid is used. The hairy side of the skins is dressed with the mercury preparation and afterwards dried in heated rooms. The skins are then brushed and afterwards cut up by machinery and sorted, this latter part of the process being generally performed by women, who have to handle the furs constantly. The sorting of the furs is attended with the evolution of much dust, which contains particles of the dried mercury salt, and the danger to those inhaling it therefore cannot be overlooked, though at the present time there appears to be little evidence that cases of mercury poison among furriers and felt-hat makers are at all common.

A preparation of mercury is also used by taxidermists in preserving and stuffing the skins of animals. Artificial flower makers also employ to some extent the iodide, sulphide, and chromate of mercury as pigments, but no special inquiry appears to have been made as to whether they suffer to any extent in health as a result of using these substances. The number of persons employed in the trades I have mentioned where mercury in some form or other was used was never large, and owing to the fact that the two largest of them—water-gilding and silvering—have been for the most part superseded by improved processes, it has of late years considerably decreased; but among those still employed, cases of mercury poisoning appear to be not uncommon, and this is not to be wondered at when we consider that the metal gives off vapour at all ordinary temperatures; that both it and its compounds are easily absorbed into the system—through the unbroken skin as well as by the respiratory and alimentary tracts; that the absorption of very small quantities will frequently produce symptoms of mercurialism; that its elimination from the body is extremely slow; and that some individuals show a special susceptibility to its action.

The symptoms of mercury poisoning vary greatly, and I do not think it necessary to describe them minutely. All I need say is that among workers exposed to mercury the poisoning is usually of a more or less chronic form, and is evidenced as a rule by salivation or an increased flow of saliva, by sponginess of the gums, fœtor of the breath, and gastric and intestinal derangements. At a later period the characteristic mercurial tremor (known as the "trembles") appears and affects the voluntary muscles, especially during movement or under emotion, but this tremor may be one of the first or almost the only symptom of chronic mercurial poisoning. If these symptoms be disregarded serious permanent injury may result, though a fatal termination of the illness is not common; and if the patient discontinues his employment before they have become marked, recovery generally takes place in a few weeks. Alcoholic intemperance both predisposes to and greatly aggravates the symptoms of mercurialism, while other predisposing causes are want of cleanliness, and an unusual susceptibility in some individuals, which may be due to an unusually slow process of elimination of the poison from the system.

Owing to the fact of mercury giving off vapours at all ordinary temperatures, and being so readily absorbed into the system, it is probable that whatever precautionary measures are adopted the workmen who are employed in such processes as water-gilding and silvering will occasionally suffer from mercurialism.

Free ventilation of the workshops is of course of great importance, and whenever possible the process should be carried on in chambers specially adapted for carrying away the mercury vapours from the workers. All mercury not in use should be kept in covered vessels, and the workers should handle the metal as little as possible. The floors of the workshops should be smooth and impervious and should slope towards gutters, so that any mercury that may be spilt can be easily collected. The workers should wear an outer dress of some washable material, well fitting at the neck and wrists, and the use of respirators is desirable, though experience has shown that it is almost impossible to get the workers to adopt this precaution. Cleanliness is most essential, and the face and hands should be frequently washed and the mouth rinsed, especially before meals, and no food should be allowed to be taken within the workshops. Temperance among the workers is also very important, and no person of known intemperate habits should be employed. Above all it is necessary that any worker showing the slightest symptom of mercurialism should be at once removed from his employment.

Passing on now to the consideration of *Phosphorus*, I come perhaps to the most important part of my lecture, for not only is its use essential in one very important industry—the manufacture of lucifer matches—but under certain conditions those exposed to phosphorus' vapours are liable to suffer from a peculiar but definite disease of a most serious nature.

There are two varieties of phosphorus, the common or yellow phosphorus, and the red or amorphous phosphorus, and they differ greatly both in chemical and physical properties. Yellow phosphorus is a waxy, semi-transparent solid which gives off fumes at all temperatures above 32° F., and is luminous in the dark. It melts at a little above 110° F., and is extremely inflammable, taking fire in the air at a little above its melting point. It produces very severe burns if carelessly handled, and is a dangerous irritant poison.

