

U. S. DEPARTMENT OF LABOR  
JAMES J. DAVIS, Secretary  
BUREAU OF LABOR STATISTICS  
ETHELBERT STEWART, Commissioner

BULLETIN OF THE UNITED STATES } . . . . No. 405  
BUREAU OF LABOR STATISTICS }

INDUSTRIAL ACCIDENTS AND HYGIENE SERIES

PHOSPHORUS NECROSIS  
IN THE  
MANUFACTURE OF FIREWORKS  
AND IN THE  
PREPARATION OF PHOSPHORUS

BY  
EMMA F. WARD  
Of the United States Bureau of Labor Statistics



MAY, 1926

WASHINGTON  
GOVERNMENT PRINTING OFFICE  
1926

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## PHOSPHORUS NECROSIS IN THE MANUFACTURE OF FIREWORKS AND IN THE PREPARATION OF PHOSPHORUS

### INTRODUCTION

Phosphorus necrosis, though not so appalling in the number of victims it claims, is one of the most disfiguring and horrible of all the occupational diseases. Phosphorus was the first industrial poison to become the subject of international legislation, and because of the intense suffering and often shocking deformity resulting from the disease almost every civilized country has taken measures to abolish the use of poisonous phosphorus in the match industry, where chronic phosphorus poisoning was most prevalent.<sup>1</sup>

In Europe, before resorting to prohibition of the use of poisonous phosphorus, every type of regulation was tried in the various countries. Among the measures resorted to were the limitation of the amount of phosphorus to 10 per cent; the requirement of certain types of ventilating machinery; the insistence on factories especially arranged for such manufacture according to regulations, specifying location and size of rooms, type of walls, floor, and ventilating apparatus; regular dental and medical inspection; limitation of hours; change of occupation; reporting of cases of necrosis; posted notices of the danger of the occupation; special clothing; and furnishing of mouth wash. In Great Britain, Oliver made the following recommendations:

If white phosphorus is to continue to be used in this country it is absolutely necessary that such structural alterations should be made in factories which will separate the mixing, dipping, drying, and boxing rooms from each other, and that each should be thoroughly ventilated by fans; that each dipping table should be so thoroughly ventilated by a fan that the fumes can not rise upward toward the worker beyond an inch or two from the slab, but must be drawn toward the fan; that the boxing rooms should be lofty and ventilated by fans; that ventilating hoods or shafts should be placed above each bench so that the fumes are drawn away from the worker as she fills the boxes. \* \* \* Provision should be made for washing; soap and towels should be provided by the firm, and facilities for washing should be offered to the workpeople, not in the open yard of the factory exposed to all kinds of weather, but in a room or shed. Gargles should be provided and each worker should have his own mug. Overalls should be worn, and there should be dental and medical inspection of the workpeople on entering the factory and at stated intervals afterwards. There should be a change of occupation for the workers; men and women should not be allowed to remain more than a few weeks at a time in any one department. The mixing of the phosphorus paste should be done in closed vessels and the paste kept until required in covered iron tanks. Plans of new factories and of proposed structural alterations in old

<sup>1</sup> See Appendix A, p. 38, for a general account of the situation in the match industry.

factories should be submitted to the Home Office. A medical and dental register should be kept in the factory.<sup>2</sup>

In spite of the stringent regulations, irksome to the manufacturer and annoying to the worker, cases of phosphorus necrosis continued to appear, and prohibition of the poisonous phosphorus seemed the only solution. In 1906 the international treaty of Berne, prohibiting the manufacture, importation, and sale of matches containing white (yellow) phosphorus,<sup>3</sup> was signed by Germany, Denmark, France, Italy, Luxemburg, Switzerland, and the Netherlands. In the report of the director of the International Labor Office for 1925 most of the nations of the world are listed as signatories of the Berne convention. In addition to the seven countries that signed the treaty in 1906, Great Britain, South Africa, New Zealand, Canada, India, Norway, Spain, Belgium, China, Czechoslovakia, Esthonia, Finland, Japan, Poland, and the Free City of Danzig have since adhered to the treaty. Argentina and Greece have adopted measures embodying the terms of the treaty. The Chilean Government in 1923 laid before the national congress a proposal for the approval of the treaty. Hungary adhered to the convention in 1925.<sup>4</sup>

In the United States, a law was passed in 1912 imposing a tax of 2 cents per hundred on all white phosphorus matches manufactured after July 1, 1913, and prohibiting the importation of such matches after that date and the exportation after July 1, 1914. The Diamond Match Co., which held the patent for nonpoisonous (sesquisulphide of phosphorus) matches, generously allowed the use of the patent to the other match manufacturers.

It seemed, then, that "phossy jaw," as the disease was called on account of the characteristic swollen jaw, was a thing of the past. In recent years, however, the disease has reappeared. Doctor Legge, chief medical inspector of factories in Great Britain, notes in his report for 1918 the recrudescence of "phossy jaw" in the preparation of phosphorus.<sup>4</sup>

In spite of the increased use of white or yellow phosphorus during the war period as a smoke-screen producer, as an incendiary agent, and also to terrorize enemy troops when used in Stokes mortar shells, Livens projectors, and hand grenades, no cases of phosphorus necrosis thus caused are recorded in England or the United States. Doctor Hamilton mentions two cases of phosphorous necrosis that developed in France during the war in the manufacture of incendiary bombs.<sup>5</sup> A recent article in a medical journal states that the use of white (or yellow) phosphorus in America during the World War had reached the tremendous amount of 1,006 tons at the time of the armistice;<sup>6</sup> between 20 and 40 workers were employed for four or five months in a Government plant in making munitions containing phosphorus

<sup>2</sup> Great Britain. Home Department. Reports on the use of phosphorus in the manufacture of lucifer matches, by Prof. T. E. Thorpe, Prof. Thomas Oliver, and Dr. George Cunningham. London, 1899, p. 96. [C. 9188.]

<sup>3</sup> White phosphorus becomes yellow when exposed to light.

<sup>4</sup> Industrial and Labor Information, International Labor Office, Geneva, Dec. 21, 1925, p. 3.

<sup>5</sup> See Appendix B, p. 40.

<sup>6</sup> Hamilton, Alice: Industrial Poisons in the United States, New York, the Macmillan Co., 1925, p. 315.

<sup>7</sup> Journal of American Medical Association, May 23, 1925, p. 1569. "Treatment for white phosphorus burns," by Duncan O. Walton.

(four workers form the ordinary peace-time force), but apparently there were no cases of phosphorus necrosis so far as is known.

The present-day hazard of phosphorus poisoning, according to Dublin, occurs among boneblack makers, brass founders, fertilizer makers, fireworks makers, insecticide makers, match-factory workers, phosphate-mill workers, phosphor-bronze workers, phosphorus-compound makers, and phosphorus extractors.<sup>7</sup>

Only one case has apparently been reported in the phosphor-bronze industry.<sup>b</sup>

It is said that white (yellow) phosphorus is also used as a substitute for camphor in the manufacture of celluloid when the price of camphor is high.<sup>8</sup>

Because of the recent occurrence of cases of chronic phosphorus poisoning in the fireworks industry, and in the extraction of phosphorus in the United States, the Bureau of Labor Statistics made an investigation of conditions in these industries during the spring and summer of 1925 to determine the extent of the evil. As some plants manufacturing rat poison make a paste of which phosphorus is an ingredient, these were also studied in order to ascertain whether any cases of phosphorus necrosis had developed, and whether phosphorus presents a real industrial hazard in these plants.

There are 57 establishments manufacturing fireworks in the United States, according to the 1920 census, but only 3 use white (yellow) phosphorus, and these were covered by the bureau's study. Twelve plants using white or yellow phosphorus as one of the ingredients of their rat paste were also investigated. Only two factories in the United States have been preparing white (yellow) phosphorus, and one of these has been closed for a number of years; information was obtained from the managers of both plants.

In addition to the paramount hazard of chronic poisoning, phosphorus fireworks present two collateral hazards—that of explosion and that of acute poisoning.

If the mixture from which the fireworks are made is not prepared with extreme care, the finished composition is very sensitive to friction. The ratio of chlorate to phosphorus must be correct and the mixture so prepared that the phosphorus is distributed in microscopic particles, each one contained in a protective sac of gum arabic. If the sawdust in which the fireworks are shipped packs too tightly at one end of the box during shipment, leaving a space at the other end, the sensitive composition is frequently brought into direct contact with the shipping container and a shock on the outside of the box will ignite the composition. (In the last 15 years 18 fires or explosions due to phosphorus fireworks have been reported.<sup>c</sup> The danger of explosion occurs during the shipment or storage of the finished product and constitutes a hazard for employees handling the product during the course of distribution to retail dealers, and

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<sup>7</sup> United States Bureau of Labor Statistics Bulletin No. 306: Occupation hazards and diagnostic signs, by Louis I. Dublin and Philip Leiboff. Washington, April, 1922, p. 26.

<sup>b</sup> International Association for Labor Legislation. *Les Industries Salubres*, Jena, 1903, p. 123.

<sup>c</sup> United States. Congress. Senate Committee on Finance. Hearings on the proposed tariff act of 1921 (H. R. 7456), Schedule I: Chemicals, oils, and paints. Washington, 1922, p. 1284.

<sup>d</sup> International Hygiene Bulletin, published by the New York State Department of Labor, December, 1924, Vol. 1, No. 6, p. 22.

thus is to this extent an industrial hazard.<sup>9</sup> This danger from explosion also constitutes a hazard of production, especially in the mixing, as well as of distribution. Marshall in his book on explosives states that mixtures of chlorates with phosphorus are considered more dangerous than those with sulphur, and their use in England was restricted in 1905.<sup>10</sup>

The danger of acute phosphorus poisoning from fireworks is not likely to be an industrial hazard. Such cases are usually those of poisoning in children who swallow the lozenges thinking that they are candy. In this respect the phosphorus fireworks constitute a danger the extent of which is unknown. As this is not an industrial hazard, however, only passing attention was paid to it in the present investigation, and no effort was made to secure the total number of such accidents. The cases of acute phosphorus poisoning of children obtained from medical records of physicians, hospitals, and bureaus of vital statistics and reproduced in Appendix C of this report (pp. 41 to 43) show vividly the result of the child's contact with the plaything. One State, Louisiana, has prohibited the sale of such fireworks in the State, and a large distributor of fireworks has refused to handle the phosphorus type and has so notified its customers.

#### CHEMICAL PROPERTIES OF PHOSPHORUS<sup>11</sup>

There are two kinds of phosphorus used industrially—white phosphorus, which becomes yellow when exposed to light and is very poisonous, and red phosphorus (obtained by heating white (yellow) phosphorus to about 288° C. in a closed vessel), which is non-poisonous when pure.

Phosphorus (white or yellow) was prepared for the first time by Brand in Hamburg about the year 1670. It has the appearance of somewhat transparent white wax and has a specific gravity of 1.83. It is soft and can be cut with a knife, but becomes brittle at 0°, melts at 44.4° C, increasing in volume, and boils at 287° C. When exposed to the light it becomes brownish yellow. Moist phosphorus oxidizes rapidly, catching fire spontaneously in the air with the formation of white fumes. It is luminous in the dark.

White phosphorus is a powerful poison and 0.1 gram is sufficient to cause death. In cases of phosphorus poisoning it is found absorbed in the liver (which is distended), in the blood, and in the expired air. The antidote consists of 1 gram of copper sulphate dissolved in half a liter of water.

Red phosphorus was discovered by Schrötter in 1845. It consists of an apparently amorphous, bright reddish-brown powder without odor, has a specific gravity of 2.19,<sup>d</sup> is not phosphorescent in the dark, does not alter in the air, and is not set on fire by friction. It is not poisonous, is insoluble in carbon disulphide, and catches fire only at a temperature above 200° C. When heated rapidly to 260° in an atmosphere of carbon dioxide it is transformed into vapors of ordi-

<sup>9</sup> New York, Department of Labor, Division of industrial hygiene, *Industrial Hygiene Bulletin*, September, 1924. "The menace of phosphorus fireworks," by C. V. Salls.  
<sup>10</sup> Marshall, Arthur: *Explosives*, Vol. II, Properties and Tests, p. 611. Philadelphia, P. Blakistons Son & Co., 1917.

<sup>11</sup> Data are from Molinari, Ettore: *Treatise on General and Industrial Inorganic Chemistry*, translated by Thomas H. Pope. Philadelphia, P. Blackiston's Son & Co. 1920, pp. 402-407.

<sup>d</sup> According to Mellor (*Modern Inorganic Chemistry*, p. 582) the specific gravity of red phosphorus varies from 2.05 to 2.39. Schrötter found that its specific gravity varied from 2.089 to 2.106 at 17° C. and that it was 1.90 at 10° C.

nary yellow phosphorus. It does not melt even at a red heat, but at 100° slowly gives off vapors. When heated for a long time to 360° in sealed tubes red phosphorus is transformed into black phosphorus.

The vapor of white phosphorus, when pure, is said by Schonbein to be odorless; the odor that is perceived is a mixture of ozone and phosphorous oxide.<sup>12</sup>

### SYMPTOMS AND TREATMENT OF CHRONIC PHOSPHORUS POISONING

The symptoms of chronic phosphorus poisoning are given in the list of industrial poisons prepared by the International Association for Labor Legislation.<sup>13</sup> According to this authority, phosphorus enters the body in the form of vapor through the respiratory organs, by means of food contaminated by the fingers, or by action on the skin.

As industrial poisoning it occurs only in the chronic form, occasioned by the absorption of very minute particles of the poison for a period of months, generally, indeed, of years. Symptoms of the disease sometimes first appear long after relinquishment of the occupation.

It is doubtful whether chronic phosphorism occurs (that is, general systematic poisoning by phosphorus).

Chronic phosphorus poisoning uniformly affects the bones of the face, beginning with inflammation and sclerosis of the bones and of the periosteum; then, by extension of the suppurative process, necrosis results. This most frequently attacks that portion of the alveolar process of the jawbone which is least protected against infection.

Swelling and ulcerations on the gums and the buccal mucous membrane, pain even in the sound teeth, loosening and falling out of the teeth, infiltration of boardlike hardness occurs in the soft parts surrounding the jaw; suppuration and destruction of the jawbone (necrosis) with numerous fistulous channels which here and there burrow through the cheek. Hand in hand with the ulcerative processes go osteoplastic formations, so that, while suppurative destruction of tissue takes place at one point, at another the formation of new bone is going on. The under jaw is more often affected than the upper; here the process goes on insidiously without formation of new bone but with local destruction of the part. The palatal and orbital bones may be attacked with ulceration and shrinking of the eyeball. By extension of the inflammation along the sheaths of the vessels there result meningeal inflammation and cerebral abscess.

There is remarkable brittleness of the bones, decline of appetite, pallid complexion, diarrhea, emaciation. Sometimes there is amyloid degeneration of the abdominal organs. Death by sepsis.

Special measures of relief recommended include the prohibition of the use of white (yellow) phosphorus wherever possible; exclusion of workers having dental caries; after the extraction of a tooth at least two weeks' exclusion from the employment; change of occupation; improvement in the general health. There is no specific medical treatment. In appropriate cases, operative intervention is recommended.

Oliver, in his book on *Dangerous Trades*, analyzes the causes of phosphorus necrosis and gives the symptoms of the disease with special reference to workers in the match industry, as follows:

It is difficult to say what is the actual cause of necrosis of the jawbone in lucifer matchmakers. As to whether it is a primary lesion or one secondary

<sup>12</sup> Oliver, Thomas: *Dangerous Trades*. London, John Murray, 1902, pp. 418, 419.

<sup>13</sup> U. S. Department of Commerce and Labor, Bureau of Labor Bul. No. 100. Washington, May, 1912, p. 755. (Translation by Dr. William H. Rand, of the U. S. Bureau of Labor, of list of industrial poisons prepared by the International Association for Labor Legislation.)

to a general or constitutional form of poisoning, medical opinion is still divided. Most writers attribute the disease of the bone to the fumes of phosphorus, i. e., to the oxides of phosphorus acting upon the decayed teeth of the workpeople. The fumes are supposed to penetrate a carious tooth and induce a periostitis or inflammation of the covering of the bone. The gum becomes swollen and painful. To such an extent has this been regarded as the explanation of the cause of necrosis that two of the large match works in this country had at their own expense appointed dentists to examine and keep in good order the teeth of the workpeople. Subsequently the home office, as a result of the opinions expressed at an arbitration with the match manufacturers, decided to accept periodical examination of the teeth of the workpeople by a qualified dentist as a substitute for medical inspection. While regarding decayed teeth as a necessary preliminary to inflammation of the dental socket, Rousset holds that it is phosphoric acid that is the destructive agent. Gubler and Lailier, on the other hand, maintain that they have met with phosphorus necrosis in the inferior jaw of a matchmaker whose teeth were perfectly sound, and that if phosphoric acid were the destructive agent the teeth ought to become softened and translucent. Gubler holds, but on what grounds we do not know, that it is phosphorus itself that penetrates into the soft tissues and destroys the nutrition of the covering of the bone. Under all circumstances "phossy jaw" is a painful affection, especially in the early stages, and although naturally it might be expected to occur with greater readiness in workpeople who are ill-nourished, scrofulous, or tubercular, yet I have seen it in male and female matchmakers who were physically strong and otherwise perfectly healthy. This circumstance, therefore, is rather in favor of phosphorus necrosis being in the first instance a local affection and primary. Once suppuration occurs, the painful tooth removed, and the pus thereby allowed to escape, pain is subsequently not a marked feature in the case.

