Prolonged contact with undergarments impregnated with D.D.T. has not produced any local or general disturbance in human subjects.

D.D.T. poisoning is characterized by nervous symptoms and the development of severe damage to the liver. Premonitory symptoms and changes in the blood picture give warning of the onset of the toxic stage.

We are indebted to the Director-General, Scientific Research and Development, Ministry of Supply, for permission to publish this investigation, and to the commandant and officers of the Army School of Hygiene and to Lieut.-Col. H. Cullumbine, R.A.M.C., for assistance in the human trials. Much help was given in laboratory experiments by Messrs. J. W. Allen and S. P. Rutland. We wish to thank Dr. F. F. West, chief chemist to Messrs. Stafford Allen and Sons Ltd., London, and Messrs. Geigy for supplies of D.D.T.

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ACUTE POISONING DUE TO PETROL VAPOUR

BY

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On July 3, 1942, it became necessary, for security reasons, to place a charge of explosive in the vicinity of a large storage-tank used for aviation spirit. A boring had been made alongside the tank a month previously, the last 12 feet being completed on the day of the accident. Into it a workman descended, and as petrol had been leaking from the tank into the boring he wore an oxygen-breathing apparatus. This had been carefully tested beforehand and found to fit accurately. About 10 minutes after he had descended those above saw that he was behaving oddly. He was standing at the bottom of the boring, holding on to a cross-bar and reeling drunkenly. His mate, who was near by, was immediately informed, and, though unprotected from the fumes, he promptly climbed down in the pit to render assistance. Arrived at the bottom, he could see that petrol was floating on some water there, and the air was filled with the fumes, so that his eyes smarted. He called for a rope and started to heave his mate, who was heavier than himself, laboriously from one horizontal strut to another up the vertical sides. After the first minute or two he could scarcely breathe owing to a sense of constriction in his chest, and he felt sick and began to retch. Nevertheless he persisted doggedly and had heaved his mate on to the top strut, within reach of the helpers above, when he was overcome by dizziness and fell to the bottom again. The shock of the fall brought him to his senses, and he once more began to climb. He had again reached the top strut, when he completely lost consciousness. This time, fortunately, he was seized from above and pulled to safety.

Case I

When the first workman had been lifted out it was found that he had ceased to breathe, and artificial respiration had to be employed for half an hour before normal breathing could be restored. The patient then became restless and violent and had to be given half a grain of omopon to keep him quiet during transit to hospital. On admission there, soon after, he was still semiconscious, but resisted attempts at examination. He was cyanosed and his respirations were slow and shallow. The pulse was strong—75 a minute—and there was no fever. He was given continuous oxygen with a B.L.B. mask, and in a few hours had regained consciousness. Next day he complained of discomfort in the right iliac fossa, and examination revealed tenderness in this region. He was now perfectly rational and showed no cyanosis. Examination of the cardiovascular and respiratory systems revealed no abnormal physical signs. The urine contained no albumin or sugar, nor were abnormal amounts of lead detected in urine or faeces. A blood film showed no punctate basophilia.

By the fourth day he felt well, apart from slight residual discomfort and tenderness in the right iliac fossa, which persisted till

the 12th day. He was discharged from hospital on the 14th day and remained well subsequently. There had been no sequelae when he was heard of two years later.

Case II

The second workman had also stopped breathing when carried to a place of safety. Spontaneous breathing, however, returned after artificial respiration had been applied for five minutes, and he regained consciousness shortly after. He then complained of a choking sensation and a feeling as of a ball in his chest, and felt that he could not take a deep breath. In the ambulance on the way to hospital he had several attacks of abdominal pain. These had become very severe when he reached hospital and were recurring frequently, being associated with much restlessness and excitement. A third of a grain of morphine failed to give relief, so that evipan was injected slowly into a vein till a quiet sleep was procured. In a few minutes, however, he was again restless, and became so violent that it required four people to hold him down. Further evipan had to be given, and this produced an adequate depth of sleep. Next day the pain had returned, but was less severe, and was readily controlled by morphine. There was also retention of urine, requiring catheterization, and headache was still severe.