Amorphous phosphorus on the other hand is usually met with as a dull red powder with a specific gravity somewhat higher than that of the yellow variety. It chiefly differs from the latter in that it is not poisonous, does not emit fumes, and is not inflammable till heated to a temperature of about 500° F. It can be handled with safety at all ordinary temperatures and its use is practically free from danger.

The manufacture of phosphorus in this country, is mainly carried on by one large firm at Oldbury, near Birmingham, which, I understand, are also the sole makers of amorphous phosphorus. Ordinary phosphorus is derived almost entirely from calcined bones which are composed chiefly of phosphate of lime. After calcination the bones are treated with somewhat diluted sulphuric acid, with the result that insoluble sulphate of lime is formed, and a superphosphate of lime is left in solution. After standing, the supernatant fluid is poured off, evaporated to the consistence of a syrup, then mixed with vegetable charcoal and evaporated to dryness. The dried compound is then strongly heated in earthenware vessels with the result that phosphorus distils over from the retorts and is received into metal pots filled with water where it condenses into cakes. It is then purified by simple means. The usual cylindrical form of pure phosphorus is given to it by melting it under water, by means of steam, in leaden vessels, from the bottom of which horizontal tubes of the required size pass into troughs of cold water. The melted phosphorus is forced by its own weight through the tubes, whose form it takes, and escapes at the distal extremeties, when it is cut up into sticks of the required length. In the early days of phosphorus making the stick form was given to it by workmen sucking it while in the melted condition into glass tubes, but this highly dangerous practice has long been abandoned.

Amorphous phosphorus is prepared by continuously heating the yellow variety in an enclosed iron cylinder at a temperature of from 400° to 500° F. for a month or six weeks. It is then ground under water, and dried at a moderate temperature on leaden slabs. The danger to the workers employed in the manufacture of phosphorus appears to be very small. Phosphoretted hydrogen and other poisonous gases, with a little phosphorus itself, are given off during the application of intense heat in the last stage of the process; but all these vapours are conducted away from the workers, burnt, and rendered harmless. Most of the other stages of the manufacture are carried on under water, and therefore without danger. The number of persons engaged in the preparation of phosphorus is very small, probably not exceeding 100, and the majority of these are engaged in work, which, under no circumstances, exposes them to its vapours. Dr. Bristowe, who, thirty years ago, carefully inspected the largest phosphorus manufactory in the country, gave as his opinion that the dangers to the workers employed therein were extremely small.

As to the industries in which phosphorus is employed, by far the most important is that of lucifer and other kinds of match-making; in fact, nearly the whole of the phosphorus manufactured is employed for that purpose. Dr. Bristowe ascertained that in 1862 there were in England about fifty-seven match-making establishments employing between them over 2,500 persons, and though at the present time many of the smaller factories have ceased to exist; on the other hand, the out-put of the larger factories is very much larger than it was thirty years ago, and the number of persons to-day employed in the industry is much greater. As showing the importance of the match-making trade, I may state in 1886 the value of matches, produced by one of the largest factories in this country, was £500,000.

In addition to the safety matches, of which I shall speak later, there are several kinds of matches in which common phosphorus is employed, viz., the congreve or ordinary wooden matches, wax vestas, and vesuvians. Formerly fusees and silent matches were made in considerable quantity, but the demands for these died out, and they are hardly ever now made in this country.

The process of manufacture of all kinds of matches is practically the same, where common phosphorus is used, as regards danger to health, and I shall therefore confine myself to giving a short account of the manufacture of the ordinary lucifer matches, and to pointing out in which processes of the manufacture the danger to health from the use of phosphorus is greatest.

The factories in which lucifer matches are produced are usually divided into several departments, where different parts of the work are carried on. The making of the boxes for holding the matches and the cutting of the wooden splints are, as a rule, carried on outside the works and need no consideration, though I may state that the splints are at first twice the length of the prepared matches, and at some period of the manufacture, before the application of the phosphorus composition, require to be cut in two—a process known as "cross-cutting."