As the periosteum is usually separated, the affected portion of bone lying underneath dies and is exfoliated. A piece of bone varying from half an inch to 3 inches is thus thrown off. The process of separation of the bone by ulceration is extremely slow. It may extend over months or years if the bone is not surgically treated, and all this time there is a constant oozing of pus into the mouth of the patient, some of which must be swallowed along with the food, thereby undermining the health and causing anemia or cachexia, or during sleep it may trickle down the throat into the respiratory passages and set up an unhealthy inflammation of the lining membrane, or it indirectly prepares the way for tubercular disease of the lungs. Either jaw may become necrosed. If anything, the inferior maxilla is more frequently affected than the superior. When the upper jaw is diseased there is a tendency for the inflammation to extend to the base of the skull and to induce a septic inflammation of the membranes of the brain, which is invariably fatal.<sup>14</sup>

In discussing the treatment of phosphorus necrosis among matchmakers, Oliver also gives the percentage of cures claimed by the advocates of the various methods. Doctor Garman, of Bow, treating his cases by the expectant method and allowing the sequestrum to be naturally separated, found that 83 per cent of his cases recovered; the practice of Kocher, of Berne, was to remove by a surgical operation the affected portion of bone, and 83.7 per cent of his cases recovered; while Kniper, of Jena, treating his patients on similar lines to Kocher, had 89 per cent of recoveries.<sup>15</sup>

#### MANUFACTURE OF PHOSPHORUS FIREWORKS IN UNITED STATES

Phosphorus fireworks were probably introduced into the United States about 1904, when two patents were taken out for this type of pyrotechnical compound, one (No. 759387, May 10, 1904) by Marius Magnard, a citizen of the French Republic, and the other (No.

<sup>14</sup> Oliver, Thomas: *Dangerous Trades*. London, John Murray, 1902, pp. 423, 424.

<sup>15</sup> *Idem*, p. 426.

775822, November 22, 1904) by Karl Hufnagel, of Germany;<sup>16</sup> the latter patent was assigned to Edward H. Wagner, of New York City, and was later bought by one of the companies now manufacturing phosphorus fireworks.

A pyrotechnist began making experiments in detonating fireworks, containing white (yellow) phosphorus, about 1904, and started to manufacture on a small scale in Belleville, N. J., later moving to Erie, Pa. His product—called at that time “crazy crackers”—was sold mostly in the South. About 1908 he was manufacturing phosphorus fireworks near Newark, N. J. In 1917 he was making the same type of fireworks, under the name of “automatic torpedoes,” at a large fireworks plant. Later he manufactured a similar product, under the name of “spit devil” in another State. In each instance, though the trade name varied, the composition was almost identically the same.

About 1904 the present superintendent of one of the factories manufacturing phosphorus fireworks, who claims to have been the first to make detonating fireworks containing phosphorus, started to manufacture them in St. Louis, and later in Memphis, Tenn., and in 1905 took charge of the fireworks factory where he is now superintendent.

Of the three factories now using white (yellow) phosphorus in manufacturing fireworks, one began to make this type of fireworks in 1905, the second about 1909, and the third about 1918.

#### DESCRIPTION OF PHOSPHORUS FIREWORKS

Phosphorus fireworks are, in general, small disks about one-eighth to one-quarter of an inch thick and 1 inch in diameter, with a covering of red or black paper, though in some instances sand has been used for a coating and sometimes a black composition coating of pitch and naphthalene has been employed. Occasionally, larger sizes,  $1\frac{1}{2}$  or 2 inches in diameter, are made. These detonating fireworks are discharged by being placed on the sidewalk and then struck by the heel or some heavy object, causing them to explode with considerable noise in a series of explosions in rapid succession, at the same time giving out bright flashes of light and jumping from place to place. During the explosion a slightly luminous flame is given off and the characteristic odor of phosphorus can be noticed.

One firm manufactures also a toy called a “tank,” which consists of a small gray pasteboard container, imitating a tank, and holding a combustible carrier sheet of tissue paper on which are mounted 30 small pastilles of the phosphorus compound, arranged at regular intervals. The fireworks are ignited by a fuse attached by an adhesive to the carrier sheet, and extending through a hole in the top of the tank. This toy explodes in the same manner as the other phosphorus fireworks.

The jumping jack made by the same firm and labeled a “Box of concentrated noise” is a similar toy, consisting of a small red pasteboard box about  $1\frac{3}{4}$  inches square with a large circular opening in the top through which the carrier sheet is ignited. The carrier sheet

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<sup>16</sup> This formula is reported to have been patented in Spain.

is similar to that in the tank, except that it has 24 instead of 30 pastilles.

Various names are given to these detonating fireworks. One factory calls its product a "spit-devil"; another uses the trade name of "son-of-a-gun," and also manufactures the "automatic torpedo"; still a third uses the name "devil-on-the-walk," and, for a slightly different form of fireworks, "jumping jacks" and "tanks". This toy is popularly called in the South "dancing devil"; and occasionally "nigger chaser," but erroneously, for that is a patented name of another type of fireworks. "Crazy cracker" and "Dixie cricket" are names that have been applied to the same type of fireworks but are no longer in use. "Holy terror stick" has also been used.

"Bingoes," "cracoes," and "flappers" are also designations used for phosphorus fireworks.

#### COMPOSITION OF PHOSPHORUS FIREWORKS

The formula for the pyrotechnical compound as given in Patent No. 775822, which was assigned to Wagner, consists of the following constituents: White (yellow) phosphorus, 1 part; red phosphorus, 1 part; potassium chlorate, 3 parts; red clay, 2 parts; and gum arabic, 5 parts. The composition of the phosphorus fireworks made in one of the plants studied is given as follows: Gum arabic sirup, 10 quarts; phosphorus, 1 pound, 14 ounces (7 sticks); magnesia, 3 pounds, 6 ounces; red mineral, 5½ pounds; and chlorate of potash, 6 pounds. Still another factory uses the following formula: Gum arabic, 40 pounds; white phosphorus, 7¾ pounds; carbonate of magnesium, 13¼ pounds; red ocher, 22 pounds; and chlorate of potash, 25 pounds.

A more recent patent (No. 1433100) taken out October 24, 1922, it is claimed, prevents the irritating acid fumes which phosphorus gives off when it oxidizes in the presence of air, by combining phosphorus with certain organic bases of high boiling point which take up or absorb the fumes of phosphoric oxide as formed and neutralize them, while serving at the same time to protect the phosphorus against too ready an oxidation.

Broadly stated, the nonfuming phosphorus composition consists of a mixture of 32 parts phosphorus, 2 parts of alphanaphthylamine, and 4 parts of dimethylaniline. To mask the slight odor of the organic bases, a small quantity of a fragrant essential oil, such as oil of sassafras, may be added to the composition. The composition may be used by itself or in admixture with chlorate of potash and the other ingredients usually employed for matchmaking compositions and for certain types of pyrotechnical devices. The claim is made that this compound is safer and less injurious than the others to handle industrially.

Chemical analysis of three samples of one type of phosphorus fireworks showed: In the first, 5 per cent of phosphorus, equivalent to 2.91 grains; in the second, 3.97 per cent of phosphorus, equivalent to 2.44 grains; and in the third, 6.50 per cent of phosphorus, equivalent to 4.63 grains.

In analyzing another type of phosphorus fireworks, weighing 3.50 grams, 0.2128 grams of phosphorus were found, or 6.08 per cent.

An analysis of a third type of phosphorus fireworks showed 4.39 per cent phosphorus, or 0.0966 grams of phosphorus, where the total weight was 2.20 grams.

#### PROCESS OF MANUFACTURE

The manufacture of phosphorus fireworks consists of five processes—the preparation of the paste or mixture, molding, drying, wrapping, and packing.

The preparation of the paste, or "soup" as it is sometimes called, varies little in the three factories. The composition is mixed in a double-jacket kettle with automatic paddle. Gum arabic and water are dissolved to a syruplike consistency, and white (yellow) phosphorus is added when the solution is heated enough to melt it. Carbonate of magnesium is then stirred into the mixture and later red ochre is added, and finally chlorate of potash is thoroughly stirred into the preparation.

Usually only one person—a man—is employed in mixing, and since the machinery is now automatic there is not the constant contact with the fumes that there was in the earlier days when the stirring was done by hand. The mixer usually dips out the paste from the kettle into a large bucket or pan, and sometimes carries it to the molding room as needed, or puts it into a shed out of doors easily accessible to the molders. In only one factory was there any ventilating system in the mixing room to carry off the "fume," and that was out of order the day the plant was visited. The odor usually associated with phosphorus is quite noticeable in the mixing room, and some fume is always rising from the paste. Only one mixer has developed phosphorus necrosis, however.

After the paste has cooled it is molded into lozenges, wrapped, and dried ready for packing. By a newer method, partly automatic, which is in use in two plants, the order of the above processes is reversed, the toy being first molded, then dried, and finally wrapped. This process has not yet been patented and is a trade secret.

The older process, at one time used by all three plants manufacturing this type of fireworks and still employed in one factory (plant No. 3), combines the molding and wrapping process, these being done almost simultaneously by one worker. The worker (women are usually employed on this process) fills a small pan with the paste and places it on the table in front of her. Over a cardboard about 8 by 12 inches she places the mold, usually an aluminum plate, with holes the size of the lozenge desired. With a spoon, flattened at the bowl end, the molder dips out the proper amount of paste, places it on a square of red or black tissue paper, which has been fitted into the mold, and folds the paper over securely. While the worker is closing the tissue paper at the top with one hand, with the other she reaches for another dip of the paste. When the mold is filled she lifts it off the cardboard, leaving the completed lozenges, which are then placed at one side. After being counted and checked, the disks are taken to the drying room opening into the molding room, where woman workers spread the damp lozenges on wire screening to dry. The finished product is packed in sawdust in small pasteboard containers by women, and these are later packed in large wooden boxes for shipping.

**WORKING CONDITIONS IN THE FIREWORKS INDUSTRY****VENTILATION**

Ventilating apparatus to remove the dangerous fumes assists in lessening the hazard. In only one plant (No. 2) covered by the bureau's survey, however, was an exhaust system in use. This factory had outside one window of the wrapping room a 30-inch ventilator connected with an electric motor. One large pipe, extending from the ventilator over the wrapping table, divided into six small pipes which in turn branched into two arms, one going to each side of the table where the girls were wrapping the fireworks. In the molding room of this factory a 24-inch (York) fan was installed; in the mixing room there was an 18-inch fan but it was not operating the day the plant was visited. The ventilating engineer who installed the system claimed that the air in the room could be changed every five minutes, but the manager stated that the air was changed every minute after improvements in the system had been made.

All of the plants had many windows in almost every room, and doors and windows were kept open as much as possible. (The plants were visited in mild weather, when this method of ventilation was possible.) The mixing in one factory was done in a semiinclosed shed, and after the composition had been mixed the buckets were kept in another shed out of doors where they were accessible to the molders who filled their pans there.

**WASHING AND LUNCH-ROOM FACILITIES**

It is possible that, in addition to the fume, particles of phosphorus paste carried by the hands to the mouth also constitute a danger. Since it is important to have hands thoroughly clean before eating, there should be proper arrangements for washing. The phosphorus-fireworks plants are situated in small villages or on the outskirts of towns, and sanitary equipment is inadequate; toilets are located out of doors, and washing facilities are meager. In one factory an outside hydrant is the only place for washing; in another plant a long trough with running water is generally used for getting rid of the particles of phosphorus. On the day the plant was visited water of a deep red color from the phosphorus paste was standing in the trough. It was stated that the trough was cleaned out every noon, but when a second visit was made in the afternoon conditions were the same. Soft soap was furnished in two plants, and paper towels in one and waste in the other, for drying the hands. On the day the former plant was visited, the paper-towel cabinet was empty.

One of the essentials in a plant where dangerous chemicals are used is a separate lunch room. No such provision was made in the plants studied, except that one establishment had a small cloak-room where lunches could be eaten. One employer said a lunch room had been provided, but had not been used and had therefore been taken over for other purposes. The employees were told not to eat in the rooms where they worked, and in good weather usually ate out of doors, but admitted that in bad weather they sometimes ate inside. Many workers went home to lunch.

## DENTAL AND MEDICAL CARE

Since phosphorus necrosis seems in most cases to occur when the workers have decayed teeth, dental care in the factory is very important. One plant furnishes a mouth wash (Dakin's solution) to its employees, and another provides bicarbonate of soda to be used at home. In two plants dental service is provided by the companies and it was claimed that regular inspections were made of all employees' teeth. In practice, however, the visits of the dentist do not seem to be so frequent as was originally intended. Those needing dental treatment are given it without charge. The dentists are given careful instructions to refer any employee who shows the slightest tendency to develop a necrosed condition to a specialist whom the plant pays. One factory estimated that two years ago the dentist's bill was \$1,700 and last year \$1,500. Another plant paid its dentist \$500 in one year.

Workers who have teeth extracted and returned to work before the jaw has healed seem peculiarly liable to phosphorus necrosis. The plant which does not employ a dentist does not permit its employees to return to work after extraction of a tooth until the wound is completely healed. The manager of this plant stated he had not known the work was dangerous until one girl who had had a tooth extracted contracted phosphorus necrosis and died.

No physical examinations are given to workers at the time of employment and there is no systematic medical inspection. One factory which employs a medical officer reported that during a period of four months 15 accidents occurred in the whole plant; of these 3 occurred in the phosphorus department, as did also 4 cases of infected fingers due to alkaline silicate of soda finding its way under the finger nail. There was also one arrested case of tuberculosis in the phosphorus department, coming from a family in which there is active tuberculosis, and an active case of pulmonary tuberculosis in another department, coming from a family having several deaths from this disease. Another factory sends its employees to be examined by the Life Extension Institute. This plant has the services of the local health officer when needed.

## HAZARD

The greatest hazards in the use of white (yellow) phosphorus are connected with processes where workers are exposed to the fumes of phosphorus. These fumes, which are given off in the process of oxidation, consist chiefly of phosphoric oxide, some phosphorus oxide, and phosphorus.

The older method of combined molding and wrapping is the most hazardous process in the manufacture of phosphorus fireworks. In the plant where this method is still used it was found that the women were paid on a piece-rate basis and, in order to increase their earnings, often sat close to the table with heads bent over their work in their eagerness to complete as large a number of fireworks as possible. A rag was kept on the table beside each worker to remove any particles of phosphorus paste which clung to the hands. Though the women washed these rags, they said, many times a day, fumes were continually rising from them, as well as from the pan of "soup," and

the characteristic odor of phosphorus could be plainly detected the day the plant was visited, although the doors and windows were wide open.

In this same plant where it is the practice to have the damp lozenges spread out to dry by woman workers, the drying room, which opens into the molding room, offers somewhat of a hazard.

The packing of phosphorus fireworks offers practically no hazard, except possibly a slight danger of explosions.

The danger from explosion and fire has caused the fireworks manufacturers to build, instead of one large plant, a number of small detached, usually fireproof buildings. One plant has 22, another 25 small buildings. Most of the plants had a separate room and in some cases a separate building for practically every process. The mixing is always done in a separate building, for the danger from explosion constitutes a particular hazard in the mixing room, though actual explosions are infrequent.

There are no signs in any of the three plants to warn the workers of the danger, except occasional labels similar to the ones pasted on the small pasteboard boxes, in packing, containing the following words:

*Phosphorus*

Poison, if swallowed.

Antidote: Give emetics and purgatives.

Do not give milk, eggs, fats, or oils.

Secure medical treatment immediately.

This warns the worker of the danger of acute phosphorus poisoning, but of the danger of chronic poisoning and the necessary precautions against it no notice is posted. Such instructions and warnings were given verbally, it was claimed.

In all the plants the employees for the most part now realize that the work is dangerous, and that there is a possibility of contracting "phossy jaw," though in the earlier days of the manufacture of phosphorus fireworks the workers were usually ignorant of the hazard. Several workers who have developed phosphorus necrosis have brought claims for compensation or damages, and their cases are known to practically all their fellow employees.

**WAGES**

Workers in phosphorus processes are usually paid higher wages than are paid to workers in nonphosphorus processes, on account of the hazard. In some cases the increased earnings make the worker willing to risk contracting phosphorus poisoning. In one plant, employees who are still under treatment for phosphorus necrosis and are now working in nonphosphorus processes, stated frankly they would go back "to-morrow" to the phosphorus process, if the doctor would permit, in order to increase their earnings. Some of the former workers in the other two plants, however, who had contracted phosphorus necrosis declared they never wanted to go near the plant again, and would never have started to work there if they had known there was a possibility of contracting such a disease.

