The Journal of the American Medical Association

Published Under the Auspices of the Board of Trustees

VOL. LXVIII, No. 20 CHICAGO, ILLINOIS MAY 19, 1917

INDUSTRIAL POISONS ENCOUNTERED IN THE MANUFACTURE OF EXPLOSIVES

ALICE HAMILTON, M.D.

CHICAGO

Accidental explosions are so great a danger in the industry of making explosives that they overshadow the less spectacular but quite as real danger of industrial poisoning. The outbreak of the great war was followed in Great Britain by a rapid increase in the notifications of occupational poisoning from certain substances as a result of the enormous increase in the manufacture of ammunition of all kinds. What the experience of France and of the Central Powers has been we dd not know, but there is no reason to suppose that they have escaped this natural consequence. Nor is there any reason to suppose that we have escaped it, since we too began to increase greatly our production of the ordinary explosives soon after the war broke out, and also to manufacture quite new ones. Consequently, it seemed desirable to learn whether here too this industry has been attended with a serious amount of poisoning, and the United States Bureau of Labor Statistics asked me to make a study of it. I visited forty-one plants in which all sorts of explosives are made except ordinary gunpowder, black powder, for its manufacture does not involve exposure to poisonous fumes or dusts. Shrapnel plants also were omitted, because shrapnel consists of steel receptacles filled with bullets and black powder. The important explosives for such a study as this are nitrocotton, smokeless powder, picric acid, trinitrotoluene, fulminate of mercury, nitroglycerin and the mixed nitroglycerin powders, and some rarer, less used explosives, belonging to the nitro-aromatic series.

In these forty-one plants there were about 30,000 Persons employed in work exposing them to poisons of various kinds. Only a minority were women', about 1,100, and of these only forty were doing work which involved serious risk. This, of course, is in great contrast to foreign munition works, in which the majority of the work is done by women, and in all probability women will from now on be employed in increasingly large numbers in our plants, for much of the work is such as women can do perfectly well. There were also few lads employed in this industry, in which carelessness may result so disastrously. But this is another feature which will probably change now.

At the time this study was made, between April and December, 1916, the industry was already large and important. The poisons to which workers are exposed are unfamiliar in this country, and it seems timely to describe them, the processes in which they are encountered, and the effects they may be expected to produce. After the war is over these plants will continue to operate, even if disarmament should follow, for there are many uses to which they can be put. The guncotton factories can produce celluloid, lacquers. artificial leather and photographic films; the picric acid plants can make dyes; trinitrotoluene can be used as a peace explosive. In addition, the compounds which have been produced for this manufacture will continue to be produced for other purposes. We shall continue to distil benzene and toluene and to make phenol (carbolic acid) long after the demand for explosives is over, so that this is not to be regarded as a temporary industry which need not demand much attention because the dangers connected with it will not last long. It has become a permanent part of our industrial life.

To discover how much illness has resulted from this kind of work is difficult; indeed, it is impossible to get full, accurate figures. Superintendents naturally hesitate to give information that may seem to put their employers in a bad light, and the company physician is often quite as unwilling. In other cases, the physician with the best will in the world cannot give usable information, because he has not the habit of keeping records and can only say vaguely that he has sometimes seen as many as twenty cases of "fume sickness" on a hot night, or that he remembers a man who died in the hospital but he was not sure what killed him; so he called it pneumonia. There were only twenty-eight factories from which trustworthy data could be secured, and I found that in those twenty-eight there had been during the preceding year a little more than 2,500 cases of industrial poisoning, with fifty-three deaths. I am quite sure that this figure is less than the truth, for many cases fail to be recognized by the ordinary practitioner.

These 2,500 persons were not all seriously poisoned. There were 111 who had nothing worse than a fulminate rash; there were 205 cases of mild anilin poisoning. But with the exception of these, the form of poisoning was always fairly serious and sometimes very serious. The 2,500 were divided as indicated in the accompanying table.

It will be noted that nitroglycerin, which has been manufactured for many years in this country, has not a single case to its credit, while benzene and toluene have proved very dangerous, and trinitrotoluene, a new explosive in America, is responsible for more trouble than any substance except the nitrogen oxids so commonly evolved in nitration works. The other substances were responsible for only a few deaths.

MANUFACTURE OF EXPLOSIVES

There is always danger of nitrogen oxid fumes in the manufacture of explosives, because they are

nitrated products and the processes of nitration are accompanied by the production of these fumes, which give rise to what is commonly called "fume sickness." Haldane states that mice die after half an hour in an atmosphere containing 0.05 per cent. of nitrogen oxids. The danger is greatest in the nitration of cotton to nitrocellulose, and in the nitration of phenol to picric acid, trinitrophenol.