The first operation in the preparation of the matches is the charring of the splints, which is done by laying the bundles on end upon a stove or other heated surface till the ends are slightly browned. The object of this process appears to be to allow of the proper adhesion of the sulphur to the ends of the matches, or their saturation by the paraffin or other inflammable substance which may be used instead of sulphur. After being charred the ends of the matches are dipped into melted sulphur, stearine or paraffin for the purpose of ensuring that the match shall take fire when the phosphorus composition is ignited. Formerly sulphur was almost exclusively used for this purpose, but the fact that irritating sulphurous acid fumes are given off when the matches are ignited has led to its being very largely superseded by stearine, paraffin or other oleaginous substances. Another disadvantage in the use of sulphur is that the sulphur dippers are apt to suffer much inconvenience from the irritating vapours given off from the heated sulphur. The next process consists in the application of the phosphorus composition to the ends of the matches. In the early days of the industry this was done by simply dipping the ends of the splints while still in bundles into the composition, and matches thus made were known as "bundle-dips," and were mostly silent matches. Of late years the matches chiefly made in this country are known as "frame-dips," and receive this name from the fact that the splints before the application of the phosphorus composition are cut to the required size of the match, and then fixed in frames or clamps in such a manner that the matches are separated from one another and their ends form a level surface on both sides of the frame. By this means the matches can be all equally tipped with the phosphorus composition.

This composition varies greatly, both as to the nature and proportion of its ingredients, but it consists essentially of phosphorus, chlorate of potash, and glue. Powdered glass is also frequently introduced, and sulphide of antimony and peroxide of manganese are sometimes employed, together with colouring matter, such as prussian blue or vermillion. The chlorate of potash and peroxide of manganese are oxidising agents and promote inflammability, and—what is of greater importance—permits of a much less proportion of phosphorus being used. The percentage of phosphorus used in the composition varies greatly in the different manufactories, and though there is no reason why it should exceed 5 per cent., a much greater proportion is sometimes used, especially in foreign factories.

The quantity of chlorate of potash employed is usually in inverse proportion to the phosphorus. In the making of the "bundle-dips" and silent matches very little chlorate of potash was used, and the phosphorus was largely in excess, as is the case also at the present day with many of the cheaper foreign matches. It is easy to understand that the greater the proportion of phosphorus employed in the composition the greater the danger to the workmen of phosphorus poisoning. In the preparation of the composition great care has to be taken to avoid accidents. The glue is first melted in a steam bath, and the phosphorus then introduced and thoroughly incorporated. The colouring matter and powdered glass are then added, and finally the chlorate of potash, previously moistened, is introduced. If the chlorate is added in a dry state, or if the phosphorus is added to the chlorate instead of in the order I have described, severe explosions are likely to occur, which may seriously injure those engaged in the mixing. Care has also to be taken that the composition does not become too dry, or explosion may occur during manipulation.

The tipping of the matches with the composition is effected by spreading some of it evenly by means of a spatula on a smooth plate heated by steam and then placing the frame containing the splints horizontally on the plate so that the ends of the splints sink evenly into the composition. On removing the frame each match is tipped with a small button of the composition, which on drying evenly surrounds the end of the splint. The matches have now to be dried, and this is as a rule performed in specially warmed and fireproof rooms, where the frames containing the matches are placed on racks, though in summer they are sometimes dried in the open air.

In the process of drying a good deal of phosphorus vapour is given off, and it is therefore important in the interests of the workman that it should be effected in a room separate from the rest of the manufactory. The last stage in the manufacture is that of boxing, or the removing of the dried matches from the frames and filling them into boxes ready for sale. During this process it is not uncommon for the matches to catch fire, when they are extinguished by pressing them into damp cloths.