In one of the establishments, which employed 145 women and 143 men in the entire plant, of whom 22 women and 12 men worked in

the phosphorus processes, the average wage in the phosphorus department was \$27.50 for the women (who were paid piece rates) and \$23.50 for the men (who were paid by the hour); in the other departments the women averaged \$15.50, \$17, and \$19 per week, and the men \$20.50, \$21, and \$22 per week.

In another plant the average wage for the woman pieceworkers in the phosphorus department was \$21 per week and in the other departments \$18.75. The men were paid by the hour, at rates of from 25 cents to 50 cents.

In the third factory the highest wage earned by pieceworkers in phosphorus processes was \$12.25 per week, the next highest \$9.80, and several earned between \$8 and \$9. The women, who were paid by the hour, received 12 cents an hour for making phosphorus fireworks, while the packers, who also had some supervisory duties, were paid 25 and 27 cents per hour; the men in the plant were paid 40 and 45 cents an hour.

The hours of work were 55 per week in two plants and 50 per week in the third. The work is somewhat seasonal in two plants; during July and August no phosphorus fireworks are made; a small force is put on from September to January, while the full force is almost always engaged from January to June.

One method of reducing the hazard to workers in phosphorus is to transfer them at intervals to processes where there is no contact with the poison. In one factory this method was used with the men but not with the women employed; in the other two factories no attempt was made to transfer the workers, the manager of one of these stating that the reason this was not done was that the plant manufactured phosphorus fireworks for part of the year only. In all three plants, whenever workers had a tooth extracted they were either transferred to a nonphosphorus department until the wound healed or were kept out of the plant altogether until the danger was past.

#### LENGTH OF EMPLOYMENT IN PLANT AND ON PHOSPHORUS PROCESSES

The workers in the three fireworks plants were interviewed while at work, and information was obtained regarding the length of time they had been employed in the plant and on the phosphorus process, their age, and nativity. These data are shown in the table on page 14.

Of the 71 workers engaged in manufacturing phosphorus fireworks at the time of the study, 15 were men and 56 were women. There were 15 colored and 56 white workers in the departments using phosphorus. All except two had been born in the United States.

Only 10 workers had been employed in the phosphorus departments three years or over, while 20 had been working one month or less, 14 had been working with phosphorus for one month but less than six months, 10 for six months but less than one year, and 17 for one year but less than three years. Only 1 worker in the manufacture of phosphorus fireworks was over 50 years old; 18 were between 25 and 50 years; 45 were between 18 and 25; and 7 employees were under 18 years.

# 14 PHOSPHORUS NECROSIS IN MANUFACTURE OF FIREWORKS

## AGE, SEX, RACE, OCCUPATION, AND LENGTH OF EMPLOYMENT OF WORKERS EXPOSED TO PHOSPHORUS

[F.=female; M.=male; W.=white; N.=Negro]

Plant and employee	Age	Sex	Color	Occupation	Length of employment in—	
					Factory	Phosphorus process
<b>Plant No. 1:</b>						
Employee No. 1.....	18	F.	W.	Wrapper.....	15 months.....	15 months.
Employee No. 2.....	18	F.	W.	do.....	18 months.....	18 months.
Employee No. 3.....	18	F.	W.	do.....	15 months.....	15 months.
Employee No. 4.....	18	F.	W.	do.....	3 months.....	3 months.
Employee No. 5.....	20	F.	W.	do.....	15 months.....	15 months.
Employee No. 6.....	18	F.	W.	do.....	2 years.....	2 years.
Employee No. 7.....	18	F.	W.	do.....	4½ years.....	4½ years.
Employee No. 8.....	15	F.	W.	do.....	1½ years.....	1½ years.
Employee No. 9.....	15	F.	W.	do.....	1 year.....	1 year.
Employee No. 10.....	29	F.	W.	do.....	4 years.....	3 years, 10 months.
Employee No. 11.....	15	F.	W.	do.....	7 months.....	7 months.
Employee No. 12.....	44	F.	W.	do.....	6 months.....	3 months.
Employee No. 13.....	18	F.	W.	do.....	1 day.....	1 day.
Employee No. 14.....	18	F.	W.	do.....	7 months.....	7 months.
Employee No. 15.....	19	M.	W.	Molder.....	3½ years.....	3 years, 5 months.
Employee No. 16.....	17	M.	W.	do.....	2 months.....	½ month.
Employee No. 17.....	45	M.	W.	do.....	2 years.....	2 days.
Employee No. 18.....	15	M.	W.	do.....	2½ weeks.....	1½ weeks.
Employee No. 19.....	20	M.	N.	Mixer.....	6 months.....	5½ months.
<b>Plant No. 2:</b>						
Employee No. 1.....	21	F.	W.	Wrapper.....	3 years.....	2½ years.
Employee No. 2.....	24	F.	W.	do.....	do.....	2 years, 11½ months.
Employee No. 3.....	33	F.	W.	do.....	4 months.....	4 months.
Employee No. 4.....	43	F.	W.	do.....	5 weeks.....	5 weeks.
Employee No. 5.....	26	F.	W.	do.....	8 weeks.....	8 weeks.
Employee No. 6.....	18	F.	W.	do.....	2 weeks.....	2 weeks.
Employee No. 7.....	19	F.	W.	do.....	4 years.....	3 years.
Employee No. 8.....	25	F.	W.	do.....	do.....	3 years, 11 months
Employee No. 9.....	19	F.	W.	do.....	2 months.....	2 months.
Employee No. 10.....	19	F.	W.	do.....	do.....	Do.
Employee No. 11.....	19	F.	W.	do.....	6 weeks.....	2 weeks.
Employee No. 12.....	19	F.	W.	do.....	2½ years.....	1½ years.
Employee No. 13.....	35	F.	W.	do.....	3 months.....	3 months.
Employee No. 14.....	21	F.	W.	do.....	do.....	Do.
Employee No. 15.....	18	F.	W.	do.....	3 weeks.....	3 weeks.
Employee No. 16.....	18	F.	W.	do.....	do.....	Do.
Employee No. 17.....	18	F.	W.	do.....	½ week.....	½ week.
Employee No. 18.....	18	F.	W.	do.....	1 year.....	10 months.
Employee No. 19.....	40	F.	W.	do.....	1 week.....	1 week.
Employee No. 20.....	18	F.	W.	do.....	do.....	Do.
Employee No. 21.....	24	F.	W.	do.....	do.....	Do.
Employee No. 22.....	23	F.	W.	do.....	2 years.....	2 weeks.
Employee No. 23.....	19	F.	W.	do.....	5 months.....	5 months.
Employee No. 24.....	22	F.	W.	do.....	2 years.....	1 year.
Employee No. 25.....	42	F.	W.	do.....	2 months.....	2 months.
Employee No. 26.....	19	F.	W.	do.....	1 day.....	1 day.
Employee No. 27.....	20	F.	W.	do.....	1 week.....	1 week.
Employee No. 28.....	34	F.	W.	do.....	1 month.....	1 month.
Employee No. 29.....	73	M.	W.	Assistant mixer and porter.	1½ years.....	6 months.
Employee No. 30.....	18	M.	W.	Porter.....	7 months.....	2 months.
Employee No. 31.....	30	M.	W.	Molder.....	3½ years.....	2 years.
Employee No. 32.....	24	M.	W.	do.....	6 months.....	6 months.
Employee No. 33.....	36	M.	W.	do.....	do.....	Do.
Employee No. 34.....	46	M.	W.	do.....	6 weeks.....	6 weeks.
Employee No. 35.....	19	M.	W.	do.....	6 months.....	6 months.
Employee No. 36.....	19	M.	W.	do.....	7 months.....	1 week.
Employee No. 37.....	22	M.	W.	Mixer.....	4 years.....	2 years.
<b>Plant No. 3:</b>						
Employee No. 1.....	37	F.	N.	Molder and wrapper.	3 years.....	3 years.
Employee No. 2.....	22	F.	N.	do.....	5 years.....	4 years.
Employee No. 3.....	18	F.	N.	do.....	3 weeks.....	3 weeks.
Employee No. 4.....	28	F.	N.	do.....	4 years.....	4 years.
Employee No. 5.....	23	F.	N.	do.....	9 months.....	3 weeks.
Employee No. 6.....	22	F.	N.	do.....	2½ years.....	6 months.
Employee No. 7.....	18	F.	N.	do.....	2 years.....	Do.
Employee No. 8.....	18	F.	N.	do.....	do.....	1½ years.
Employee No. 9.....	17	F.	N.	do.....	1 year.....	1 year.
Employee No. 10.....	20	F.	N.	do.....	1½ years.....	1½ years.
Employee No. 11.....	17	F.	N.	do.....	1 year.....	1 year.
Employee No. 12.....	37	F.	N.	Drier.....	2 months.....	1 month.
Employee No. 13.....	18	F.	N.	do.....	3 years.....	3 years.
Employee No. 14.....	(1)	F.	N.	do.....	1 year.....	11 months.
Employee No. 15.....	25	M.	W.	Mixer.....	10 years.....	About 10 years.

<sup>1</sup> Over 18 years of age.

## PREPARATION OF WHITE (YELLOW) AND RED PHOSPHORUS

In preparing white (yellow) phosphorus the process consists, as a general rule, of mixing crushed phosphate rock, coke, and sand in electric furnaces which are heated to a high temperature—1,700 or 1,900° C. The process is a continuous one; the phosphorus passes off at the top into a water condenser, where it becomes solid in the form of small crystals; the rest of the material in the furnace is usually run out at the bottom in the form of slag.

The phosphorus is transferred under water to a steam-jacketed kettle, where it is melted. It is then siphoned into another steam-jacketed kettle, treated with acid, filtered through a heavy canvas, and siphoned into another tank, from which it is dipped and poured into molds consisting of a series of brass tubes. Since the phosphorus is heavier than water, it sinks to the bottom of the tube and the water stays on top. During the filtering process, the molds are placed in hot water until filled, the mold being then lifted out and placed in cold water where the phosphorus is solidified in the form of a yellow stick. These sticks are pushed out of the mold under water and are then taken out and packed in tin cans by hand, and the can is filled up with water and the top soldered on. The sticks as they come out of the water are covered with a film of water, and this has to dry off before the atmosphere will affect the phosphorus. If the work is done rapidly a man has plenty of time to get the phosphorus out of the tank and into the can before any fumes whatever are given off, but it would not do for the man to hold the stick in his hand very long.

In preparing the red, or so-called amorphous, phosphorus, generally the yellow phosphorus in liquid form is dipped out into a bucket together with water, so that the liquid is under water all the time, and taken to an electric heater where the water is driven off and the phosphorus is heated to 288° C., in the absence of air. Under these conditions, it is gradually converted into phosphorus. The red phosphorus is then chipped out of these heating pots, put into a revolving crusher, and ground up into a mudlike substance. This substance is then treated for acid and pumped into a filter press and the water is squeezed out of it. Any remaining moisture is taken out in a vacuum drier. The material as it comes from the drier is crushed by a wooden roller and packed in cans in the form of a dry powder.

There are only two phosphorus-extraction plants in the United States, and one of these has been closed since November, 1920. No red phosphorus is being transformed from yellow phosphorus in the United States at the present time; the entire amount used is imported. About 10,000 pounds of yellow phosphorus a week were prepared at one plant in 1918, 1919, and 1920. Some 32 men were employed in this plant normally and 45 at the time of greatest production. Working conditions were fairly good in this plant. The lavatories had three toilets and two washstands, and in addition two bathtubs were provided. The men were warned not to eat without thoroughly washing their hands, and were advised to keep their teeth in good condition, since the poison seemed to enter the system primarily through decayed teeth, or through the jaw where a tooth

had been extracted. A dentist had examined the employees at intervals, but there was no regular dental inspection.

In the other plant the following notice was posted in Spanish, Italian, Polish, and English, at three separate places—at the entrance gate, in the plant, and in the wash room:

*Notice*

It is important that all the men working in the phosphorus plant and in plants where phosphorus is used keep their teeth clean and in good condition. The company's dentist will examine all such men every three months, and repair any defective teeth. In the case of any man having trouble with his teeth during the period between examinations, the same should be reported to the foreman, who will have the dentist attend to them at once.

The teeth should be cleaned at least once every day by scrubbing thoroughly with a brush.

Since the sign was posted dental inspections have been made more frequently.

Twenty-five per cent of the employees of this second plant have worked there more than six years and 85 per cent have been employed over one year. Almost since the plant was started (over 25 years ago) regular dental inspections have been made and repairs to teeth have been taken care of at the firm's expense. This constant care probably has been an important factor in reducing the hazard from phosphorus poisoning.

#### CASES OF PHOSPHORUS NECROSIS

The table below contains the data gathered as regards cases of phosphorus necrosis which have occurred among the employees of three fireworks plants and of the factory formerly preparing both yellow and red phosphorus but which had not been operating for the past five years.

In the fireworks industry 13 of the 14 cases were women. This is probably due to the fact that women were employed in larger numbers in the process which demanded constant exposure to the fume rising from the pans of phosphorus paste. The fourteenth case, a man, was a mixer. Very few men (usually one man with sometimes an assistant) are employed in this process.

In the match industry, phosphorus poisoning seems to be slow in onset.<sup>17</sup> Among the fireworks employees who had developed phosphorus necrosis, however, one worker had been employed in the plant during a period of over two years, had worked in the phosphorus process at intervals, aggregating about three months altogether. Another had been exposed to phosphorus about six months. Several others had been working in phosphorus for two years or less, two workers for three years, two for five years, and only one for as long as six years.<sup>18</sup> Many of the colored workers were very indefinite about the time they had been working in the plant and on phosphorus, and

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<sup>17</sup> Hamilton, Alice: *Industrial Poisons in the United States*. New York, the Macmillan Co., 1925, p. 311.

<sup>18</sup> In England the workers cited by Oliver had been employed 7 to 15 years; in Germany a group of 82 matchmakers with "phossy jaw" had averaged 6.6 years' employment; another group of 87 had averaged 5 years. In Austria 41 cases were reported in men working from 11 to 20 years, and 13 for over 20 years. One of Lorinser's cases, however, had worked only 7 months.

as no record had been kept at the factory only the approximate time could be determined.

Two of the 14 cases in the fireworks industry were fatal, about 14 per cent of the total number. Doctor Hamilton gives the mortality of phosphorus necrosis as usually about 15 or 20 per cent.<sup>17</sup>

The duration of the disease, as given in the table, is perhaps not always accurate, since in the cases where dates of hospital records were not available it was necessary to rely on the memory of the worker or the worker's family. In case No. 9 the disease was particularly rapid, lasting only about six months before the patient succumbed; in the other fatal case the disease ran a little over a year.

In the fireworks industry, of the 14 cases, in 9 the necrosis developed in the lower jaw, in 4 in the upper, and in 1 case in both jaws.

The four cases occurring in the preparation of phosphorus were among men who had been employed in phosphorus processes from 3 to 12 years before necrosis developed. Three of these workers lost the entire upper jaw, and in one case the lower jaw is also affected and the patient seems to be in a serious condition; the fourth worker who developed "phossy jaw" lost part of the lower jaw on both sides and is still having minute particles of bone thrown off. No records from doctors or dentists recording the exact duration of the disease among the phosphorus extractors are available, and only approximate figures can be given.

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<sup>17</sup> Hamilton, Alice: *Industrial Poisons in the United States*. New York, the Macmillan Co., 1925, p. 311.