NITROCELLULOSE

Cotton which has been previously purified and finely divided is mixed with acids and allowed to digest till the change to nitrocellulose has occurred. The acids are nitric — which is sometimes used in 100 per cent. strength — and sulphuric acid, the latter being added to take up the water liberated in the reaction which otherwise would dilute the nitric acid. When nitration is complete, the cotton is transferred to a centrifuge — called a wringer — and the acid removed, after which it is "drowned," that is, dropped into a large tank of water and washed thoroughly. It is in the wringing and drowning that the greatest danger of fumes arises. If the acid is not strong enough, the cotton matted or not thoroughly cleansed, or if a few drops of water find their way into the wringer, there may be a rapid decomposition with an evolution of nitrogen oxids so violent that the lid of the wringer is sometimes blown off, the acid splashed about, and

SOURCES OF POISONING

Poison	Men	Women	Total	Fatal Men	Fatal Women	Fatal Total
Nitrogen oxid	1,389	..	1,383	28	..	28
Trinitrotoluene	660	43	703	11	2	13
Benzene	14	..	14	7	..	7
Nitrobenzene and toluene.	12	..	12	1	..	1
Ether	52	..	52	1	..	1
Phenol	2	..	2	1	..	1
Mixed acids	2	..	2	1	..	1
Sulphuric acid	4	..	4	1	..	1
Picric acid	7	..	7	..	..	..
Anilin	205	..	205	..	..	..
Fulminate	79	32	111	..	..	..
Ammonia	1	..	1	..	..	..
Mercury	1	..	1	..	..	..
Nitronaphthalenes	2	..	2	..	..	..
Chlorin	3	..	3	..	..	..
Total..:	2,433	75	2.508	51	2	53

the whole room filled with a fine-spray of atomized acid as well as fumes. Such an accident results not only in fume poisoning but also in severe bums if the workmen are anywhere near. In drowning, the fumes are not so heavy, and there is not the danger of acid bums.

The higher the nitration, the greater the danger. Highly nitrated cotton is used for military guncotton, for the making of the so-called nitroglycerin powders, such as ballistite and cordite. We are manufacturing ballistite for our own use and cordite for the British. Both are mixtures of high nitration nitrocotton and nitroglycerin. Cotton of lower nitration is used for the manufacture of smokeless powder, and a still lower variety for celluloid and lacquers and photographic films.

I am told that improvements in technic have lessened the number of such fires, as they are called, in cotton nitration works since I visited them last summer and fall. At that time they were so frequent as to arouse no comment at all. Eight times during a visit to one large works I saw the angry, orange yellow fumes come pouring out, the workmen fleeing before them, and the general suspension of work till the air had had time to clear. The workmen become accustomed to the fumes in great measure, and I have been choked and blinded and speechless in an atmosphere that seemed to cause them no discomfort. There is, however, no real immunity to nitrogen oxid fumes. Old hands (any one who has worked as long as eight months in the explosive industry is an old hand) may succumb as quickly as new ones to an unusually severe exposure.

Cases of Poisoning from These Compounds.—The list given in the tables begins with 1,389 cases of poisoning from nitrogen oxids (995 from nitrocotton plants, 381 from picric acid, and thirteen from nitric acid works). These varied all the way from light to fatal. In light cases, the man "chokes up," the irritation of the fumes causing a spasmodic contraction of the bronchi such as takes place in bronchial asthma, and, indeed, the attack much resembles an asthmatic seizure. Often there is cramplike pain in the abdomen as well. These symptoms are relieved by the usual first-aid remedies, chloroform shaken up in water, and often the man can go back to work on the same shift, though it is considered safer to send him home to bed. Severe and fatal cases present the same picture as the gassed soldiers from the trenches. British and French medical journals have been full of the symptomatology and pathology of chlorin poisoning as it is seen at the front, and their descriptions would fit accurately the industrial nitrogen oxid cases in our explosive works. There is the same tardy onset of serious symptoms, the man usually going home in fair condition and some hours later developing intense and increasing dyspnea; the same gastric symptoms, which are, however, often masked by the much more distressing air hunger; the same gradual filling up of the lungs with fluid which usually results in death. Among the twenty-eight deaths from nitrogen oxid poisoning on my list, sixteen were from edema of the lungs.

There is not much fear that such a case would fail of recognition, but the less violent poisoning. which results in various forms of pneumonia often passes for ordinary nonoccupational sickness. This is even more the case with slowly developing inflammations of the lungs, or a recurrence of pneumonia some weeks after the original trouble. In a hospital not far from a large cotton nitration works I found the record of a young man who was exposed to an unusually large amount of nitrous fumes, recovered from the immediate effects, and then for three days suffered from headache, but without any lung involvement. On the fourth day he was taken ill, and signs of consolidation cf the lung developed rapidly. He was taken to the hospital, where the diagnosis of acute miliary tuberculosis was made, but after death his lungs were found to be gangrenous. .Evidently this was a secondary effect of the original injury sustained from the acid fumes. Other instances of pneumonia, sometimes fatal, were related to me by physicians who knew the nature of the processes camed on in the plants and could interpret the dangers to which the men were exposed; but many others had never thought of inquiring as to the men's occupations, and it was only when I questioned them that they began to think back and wonder whether or not the pneumonias they had seen were of this class.'