Of late years matches known as "safety matches" have come greatly into use in this country, and are manufactured largely by several London firms and also in enormous quantities in Sweden. In these matches the use of ordinary phosphorus is entirely dispensed with, and they are not spontaneously combustible, so that the dangers inseparable from the production of ordinary phosphorus matches and from their ready inflammability are almost entirely removed. The mixture with which these safety matches are tipped consists chiefly of chlorate of potash and glue, with varying proportions of sulphide of antimony, peroxide of manganese and powdered glass. For the ignition of these matches they require to be rubbed on a portion of the box which has been covered with a paste, the chief ingredient of which is the harmless amorphous phosphorus. Unfortunately these matches as made in England are slightly more expensive than the ordinary matches and are not quite so convenient, and for these reasons they have not supplanted the common lucifer to the extent that might have been anticipated from the obvious advantages they possess. Safety matches have also been made in which amorphous phosphorus is contained in the heads of the matches, but there appear to be serious difficulties in their manufacture which up to the present have prevented them coming into general use.

In the production of lucifer matches the persons who have to do with phosphorus, and who are, therefore, liable to exposure to its vapour are especially those engaged in making the composition, and in applying it to the ends of the matches. Both in the "mixing" and the "dipping," as these processes are called, and in the drying of the matches, phosphorus fumes are largely given off and the workers who perform this part of the industry are especially exposed to the dangers of phosphorus poisoning. Phosphorus is also given off from the dried matches, and those occupied as frame emptiers and box fillers are therefore to some extent exposed to its vapours. On the other hand the frame fillers, who form a considerable proportion of those engaged in match manufactories, need in no way be exposed to the fumes of phosphorus, though formerly it was not uncommon for the frame fillers to work in rooms where phosphorus was employed and therefore to be exposed to its effect. The amount of phosphorus vapour given off in the various stages of the manufacture depends greatly on the quantity employed in the composition, being much more abundant where the proportion of phosphorus used is large, and then the liability of the workers to phosphorus poisoning is much increased.

In the manufacture of safety matches no vapours of phosphorus are given off in any stage of the manufacture.

Phosphorus is also used in the preparation of certain vermin pastes, but not to any large extent, and its proportion in these preparations is usually under 5 per cent.

During the last few years phosphorus has been also somewhat largely employed in the manufacture of phosphor bronze. The trade however is, I believe, a very limited one, and the phosphorus used in the process is dealt with by some responsible person. There appears to be no special diffusion of phosphorus vapour, and neither in this trade nor in the preparation of phosphor vermin pastes is there any evidence to show that the workers suffer from exposure to the fumes of phosphorus.

As to the liability of workers in *phosphorus* to poisoning by that substance,—it was noted as far back as the year 1845 that those employed in the manufacture of matches in Germany and Austria were apt to suffer from a disease of the jaw, which proceeded to the necrosis or death of the bone and frequently ended fatally. Though this disease did not appear to be so prevalent in this country, cases were reported from time to time, and as a result of his enquiries in 1862 Dr. Bristowe ascertained that there had been at least fifty-nine cases of this jaw disease in England. The persons affected were as a rule those who had been for some years much exposed to the vapours of phosphorus, as dippers or mixers. The disease was entirely confined to the bones of the jaw, the lower jaw being most frequently affected, though in several instances both jaws were attacked. The first symptoms were usually those of toothache, which was not relieved by extraction of the tooth, but was followed by ulceration and destruction of the subjacent bone till at length the whole jaw might be destroyed. The duration of the disease varied. In some instances where destruction of the bone was but slight, recovery took place in a few months, but this was often delayed for years, and in many instances death resulted from exhaustion or from some wasting disease, such as phthisis. While the exciting cause of the disease is undoubtedly the exposure to phosphorus' vapours, the predisposing cause appears chiefly to be some unhealthy condition of the gums or teeth, and most authorities are agreed that the disease mostly occurs in workers whose teeth are decayed. That the prevalence of the disease was also greatly dependent on the conditions under which those engaged in the match industry worked, is shown by the fact that in the large well-ventilated and well-arranged factories cases of jaw disease are extremely rare, while in those factories which were formerly badly ventilated and where the processes of mixing, dipping, and drying were carried on in the same room that the workers engaged in frame filling, boxing, &c., were employed, phosphorus poisoning was by no means uncommon. Dr. Bristowe gives an excellent example of the effect of the conditions of employment on the health of those engaged in the manufacture of matches, and I cannot do better than quote from his report.