## AGE, SEX, RACE, OCCUPATION, DURATION OF EMPLOYMENT, PART AFFECTED, SEVERITY OF ATTACK, LENGTH OF ILLNESS, AND PRESENT CONDITION OF WORKERS WHO CONTRACTED PHOSPHORUS NECROSIS

[F.=Female; M.=Male; W.=White; N.=Negro]

Case	Age	Sex	Race	Occupation		Duration of employment in—		Part affected	Severity	Length of illness	Present condition
				In phosphorus process	Present	Factory	Phosphorus process				
Case No. 1...	22	F.	W.	Molder and wrapper.	None.....	5 years....	5 years....	Right and left upper jaw.	Severe..	Sept., 1922, to June, 1924...	Part of jaw gone. In good health.
Case No. 2...	20	F.	W.	.....do.....	Fireworks, nonphosphorus.	18 months.	18 months.	Lower jaw....	Slight...	About Oct., 1923, to Mar., 1924.	In fair health.
Case No. 3...	19	F.	W.	.....do.....	None.....	.....do.....	.....do.....	Left upper, right lower jaw.	Severe..	Mar., 1923, to June, 1924....	Some deformity. In fair health.
Case No. 4...	19	F.	W.	.....do.....	.....do.....	17 months.	17 months.	Right and left lower jaw.	Very severe.	Mar., 1923, to present.....	In hospital; condition serious.
Case No. 5...	24	M.	W.	Mixer.....	Unknown....	About 2 years.	Less than 3 months.	Lower jaw....	Slight...	Mar. 18, 1924, to 1925.....	Unknown.
Case No. 6...	28	F.	W.	Molder and wrapper.	Fireworks, nonphosphorus.	3 years....	22 months.	Right upper jaw.	Moderate.	Jan. 8, 1925, to present.....	1 small necrotic area still exists.
Case No. 7...	18	F.	W.	.....do.....	.....do.....	2 years....	1½ years....	Left lower jaw.	Slight...	June 17, 1924—May, 1925....	No deformity. Cured.
Case No. 8...	21	F.	N.	.....do.....	.....do.....	About 6 years.	About 6 years.	Upper jaw....	Fatal...	—, 1919, to Oct., 1920....	
Case No. 9...	22	F.	N.	.....do.....	.....do.....	2 years....	2 years....	Lower jaw....	.....do.....	Sept. 7, 1921, to Mar. 13, 1922	
Case No. 10...	25	F.	N.	.....do.....	School-teacher	About 9 months.	About 6 months.	.....do.....	Slight...	2 years.....	In good health.
Case No. 11...	21	F.	N.	.....do.....	General housework.	17 months.	14 months.	Right upper jaw.	Moderate.	—, 1920, to summer of 1923.	Slight deformity. Cured.
Case No. 12...	21	F.	N.	.....do.....	None.....	3 years....	3 years....	Lower jaw....	.....do.....	Mar., 1923, to present.....	Under treatment.
Case No. 13...	21	F.	N.	.....do.....	.....do.....	5 years....	5 years....	.....do.....	.....do.....	Apr., 1925, to present.....	Secondary infection, not arrested.
Case No. 14...	22	F.	N.	.....do.....	.....do.....	3 years....	3 years....	.....do.....	Slight...	May, 1925, to present.....	Under treatment.
Case No. 15...	55	M.	W.	Dipper.....	Railroad....	10 years....	About 10 years.	Upper jaw....	Moderate.	About 4 or 5 months in 1912.	Upper jaw gone. In good health.
Case No. 16...	50	M.	W.	Grinder and sciver of red phosphorus	Paper mill..	3 years....	About 3 years.	.....do.....	.....do.....	Apr., 1916, to 1917.....	Upper jaw gone. In fair health.
Case No. 17...	34	M.	W.	Weighter of yellow phosphorus.	.....do.....	6½ years.	4½ years.	Both sides of lower jaw.	.....do.....	Several years.....	In fair health. Particles of bone still being thrown off.
Case No. 18...	64	M.	W.	Mixer, 8 years; refining yellow phosphorus, 4 years.	None.....	12 years....	About 12 years.	Upper and lower jaw.	Very severe.	July, 1920, to present.....	Continually getting worse.

**MEDICAL HISTORIES**

The medical histories, abstracts of which are given below, of the 14 cases which occurred among the employees in the three fireworks plants studied were obtained from hospitals, doctors, and dentists. In some of the earlier cases records had been lost or the attending physicians had died, and the histories are therefore not so complete as later ones. There were instances where a dentist thought he remembered a case of "phossy jaw" many years back, but no corroborating records could be secured, and such cases were therefore ignored as being too vague. In one factory, many of whose workers were from out of town and simply boarded in the village, fellow employees spoke of girls who had been taken ill and had gone home, but as the location of their homes could not be ascertained the nature of the illness could not be learned. In another plant a worker died of pneumonia at the local hospital and one of the hospital physicians thought there was a connection between the occupation and the disease, but neither the hospital nor the death record sustained this theory, so it was not included among the cases described below.

The four cases in one plant extracting phosphorus developed five years ago, before the plant closed down, and the attending physicians and dentists had in most instances moved away or died or had destroyed their records. Some of the workers affected, however, had preserved the parts of the jaw which had loosened and come off, in some cases the entire shell; that is, the roof of the mouth and the upper jaw.

In the other plant preparing phosphorus, one man who had a diseased antrum (but not "phossy jaw," according to the attending physician) from which pus oozed had died the year before the bureau's investigation was made. Another employee had had a slight case of necrosis many years ago, involving the curettement of the sockets of two teeth. The physician who treated most of the illnesses at the plant said there might be some doubt whether this necrosis was caused by phosphorus. These were the only two cases of possible necrosis that had occurred in the plant during the 20 or 25 years it had been running, according to the statements of the manager, of the plant dentist who had been in attendance at regular intervals almost since the time it had been started, and of the physician who had been called in for a number of years for any case of illness at the plant. The manager attributed the freedom from chronic phosphorus poisoning to the regular dental inspections and the compulsory dental care given to any whose teeth were defective.

**PLANT NO. 1****Case No. 1**

Age, 22; white; female.

Length of time exposed to phosphorus, five years.

The hospital records showed that the patient entered the hospital on January 30, 1923, having an extensive necrosis of the right side of the upper jaw and a smaller area of involvement in the left side. She had been operated upon four months previously, with no results. She was 20 years old, had been working in a fireworks factory, had had no injuries and no previous illnesses except measles, weighed 100 pounds at time of entering the hospital and 115 pounds six months previously.

A smear revealed the presence of large numbers of fusiform bacilli of Vincent. It appears to be characteristic of extensive osseous infections of the

jaw that the Vincent's organisms, both the fusiform bacilli and the spirilla, are present in abundance. "They are undoubtedly secondary to the original infection, but become markedly active as the disease progresses." To combat this, neosalvarsan was administered at first locally, then intravenously.

On February 6 large sequestra on the left side were removed, together with several teeth, and from time to time until December 1 smaller sequestra were exfoliated. Irrigation several times a day with very weak iodine solution and sodium bicarbonate was advised.

During all this time there was a marked and persistent anemia, the patient's hemoglobin falling as low as 40 per cent and her blood sugar as low as 50 milligrams per 100 cubic centimeters.

"The differential diagnosis of phosphorus necrosis, concerning which medical literature is practically a blank, seems to be that the line of demarcation, so universally apparent in all forms of necrosis except osteomyelitis, is entirely missing, and there is a marked eburnation, instead of the soft and cheesy condition of the osseous structure involved."

On December 1, 1923 an operation—a subperiosteal resection of entire upper jaw—was performed. The anterior tip of the soft tissue overlying the hard palate was sutured to the anterior central mucous surface.

Six months later she was supplied with a full set of artificial teeth and has been in apparently perfect health ever since.

#### Case No. 2

Age, 20; white; female.

Length of time exposed to phosphorus, 18 months.

The patient was admitted to the hospital February 5, 1924. The sequestrum was removed and there was a slight curettement.

The report of the dentist who had attended her showed that pressure on the lower jaw caused the appearance of pus through fistula, and that there was some granulating tissue in the region of a socket from which a tooth had been extracted.

#### Case No. 3

Age, 19; white; female.

Length of time exposed to phosphorus, 18 months.

The patient went to the hospital April 23, 1923, where a provisional diagnosis showed facial cellulitis and osteomyelitis of the jaw. She was 17 years old at that time. She had had an abscessed tooth removed prior to admission. The dentist had incised the swelling of the lower right jaw, but as this gave no relief the patient was advised to enter the hospital. Two incisions were made along the border of the lower jaw, with the discharge of considerable pus, and drains were inserted. Hot poultices were applied and Dobell's gargle was used. The patient improved and was discharged from the hospital April 29, 1923.

The girl was readmitted to the hospital May 8, 1923. Operative findings were necrotic osteomyelitis of lower jaw (corroborated by X ray May 13). The bone was found to be necrotic and was curetted; a molar tooth was removed; bone was curetted also from the inside of the mouth. She was discharged May 23.

She was admitted a third time on August 4, complaining of swelling on right side of face, of a discharge from the mass externally, of discharge from the mouth, and of pain over the upper portion of the mass. (During her illness patient had lost 30 pounds.) Culture of smear of pus showed Vincent's organism on August 4, and on August 9 revealed fusiform bacilli and spirillum forms of Vincent's angina.

In operating, the bicuspsids of lower set of teeth were removed; an external incision was made along the lower jaw, the periosteum retracted, and the sequestrum removed. The floor of the mouth was reconstructed, obliterating the fistulous tract to the outside, and tissues were sewed in layers. A rubber tube was inserted in the lower angle. On September 4 a blood transfusion of 450 cubic centimeters of blood was given because of the patient's condition—white blood count very low and 45 per cent hæmoglobin with 1,710,000 red blood count. Patient received Alpine light treatment. She was discharged on December 19, 1923, in an improved condition.

She entered a hospital again March 4, 1924, with her face swollen and tender, complaining of slight pain on moving the jaw. Her blood count showed a slight increase in white corpuscles during a period of some seven days. Two large sequestra were removed from right lower jaw and one from left upper jaw, and the patient was discharged March 11, 1924.

## PLANT NO. 2

## Case No. 4

Age, 19; white; female.

Length of time exposed to phosphorus, 17 months.

According to the hospital record (April 8, 1923), the patient, though rather anemic and frail in appearance, stated that she had always been well and healthy, and had never had very much sickness of any kind. About two years before she had begun to work in a fireworks factory and almost ever since had been troubled with a cough. The complaint for which she was admitted to the hospital had begun several days before with a severe chill and a "stitch" in her right side. Her cough was dry and harsh, without any expectoration. Patient was treated for pneumonia, and was discharged April 18, 1923.

The report of the physician (November 20, 1924) stated that the girl had entered the fireworks factory in the latter part of November, 1921. At that time she was a well-developed country girl of 16 years, in excellent health, and with perfectly normal teeth. The first symptom observed by her, after having been exposed to fumes of phosphorus, was an irritating cough unaccompanied by any expectoration. (A large proportion of her fellow employees had a similar cough.) About January, 1923, she began to feel unusually tired, her appetite became impaired, and in March, 1923, two of her teeth showed signs of caries and had to be extracted. After extraction the wound did not heal and necrosis of the jaw began. This dental caries and subsequent necrosis of the lower jaw was bilateral and progressive. In April, 1923, she developed considerable fever and was confined to bed for about two weeks. Later, the fever subsided and she again returned to work in the factory and continued to handle the phosphorus paste until June, 1923. In September, 1923, she came to the dispensary of the hospital and was examined by Doctor H. At that time several of the lower teeth had become loosened and extensive necrosis of right and left lower jaws had occurred. Doctor H. diagnosed the condition as "phossy jaw," which diagnosis was concurred in by Doctor L. Shortly after her admission to the hospital Doctor L. operated, removing all her loose teeth and thoroughly curetting the necrosed bone. Various hygienic and medicinal measures were instituted and three subsequent operations were performed, but the necrosis continued to progress, unaffected by any treatment. More than 18 months have elapsed since the necrosis first began about the molar teeth and 14 months since the first operation, but the condition shows no sign of being arrested and there is every reason to believe that the entire lower jaw will be destroyed. The case first came under the personal observation of the reporting physician in November, 1923, when it was considered advisable to investigate the case from the standpoint of the internist. At that time the patient had lost considerably in weight, could swallow food only with great difficulty, exhibited a profound anemia and had a septic type of fever, reaching 103° to 104° daily.

The examination of the lungs revealed no abnormal signs, and the results of the X-ray examination were negative. The sputum contained no tubercle bacilli, nor did the discharge from the wounds along the jaw, nor the scrapings from the bone. The heart was normal in size and position, with no audible murmur. The muscle tone of the heart was decidedly impaired, probably due to the prolonged period of sepsis. The pulse was rapid and feeble, but the rhythm was normal. The blood examination showed evidences of decided anemia and a leucocytosis. The Wassermann test was repeatedly negative. The urinalysis showed no abnormality of importance.

The X-ray films of the jaw showed extensive bilateral necrosis, involving the rami of both right and left lower jaws, extending backward to the angles of the jaw. The entire anterior portion of the jaw seems to be separated from the rami. X-ray films were made of various long bones of the body, but no pathological changes could be demonstrated.

"Every effort was made to secure good surgical drainage; the diet was forced as much as possible, and the patient was kept in the fresh air on suitable days; as the swelling in the neck subsided the patient was able to eat better; and, after several months' duration in the spring of 1924, the septic fever began to drop and gradually reached normal. As the septic condition improved the pulse became less rapid, and the tone of the heart muscle improved. Otherwise there has been little change in the patient's condition. The necrosis of the bone still continues; there is a profuse, foul-smelling dis-

charge from the sinuses on either side of the cheek and neck, and the patient continues in a very feeble state of health. The ultimate outcome of this case is difficult to prognosticate. It seems certain that the entire lower jaw will be destroyed by necrosis. This may require a period of two or four years. Should the patient be able to stand this prolonged period of septic poisoning, it is conceivable that she may partially regain her health. This has occurred in some instances. It is my opinion, however, that a fatal termination is more than probable."

The following reports are taken from testimony given under oath at the trial of the girl's suit for damages for injuries sustained during her employment:<sup>19</sup>

Doctor H. stated that when he first saw the girl, October 10, 1923, she had an immense swelling about her jaw and extending down her neck. She had difficulty in opening her mouth and said she felt pain around her lower jaw. Opening her jaw he found marked swelling about the mucous membrane on the side, which was very tender to the touch. Two or three teeth were out on each side and the gums had receded, exposing the jawbone, "which looked dark—a blackish condition." Her breath was particularly fetid and foul and had an odor of garlic. When the gum on the inside where the mucous membrane was associated to the jawbone was pressed some blood and pus came out.

Doctor H. diagnosed the case as chronic phosphorus poisoning, after having the patient under observation from October 10 to October 21 or 22, 1923, and making tests and taking X rays.

She was operated on October 23, 1923, the left side of the jaw being opened. "An attempt was made to go through the gum on the inside, through a local anesthesia. Owing to the severity of the hemorrhage going into the throat we were not able to go further. She was given an anesthesia, and a lot of rotten bone was removed from the left side. We could not do an extensive operation, on account of the condition of the girl. She was put back to bed, and got in better shape and the temperature began to come down and she felt better. We thought we would get her out in the air so she might recuperate a little better and return to the clinic every day, which she did faithfully. She went out on November 11. During the period from November 11 to December 5 I observed her every day, and she began to get worse again. There was evidence of septic poison continuing."

She was brought into the hospital again on December 5, and on December 12 another operation was performed, this time on the right side. The left side, which had already been operated on, was oozing pus and it was treated and drained. "The second operation was on the right side and was about the same as was done on the other side, with the exception of removing a quantity of rotten bone with a lot of pus formation. She has been in the hospital ever since that day. There were days on which she was some better, and other days on which she was worse. We were required to give her anodyne at night for quite a little period, in order that she might have sleep. She hasn't been able to take any food by the mouth except liquid form. In January, instead of our operation being a success and abating this rotten bone, the condition progressed, which was shown by our X ray. On January 14 she was operated on again on the right side, in which the severity of this rotten bone was discovered." In that operation a great deal of bone had to be removed nearly up to the top of the jawbone. It was a severe operation and hemorrhage was almost continuous. "She went bad on the table and we almost lost her, we had to stop the operation. \* \* \* She got along better after that and improved to a certain extent, but the old condition was there; pus was oozing from the wound continually and it was necessary to have it redressed every day, sometimes twice a day. \* \* \* The girl was in a terrible condition. She is still under our care."

An examination of her urine showed that she had toxic nephritis; her heart was rapid, 110 to 120 almost continually, and her temperature averaged around 100° or 101°.

Doctor L. stated that at the time he first saw this case, at a surgical staff meeting, she had swelling of the jaw on both sides, with her mouth partially ankylosed.

From the findings of the various reports, including the X ray, pathological, and Wassermann test, from the clinical history, and from the statement of

<sup>19</sup> See p. 34.



FIG. 1.—CASE NO. 4: BEFORE CONTRACTING PHOSPHORUS  
NECROSIS

22—1



FIG. 2.—CASE NO. 4: FRONT AND SIDE VIEWS, TAKEN DECEMBER 26, 1923

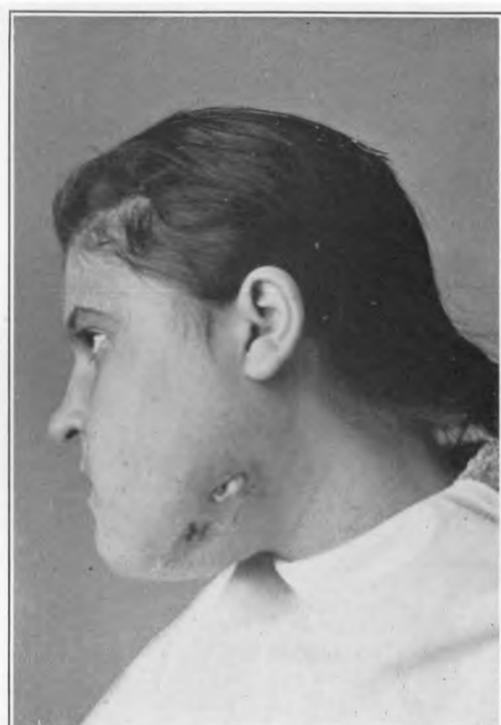


FIG. 3.—CASE NO. 4: FRONT AND SIDE VIEWS, TAKEN MARCH 24, 1924

the patient that she had been working in a factory where there were fumes that smelled like matches, the physicians suspected phosphorus poisoning. Doctor L. referred to the operations mentioned above, and continued:

"She has gradually improved so she is able to be about. She still runs an abnormally high temperature, but not like it was before the operation." The effect of the disease on the general health has been very destructive; "her kidneys are showing evidence of degeneration, and she shows marked myocarditis, which means weakness of the walls of her heart, and she is anemic, of course."