1. J. N. Hall and C. E. Cooper (The Effects of the Inhalation of the Fumes of Nitric Acid, THE JOURNAL A. M. A., Aug. 5, 1905, p. 396) followed the subsequent history of a number of firemen who had breathed enough nitrogen fumes to affect them seriously. Two who recovered from the immediate effects died of pneumonia four and five weeks later. A necropsy on one of these showed bronchopneumonia with early fibrous change in the solid areas. Fraenkel has described a case of bronchiolitis obliterans in a man who died in the third week after he had inhaled nitrogen oxid vapors.

Another often unrecognized form of nitrogen oxid poisoning is even more rapidly fatal than pulmonary edema. Here the poison seems to act directly on the nervous centers, and the changes found after death are comparatively insignificant. For instance, a foreigner applied for work during the heat of last summer in a picric acid plant where the fumes are unusually bad and very little attention is paid to the safety of the men. He went on with the night shift, and at 4 in the morning he was found lying unconscious in the yard. An ambulance was sent for but he died before the hospital was reached. The necropsy showed only a slight congestion of the meninges, some congestion of the lungs, the heart empty, and the blood fluid and dark.

Fortunately we have a more carefully worked up postmortem examination of this form of nitrogen oxid poisoning. Dr. George Apfelbach of the Illinois Factory Inspection Department had the opportunity to examine the body of a man who, like the one just described, died during the first shift of work. This was in a cotton nitration works on a very hot night, but the fumes from the acid were not bad enough to make any of the other men apply for treatment at the company dispensary. He had worked only about four hours, when he went out saying that the fumes were too much for him, immediately became unconscious, and died in about half an hour. Dr. Apfelbach found the lungs congested; the alveoli containing frothy fluid; the bronchi, trachea and larynx reddened; the kidneys, *brain, heart, stomach and intestines absolutely negative; the spleen congested, and the blood fluid, not clotting, and dark in color. A sample of the blood was submitted to Dr. William D. McNally of the coroner's office of Cook County, who found no methemoglobin, but did find the blood slightly acid and containing traces of nitric oxid.

Among the twenty-eight deaths from nitrogen oxid poisoning on our list, sixteen were from pulmonary edema, five were of this extremely rapid form, and seven were from pneumonia.

Inflammation of the throat is not rare, and is occasionally serious. I have records of three cases of laryngeal edema, in one of which intubation had to be performed. This man did not realize that the fumes had injured his throat until about six hours later, when pain and swelling began and increased, and he had to be sent to the hospital for the dangerously increasing dyspnea.

We do not know what are the effects of long continued exposure to these vapors, beyond the fact that they act on the enamel of the teeth, so that men on the nitration area soon lose their front teeth. The wire screening in the windows of company hospitals soon rots away; the men wear pure wool shirts because cotton will not last at all, but even the thread in the seams of shirts rots away and the garment falls apart. It seems incredible that acid strong enough to attack metal and enamel should be without any effect on the mucous lining of the respiratory tract, yet I have not been able to find any evidence of chronic trouble. This is perhaps explained by the continual labor turnover, which is great in all departments of a munition plant, but always greatest in the nitrating areas.

After the cotton is nitrated there is no further danger of poisoning in a nitration works, for the washing and purifying is quite harmless. The next step is the conversion of nitrocotton to smokeless powder or powders; but this is usually carried on in another plant and will be described later, as it involves quite different poisons. The explosive that follows logically after nitrocellulose is picric acid, for its manufacture gives rise to a great deal of nitrogen oxid fume poisoning, more, I believe, in proportion to the men employed, than does the making of nitrocotton.

PICRIC ACID

This is chemically trinitrophenol, and is made by the action of mixed acids on phenol (carbolic acid). It is itself a poison, and so is phenol; it follows, therefore, that while in a nitrocotton works only a minority of the force are exposed to occupational poisoning, in one making picric acid, almost all are so exposed.

The making of picric acid seems to be comparatively simple and can be carried on with a primitive equipment. The consequence is that soon after the beginning of the war many picric acid works were started in abandoned factories or hastily constructed plants, and the production was rushed in a most reckless fashion in order to fill war contracts. The worst conditions I saw anywhere were in picric acid works, not only in the small plants, but also in large establishments employing some thousands of men. The moment the mixed acids meet the phenol, there is an evolution of nitrogen oxid fumes, and if nitration is done in partly open receptacles, and hand stirring required, and if no adequate exhaust system has been installed, there may be at times a condition inside the nitration sheds that is a menace to life. Unfortunately it is in just these recklessly managed plants that medical care of the men is poorest, and provision for personal cleanliness most insufficient.

A further danger in this industry is the handling of picric acid, especially if it is dried down to less than 1 per cent. of moisture, when it becomes very dusty to handle. As a usual thing it is shipped with 10 per cent. of moisture left in. Men who handle it and get dusted over with it suffer from a dermatitis which may be extremely irritating, as I can testify from my own experience after a visit to a drying house one hot day last July. The better managed companies take pains to protect their men by baths and changes of clothing, but in the newer plants "picric itch" is taken as a matter of course.