He says:—"By far the most remarkable and instructive "experience of the disease, however, is that afforded by a "congreve manufactory in Manchester, which is one of the "largest in England, and in which 250 persons, exclusive of "box makers and splint cutters, are constantly employed in the "various processes of match making. This factory has been in "existence for about twenty-five years, and during the first "twenty years of its operations, no less than twenty-four cases "of jaw disease occurred. The disease, too, in this case was not "limited, as in most other factories, to the dippers and mixers, "and consequently to adults, but the boxers, the cross cutters, "and the pickers out, formed a large proportion of those affected, "and children from twelve to fifteen years of age suffered as "well as their elders. The explanation, however, is easy, and "was pointed out to me with great candour by one of the pro- "prietors. The fact is that all those various conditions which "tend to the production of the disease were here concentrated "and combined, and all the operatives became nearly equally "exposed to the fumes of phosphorus. A very large number "of workpeople was employed; they were confined in low, ill- "ventilated, overcrowded rooms; the dipping, the drying, the "boxing, &c., were all carried on in the same apartment; "bundle-dips formed a large proportion of the matches which "were manufactured; and the composition employed contained "one-third of phosphorus. Further, at one period (and about "that time the disease was most prevalent) the operatives "worked far into the night as well as by day. About five "years ago the proprietors, who had been much concerned by "the frequent occurrence of the disease, set to work seriously "to remedy the defects on which they believed it to depend. "They constructed large, airy, well-ventilated rooms; they "gave up the manufacture of bundle-dips; and they diminished "by one-half the strength of the composition. The result has "been that not a single case of the disease has originated in "the factory during the five years that have elapsed since the "above improvements were effected."

Excepting for the jaw disease, there appears to be no form of sickness to which workers in phosphorus are specially liable, though those who have been long employed in the manufacture of matches are said to often look sallow and unhealthy, and to be liable to gastric derangements. In the manufacture of phosphorus itself, and in the preparation of vermin pastes and phosphor-bronze, the workmen appear to suffer no ill-effects, and I am not aware that a case of jaw disease has ever occurred among those employed in these industries.

Of the precautionary measures to be taken to obviate the dangers arising from the vapours of phosphorus to those engaged in the manufacture of matches, the most important is undoubtedly the substitution of amorphous for common phosphorus; and there is no practical difficulty to prevent this being carried out, the only objection to safety matches being that they are not so convenient, as they will only as a rule ignite when rubbed on a prepared surface and that they are slightly more expensive than the common lucifer. In fact, for nearly twenty years the use of matches containing ordinary phosphorus has been prohibited in Denmark and Switzerland, and only safety matches are allowed to be used in these countries. Experience has shown, however, that with proper precautions the dangers arising from the use of common phosphorus can be very greatly minimised, if not altogether prevented. For this purpose :—

1. The proportion of phosphorus in the composition should be as small as possible, and there is no reason why it should exceed five per cent.

2. The workmen engaged in the processes of mixing and dipping should occupy well-ventilated rooms, separate from the other operatives, and, as far as possible, their work should be carried on under specially ventilated hoods.

3. The workshops in which the frame emptiers, box fillers, and others are employed should also be large and well ventilated, and the frame fillers should, if possible, occupy a separate room so that they may in no way be exposed to the phosphorus fumes.

4. The matches should be dried in special fire-proof rooms, and all persons entering them should be required to wear respirators.

5. Persons suffering from bad teeth or from any inflammatory affection of the gums, should be debarred from working in any of the departments of a match factory where phosphorus is employed.