By eliminating all such diseases as syphilis and actinomycosis, and from the appearance of the gum and the unusual foul odor, and especially because of the history of exposure to the fumes of phosphorus, Doctor L. came to the conclusion that the disease was "phossy jaw" rather than other forms of necrosis of the jaw. It differs from ordinary osteomyelitis of the jaw in the "peculiar, garlicky odor which, once smelled, will never be forgotten."

The X-ray diagnostician's report showed that there is a large and diffused necrosis of the bone spreading out over a great area. There is a sequestrum formation. "The pieces vary in size; they have been undermined by the death of the bone and are lying loose in the tissue. At various times individual teeth have shown to be loosened in their sockets. At the last examination (April 10, 1924) one of the wisdom teeth, on the lower side, which had been uninterrupted, was found to be lying loose on the surface of the process in which the teeth grow, at right angles to its normal position. Toward the front angle of the jaw there exists \* \* \* what is known as a pathological fracture, which means the bone has broken itself from its wedging due to lack of bone tissue in that neighborhood. On the under surface of the jaw, on both sides, the normal covering of the bone is shown to be separated from the bone and markedly thickened. The bone destruction, at our last examination, has extended back to the angle just back of the wisdom tooth. These X-ray findings, in my opinion, constitute a diagnosis of chronic diffused osteomyelitis, with necrosis and sequestrum formation."

#### Case No. 5

Age 24; white; male.

Length of time exposed to phosphorus, about two years.

The hospital record showed that this man was first admitted to the hospital on April 3, 1924, suffering from necrosis of the lower jaw, due to chronic phosphorus poisoning. His occupation was given as "maker of fireworks."

An X-ray examination made on April 4, 1924, showed a slight enlargement of heart to the left; the diaphragm on both sides was normal, and there was no evidence of a tubercular lesion. A film made of the lower jaw showed evidence of necrosis about the anterior molar on the right and the second molar on the left side, and also at the apex of the root of the first molar tooth. On April 10, 1924, the lower left second molar and two roots of first molar were extracted, and the socket was curetted and a smear sent to the laboratory. The patient refused to have the first molar on the right side extracted. The smear consisted of some tiny bloody fragments which on microscopic examination showed granulation tissue.

An operation was performed April 11, 1924, when small bits of sloughing tissue were removed and the sinus of left lower jaw was drained and curetted.

The patient was discharged April 12, 1924, in an improved condition.

He was admitted to the hospital a second time on April 25, 1924, with the same diagnosis as before. X rays made of the right jaw showed evidence of bone change involving the horizontal ramus about the area of the canine tooth. After treatment he left the hospital on May 3, 1924.

The case was admitted a third time on May 10, 1924, again with the same diagnosis. An X ray, of May 10, of both legs and both arms showed slight cloudiness about the knee joints, but no evidence of periosteitis or of osteitis or other bone change. X rays made of the right and left upper posterior teeth disclosed that the right upper first molar showed an area of necrosis at the apex of the anterior root; posterior root showed considerable absorption between it and the second molar; and the entire crown absent. On the left side there was necrosis about the alveolar process where the second bicuspid root had previously been; this extended to the apex of the root of the first bicuspid. Both molars were normal; the third molar had not erupted.

The patient remained in the hospital under treatment until October 13, 1924, during which time his condition remained about the same.

According to the testimony of Doctor G., given under oath at trial of another worker who had developed phosphorus necrosis and had entered suit for damages, he first treated this man professionally on March 18, 1924, when he called at the doctor's office, at the request of the superintendent of the factory, for an examination. The man was suffering at the time with infection on the side of his jaw which was draining to a slight extent. He had had a tooth extracted and was still having pain and swelling on the right side of jaw. He said this swelling had been more or less persistent over a period of a few years. The wound was redressed March 18, 20, 23, 26, 28, and 31. It improved after being reopened and allowed better drainage.

#### Case No. 6

Age, 28; white; female.

Length of time exposed to phosphorus, 22 months.

This worker was admitted to the hospital January 8, 1925, with a diagnosis of osteomyelitis of the upper jaw. She complained of pain in her right jaw and cheek. It was found that there was necrosis of the upper jaw involving the upper jawbone and antrum. Considerable dead bone was removed, and the patient was discharged January 16.

She was admitted a second time on February 16, 1925, with a diagnosis of moderate osteomyelitis of the right frontal bone. In operating, four upper incisor teeth and some necrotic bone were removed. The patient was discharged February 17, 1925.

The physician who performed the second operation reported that he removed teeth and jawbone in three different places from three different foci, all the front teeth, and a piece of bone 1 inch long and one-half inch thick.

Since this operation another bone fragment has been removed. At present time (April, 1925) patient is doing very well, though still under treatment and not yet cured. One small necrotic area still exists.

#### Case No. 7

Age, 18; white; female.

Length of time exposed to phosphorus, one and one-half years.

The hospital record showed that this young woman was admitted to the hospital June 17, 1924, complaining of pain in the left side of her jaw. The diagnosis—osteomyelitis of the left lower jaw with cellulitis of the neck—was confirmed by an X-ray picture taken before operation. The examination showed a large boggy swelling under the left lower jaw and she was unable to open the jaw. The lower jaw showed evidence of the membrane being stripped off and of a definite osteomyelitis of the jaw extending for about 2 inches.

An incision was made along the lower border of the jaw and a tube inserted up to the floor of the mouth; the diseased portion of the jaw was curetted and an iodoform drain inserted.

The attending physician reported that after this operation the patient got along very well for three or four days, after which her neck became swollen and the anterior portion of left side of neck was involved. The physician operated on June 26, 1924, opening the anterior portion of the jaw for drainage and removing teeth but no bone. On September 15, 1924, he extracted more teeth, curetted the lower jaw, and removed a small fragment of necrotic bone.

The woman returned to the hospital February 16, 1925. The findings were necrosis of the small incisor and the first bicuspid. One tooth was removed and the socket curetted. After a lapse of three months (May, 1925) the physician considered the girl cured without any deformity.

#### PLANT NO. 3

The following seven cases of phosphorus necrosis, contracted in plant No. 3, were all treated by one dentist, who, when necessary, referred the patients to a physician or sent them to a hospital for treatment. These cases extended over a period of six years, and since many of them were treated without charge, exact dates and history have not always been recorded in great detail. It is probably due to the accurate diagnosis and careful treatment of this dentist, who has been on the lookout for incipient cases, that more cases have not terminated fatally.

## Case No. 8

Age, 21; colored; female.

Length of time exposed to phosphorus, about six years.

The dentist treated her during 1919 for a necrotic first upper molar socket, the tooth having been extracted five months previously. The teeth adjacent to socket were loosening from the spreading infection, which was accompanied by much pain and swelling. The case at first, on the report of a physician, was taken to be syphilitic in origin, but no positive test was made. Anti-syphilitic treatment was used, but without result. Gradual curettement with constant application of various antiseptics brought little relief. An X ray was taken of the jaw which showed an abnormal condition of the area surrounding the socket. The infection continued to spread, as was shown by a rise of temperature to  $102\frac{1}{2}^{\circ}$  F. The patient was ordered to the hospital but died before admission, October 8, 1920, after months of suffering. For a long time both before and after the extraction of the tooth she had worked in a fireworks plant.

The death record gives septicemia (duration, seven days) as the cause of death and abscess of third upper molar tooth (duration, three months) as a contributory cause. The occupation of deceased is given as "Laboress—made fireworks."

## Case No. 9

Age, 22; colored; female.

Length of time exposed to phosphorus, two years.

The dentist reported that this young woman appeared at his office September 7, 1921, having a hardened mass below a badly decayed lower first molar, resembling an alveolar abscess. The tooth was loosened and the jaw very painful. The tooth was extracted and the socket curetted; the jaw was treated every other day to reduce the inflammation. The swelling and pain continued, the abscess pointing outside on face. The abscess was lanced, first inside of the mouth and then outside on the face, and antiseptic solutions were used continuously. The patient gave a history of work in a fireworks plant for a long time previous. To eliminate the possibility of syphilis, a Wassermann test was made by her physician, which was negative. Her condition improved for a while, but later other fistulous areas formed lower down on the neck, and she was advised to enter the hospital for treatment. An operation to remove necrosed bone was performed at the hospital but the infection continued to spread. This case was very rapid in its course and her suffering was intense. "Being the sole support of her two children, she struggled to live but succumbed to septicemia and exhaustion." The death record gives exhaustion as the cause of death, and "necrosis of jaw due to extraction of teeth" (duration of three and a half months) as a contributory cause.

The only record obtainable at the hospital was the date of entry, November 27, 1921, and the date of death, March 13, 1922. The abscess on the jaw was opened November 28, 1921, and December 10, 1921.

The operating physician reports as follows:

"This is to state that I operated on a colored woman by the name of ———, a former employee of the ——— fireworks company. This operation was for a necrosed lower jawbone, the right side being involved from the angle to midline. This was done in 1921. I felt certain at the time, in spite of her attributing it to the extraction of a tooth, that this was a case of phosphorus poisoning.

"At the time of the first operation, I removed large masses of dead bone from the outer side of the jaw. There seemed to be a thin, firm shell of new bone on the inner side. She did well for several weeks and then developed necrosis about the chin and angle of jaw. I reoperated and removed some more dead bone, but this was followed by no improvement of any note.

"This case possessed a most horrible, sweetish, fetid odor that was almost intolerable. She died of exhaustion in spite of all the supportive treatment usually indicated in such conditions."

## Case No. 10

Age, 25; colored; female.

Length of time exposed to phosphorus, six months.

The dentist to whom she went in the latter part of 1920 reports that she had a necrosed first lower molar socket; the tooth had been extracted three or four months previously but the gum refused to heal. She was a school-

teacher, but had been working during the summer months of 1919 and 1920 in a fireworks plant. The dentist ordered her to stop work in the plant immediately and began treatment of her jaw. He had a Wassermann test made, but the report was negative and administration of mixed treatment was ineffective. He treated jaw "expectantly," waiting for the sequestrum to form, using various antiseptics continuously, with general supportive treatment. After more than a year the sequestrum gradually worked away from the healthy bone and was removed, bringing about complete healing. Being intelligent, she followed his advice closely, coming in from her school in the country at intervals for treatment. While she suffered considerable pain and discomfort, fistulous areas and extensive swelling were prevented and she lost only a portion of the bone below the tooth which was extracted.

The physician to whom she was sent for a blood test reports: "Patient came for treatment in 1920 for a checking of the condition of her blood, complaining of pain and swelling in her jaw from which a tooth had been extracted. She had been working in a fireworks plant. A Wassermann was taken of her blood, which was negative. A positive diagnosis of phosphorus poisoning was made, and she was referred to her dentist for treatment."

#### Case No. 11

Age, 21; colored; female.

Length of time exposed to phosphorus, 14 months.

The dentist reports that this patient came to him during the summer of 1921 with a necrosed first upper molar socket; the tooth had been extracted nearly a year before. "Jaw was swollen and painful. Three Wassermann tests were made of her blood, all of which were negative, one or two of the tests being made before any administration of drugs for syphilis. No response to mixed treatment. She gave history of working in the fireworks plant \* \* \* before and after the extraction of tooth, and the necrosis was made much more extensive by her continuing to work there without my knowledge and against my advice, while I was opening up her jaw and treating it, thus allowing more phosphorus to enter. Expectant treatment, with various antiseptic and supportive measures, was used. The necrosis spread beneath the second and third molars, extending to the antrum of Highmore, accompanied by much swelling and pain. Waited about two months for signs of formation of sequestrum, but when area became more extensive ordered her to hospital. At ——— hospital a partial removal of the upper jaw was resorted to and patient dismissed. Case was watched, as there were still positive evidences of further infection. Patient began to lose weight and experienced more pain, and showed a rise of temperature ( $101\frac{1}{2}^{\circ}$ ), weakening rapidly from the infection." She was advised to enter the hospital again, and went to one in another city. She was treated there for a long period, more of the upper jaw being removed, the loss of tissue being supported by the insertion of silver and a drain being left for further recurrence. "A plate was made to restore teeth. She has a facial deformity, but, considering the course, duration, and extent of the necrosis, she is fortunate. Her general condition when last seen (1924) was good, and jaw seemed to be healed."

Report of first physician:

"Treated during 1920 for a necrosed jaw in the upper molar region. There was much swelling and pain and she was given codeine tablets for pain and sent back to her dentist after three Wassermann tests (negative) were made. She had been employed in fireworks plant. Patient returned after a few months, during which time she was operated on at hospital for a partial removal of the upper jaw. There were evidences of necrotic tissue, and in a short time the necrosis began to spread farther up into the face and patient began to lose weight rapidly, temperature going up to  $101\frac{1}{2}^{\circ}$  F. She went to a hospital in another city, where an operation was performed to eliminate the necrosis. An extensive one was performed, as quite a bit of the upper jaw was necrosed.

"On her return in 1924, found her jaw in process of healing with small drain in place, and, while her face is deformed, she seems to be in good health otherwise."

Report of second physician:

"March 22, 1922, right maxillary sinusitis. History: At 14 months prior to March 22, 1922, had an upper tooth on right side extracted and, following this, there was an uncomfortable sensation in right jaw and formation of

pus. At time patient was seen, sinus was cloudy and a funguslike growth had developed in cavity, of a very peculiar consistency.

"Operation: Did the Carwell-Luc. Suspected phosphorus necrosis.

"When patient was last seen was much improved, but not entirely cured, but failed to return for further treatment."

According to the records of the second hospital to which the girl went, she was admitted to the hospital on March 26, 1923, complaining of loss of sense of smell on the right side of her nose. Her general health had always been good; there had been no definite history of acute infectious diseases and no luetic infection. The family history showed no tuberculosis and no cancer.

She stated that for the past two months she had been troubled by chronic nasal discharge of a foul mucopurulent nature, from the right nostril, and had lost completely the sense of smell. Two years before two abscessed teeth had been extracted from the right upper jaw, because of an abscessed condition. The area healed but subsequently broke down again and was later complicated by pain, swelling of right cheek, and nasal symptoms. At the time of a visit made by her to the laryngology dispensary in October, 1922, a luetic condition was suspected, but the Wassermann tests were consistently negative. An X ray of her head was negative. Six injections of diarsenol (0.3) were given.

Examination of the nose showed that the mucous membranes were a fairly good color. On the floor of the right nostril there was an area of granulation tissue described as being "greyish in color and boggy," through which a probe could easily be passed to the bone beneath. The extent of this tissue backward into the nose could not be satisfactorily determined at this examination. The under surface of the inferior turbinates seemed to be also involved. The middle turbinate on the right seemed normal and no discharge was noted. The left nostril was normal. An X ray of the sinuses showed the remains of an old infection of the right antrum.

An examination showed the teeth to be in very poor condition, with several missing, particularly from the right upper jaw. There were a few fillings and several carious teeth. She also had pyorrhea. The tonsils were slightly enlarged, particularly on the left; the surface was ragged and crypts somewhat congested; adherent to both anterior and posterior pillars.

In the sinuses there was some tenderness, on pressure, over the right antrum, and a slight definite swelling. On transillumination there was clouding of the right antrum.

The case was diagnosed as chronic osteomyelitis of the right upper jaw.

On March 29, 1923, a radical operation was performed on right antrum, and the sequestrum was removed. On April 11, 1923, a plastic closure of the antrum was made.

She was discharged from the hospital on April 28, 1923. "General condition is very good. No swelling of soft parts overlying antrum. There remains, however, some tenderness on pressure just at edge of right nares. The suture line was held except for small posterior portion described above. This has not increased in size for past week and impression is that it will probably hold. Patient's hard palate is in good condition. No nasal discharge. (Antrum has always seemed clear and swab passed through nose showed no evidence of pus within antrum.) Patient advised to continue mouth washes carefully and to return to dispensary frequently."

Supplementary note, April, 1925: "Patient worked in phosphorus until 1920, when her present illness began, following a tooth extraction. This makes it likely that there is a case of phosphorus necrosis of the maxilla."

#### Case No. 12

Age, 21; colored; female.

Length of time exposed to phosphorus, three years.