Systemic poisoning from picric acid has been known to the French for some time[2] because the favorite high explosive of the French, melinite, consists chiefly of picric acid. The British picric acid mixture is known as lyddite. There are not many cases of picric acid poisoning to be found in our plants, perhaps because this compound is slowly absorbed and labor in these places changes rapidly, the turnover being truly enormous in some of them. A few instances were related to me of symptoms such as the French describe, abdominal cramps, vomiting, diarrhea, loss of appetite and loss of weight, leading the man to quit work for fear of serious consequences.

An unusually severe form was described by Dr. T. F. Harrington of the Massachusetts Board of Labor and Industry:

> Two men spent Sunday repairing leaky ducts in the building in which nitration of phenol was carried on. The next day, one of them began to feel very weak, his pulse was small and irregular, he was pale with a slight bluish tint, and he had headache and dizziness and palpitation of the heart. The other man went to the company physician on Friday complaining that he had felt ill ever since his Sunday's job, had been unable to eat, had nausea, headache, cough and difficulty

2. Chéron: Jour. de thérap., 1880, p. 121.

in breathing on slight exertion, and that he felt dull and confused and very weak. These men lost two and three weeks from work.

PHENOL

The synthetic preparation of phenol, C_6H_5OH, consists in sulphonating benzene, forming benzene sulphonic. acid, $C_6H_5SO_2OH$, and then alkaline fusion by which the OH group is introduced in place of the sulphonic acid group. The greatest danger in this work has already been spoken of, fumes of benzene. Phenol bums are common; systemic poisoning seems to be rare.

A fatal case was reported by Dr. **T. F. Harrington, of a young chemist who stepped into a pool** of **phenol waste and soaked his leg in it. Soon he began to complain of ringing in the ears, dyspnea and dizziness. Then he became dazed, excited and almost hysterical. He was allowed to leave the building in this condition, but evidently he soon lost consciousness, for the next morning he was found dead on the road. The leg was then greenish black up to the knee.**

BENZENE[3] AND TOLUENE,[4] OR METHYLBENZENE

These two may be considered together, since their toxicity is about equal and the symptoms of poisoning much the same. Benzene is third on my list of poisons, and just half of the cases were fatal. This is partly because slight poisoning from benzene passes over quickly and excites little attention and the cases are not remembered. All those reported to me were serious.

Benzene and toluene are poisons with: *(a)* a specific action on the nervous system, leading to dizziness, confusion, transient excitement followed by dulness, muscular twitchings, stupor, coma, respiration rapid then slow, pulse rapid and temperature subnormal; *(b)* the production of multiple hemorrhages through a solvent action on the capillary endothelium, or through the lodgment of fat emboli, causing rupture of the capillary **wall,**[5] and **(c)** changes in the constituents of the blood, the most striking of which is a leukopenia.

Of the seven deaths from benzene on my list, five occurred in connection with repair work in or round a still. The other two patients were engaged in sulphonating benzene for the synthetic production of phenol. All were sudden, sometimes shockingly sudden. Thus one man went to the top of a still to stop a leak, was overcome, and died in less than five minutes' time, while two fellow workmen who went to his assistance were **also** overcome and with difficulty revived. In another case, the men were inside the still, which was supposed to be free from benzene, became excited and then stupified, and were pulled out quite unconscious; the one who had been in longer was revived with oxygen, and the other died.

I am indebted to Dr. H. S. Martland, pathologist of the Newark City Hospital, for the records of two necropsies performed by him on men who died from benzene poisoning as a result of inhaling fumes in the sulphonating room of a phenol works. One was found dead beside the "liming vat" into which the sulphonated benzene — doubtless carrying some unchanged benzene with it — flowed, and because of the heat was volatilized at once; the other was found dying near the benzene supply pump in the same room. Dr. Martland found in the first: cyanosis of the liver, spleen and kidneys, dilatation of the right heart with dark blood. pleural ecchymoses, and small areas oi acute interstitial emphysema in the lungs. In the second **man** the changes were similar, but here a decided odor of benzene was perceived when the lungs were sectioned, and there were tiny hemorrhages into the pleurae and pericardium. The urine contained an abnormal quantity of phenol, but no benzene.

NITRO AND AMIDO DERIVATIVES OF THE BENZENE RING

There are several of 'these compounds made for use as explosives, and others that are steps in the production **of** explosives. Most important of the iormer is picric acid, already described, and trinitrotoluene (triton or T. N. T.) ; less important are the citronaphthalenes, diphenylamin or diamidobenzene, tetranitranilin (T. N. A.), and tetranitromethylanilin (tetryl). For the production of explosives, we find nitrobenzene and amidobenzene or anilin, chlorobenzene and diriitrochlorbenzene.