6. Personal cleanliness among the workers is of the greatest importance, and the hands should be washed before taking food, which should not be taken in any part of the factory where the fumes of phosphorus are evolved.

7. Owing to the fact that turpentine retards the oxidation of phosphorus, its use has been advocated in rooms where phosphorus is employed, and in some factories the workers carry flasks, or sponges containing turpentine, on their chests, so that they may breathe air impregnated with it. It is doubtful, though, if this precaution is of much value though the work-people generally believe in its efficacy.

It is satisfactory to know that most of the above precautionary measures have been adopted by the leading match manufacturers in this country, and as a result cases of phosphorus necrosis or jaw disease are now of very rare occurrence.

Owing to its inflammability, the careless handling of phosphorus may produce severe burns which are extremely painful and very slow of healing; while, as I have previously stated, want of care in the making of the phosphorus composition may cause serious explosions and danger to the workers. Such accidents, however, are not common, but the fact that they may occur furnishes another argument in favour of the use of amorphous phosphorus.

Before leaving this part of my subject, I should like to mention an incident of which I was a witness and which demonstrates that even the use of safety matches may not be free from danger. I was one day travelling in a railway carriage, when I noticed that the coat of a gentleman sitting opposite to me was slowly burning. The fire was quickly extinguished and at the time was attributed to some loose matches in his pocket having accidentally been set on fire. A short time afterwards, however, I was again travelling with this gentleman when a repetition of the accident occurred, and as he was this time wearing an overcoat, his garments where badly burnt before the accident was discovered. On carefully examining the contents of his pockets this apparently extraordinary accident was easily explained, for in the pocket where the fire originated were found a box of safety matches and some loose chlorate of potash lozenges which the gentleman was in the habit of carrying with him for a relaxed throat from which he suffered. The accidental friction of the lozenges against the prepared surface of the box containing amorphous phosphorus had undoubtedly caused ignition, the chlorate of potash lozenge being composed largely of the chief ingredient contained in the head of a safety match.

Sulphur (and under this heading I shall include those compounds of sulphur which are of industrial interest) is the last subject I have to deal with. Sulphur does not occur in this country in a free state, though as a sulphide in combination with iron and copper (pyrites) and lead (galena) it is by no means uncommon. Most of the sulphur used in this country is, however, imported from Sicily, where, as also in other volcanic districts, it is found in a native condition and only requires to be purified from the earthy matters with which it is always to some extent associated.

Of late years sulphur has been extracted on a large scale in this country from the tank waste produced in the manufacture of alkali. The process is known as the Sulphur Recovery

Process, of which I shall speak later, and at one large alkali works on the Tyne over 200 tons of pure sulphur are produced weekly.

Sulphur in its ordinary form is, as you all know, a yellow, brittle solid which possesses very little taste or smell and is insoluble in water. It melts at a comparatively low temperature (115° C) and is combustible, burning with a blue flame and forming sulphur dioxide gas. From an industrial point of view sulphur itself is not of much importance, and the dangers to those working in it are not great. It is chiefly employed in the manufacture of gunpowder, in the vulcanization of india-rubber, in the manufacture of matches, and for the production of sulphur dioxide gas.

Sulphur grinders and those working in powdered sulphur sometimes suffer from redness and irritation of the skin, which causes considerable inconvenience and irritation; while inflammation of the eyes is not uncommon. Other symptoms as a result of the entrance of the sulphur dust into the alimentary canal are loss of appetite and looseness of the bowels, and, as might be expected, persons who have worked for a long time as sulphur grinders are somewhat liable to bronchitis as a result of the irritation of the respiratory mucous membrane by the sulphur dust.

In match manufactories melted sulphur is sometimes used for tipping matches, and those engaged in this process often suffer considerably from irritation of the eyes and the respiratory tract owing to the evolution of sulphur dioxide. The shorter the hours of labour the less likely are sulphur workers to suffer from their employment, while other precautionary measures to be observed are frequent cleansing of the skin and the covering up, as far as possible, of the nose and mouth.