According to the dentist's report, when the patient came to him in November, 1923, she had an opened necrosed first lower molar socket from which a tooth had been extracted on the 1st of March, 1923. "She had complained of pain and soreness beneath the wisdom tooth, which was sore to percussion, the second molar not being in place." She had worked in a fireworks plant for two or three years and had gone back to work immediately after the tooth was extracted. A Wassermann test taken by local health department

was negative. The swelling and pain in her jaw continued to increase in spite of application of measures mentioned, the abscess opening in two places in her face. Her temperature was 101° F. She was ordered to a hospital in another city but, having no funds, was not admitted. On return, went to the local health department and was given seven injections for syphilis, with no results. She was then referred to an oral surgeon, a member of the State board of health, who took an active interest in her case and began treatment of her jaw with encouraging results. An X ray taken by him showed evidences of a mineral poison and secondary bone formation. The fistulous areas in her face have healed and the sequestrum, which extends from the first bicuspid to the ramus of jaw, is gradually working away. The patient is still under treatment "with prognosis favorable if her vitality can be kept up to wall off the necrosed tissue. A strong solution of potassium permanganate (30 to 60 grs. to pint) with administration of bicarbonate of soda is being used and a close tab is kept on patient in order to develop a high state of resistance. She is not suffering to a great extent at present, but jaw is large on account of secondary bone formation."

Report of physician:

"Was called into treatment of this case by dentist who, realizing the serious condition of patient, desired medical aid. She was a worker in a fireworks plant. A report from the health department of a Wassermann test was negative. She was suffering intensely from a necrosed jaw, which finally opened in two places on outside of face, and these were running continuously. Her temperature was 101° F. and she was ordered to hospital for treatment, but was not entered on account of lack of funds. At present, after being treated by an oral surgeon, she is in much better condition with prognosis favorable, if vitality can be kept up."<sup>20</sup>

Case No. 13

Age, 21; colored; female.

Length of time exposed to phosphorus, five years.

The dentist reports that this girl came to him April 29, 1925, with a necrosed first lower molar socket which was swollen and painful. Tooth had been extracted September 1, 1924. "She has been a worker in the fireworks plant here at times for the past five years, and went back to work immediately after tooth removal. A Wassermann test was made at the health department here and was negative. Socket was cleaned and a strong solution of potassium permanganate given as a mouth wash with administration of bicarbonate of soda. Swelling has continued until abscess has opened on face, and pain has been very severe and very hard to relieve. Have administered two or three sedative combinations, but with little relief, and since there has been a free drainage for pus on face, she has become more comfortable. I am treating case every three or four days and am attempting to keep the necrosed area confined to one or two teeth. On her last visit it was noticed that the first opening on face had partially closed and another one had formed about an inch away, giving rise to pain, and this also was opened. General supportive treatment is also being given. She is at this time in danger of further spreading of the secondary infection, which has not been as yet arrested, but it is hoped the measures taken will accomplish it."

A blood analysis, made June 15, 1925, by the bacteriologist of the local health department showed the following:

Hemoglobin -----	72
Color index -----	95
Leucocytes -----	6,400
Total red -----	3,424,000
Differential:	
Polymorphonuclears -----	44
Lymphocytes -----	54
Eosinophiles -----	2

Swab from abscess gave no growth on culture.

NOTE.—This case later entered into agreement with the fireworks plant, relieving the company of all responsibility on the payment of \$50.

<sup>20</sup> See p. 35 for an account of the claim of this worker for compensation for her injury.

## Case No. 14

Age 22; colored; female.

Length of time exposed to phosphorus, three years.

The dentist reports that this patient came to him on May 10, 1925, with her first lower molar socket necrosed and practically closed, save for a small opening of about one-eighth of an inch. "Her jaw had been sore for a few months but there has been no swelling. Pus runs continuously from the small opening which has been enlarged, and the mouth wash mentioned (in Case No. 13) has been given along with other measures."

This young woman had been employed in a fireworks plant for about three years.

"The extraction of tooth was made in November, 1923. \* \* \* Another tooth was extracted on the opposite side in lower jaw and this socket has a very small opening in gum also. This is slightly painful, but no swelling has resulted. This jaw is being watched closely, for if both sides of the jaw are attacked by the secondary infection, the prognosis of case would be unfavorable, as patient is highly nervous, not so strong physically. No Wassermann has as yet been made, but the signs are positive for phosphorus poisoning. This case shows that the action of phosphorus is very slow in some patients and works under a gum that seems to have closed over a long time before reaching the abscess stage."

## PHOSPHORUS PREPARATION PLANT

In one of the plants preparing phosphorus, four cases of chronic phosphorus poisoning were discovered. A physician who treated three of the men said he had no records of the cases, since he had attended them a number of years ago, but he diagnosed all three as phosphorus necrosis and stated they all suffered from pain, some fever, and finally a shedding of the bones of the jaw.

One man suffered from necrosis of the lower jaw, three from necrosis of the upper jaw, and one of the latter seems to have had necrosis in the lower jaw also.

## Case No. 15

Age, 55; white; male.

This man contracted phosphorus necrosis after working about 10 years in the plant, mostly in the yellow phosphorus process, handling the phosphorus after it came from the furnace. The fumes from the phosphorus were very heavy. The trouble started in what seemed to be a toothache, in 1912. The man visited a dentist, who refused to pull any teeth and told him to go to a doctor. Three teeth came out as clean as if scraped and scoured. The man stated that every tooth, with the possible exception of one, was in good condition. A tooth was pulled several days afterwards; in two weeks, three more, and two weeks later, three more; then all the remaining teeth were taken out. Later the jawbone came out. The flesh seemed to be eaten off first, then the jawbone; and for about three months the odor was terrible. After the bone came out the gum healed over. A mustache hides the deformity. It has been impossible to get a plate to fit in his mouth. The man has been working for the past 13 years on a railroad and is apparently in good health.

## Case No. 16

Age, 50; white; male.

This man had been engaged in grinding, sciving, and working in red phosphorus for three years and developed phosphorus necrosis of the upper jaw as a result of the contact with impurities in the red phosphorus. The entire upper jaw and roof of mouth gradually loosened, and after 12 or 14 months came out. He had had no teeth in the upper jaw but had been wearing a plate when he contracted phosphorus necrosis. (See fig. 4.) He had contracted necrosis in April, 1916, but remained at work until August, 1916. He claimed he was informed that red phosphorus was not poisonous and that he could not develop necrosis from it. As plaintiff in a suit to recover damages for injury, in January, 1917,<sup>21</sup> he claimed that he did not know there was any danger or peril to health from contact with red phosphorus, and was not informed of any such danger, although that there was such danger was well known to his employer. He stated that at the time of entering the

<sup>21</sup> See p. 35.

employment, as an inducement to his accepting the position, he was assured by his employer that the said red phosphorus, in the treatment and production of which he was set to work, was not poisonous and that the work required of him would not hurt him. He is now employed in a paper mill and is in fair health.

Case No. 17

Age, 34; white; male.

This was a worker at the phosphorus extracting plant, who contracted phosphorus necrosis on both sides of the lower jaw. He had been working in the plant about six and one-half years and in the processes which brought him into contact with poisonous phosphorus about four and one-half years. At first he helped to unload cars; he later went into the refining room, where he weighed phosphorus, probably one of the most hazardous processes. After he contracted phosphorus necrosis, for a month he was unable to work; he suffered intense pain and could not sleep night nor day. Two good-sized pieces of bone worked loose from his jaw—one an inch long and the other 2 inches long. He is at present employed in a paper mill and is apparently in fair health. He suffers some pain every now and then, and small particles of bone are still being thrown off. The teeth in the front of the jaw are still in place, but the teeth on both the right and left sides are missing.

Case No. 18

Age, 64; white; male.

The hospital record of this last case shows that the patient was admitted to the hospital November 20, 1920, complaining of pain in his upper jaw, which he had first noticed about 10 weeks before. The pain grew gradually worse and soon his upper jaw became swollen and the teeth became loose and were easily pulled out, one at a time. For seven weeks before coming to hospital he had noticed a discharge of pus from the upper jaw. The pain had been increasing and patient had been getting steadily weaker and had frequent headaches. During the last four weeks the teeth in right lower jaw had also become loose and had been pulled out and the lower jaw had recently become sore.

The history of the patient showed that he had been working for 12 years in a factory in which he was obliged to handle phosphorus and breathe phosphorus fumes a great deal. He had had typhoid fever 45 years ago; had never had pneumonia or acute rheumatism. His nose was deformed as a result of a fracture some years ago, and he had difficulty in breathing through it.

The examination of his mouth showed the absence of all teeth except two in the upper jaw, with redness, swelling, and tenderness of the gums and discharge of pus from two or three places; the lower jaw showed the absence of several teeth on the right side, loosening of the incisors, and redness, swelling, and tenderness of the gums. X ray of upper and lower jaws showed no evidence of necrosis, except as localized abscesses around the dental roots. There was a heavy clouding of both antra, especially the left, suggestive of a collection. The Wassermann report was negative.

This man is not able to work at all; he suffers a good deal of pain, and seems to be continually getting worse. At one time the pain in the upper jaw was so severe and the bones of the jaw and the roof of the mouth were so loose that he pulled out the entire shell. (See fig. 5.)

### MANUFACTURE OF RAT PASTE

Phosphorus has been used for a number of years as the chief ingredient in compounds designed to destroy certain pests. As early as 1878 a patent (No. 204405) was taken out which claimed to make a new and useful improvement in vermin-destroying compounds by first boiling four gallons of sirup, then adding flour until the mass assumes the consistency of a salve, then reheating same and adding for each gallon of sirup 8 inches of ordinary phosphorus stick.

Rumors that workers in the rat-paste industry, where white (yellow) phosphorus is used in the rat poison, contract "phossey jaw," led to a survey of some of the factories which manufacture rat paste con-

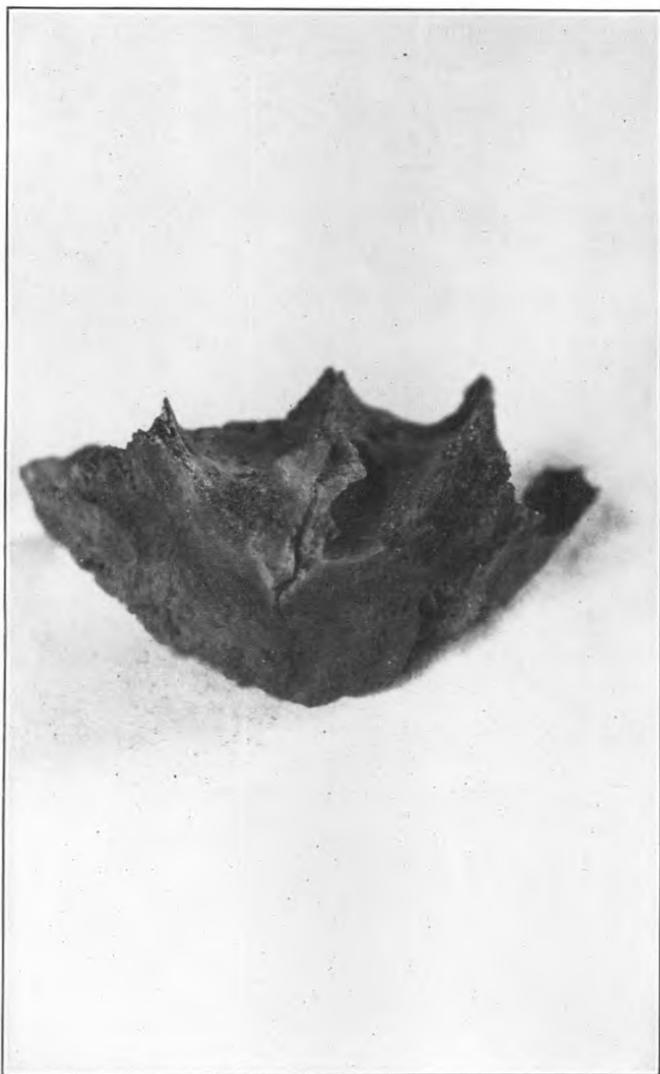


FIG. 4.—CASE NO. 16: UPPER JAWBONE, WHICH CAME AWAY  
12 OR 14 MONTHS AFTER NECROSIS DEVELOPED

30-1



FIG. 5.—CASE NO. 18: UPPER JAWBONE. MAN QUIT WORK  
AUGUST 29, 1920. JAWBONE CAME OUT JANUARY 22, 1923

30-2

taining white or yellow phosphorus. The 12 plants visited ranged from a drug store which prepared a batch, containing about 50 pounds of the mixture, two or three times a year to a factory which made rat paste 20 days a month, using 244 pounds a day. Many establishments were not operating on the day the visit was made, and one plant had been discontinued.

One of the former workers at this plant which was no longer in operation knew most of the workers who had been employed in the factory. She had helped make the paste 43 years ago, but had continued in the work only a few years. She remembered that the mixing of the paste had been done by hand by one man, and three or four woman workers filled the small tin cans by hand and worked steadily for 9 or 10 hours each day, but she had never heard of any of the workers being ill or having trouble with their teeth.

In the rat-paste industry the largest batch mixed in any factory, 4,500 pounds, is made only once a week. In this case the paste is mixed in a huge covered, cylindrical vat which extends almost to the top of the small two-story wooden building. The ingredients are poured in at the top and after being stirred for several hours by an automatic agitator are released at the bottom of the vat into a hopper through which the paste runs into cans, four of which are relayed at a time along a conveyor and filled. The tops are put on automatically. The only workers employed are men—a feeder, who has been doing this work for 25 years, and his assistant. Fumes arise during the filling process, but the filling takes only part of a day once a week. A Sirocco blower carries off the fumes at the top of the vat. The operator explained that as a general rule the cans were filled when the mixture was cold, but on the day the plant was visited they were in a hurry for an order and had not waited for the paste to become cold, and for that reason the fumes were worse than usual.

Most of the factories use an ordinary dough mixer in combining the ingredients. The base, glucose and flour, is heated to about 82° C. Later, into the warm mixture the phosphorus, which has been broken by hand under water (the men for the most part using rubber gloves) is dropped in. After this is properly mixed the machine is tilted over and the paste poured into a filler pressure machine which is kept closed. One man removes the filled tubes from the machine and they are put aside until the next day, when a girl closes the tube by machine. Some plants use a combination filling and clinching machine. Usually an exhaust is provided for removal of fumes. Occasionally a more primitive method of filling is in use, where the paste is run into containers from a spigot in the filling machine through funnels. The containers are placed in position and removed when filled by male workers.

One of the manufacturers, who did not make rat paste more than once a month, said that in his factory a batch was never mixed on a damp day, for the fumes were much worse when the air was heavy.

A manager of a large factory said, when he was experimenting with phosphorus rat paste and working in phosphorus fumes every day during the entire working-day, he had become anemic, was always tired, and had a headache all the time. He thought that at one time he had had a slight cough. He had never had any trouble

with his teeth. He stated he would not allow his workers to handle the paste every day, for he was sure it would be harmful.

There are very few workers employed in the rat-paste industry, not more than eight in any factory visited, and usually two or three, sometimes only one. Almost all of the plants manufacturing rat paste make other chemical compounds as well. A large batch is usually mixed at one time and a sufficient amount can be prepared for the market without manufacturing the product every day. In most plants the entire process can be completed in a day.

The workers all seem to know that white phosphorus is poisonous, and state that they are very careful about thoroughly washing their hands before eating. At only one plant was dental service given (twice a year), and the workers could consult the dentist or not as they pleased. Many take advantage of this service. At the same plant a physical examination is given at the time the worker is hired. No cases of illness as a result of the use of phosphorus were known in any of the plants manufacturing rat paste.<sup>22</sup>

### LEGAL PROVISIONS RELATING TO PHOSPHORUS

#### EMPLOYMENT OF CHILDREN IN PHOSPHORUS PROCESSES

Admission of young persons to employment involving the use of phosphorus is fixed at 15 years in Italy and Japan, at 16 in Belgium, Spain, and Greece, and at 17 in the Netherlands.<sup>23</sup>

In the United States, most of the State child labor laws which mention phosphorus prohibit the employment of children only in the manufacture of phosphorus or of phosphorus matches or both. Even though poisonous phosphorus matches are no longer made in the United States, as a result of the Esch Act passed in 1912, which imposed a prohibitory tax on matches containing yellow or white phosphorus, States which have recently passed child labor laws include in their law this particular employment.

In the following 21 States a State board of labor or health has authority to determine which occupations or processes are dangerous or injurious to children under specified ages (usually 16 or 18 years) and to prohibit their employment therein: Alabama, Arizona, Arkansas, California, Delaware, Illinois, Massachusetts, Michigan, Missouri, Nevada, New Jersey, New York, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, Utah, West Virginia, Wisconsin, and Wyoming.<sup>24</sup>

Another type of provision is that prohibiting the employment of minors under specified ages, usually 16 or 18 years, in any dangerous or injurious occupations.

#### EMPLOYMENT OF WOMEN IN PHOSPHORUS PROCESSES

In certain countries the employment of women is prohibited in the manufacture of white phosphorus—in the Netherlands, in all

<sup>22</sup> The only recorded case of phosphorus poisoning in this industry that could be discovered occurred in New Zealand. For an account of this case, see Appendix D, pp. 43 and 44.

<sup>23</sup> International Labor Office. Occupation and Health Brochure No. 6: Phosphorus, by Dr. L. Ferrannini, Geneva, 1925, p. 7.

<sup>24</sup> United States Children's Bureau Bulletin No. 93: Child Labor, Washington, September, 1924, p. 32.

employments using any kind of phosphorus, and in Japan, in any place where dust, vapor, and gas are given off from phosphorus or its compounds.