On examination he was perfectly rational. His pupils were small but equal and reacted to light. The knee- and ankle-jerks were equal and active, and the plantar responses flexor. There was marked abdominal tenderness and guarding, especially in the epigastric region. Examination of the alimentary system proved otherwise negative, and no abnormal signs were found in the cardiovascular or respiratory system. On flexion of the cervical spine there was complaint of pain in the chest. The temperature, pulse, and respiration rates were unaffected. There was no albumin or sugar in the urine, and no abnormal amounts of lead were detected in urine or faeces. A blood film showed no punctate basophilia. The cerebrospinal fluid was clear and colourless, had a pressure of 150 mm., with protein 36 mg. per 100 c.cm., and no increase of globulin or cells.

Attacks of abdominal pain requiring morphine for relief continued till the fourth day, headache being troublesome up to the third day. A urinary infection then supervened, but this responded rapidly to sulphanilamide. The patient was discharged from hospital on the 18th day, having made a complete recovery. A cough developed soon after discharge and persisted for a year. When seen two years later he was in excellent health.

Factors in Toxicity of Petrol

Originally motor spirit was derived entirely from petroleum by simple distillation. From the crude petroleum the portion distilling up to 150° C., and known as raw benzine or naphtha, was first separated, and from this, by re-distillation, petrol boiling at 50–140° C. and pure benzine boiling at 120–150° C. were obtained. Petrol so produced is known as straight-run petrol, and consists largely of pentane, hexane, and heptane. Petrol is also obtained by "cracking" or splitting up the higher paraffins in the petroleum; it then contains olefines as well. The hydrocarbons in these two types of petrol are subject, when used as a motor spirit, to "knocking," or detonative explosion with air. Petrol containing a high proportion of octane is less prone to this fault. As neither crude nor cracked petroleum yields petrols containing an appreciable amount of octane, this is made by the re-forming of either "cracker" gases or straight-run petrol into branched-chain hydrocarbons such as iso-octane (2:2:4-trimethylpentane) by processes of catalytic combination. Such processes are used particularly in the production of aero spirit. Unfortunately the toxicity of the aliphatic hydrocarbons increases in proportion to the specific gravity and boiling-point (Tscher-nikow *et al.*, 1935). N-octane, for example, is seven times as toxic as pentane. It is possible that the iso-octane in aero spirit may not be quite so toxic as n-octane—as dimethyl hexane, for instance, is only three times as toxic as pentane. Petrol produced by "cracking" petroleum has a toxicity similar to that of straight-run petrol (Lazarew, 1929).

Aero spirit was the toxic agent in the cases here described. It has a 10% evaporation point of 75° C., whereas in ordinary winter motor spirit the 10% evaporation point is 52° C. The final boiling-point is 180° C., as compared with 140° C. for motor spirit. Like the latter, it may contain a small percentage of benzene and other aromatic hydrocarbons, and these are of still greater toxicity. Benzene, or benzol, which is normally obtained from coal-tar distillation but is also present in certain petroleum, particularly those from Borneo, Rumania, and Galicia, should not be confused with benzine, which comes solely from petroleum, as already described. As benzine and

motor spirit differ but little in composition, the clinical picture in such intoxications is also alike, and the group will therefore be considered as a whole.

Lead tetra-ethyl is not a hazard except to those who produce or blend it or to cleaners of storage-tanks in which evaporation and concentration may have occurred. The amount normally present in petrol is too small to be toxic.

The concentration of petrol vapour required to produce toxic symptoms in man was investigated by Fieldner, Katz, and Kenney (1921) after the death of a rescue worker who entered a petrol tank wearing a half-hour type of oxygen-breathing apparatus. They found that 1 part per 1,000 produced drowsiness at the end of 15 minutes, and vertigo, ataxia, and nausea after one hour, and 7 parts per 1,000 definite intoxication in 5 minutes. In dogs Haggard (1921) found that 10 parts per 1,000 caused convulsions or spasm, 20 parts unconsciousness, and 25 parts death. The effect was similar to that of ether, but the stage of excitement was replaced by convulsions, and the stage of surgical anaesthesia was very brief. Susceptibility is an important factor in toxicity, tolerance resulting from repeated exposure (Machle, 1941).