There are, however, several compounds of sulphur which are important in their industrial application, and the chief of these is *sulphur dioxide*, which is easily obtained by burning sulphur or calcining the metallic sulphides in the presence of air. This compound (sulphur dioxide) is a colourless gas and is very soluble in water, in combination with which it forms sulphurous acid. In its pure state it is quite irrespirable, and even greatly diluted causes much irritation to the respiratory passages; it is highly destructive of all forms of animal life, and is therefore used largely as a germicide and disinfectant, and it is possessed of strong bleaching properties. Sulphur dioxide is employed or produced in a number of industries to a greater or less extent.

In the manufacture of sulphuric acid it is produced in enormous quantities by burning pyrites in large furnaces, from which it passes into leaden chambers, where it comes in contact with nitro-oxygen vapours and steam, with the result that sulphuric acid is formed. The furnaces and other apparatus employed in the manufacture of sulphuric acid are however so well contrived that the process appears to cause but little danger to the health of the workmen, though in most of the factories the odour of sulphur dioxide is distinctly perceptible. Several accidents have, however, occurred to the workmen employed to clean out the furnaces in which the pyrites is burnt, owing to their entering the chambers before the sulphur dioxide has entirely escaped, but such mishaps are the result of recklessness on the part of the workmen and not of any defect in the process of manufacture.

But if we except the manufacture of sulphuric acid, the chief application of sulphur dioxide is as a bleaching agent, and it is especially useful in the bleaching of woollen, silk, and straw goods. In the bleaching of straw it is necessary that the articles be turned or changed from time to time, and for this purpose it is usual for a workman to enter the bleaching chamber, to do which he has to hold his breath for one or two minutes. This practice is undoubtedly a dangerous one, and those engaged in it usually suffer to some extent from the effect of the gas.

Sulphur dioxide is also useful as a preservative, and for this purpose is somewhat largely used in the preparation of hops. The chief danger to those engaged in occupations in which sulphur dioxide is employed arises from the irritating and suffocative properties of the gas. Those much exposed to it are apt to suffer from dryness of the throat, difficulty of breathing, and spasmodic cough, while loss of appetite and intestinal derangements are also stated to result from such exposure. Sulphur dioxide is also largely evolved in the roasting of pyrites for the extraction of the copper, and along with other gases in the manufacture of alkali by the Leblanc process, and in cement and coke making, brick-making, &c.

Another compound of sulphur of some industrial interest is *sulphuretted hydrogen*, a compound of sulphur and hydrogen. It is a gas which has a most offensive odour of rotten eggs, is combustible, burning with a pale blue flame, and is soluble in water, to which it imparts its disgusting odour. This gas is frequently given off in considerable quantity in the neighbourhood of alkali works from the "tank waste" or waste heaps, which consist largely of a sulphide of lime. In a pure state sulphuretted hydrogen is highly poisonous, and even when extremely diluted appears to have a serious effect on the health of those exposed to it, if we accept the opinion of

Dr. McNicoll, the Medical Officer of Health of St. Helens. In that town, where much sulphuretted hydrogen is given off from the waste heaps of numerous alkali works, Dr. McNicoll has stated that the diffusion of that gas in the atmosphere increases the amount of sickness, greatly increases the infant mortality, and is the cause of many epidemics of infectious disease assuming a malignant type. In South Shields and Jarrow, where the air was frequently polluted by the large quantity of this gas given off in the neighbourhood of alkali works, both my own experience as Medical Officer of Health and that of my predecessor, Mr. Spear, confirmed to some extent the opinion of Dr. McNicoll that the presence of even a small quantity of this gas had a lowering effect on the health of those breathing it, and was apt to cause malaise, general depression, and even sickness.