In the United States, while some States forbid certain employments to women, no law specifically includes phosphorus in the list of forbidden occupations. In certain States, however, if the proper authority so decides, phosphorus processes as well as other dangerous processes can be forbidden to women. Thus, a Michigan act (No. 239, Acts of 1919) forbids the employment of any woman in any place detrimental to her health, and the Wisconsin law (Stats. of 1923, sec. 103.05 (2)) forbids the employment of any woman in any employment or place prejudicial to her health or safety, the matter of determining which occupations or places are dangerous being left to the industrial commission. Also improvement of conditions in plants where phosphorus is being used can be effected under the general provisions of a number of State laws. Thus, the Kansas minimum wage law, which has been declared unconstitutional as regards the fixing of a minimum wage for women, also contains a general provision (unaffected by the above decision) authorizing the court of industrial relations to issue orders to remedy working conditions which are, in the opinion of the court, prejudicial to the health of the woman employees.

#### REPORTING OF CASES OF PHOSPHORUS NECROSIS

Reporting of cases of phosphorus necrosis is obligatory in Austria, Baden, Bavaria, Great Britain, Hungary, the Netherlands (in the chemical industry and in laboratories), Poland, Prussia, Saxony, Serb-Croat-Slovene Kingdom, Switzerland, in the British Dominions (Alberta, South Australia, British Columbia, Manitoba, New Brunswick, Nova Scotia, New South Wales, Ontario, and Queensland).<sup>25</sup>

In the United States, the laws of Maine, Maryland, Michigan, New Hampshire, New Jersey, New York, Ohio, Rhode Island, and Wisconsin require all physicians treating cases of phosphorus poisoning to report them to the State board of health. The Illinois and Missouri laws do not specify any particular disease but require the reporting of all diseases arising from the use of dangerous chemicals. Under the laws of Connecticut, Minnesota, and New York, physicians must report all cases of phosphorus poisoning to the commissioner of labor; in Michigan, the board of health reports such cases to the commissioner of labor; while the Massachusetts act provides that the department of labor may require physicians to report to it diseases contracted as a result of the nature of their employment.<sup>26</sup>

#### PHYSICAL EXAMINATIONS

The Illinois and Missouri laws require monthly physical examinations of all workers in dangerous chemicals, that of Missouri specifying phosphorus in addition to other chemicals.<sup>27</sup>

<sup>25</sup> International Labor Office. Occupation and Health Brochure No. 6: Phosphorus, by Dr. L. Ferrannini, Geneva, 1925, p. 8.

<sup>26</sup> United States Bureau of Labor Statistics Bulletin No. 370: Labor laws of the United States. Washington, May, 1925.

<sup>27</sup> Such examinations were one of the measures emphasized by Doctor Ferrannini, as was also special attention to the teeth. (International Labor Office. Occupation and Health Brochure No. 6: Phosphorus, by Dr. L. Ferrannini. Geneva, p. 8.)

The New York Consolidated Laws of 1909 (as amended by sec. 28, ch. 642, Acts of 1921) authorize the industrial board to issue special regulations when it finds that any industry, trade, occupation, or process involves such elements of danger to life or health as to make regulation necessary; it may, in carrying out the provisions of the act, require "medical inspection and supervision of persons employed or applying for employment."

#### COMPENSATION FOR CHRONIC PHOSPHORUS POISONING

In most of the States which have enacted legislation designed to compensate workers for injuries received in the course of employment, no provision is made for injury from disease due to the employment. Only 12 States and the Federal Government provide compensation either for occupational diseases generally or for designated diseases of this class.<sup>28</sup>

Minnesota, New Jersey, New York, and Ohio enumerate the occupational diseases for which compensation may be awarded and include phosphorus poisoning in the list. Under the New Jersey law, however, occupational diseases can be compensated for only when the exposure occurs during the employment and the disability commences within five months after the termination of such exposure. That this limitation may lead to serious injustice in the case of chronic phosphorus poisoning is indicated by the fact that, according to Oliver, phosphorus necrosis does not always develop during the time the individual is exposed to the hazard, but has been known to occur two years after leaving the factory.<sup>29</sup>

The Federal Government, California, Connecticut, Hawaii, Massachusetts, North Dakota, Porto Rico, and Wisconsin have workmen's compensation laws under which it is possible to compensate for chronic phosphorus poisoning, but this industrial disease is not specifically mentioned.<sup>30</sup>

In States, therefore, which do not make provision for compensation of occupational diseases (and of the factories included in the present survey only one is located in a State which does compensate for phosphorus poisoning) employees attacked by phosphorus necrosis have recourse only to common law for damages. Three of the employees whose cases have been noted in this study have tried to recover for their injuries, under either common law or the workmen's compensation law of the State, with what success is shown in the short account of the cases given below.

In the first instance, the girl (case No. 4, already described, pp. 21 to 23), who had been employed in a phosphorus-fireworks plant for about 15 months, developed phosphorus necrosis and had to have a large part of her jaw removed. Disfigurement for life will be the probable result, and the prognosis seems to be that she will not be able to survive for more than a few years. She brought suit under

<sup>28</sup> United States Bureau of Labor Statistics Bulletin No. 379: Comparison of workmen's compensation laws of the United States as of January 1, 1925. Washington, January, 1925, p. 6.

<sup>29</sup> Oliver, Thomas: *Dangerous Trades*. London, John Murray, 1902, p. 428.

<sup>30</sup> Foreign countries which make provision for compensation for necrosis are Great Britain and its dominions, Argentina, Brazil, Japan, Serb-Croat-Slovene Kingdom, and Switzerland. (International Labor Office. *Occupation and Health Brochure No. 6: Phosphorus*, by Dr. L. Ferrannini. Geneva, 1925, p. 8.)

the common law, and in April, 1924, was awarded damages of \$22,500. When the case was carried to the court of appeals it ruled that the disease was an accidental personal injury, and as such came within the workmen's compensation act. A new trial, however, was requested and granted on the ground that the girl was illegally employed, being at time of employment under 18 years of age (the age required by the child labor law of the State for those employed in designated dangerous processes) and so not permitted to appeal for compensation under the workmen's compensation law. The case was finally settled out of court, for \$16,500, before the time came for the new trial.

In the second instance, the worker (case No. 12, p. 27) who had contracted phosphorus necrosis in a fireworks plant applied to the State industrial commission for compensation, in the spring of 1925. Her claim was rejected on the ground that phosphorus necrosis was an occupational disease, and as such not compensable under the workmen's compensation law of the State.

In the third instance the man (case No. 16, p. 29) attempted to obtain damages in a suit at common law. He had been employed in a plant which prepared red phosphorus from white (yellow) phosphorus, and had developed phosphorus necrosis. The district court ruled that the case came under the jurisdiction of the State industrial commission. The referee of the industrial commission on May 3, 1917, refused compensation on the ground that the claimant was suffering from phosphorus poisoning, an occupational disease, contracted in the course of his employment, which was not due to nor did it result or develop from any injury or violence to the physical structure of the body and any disease or infection as naturally results therefrom. The fact was also mentioned that in the phosphorus plant the man had been paid a wage of \$14.80 per week, while in the new employment which he later entered he earned \$16.80 per week, thus showing that he had suffered no diminution in earning power.

### SUMMARY AND CONCLUSION

Of the industries offering exposure to phosphorus poisoning three were studied—the phosphorus-fireworks plants, the vermin-exterminator industry, and the phosphorus-extracting plants.

In the three plants manufacturing phosphorus fireworks 366 people were employed—181 men and 185 women. The workers engaged in the phosphorus processes numbered 71, of whom 56 were women (3 were minors under 16) and 15 were men (1 was a minor under 16). Among the employees of these three factories there had occurred 14 definite cases of phosphorus necrosis, 2 of which were fatal. Three workers who had had cases of phosphorus necrosis were still employed in the fireworks factories, but were no longer working in phosphorus processes. In some instances the victims of phosphorus necrosis had known that the material on which they were working was poisonous, and had been warned to take precautions, but the majority had not realized the harmful nature of their occupation.

Two phosphorus-extraction plants were studied. In one of them four cases of phosphorus necrosis had occurred during a long period of years. This factory has been shut down for the last five years.

The second factory has given particular care to the teeth of employees, furnishing free dental care, and inspecting the teeth of all workers in phosphorus at frequent intervals. The doctor who has been attending all cases of illness at this plant for the past 20 years remembers only one case of necrosis (probably phosphorus), which occurred almost 20 years ago, and which required curettement of the tooth sockets. There was also a case of a diseased antrum in a man who died about a year ago; this case, however, was not diagnosed as phosphorus necrosis.

In the manufacture of rat paste, probably because of the intermittent character of the industry, no case of phosphorus necrosis was found to have occurred.

The present study has demonstrated that there is still a real industrial hazard from phosphorus, although the number of workers exposed to the hazard is small.

The contrasting experience in the two phosphorus-preparation plants would seem to indicate that in that industry, by constant preventive measures and special attention to the teeth of the workers in phosphorus, cases of phosphorus necrosis can be almost entirely eliminated.

The greatest hazard from white phosphorus is in the phosphorus-fireworks industry. The danger can be decreased by various measures, some of which have already been adopted. Suitable ventilation and exhaust pipes to remove the poisonous fumes before they rise far enough to be breathed by the workers, adequate and convenient washing facilities, provision of a room removed from the phosphorus processes where the employees may eat their lunch, transfer of employees to nonphosphorus processes from time to time, regular dental and medical inspection, transfer to nonphosphorus work of employees after extraction of a tooth, furnishing of mouth wash—all of these are measures which will serve to reduce the danger of chronic phosphorus poisoning. Introduction of automatic machinery for shaping and wrapping of lozenges would also doubtless tend to lessen the possibility of poisoning. It is absolutely essential, as well, that persons employed on phosphorus processes realize not only that there is a danger involved but also the possible outcome of chronic poisoning, and notices and instruction on these points should be provided.

The hazards inherent in the manufacture of phosphorus fireworks are fully realized by the manufacturers themselves, and they have been experimenting for some time to find a less dangerous substitute for the white phosphorus. One manufacturer considers the work so hazardous that he advocates the prohibition of use of white phosphorus. In a letter to the Bureau of Labor Statistics, dated April 14, 1925, he says:

We are willing to, in fact, desirous of eliminating the use of white or yellow phosphorus in the fireworks industry as being detrimental to the industry as a whole, but have felt compelled to continue along this line until such time as our competitors are willing to take similar action, by eliminating the use of this material entirely in their operation. Pending this time, we have exerted every effort toward the development of equipment and automatic machinery, so as to prevent human contact with this element to the greatest possible extent, and through recent development we will have reached the point within the next few weeks whereby no handling of this merchandise in which white or yellow phosphorus is used will be done by our employees.

In spite of these developments, however, we are still averse to the use of phosphorus, and believe that Federal prohibition of the employment of this ingredient will be to the ultimate advantage of all concerned.

The difficulties in the way of the elimination of the poisonous phosphorus are just those stated by this manufacturer. The phosphorus product—known variously as “spit devil,” “son-of-a-gun,” “devil-on-the-walk,” “automatic torpedo,” “jumping jack,” “tank”—is extremely popular with children on the Fourth of July and in the South at Christmas time, and manufacturers, while regretting the necessity of using poisonous phosphorus, insist that, because of the great public demand, if one factory does not manufacture the toy another will, and unless all firms agree to give up this variety of fireworks or unless the manufacture is prohibited it would be unlikely that an individual concern would make such a sacrifice even though favoring the elimination of poisonous phosphorus.

It is worthy of note in this connection that at the semiannual meeting of the U. S. Fireworks Manufacturers' Association, held January 30, 1926, in New York City, the following resolution was passed:

It is the sense of the meeting that the U. S. Fireworks Manufacturers' Association support the efforts of the Department of Labor to eliminate white phosphorus from the fireworks industry.

## APPENDIX A.—PHOSPHORUS NECROSIS IN MATCH INDUSTRY

### EUROPE

The report by Professors Thorpe and Thomas Oliver and Dr. George Cunningham on the use of phosphorus in the match industry<sup>1</sup> gives in great detail the European experience with phosphorus necrosis in the match industry. According to this report, in Great Britain and Ireland, in 1896, the 25 match factories employed 4,311 workers, 1,700 of whom worked in processes involving the use of phosphorus; between 1893 and 1898 there were 37 cases of phosphorus necrosis reported. The match industry in Holland was comparatively small, employing about 570 workers in three factories, and seven cases of necrosis were reported, but the number was probably much larger. In Belgium, where in 13 factories about 2,600 workers were employed, from 1860 to 1895 one hospital operated on 34 men for phosphorus necrosis. When 30 per cent of phosphorus was used, there were many cases of phosphorus poisoning, but the number decreased somewhat with the manufacture of matches made with only 8 per cent of phosphorus. Seven factories in Denmark employed 76 adults and 180 children in 1874. In five years two hospitals had treated 11 cases of phosphorus necrosis, but between the passing of the law of 1874, prohibiting the use of white phosphorus in matches, and the time of the report, not a case of phosphorus necrosis had been known. In Germany, where 30 of the 90 match factories were exclusively engaged in the manufacture of phosphorus sulphur matches, 11 cases of necrosis were reported in 1894, 5 of these in three factories. In Austria-Hungary, from 1881 to 1897, there were 140 cases of phosphorus necrosis in the 90 factories manufacturing the phosphorus matches; 47 of these cases occurred in one year. In Switzerland, 5 to 10 cases of phosphorus necrosis occurred among the 300 match workers every year. In Norway, 400 of the 600 match workers were employed in manufacturing ordinary phosphorus matches, and in the 6 phosphorus-match factories, 28 cases of phosphorus necrosis occurred between 1880 and 1893.

In Sweden the match industry began to increase rapidly about 1840. Between 1860 and 1870 there were 69 cases of phosphorus necrosis, according to Lundgren's article on phosphorus poisoning in Sweden.<sup>2</sup> In 1870 a law was passed regulating the industry. These regulations included the following provisions: Specially constructed building; separate rooms for (a) preparation of paste and dipping, (b) drying, (c) packing; special methods of ventilation; size of rooms in proportion to number of workers; inspection before commencement of operation; prohibition of employment in preparation of paste and in dipping for workers less than 15 years of age; employment in preparation of paste and dipping for not more than six months at any one time, with an interval of two months in other departments before return to dangerous processes; record of workers, giving date of entrance and leaving phosphorus processes; medical examination every three months, duly recorded; special working garments; clear water and soap accessible to workers; cleaning of workrooms once a day and washing of floors and walls every fourteenth day; and prohibition of eating in workrooms.

The above was the first modern legislation concerning working conditions in industry, and resulted in a decrease of cases of phosphorus necrosis. An act, effective July 1, 1897, made the regulations even stricter, prohibiting the employment of any minor under 18 in the preparation of the paste or dipping, and any minor under 14 in drying and packing matches. Workers under the

<sup>1</sup> Great Britain. Home Office. Reports on the use of phosphorus in the manufacture of lucifer matches, by Prof. T. E. Thorpe, Prof. Thomas Oliver, and Dr. George Cunningham. London, 1899. [C. 9188.]

<sup>2</sup> Nordisk Hygienisk Tidskrift, Bind II, 1921, pp. 128-143: "Åtgärder inom tändstick-industrien i Sverige till förekommande av fosfornekros," by P. G. Lundgren.

new regulations were not permitted to work more than one month at a time in the preparation of paste or in the dipping of matches, and were to have intervals of employment in other processes of at least one month before working again in the dangerous phosphorus departments.<sup>3</sup>

In spite of these strict regulations, cases of necrosis continued to develop, and in 1920 Sweden amended the law of 1900 which forbade the sale of phosphorus matches so as to include the manufacture and importation.

Lundgren gives a table showing the number of cases of phosphorus necrosis in Sweden, by five-year periods, and the number of workers employed. The data shown in this table are as follows: 1901 to 1905—5,923 match workers, of whom about 1,100 were in phosphorus-match factories, and 27 cases of phosphorus necrosis, or 24.5 per thousand workers; 1906 to 1910—6,558 match workers, of whom 1,200 were making phosphorus matches, and 15 cases of phosphorus necrosis, or about 12.5 per thousand workers; 1911 to 1915—7,172 match workers, of whom 600 were in phosphorus-match factories, and 6 cases of necrosis, or about 10 per thousand workers.<sup>4</sup>

#### ASIA

In Japan the match industry employs large numbers of workers, and in Spain many workers are engaged in the manufacture of matches, but no figures are available on the number of cases of phosphorus necrosis which occurred before the use of poisonous phosphorus was prohibited in these countries.<sup>5</sup>

A recent study of phosphorus necrosis in the match industry in China, undertaken for the industrial committee of the National Christian Council of China, notes about 40 cases of necrosis—reports of 20 of which were obtained from hospitals and 20 from managers of factories, among a possible 15,000 workers; but the writer considers the number a decided understatement of the hazards of the industry, due to the following causes: Failure to diagnose the disease as phosphorus necrosis; the possibility that such patients return to their country homes and eventually seek treatment at hospitals in cities where there are no factories; the large labor turnover which results in few workers remaining long exposed to the poison; sounder teeth among Chinese workers than among the class of Europeans who used to work in western factories (although there is no conclusive evidence that this is true); and better natural ventilation in the loosely constructed Chinese buildings than in the more solid structures of the west.<sup>6</sup> China is now a signatory of the international (Bern) convention and has prohibited the use of white phosphorus in match factories since June, 1925.