These compounds have certain characteristics in common, but cases of industrial poisoning from different members of the group vary quite a little. Curschmann[6] believes that the higher the nitration the greater the toxicity: but sometimes the lower nitrations are more volatile or more easily absorbed through the skin and therefore in actual practice more dangerous. It must also be remembered that these explosives are often not chemically pure. Crude trinitrotoluene may contain not only dinitrotoluene, but also the far more poisonous dinitrobenzene, if the toluene contained an admixture of benzene.

Briefly described, the symptoms typical of poisoning by this group depend on a direct action on the nerve centers, respiratory, heat regulating and vasomotor, and on changes in the elements of the blood, the 'most important of which are the formation of methemoglobin and the destruction and subsequent regeneration of red corpuscles. Some would ascribe all the symptoms to the presence of methemoglobin, but Heubner[7] has shown that they may be produced in rabbits before methemoglobin is formed, through action on the lower centers, death occurring from respiratory paralysis.

The volatile compounds, such as anilin, nitrobenzene, diphenylamin (used as a constituent of smokeless powder) and nitrochlorbenzene, produce their effects rapidly. The following case is typical **of** nitrobenzene poisoning:

The man had been exposed to fumes of nitrobenzene and had become dizzy and 'faint, so that he was obliged to go out into the open air. His face, which had been flushed, grew cyanotic, his distress increased, and a severe throbbing headache came on, the pulse became rapid and small, and respirations quick and shallow. He was taken home and put to bed where he soon lost consciousness. He lay in stupor, deeply cyanosed, almost pulseless, for several hours; then convulsions came on, and he died in less than twenty-four hours after the beginning of the attack.

Blood drawn during such an attack is chocolate colored, but methemoglobin may not be demonstrable till later unless the red corpuscles are dissolved in water.[8] Hudson[B] finds quite constantly in nitrobenzene poisoning an early leukocytosis soon changing

3. Rambousek (Concordia. 1910, p. 448) thinks benzene the more toxic.
4. Lehmann (Arch. f. Hyg., 1911, 74. 1) finds that narcosis from toluene is more rapid and lasts longer.
5. Santesron: Arch. f. Hyg., 1897. **31,** 336.
6. Curbchmann: Internat. Cong. Indust. Hyg., Brussels, 1910.
7. Heuhner: Zentralbl. f. Gewerbehyg., 1914, **2,** 409
8. Roth: Zentralbl. f. inn. Med., 1913, **34.** 417.
9. Hudson: Med. Rec., New York, 1917. **81.** 89.

to a pronounced lymphocytosis, and destructive changes in the red blood cells. The urine is dark and contains urobilin, but no hemoglobin nor bilirubin.[10]

Nitrobenzene causes fewer cases of poisoning than anilin, but the cases are of a severer type. In the explosives industry I did not find serious trouble from anilin. There is a good deal of poisoning of a mild type in the one factory in which I found nitrobenzene being reduced to anilin and the latter used for the production of explosives, but the men are well protected against serious poisoning. It seems not to be so dangerous to breathe anilin fumes as to spill the oil over the skin, and in this plant such an accident is always followed by prompt stripping and bathing. Of course we shall probably begin to have chronic anilin poisoning as the Germans have described it, profound anemia simulating valvular heart disease, with its dyspnea and cyanosis. We ought also to be watching for the bladder tumors which the Germans have found to be unduly common among anilin workers.

The local effect of some of these compounds on the skin is much more pronounced than in the case of others; indeed, the irritating dermatitis caused by picric acid is so common as to constitute typical picric acid poisoning in the eyes of powder works physicians, while anilin gives little trouble of this sort. A more or less deep yellow staining of the skin and hair is caused by most of them. Picric acid workers are the most deeply dyed and are usually called "canaries" by the countryside. Trinitrotoluene causes a less vivid stain, tetranitromethylanilin a stain with a greenish tint. This yellow color is so conspicuous as to confuse the inexperienced and lead in some cases to a diagnosis of jaundice."

The confusion is increased by the fact that the staining of the skin is not only a mechanical effect of contact with the dye, but is in part caused by its deposit in the deeper layers. White[12] exgerimented on himself with trinitrotoluene, which he rubbed into the skin of the arm, and a yellow color appeared under his nails. In the same way the sclera may turn yellow when there is no jaundice.

Dermatitis is said to be most severe from dinitrochlorbenzene, next from tetranitromethylanilin, then from trinitrotoluene, and then from picric acid.

TRINITROTOLUENE

Usually the cases of poisoning from trinitrotoluene do not conform to the type given above, for absorption takes place more slowly and there is time for degeneration in the parenchymatous organs. This may be true even of more volatile compounds than trinitrotoluene. In 1906 a case was reported in England of a man who died of acute yellow atrophy of the liver from nitrobenzene poisoning, but it is much more common in connection with trinitrotoluene. The British factory inspection reports now contain a new occupational disease, toxic jaundice. In answer to a question in the House of Commons last September, a member of the government said that there had been in the previous nine months 120 cases of toxic jaundice, with thirty-three deaths, and of these, ninety-five with twenty-eight deaths had been caused by trinitrotoluene, and the others by that new industrial poison used in aeroplane "dope," tetrachlorethane.