Of late years means have been devised for the recovery of the sulphur contained in the heaps of tank waste produced at chemical works. The process is known as the "Sulphur Recovery Process," and it is carried out on a very large scale at a few manufactories in this country. Stated shortly, the process consists in intimately mixing with water the powdered tank waste, which, as I have already mentioned, consists chiefly of a sulphide of lime. This mixture, which is known as "slurry," is then conducted to a series of large iron tanks connected with one another, and carbonic acid gas is forced through it, with the result that sulphuretted hydrogen is liberated, and ultimately collected in large gasometers. The sulphuretted hydrogen gas is then mixed with air, and passed into large heated chambers through a layer of oxide of iron contained therein, when further decomposition takes place and sulphur is produced. A little sulphuretted hydrogen escapes decomposition, and together with some sulphur dioxide gas which is produced are passed through a furnace to render them harmless before being discharged into the air.

I recently visited a large alkali works where 4,000,000 cubic feet of sulphuretted hydrogen gas are produced every day by this process. Every precaution is taken to prevent the escape of this gas, but nevertheless on the day of my visit the chamber where the slurry is decomposed by carbonic acid gas, smelt strongly of sulphuretted hydrogen in some parts, and though only breathing it for a short time I suffered afterwards from marked depression and cardiac weakness. I was told that the escape of gas on the occasion of my visit was quite unusual, and the workmen employed in this part of the works certainly appeared to suffer no ill effects. The length of time this process has been in operation is, however, too short to judge of its effect on the health of those employed in it, but unless the strictest precautions are taken to prevent the escape of sulphuretted hydrogen I am convinced that the health of the worker must in time be seriously affected.

The only other compound of sulphur of industrial importance is *bisulphide of carbon*, which is employed in india rubber manufactories in the vulcanization of the rubber. It is a very inflammable and highly refractive liquid, which at all temperatures gives off a very poisonous vapour, which is also as a rule most offensive. M. Delpech, thirty years ago, pointed out its serious effects on the health of workpeople employed in the small and often insanitary india rubber works which then existed in the neighbourhood of Paris, and although the manufacture of rubber in this country is conducted in spacious, well-ventilated factories, and the use of bisulphide of carbon has been much curtailed, still it must not be lost sight of that unless proper care is exercised the health of those who have to deal with this substance may be seriously affected. Instances of poisoning by carbon bisulphide in this country appear, however, to be of very rare occurrence, though cases have been recorded. Bisulphide of carbon is also employed at a factory near Bradford for the recovery of the grease from the soapsuds resulting from the washing of wool; but here also, owing to the precautions taken, there appears to be no evidence of injury to the health of those employed. To diminish the dangers to the workers from these compounds of sulphur to which I have referred, it is necessary that the work should be carried on in spacious, well-ventilated factories, and that special means should be adopted as far as possible to carry off from the workman and to destroy the poisonous vapours.

In the manufacture of sulphuric acid and in the bleaching processes the plant should be as perfect as possible to prevent the unnecessary escape of the sulphur dioxide gas, and the same remark applies to the use of sulphuretted hydrogen in the sulphur recovery process. In the processes where sulphur dioxide is used, absorbents such as moist sawdust or milk of lime, may with advantage be employed in the factory. It is difficult to prevent the escape of sulphuretted hydrogen from the huge heaps of tank waste of the alkali works, but by proper drainage of the heaps, and as a result of the gradual oxidation of the portion exposed to the air, the nuisances from the old heaps are now much diminished, and owing to a great change in the process of alkali manufacture and to the fact that the sulphur can now be recovered from the tank waste, these heaps are now no longer deposited to any extent.

I think you will have gathered to-night that while in the early days of the industries in which mercury and phosphorus were employed, the dangers to the health of the workers from the vapours given off by these substances were very great, fortunately at the present day, owing to the adoption of improved processes and the administratien of the Factory and Workshops Acts, together with the exercise of greater care both by the employers and workers, the dangers resulting from these occupations have been very greatly reduced; but in all industries where injurious vapours or dust are evolved, a great deal depends on the attention to personal cleanliness and the adoption of reasonable care by the workers themselves, who above all others should also be temperate and regular in their habits. Otherwise injury to health will from time to time occur, however well adapted the factories may be, and whatever legal enactments are in force