#### UNITED STATES

The cases of phosphorus necrosis discovered by the agents of the Bureau of Labor in a general investigation of the employment of women and children in 1908 and 1909 led to a special study, under the auspices of the Bureau of Labor and the American Association for Labor Legislation, of the extent of phosphorus poisoning from the use of white (yellow) phosphorus in the manufacture of matches.

Fifteen of the sixteen match factories in the United States were visited. These factories had in their employ 3,591 persons—2,024 men and 1,253 women 16 years of age and over, and 314 children under 16 years of age (121 boys and 193 girls). Of the workers 65 per cent were employed under conditions exposing them to the fumes of phosphorus and to the dangers of phosphorus poisoning. A large percentage of women and children were working in phosphorus processes—95 per cent of the women and 83 per cent of the children under 16 years. The cases of phosphorus necrosis discovered numbered over

<sup>3</sup> Molin, A., and Marcus, M.: *Författningar rörande arbetarskydd*. Stockholm, 1912, pp. 103-116.

<sup>4</sup> *Nordisk Hygienisk Tidsskrift*, Bind II, 1921, p. 143: *Åtgärder inom tändstick-industrin i Sverige till förekommande av fosfornekros*, by P. G. Lundgren.

<sup>5</sup> International Association for Labor Legislation. Report of the Fifth General Meeting of the Committee of the International Association for Labor Legislation, held at Lucerne, Sept. 28-30, 1908. London, 1909, p. 47.

<sup>6</sup> Maitland, Charles T.: Phosphorus poisoning in match factories in China. Reprinted from the *China Journal of Science and Arts*, February and March, 1925.

150; 4 of these were fatal, and many involved horrible suffering and deformity.<sup>5</sup>

### APPENDIX B.—PHOSPHORUS POISONING IN GREAT BRITAIN AFTER 1915

Dr. T. M. Legge, chief medical inspector of factories in Great Britain in his annual report for the year 1918, discussed as follows the cases of "phossy jaw" which have developed in that country in recent years:

"'Phossy jaw' underwent recrudescence in 1915-1918, during which time 11 cases were reported from the one factory in which the manufacture of phosphorus is carried on. Until these cases, an apparent immunity, extending over many years, had been enjoyed. Although the number of individual workers brought into contact with phosphorus for one and another war purpose had been considerable, only one case has been reported in processes other than the manufacture. With this exception, all had worked for years in phosphorus processes. In the factory in question, examination of the dental condition by a surgeon and reference by him to a dentist of those whom he considered needed treatment had been relied on in past years, instead of examination by a dentist in the first instance, which would, in my opinion, have been the wiser course. After the first case (which proved fatal) in 1914, the firm engaged the services of a dentist with the intention, since carried out, of putting the teeth of all those coming into contact with phosphorus into a sound condition, and linking up the work of the dentist with that of a consulting surgeon of the highest standing in case of need. The dentist attends two afternoons a week in the well-equipped dental surgery on the works and quarterly examination of all the workers has been arranged for. This examination has led to the detection of the cases of necrosis the presence of which was shown after the removal of the decayed teeth. No case has been reported since July, 1918. Dealing with these cases Mr. Thomas (Walsall) reports as follows:

"'With three exceptions, all the cases reported as suffering from phosphorus poisoning have been employed in connection with the condenser plant. The condenser plant is situated at the back of the furnaces, and the whole is contained in one large lofty building. Men employed in the phosphorus process can be divided into two sections—furnace men and condenser men. It is noteworthy that among the furnace men no cases have been reported. These men do not handle phosphorus but are subject to the pentoxide fumes of burning phosphorus when any slight leak occurs on the furnace. Although in the same building as the condensers, the fumes from the condenser side do not appear to reach these men to any extent. This is probably due to the heated air rising from the furnace acting as a kind of screen. A much larger number of men are employed in handling phosphorus and phosphorus mud on the condenser side.

"'In emptying the condensers the crude phosphorus is siphoned off while in the molten state and run under water into cast-iron molds where it solidifies. After the phosphorus is drawn off, the residues, known as phosphorus mud, are also siphoned off and removed for further treatment.

"'During the siphoning and subsequent handling of the crude phosphorus and mud, fumes consisting of the lower oxides of phosphorus arise and similar fumes come from the mud which has splashed onto the wet floor. It was hardly practicable to remove these fumes by exhaust ventilation, as there were so many points of origin. The efforts of the firm were concentrated on improving the condensers and the drainage of floors. Concrete was largely used in place of wood for the condensers and the floors between condensers were relaid. This improved the conditions, as splashes of phosphorus or mud could easily be swilled away. In addition, the sides of the building were opened up, so as to obtain better general ventilation. With improved condensers improved methods of working were introduced, so as to reduce the amount of handling and consequent exposure to air of the crude phosphorus and phosphorus mud. The amount of fume in the air became noticeably less, but there was still room for improvement. Further experiments were made which have proved that in the future it will be possible to draw off the phosphorus and phosphorus

<sup>5</sup> United States Bureau of Labor Bulletin No. 86. Phosphorus poisoning in the match industry in the United States, by John B. Andrews. Washington, January, 1910.

muds from the condensers in such a way that fumes can only escape at one or two points. These points of escape can easily be dealt with by means of exhaust ventilation.

"Two cases of phosphorus poisoning occurred in the amorphous phosphorus department. In this department yellow phosphorus is converted into the amorphous or red variety. The amount of fume in this process is not great, and, as the fumes are given off at definite points, they can be dealt with by means of exhaust ventilation. A satisfactory system of exhaust ventilation is now working."<sup>9</sup>

One case of phosphorus necrosis was reported from the factory in which phosphorus and its compounds were prepared. The case was unusual in that duration of employment had been four years only, and the man was employed in the drying and finishing room for phosphorus sesquisulphide, where exposure to phosphorus fumes would occur only when firing took place. This was the first case that had occurred in this department. Necrosis involved the right lower jaw.<sup>10</sup>

In Great Britain the law requires that cases of certain industrial poisons, including phosphorus, be reported. The following cases of phosphorus poisoning were reported from 1900 to 1918.<sup>11</sup> So far as is known no cases have arisen since 1919.

	Number of cases
1900 -----	3
1901 -----	4
1902 -----	<sup>12</sup> 3
1903-1905 <sup>13</sup> -----	<sup>14</sup> 2
1906-1908 <sup>13</sup> -----	1
1909-1911 <sup>13</sup> -----	1
1912-1914 <sup>13</sup> -----	0
1915 -----	3
1916 -----	2
1917 -----	3
1918 -----	3

One case was reported in 1919 from the factory in which phosphorus and its compounds are prepared.<sup>a</sup> No cases have occurred since 1919.

#### APPENDIX C.—ACUTE PHOSPHORUS POISONING FROM FIREWORKS

Phosphorus fireworks containing poisonous phosphorus are manufactured primarily for the use of children, and are sold extensively around the Fourth of July and in the Southern States at Christmas time. Some forms of these fireworks resemble candy lozenges, and children, mistaking them for candy, often put the toy into their mouths and perhaps swallow part of it, with fatal results, as is shown by the following cases, obtained from the medical records of physicians, hospitals, and bureaus of vital statistics, which have come to the attention of the bureau but which by no means include all such cases:

Thelma B., aged 11 years, died in Baltimore July 11, 1923. "as a result of phosphorus poisoning from swallowing a piece of firecracker containing poison."

Vashtie H., aged 7 years, died July 7, 1923, in Baltimore. The cause of death was given as poisoning, following the eating of a "spit devil." Her illness lasted three days.

Catherine F., aged 5 years, died July 5, 1922, in New York City, of acute phosphorus poisoning, after an illness of six days, which began with vomiting, pain in the region of the liver, nausea, and constipation. She was taken to the hospital July 5, at 10 a. m. and died at 8.15 p. m. the same day. The following symptoms were recorded when patient was examined, after admission to hospital: The child was unconscious, slightly jaundiced, pupils dilated, equal

<sup>9</sup> Great Britain, Chief inspector of factories and workshops. Annual report for the year 1918. London, 1919, p. 67. [Cmd. 340.]

<sup>10</sup> Idem, 1919. [Cmd. 341], p. 62.

<sup>11</sup> Idem, p. 62.

<sup>12</sup> Idem, 1918. [Cmd. 340], p. 65.

<sup>13</sup> Two fatal.

<sup>14</sup> Average.

<sup>15</sup> One fatal.

reaction to light; crepitant râles heard on both sides of chest, heart regular, abdomen tenderness, enlargement of liver, abdomen distended. Temperature, 100°; pulse, 112°; respiration, 28.

Katherine C., aged 2 years, died July 8, 1922, in New York City, after an illness of two days. She was taken to the hospital at 6.30 p. m. in an unconscious state and died at 8.30 p. m.

George S., aged 9 years, died September 4, 1922, in New York City, from phosphorus poisoning, following the eating of a "nigger chaser." The child came home the day before his death complaining of nausea, vomiting, and "feeling sick" and told his parents he had eaten a "nigger chaser." He developed convulsions at noon, lasting one-half hour, and died at 10.40 p. m. the same day.

Ruth K., of Jersey City, aged 2½ years, swallowed a "son-of-a-gun" on June 17, 1924 at 3.30 p. m. and became seriously ill. She was taken to the hospital and died at 5.15 the next morning.

James Burleson, aged 13 months, and Ida Bell Vann, 18 months, both of Pensacola, Fla., died December 25, 1923, from chewing fireworks known as "dancing devils."

Doctor S., health officer at Lyons, N. Y., reports the death of a little girl, 5 years old, from eating "devils-on-the-walk." When a physician was called on July 7, she was beyond help.

Doctor J., of Whistler, Ala., reports the death of Cammie G., aged 2 years, on December 20, 1923, from "acute gastritis" due to eating a form of fireworks known locally as "son-of-a-gun."

John F., of Minneapolis, Minn., aged 1 year, died July 5, 1924, from accidental poisoning from ingestion of phosphorus in fireworks. The night previous to his death, he ate some pieces of "sons-of-a-guns" and vomited; no doctor was called. He seemed to improve, but during the afternoon of the day of his death he became worse and a doctor was called. Death occurred at 4.15 p. m.

A child in Hartford, Conn., 3½ years old, died February 9, 1924, from acute phosphorus poisoning, as a result of eating fireworks containing white (yellow) phosphorus.

A child 2 years old died July 7, 1924, at Rome, N. Y., as a result of acute phosphorus poisoning from eating phosphorus fireworks.

A child in Montgomery, Ala., 2 years old, died December 22, 1924, from acute phosphorus poisoning as a result of eating fireworks containing poisonous phosphorus.

In a recent article in the Journal of the American Medical Association,<sup>18</sup> the danger to children from fireworks containing white or yellow phosphorus is discussed. The case of a 3-year-old child of Kansas City, Kans., is reported, who, on July 4, 1924, ate a "spit devil," and next day suffered great abdominal pain and vomited frequently. Treatment consisted of 1 ounce of castor oil and one-half ounce of Epsom salts, which was soon vomited. Three days later he was taken to the children's hospital where death occurred at 4.30 a. m., July 8.

In Eunice, La., Gary C., aged 2 years, died March 27, 1924, from poisoning due to eating "spit-fire." On January 12, 1924, after an illness of three days, Gloria O., aged 1 year and 7 months, died of poisoning from the same cause.

The American Museum of Safety reports that the following children died as a result of eating phosphorus fireworks, about the Fourth of July, 1925:

Emmet Holden, Rochester, N. Y., 4 years old.

Henry Trueheart Adriance, Galveston, Tex., 2½ years.

Thomas G. Ramsey, Kansas City, Mo., 3 years.

James Vernon Blizzard, St. Joseph, Mo., 6 years.

Hazel Lewis, Kansas City, Mo., 2 years.

Theresa Brule, Rumford Falls, Me., 7 years.

Richard E. Tracy, Rochester, N. Y., 3½ years.

Ernestine Nye, Patchogue, Long Island, N. Y., 2 years.

Lillian Lensing, Rochester, N. Y., 4 years.

After the death of the two Louisiana children, an aroused public opinion resulted in the passage of the following law (Act No. 104, Acts of 1924):

<sup>18</sup> Journal of the American Medical Association, Apr. 25, 1925, p. 254: "Phosphorus poisoning in a child from the ingestion of fireworks," by Hugh L. Dwyer, M. D., and Ferdinand C. Helwig, M. D.

"SECTION 1. It shall be unlawful for any person, firm, or corporation to sell, exchange, barter, or in any other manner dispose of 'spit devils,' 'devil on the walk,' and 'son of a gun,' or other similar device, or any other friction firework containing white or yellow phosphorus.

"SEC. 2. The term 'spit devils,' 'devils on the walk,' 'son of a gun,' or other similar device, or any other friction firework containing white or yellow phosphorus, is hereby defined to be a noise-making firework, resembling a piece of candy in size and general appearance.

"SEC. 3. Any violation of the provisions of the act shall, upon conviction, be punished by a fine of not more than \$50, or imprisonment for not more than 60 days, or both, at the discretion of the court."

So dangerous are these fireworks regarded even in the fireworks trade that a large distributor of fireworks has since early in 1924 refused to handle them, so advising its patrons in the following letter:

JANUARY 10, 1924.

"We wish to advise you that on account of newspaper reports such as the following, of deaths resulting from children mistaking for candy the phosphorus item which is sold under different names, such as son of a gun, devil on walk, spit devils, dancing devils, we have decided not to handle same:

"Pensacola, Fla. Dec. 25.—James Burlison, 13 months, and Ida Bell Vanu, 18 months, are dead from chewing fireworks known as 'dancing devils.'

"We have not manufactured these goods, but have from time to time handled them for the accommodation of our jobbing friends, so under the circumstances we will not ship you these items on your order.

"We are advising you as above so that you may be governed accordingly. Life is too precious to be jeopardized by the sale of an item reported as so dangerous."

#### APPENDIX D.—CASE OF PHOSPHORUS NECROSIS IN EXTERMINATOR INDUSTRY IN NEW ZEALAND

The following case of phosphorus poisoning which occurred in New Zealand is the only one that has been discovered in the exterminator industry. It is recorded as follows:

"'Phossy jaw,' as phosphorus necrosis of the jaw is called by factory workers, is becoming increasingly rare since the use of the poisonous yellow phosphorus has been prohibited by law. The present is the only case I have any cognizance of in which the 'phossy jaw' was acquired through mixing rabbit poison (phosphorus and pollard, etc.).

"The patient, a man, age 60, had been engaged for many years in mixing such rabbit poison in Central Otugo, New Zealand. About 12 months ago he began to have pain in a lower wisdom tooth; this was extracted, and he went on with his work. About a month afterwards he was sent down to me with a well-marked periostitis and necrosis on the left side of the mandible, which, despite very free incisions and efficient drainage, both inside the mouth and under the jaw externally, rapidly spread all around the jaw. The pain during this period was severe, and only morphia controlled it. The acute stage, however, soon subsided, and the tissues settled down to sequestration, accompanied by much suppuration for which free external drainage was provided on both sides of the jaw. The patient's health was maintained at as high a level as possible during this period by a very nourishing diet, tonics, and fresh air. His resistance kept up well and he showed no signs at all of a general toxæmia, which is the cause of fatal termination in such cases.

"At the end of six months, judging sequestration to be complete with the development of a considerable involucrum all around the jaw, I proceeded to remove the necrosed bone. This was done in two stages. The left half was removed first in two sections through a long incision below the mandible, the involucrum being split along its lower border to allow of removal of the contained sequestrum; this was accomplished without any very great difficulty. Three weeks later the right side of the jaw was treated in similar manner with an equally satisfactory result. It is essential that such cases be left until complete sequestration has taken place, in order to stimulate the formation of new bone; the old method of curretting led to disastrous results.

"The four pieces of the necrosed mandible, on being put together, showed that the sequestrum consisted of a complete mandible—constituting a somewhat unique specimen.

"The patient has made an excellent recovery \* \* \* there is a small amount of deformity. The formation of new bone is taking place freely. For some time—about a fortnight—he had difficulty in controlling his tongue and preventing it from falling back into his pharynx, especially at night, but when the involucrum—new mandible—united again this trouble ceased.

"The interest in this case centers around several points:

- "1. The extensive destruction of bone.
- "2. The excellent stimulus to new bone formation derived from the presence of the sequestrum.
- "3. The advantage obtained by not being in too great a hurry to remove the sequestrum, and especially the avoidance of continual currettings.<sup>16</sup>

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<sup>16</sup> British Journal of Surgery, January, 1923, p. 380: "Phosphorus necrosis of the mandible," by H. P. Pickerill.