There are 703 cases of trinitrotoluene poisoning on my list, with thirteen deaths. I should have added six more deaths, had it not been for my rule not to include a case unless it was reported by the physician who saw it. These came to me at second hand, and first hand information was refused.

Trinitrotoluene is a new explosive in this country, though a plant in northern Wisconsin has been making it for some years. Even in England it was unknown before the war, for nitrobenzene had been used instead. Now it is made in great quantities, since it is the chief constituent used in high explosive shells, together with a detonator of fulminate of mercury with perhaps some tetranitranilin. There is, I believe, less danger of poisoning in the nitrating of toluene than in the subsequent handling of the trinitrotoluene, and the danger from nitrogen oxid fumes in nitrating seems to be slight. It is in the melting, pouring, pressing, boring and planing of the charges for shells that the greatest number of cases occur. There are both dust and fumes in this sort of work, sometimes to an excessive degree, especially in the boring process, when the detonator hole must be made in the solid charge. Even small amounts of dust may be dangerous. I found a woman suffering from a severe form of toxic hepatitis whose work had been weighing charges and scraping off with scissors a little of the trinitrotoluene if the charge was too heavy. She sickened after only five weeks' employment.

Typical trinitrotoluene poisoning is not rapid. The British show that 83 per cent. of their cases of jaundice have occurred between the fifth and sixteenth weeks of work.[13] I might cite the following cases from among those reported to me, as typical of various forms of trinitrotoluene poisoning. The first was only moderately severe:

The man was employed on a machine for boring detonator holes in trinitrotoluene charges, and the shield that was supposed to hold the dust produced in boring was broken, so that he had to breathe contaminated air. He began to have an obstinate cough after three weeks' work, and expectorated yellow mucus which would stain water yellow. Later he was put into the molding room where trinitrotoluene is melted in great, partly open kettles, and fumes escape. By this time he felt very ill and attributed it to the fumes, which seemed to give him headache, nausea and even vomiting. He had pain about the navel and in the joints. At night the joints were swollen, especially the ankles. His headaches increased in severity, he had no appetite, and grew so weak that he was obliged to quit work.

This man paid several visits to the company physician, who regarded the symptoms as unimportant and sent him back to the same sort of work. British authorities emphasize the great risk of doing this, for at any moment a slight case may develop into one rapidly fatal. They attach importance to such symptoms as a persistent cough due to no known cause, unaccustomed shortness of breath, fatigue not explained by exertion, and pains coming on suddenly in the feet and legs. These persons should at once be shifted to safe occupations. That this may not

10. Mohr: Dentsch. med. Wchnschr., 1902, 28, 73.

11. We read that, in the British and French armies, soldiers who want a leave of absence sometimes take a small dose of melinite, which makes than vomit, suffer from cramps and diarrhea, and finally turn yellow, simulating in every way, except for clay-calor& stools, an attack of hepatic jaundice.

12. White: Lancet, London. 1916, 1. 400.

13 Lancet, London, Dec. 16, 1916.

be enough tu save the patient is shown by the history of one of my patients:

A girl, aged 19, for some months had been dipping trinitrotoluene charges in melted paraffin, and then she was sent to work in the office. It was after she had left the trinitrotoluene department that she developed symptoms of poisoning. At first they were slight, nausea and constipation without jaundice, but they increased rapidly, persistent vomiting came on, deep jaundice, complete suppression of urine, and death after twelve hours of coma.

Two cases of the same kind in men were reported from another factory. Both patients had symptoms typical of acute yellow atrophy of the liver, vague discomfort and a feeling of weakness, then marked gastro-intestinal disturbance, griping pains across the abdomen, increasing jaundice, fever, dropsy, delirium, coma and death. There were also petechial hemorrhages over the body.

No necropsies were performed in any of these cases, but Martland[14] has recently published the record oi such an examination of a fatal case of trinitrotoluene poisoning, and also of one that presented a picture of aplastic anemia.

Less typical forms of trinitrotoluene poisoning occur when there has been a massive exposure to the poison. Three instances of this were related by Dr. T. F. Harrington but one will suffice to illustrate this class of cases:

A man, aged 42, employed as a carpenter in a building in which toluene is nitrated. became dizzy from the fumes from a duct near which he was working. He went out into the air and revived, but when he tried to resume work the dizziness returned and he was obliged to quit and go home. The next morning he came back, but as soon as he reached the place at which he had been at work the day before, he was overcome with faintness and nausea and had to be helped out of the building, when he began to vomit. It was a 2 mile drive to his home, and the fresh air revived him somewhat; but the next day he felt chilly and suddenly became very ill, had convulsions, and died about midnight. As the cause of death the coroner's report gave "red cell destruction and secondary oxygen starvation, especially of brain and nervous system; general congestion of organs."

According to British authorities, women are no more susceptible to trinitrotoluene than are men, but the immature worker of either sex is decidedly more susceptible than the mature. These authorities advise forbidding the employment of persons under 20 years of age, since they have discovered that while the general mortality from toxic jaundice, recognized as such, was 33 per cent., among the eleven patients who were under 18 years of age, no less than eight died.

OTHER POISONS

Tetranitromethylanilin *and* Tetranitrandin.—These are powerful explosives, used to an increasing extent in Europe as constituents of detonators, but so far too expensive in this country to meet general use. Their manufacture involves the danger that inheres in such compounds as anilin, methyl alcohol and nitric acid, and they are poisons belonging to the nitro-aromatic group. I did not find any trouble among workers with these substances, except a rather distressing dermatitis among the men drying and packing tetranitromethylanilin.

Fulminate *of Mercury.*—Mercury is digested with nitric acid, and the resulting nitrate is mixed with alcohol, during which latter process there is a lively evolution of fumes of complicated composition, the most important constituent being ethyl nitrite. There is some risk of mercurial poisoning—I was told of one case of salivation—and the ethyl nitrite fumes may be strong enough, especially in hot humid weather. to make work almost intolerable; but there seems to be no serious depression irom it.

Fulminate is extremely explosive and is the essential part of percussion caps and detonators. There are several thousand men and women employed in making caps and detonators in our munition plants. Apparently, from German reports, mercurial poisoning is not unknown among such workers. Not long ago Oppenheim[15] reported cases of fulminate dermatitis from Austrian works, and among thirteen there were eight with "stomatitis mercurialis." The British Health of Munition Workers Committee found mercurialism from this source rare, but the occurrence of anorexia, headache, nervousness and depression among fulminate workers may be attributable to this element.

It is well to bear in mind the possibility of this form of industrial poisoning in fulminate workers, for at present the only kind recognized by American physicians seems to be the dermatitis, which is quite common. I found it more prevalent among men than among women, probably because women dread a disfiguring eruption more than men do and take more pains to protect themselves. Among 1,070 women working in one plant, only thirty-two had had skin lesions as a result of handling the fulminate, while thirty-six of the 505 men had had them.

Smokeless Powder.—This is not a powder at all, nor are the so-called nitroglycerin or mixed powders. They resemble in appearance chopped brown macaroni or spaghetti or vermicelli, with many tiny canals running the length of the string. In order to make these powders, nitrocotton is dehydrated and then changed to a rubber-like consistency by mixing with some partial solvent, ether-alcohol, or amyl acetate, or a mixture of nitroglycerin and acetone. Then the rubbery mass is pressed through macaroni machines and the cords cut into proper lengths, during which a great deal of the solvent evaporates.

Ether-Alcohol.—Ordinafy smokeless powder, not cordite or ballistite, is made by driving the water out from nitrocotton by alcohol in a hydraulic press. So far as I have seen, the alcohol used is always ethyl. In making celluloid, large quantities of methyl alcohol may be used, but not in powder work. The alcohol fumes may be very strong at times, but the real trouble comes from the ether, especially in the pressing and cutting department, in which the temperature must be kept at from 85 to 95 F.

Acute ether intoxication, "ether jag," is *so* usual as to be taken as a matter of course. New hands suffer almost always, and some men cannot become accustomed to it. They pass through all the stages of anesthesia, excitement, with loud laughter and singing or unreasonable anger, and then increasing dulness, *so* that by the time the company physician sees them they are usually already somnolent. They are put to bed and the next day they have headache, more or less nausea and general discomfort. Most company physicians refuse to believe that the ether has any further effect, or that systemic symptoms are to be expected after long exposure to it; but it is not difficult to find instances of men who have had to quit work because of chronic indigestion, constipation, loss of weighr and strength,

14. Martland. H. S.: Trinitrotoluene Poisoning. THE JOURNAL A. M. A., March 17, 1917, p. 835.

15. Oppenheim: Wien. klin. Wchnschr., 1915, 28, 1273.

and loss of appetite because of the continual taste of ether in the mouth.

Nephritis also is noted by some physicians as a possible result, and one company physician is careful to shift to other work men who show any symptoms of kidney involvement. The fatal case of ether poisoning on my list was one of uremia, but the man was a syphilitic and doubtless had damaged kidneys when he went to work.

Sometimes the narcosis is profound and is accompanied by signs of irritation in the lungs, which may develop into a bronchopneumonia, Since diphenylamin is added to many of these smokeless powders, one should remember that the symptoms of an amidobenzene may be also present in poisoning from this solvent.

In 1910, Sand[16] presented the results of experiments on dogs with ether-alcohol fumes. His findings are significant in connection with the possible chronic poisoning of these ether workers in explosive manufacture. The ether-alcohol administered in vapor form, 500 *gm.* being evaporated during ten hours in a kennel 1.cubic meter in size. These animals showed all the manifestations of "ether jag" as they are seen in industrial poisoning. Then tolerance was gained and they did not suffer in health; in fact, three of them gained somewhat in weight; but when two were killed and examined, a general condition of stasis was found in the organs and brain, with fatty degeneration in the liver and in the kidney epithelium.

Amyl Acetate; Acetone.—These are the solvents used for other powders. Amyl acetate is called banana oil by the workmen ; and perhaps because of its strong, sickeningly sweet odor, they attribute to it the headache, dizziness, smarting of the eyes, and other symptoms from which they suffer when using a mixture containing it.[17] Lehmann,[18] however, experimenting on men as well as on animals, found it slightly toxic, and in powder works, when it is not used in combination with other poisons, it does not seem to cause any discomfort. Acetone is listed by Sommerfeld as a poison, but Kobert thinks industrial poisoning from it hardly thinkable. I found the men in one plant using it as an eye wash when they got a foreign particle in the eye, and in another plant the physician told me that acetone was a good substitute for iodin in the treatment of slight wounds.

Nitroglycerin.—It sounds strange to say that this very dangerous explosive is the safest of all, but that is true if one is considering poisoning, not 'accidents. Indeed, it is probably true of accidents also, because we have been making nitroglycerin a great many years and have learned how to do it, as we have not learned how to make the newer explosives. All the precautions taken in nitroglycerin works against accidents serve also as preventives of poisoning: strict cleanliness of the premises, separation of different processes so that as small a number of men as possible will be in any one building, close watch against decomposition during nitration, and prompt drowning of the charge when that occurs.[19]

There are a few other poisons given off in gaseous form during the preparation of compounds used in this industry. There is chlorin gas, which passes off during the early stage of nitric acid manufacture, when the sulphuric acid acting on Chili saltpeter meets the common salt that is always present as an impurity. Most acid works try to provide in some way for the carrying off of these fumes, and they are in any case so irrespirable that men get away as soon as possible, before much harm has been done. There is ammonia from the aqua ammonia used in dynamite plants for ammonium nitrate, which is added to the "dope." Sulphur dioxid, very irritating and dangerous, is given off in the making of sulphuric acid and at one stage in the manufacture of phenol.

This hasty review of the substances which are necessary for the production of explosives is enough to show that it is an industry full of dangers to the workers quite aside from the ever present danger of violent explosions. Indeed, it offers an unusually rich field of research for those who are interested in the effect of volatile poisons on the human subject.

Hull House.

16. Sand, René: Internat. Cong. Indust. Hyg., Brussels, 1910.

17. Paint removers and varnish removers which smell strongly of amyl acetate contain in addition such volatile poisons as benzene, methyl alcohol and carbon disulphid, but the odor of the banana oil overpowers or masks the others.

18. Lehmann: Arch. f. Hyg., 1911, 74, 1.

19. The singular absence of symptoms such as one would expect in nitroglycerin workers has been discussed by C. E. Laws (Nitroglycerin Head, TAB JOURNAL A. M. A., March 5, 1910, p. 738); by C. E. Ebright (The Effects of Nitroglycerin ea Those Engaged in Its Manufacture, ibid., Jan. 17, 1914, p. 201), and by Hudson (Mal. Rec., New York, 1917, 91, 89).

THE THERAPEUTIC VALUE OF PERTUSSIS VACCINE IN WHOOPING COUGH*

ANNA I. VON SHOLLY, M.D.
JULIUS BLUM, M.D.
AND
LUELLA SMITH
NEW YORK

This study was made during the late summer of 1916, as part of the investigation by the Research Laboratory of the New York City Health Department on the value of pertussis vaccine in whooping cough.

Because of the infantile paralysis epidemic, car strikes and the expiration, October 1, of the lease of the building used for clinical purposes, the number of patients used for this study is far less than we could wish. The deductions, however, are suggestive, and show the danger of drawing conclusions too hastily and without making a critical comparison with control cases.

Dr. Luttinger, in his report of May, 1915, pointed out the pitfalls in accepting the statements of patients in the clinic; but in spite of the difficulties he encountered, he gathered from his records that pertussis vaccine lessened the duration of the whoop by 37.5 per cent. as against treatment with drugs. Hoag[1] is enthusiastic about the vaccine, claiming a reduction of the whoop to from sixteen to nineteen and one half days, after from three to ten injections of the vaccine, in contrast to the duration, from fifty to one hundred and forty-five days, in cases in which only one injection is given. Many other physicians, who have received and used the New York Health Department pertussis vaccine, verbally and by letter have reported most encouraging results. Drs. A. F. Hess and Matthias Nicoll are among those who are skeptical of the marked curative effects of a vaccine. Dr. Hess believes it has some prophylactic value. Before tabulation of our records, we had the impression that pertussis vaccine had had a somewhat favorable influence on the disease, but in scientific work, impressions,

* From the Bureau of Laboratories, New York City Health Department.

1. Hoag, W. B.: Am. Med., 1916. 11. 255.