Circumstances in which Poisoning Occurs

Severe cases of poisoning by inhalation have occurred for the most part in workmen entering benzene tanks or stills to clean or scale them (Foulerton, 1886; Jansen, 1937; Rambousek, 1913), or while emptying such containers (Stiefler, 1928; Petrie, 1908). Coste and Wolz (1935) have recorded two fatal cases due to overflow of petrol filters in a confined space, and Wichern (1909) a case of severe poisoning due to benzene left overnight in the conduit leading from a benzene storage-tank. The victim may become unconscious so rapidly that he is unable to save himself or call for assistance, and may be found dead some hours later. Similarly in excavations or in the pit of a garage (Petrie, 1908; Plummer, 1913), a small amount of petrol may result in dangerous concentrations of vapour, as, being heavier than air, it collects at the bottom.

Mild intoxication is frequent in rubber factories, where it is known as "naphtha jag." While cleaning the rubber churns, for example, workmen may be overcome by the fumes, and in the dipping-room, where they work over large tanks of rubber dissolved in naphtha, severe poisoning may result, as the temperature of the room is kept above 90° F. to aid evaporation. A fatal concentration of the vapour may be found in the drying cupboard in which rubber-leather fabric is hung during its manufacture (Floret, 1927). Kulkow (1926) described mass poisoning when the ventilation system broke down for three-quarters of an hour in a factory making galoshes. In all some 90 persons were affected, 30 requiring transfer to hospital.

The use of petrol in any enclosed space such as a garage may give rise to toxic concentrations. Potts (1915) has described how a man filling automobile tanks fell over unconscious, remaining so for several hours. Permanent damage to the central nervous system, with ocular palsies and pyramidal and cerebellar signs, resulted. Painters working with quick-drying paints in interior decoration may complain of mild symptoms. Lives have been lost from benzene fumes in a carpet-cleaning establishment (Hamilton, 1925).

Leakage or spilling of petrol has been a frequent cause of severe poisoning, as from a bottle of petrol broken in a druggist's cellar (Siemon, 1896), or while cleaning the engine-room of a ship (Johnstone, 1941). Even drawing off benzene into cans in an ill-ventilated room such as a back shop or cellar may result in unconsciousness and death (Floret, 1927). In the home the use of petrol or benzene for cleaning clothes has at times had serious consequences, as when the clothes are soaked in a basin indoors. Petrol has also been used to clean the scalp by pouring it over the hair (Houghton, 1908). This incidentally causes, in addition to general symptoms of intoxication, severe pain and oedema of the scalp. The use in a bedroom of a floor polish containing petrol may result in severe poisoning if ventilation is poor (Roth, 1933).

It is rare for petrol fumes from an internal combustion engine to cause poisoning. Carbon monoxide is a much greater danger. Johnson (1913), however, has described how a number of workmen were affected on several successive days when a petrol engine was used in a tunnel. Carbon monoxide was excluded

in this instance. Poisoning from petrol fumes while driving a motor-car is extremely uncommon. Only when the vehicle is manoeuvred in a small closed garage while running on a very rich mixture is intoxication likely (Box, 1908).

In wartime petrol may have to be dispatched over-seas in cans stacked in the hold of a ship. If too great a load is put on these the cans in the lower layers may collapse and petrol escape into the hold, thus exposing dock-workers to a high concentration of the vapour. Rudd (1944) has described how in such circumstances men have become unconscious two or three times in one day. Another wartime aspect mentioned by the same author is poisoning due to petrol floating on the sea after the sinking of a tanker. Sailors in lifeboats, intoxicated by the fumes, sprawled over the gunwale and were drowned while sitting in their seats.

Symptomatology

Mild poisoning from petrol or benzene fumes is common in industry, producing symptoms like those of alcoholic intoxication. There is excitement, or euphoria with a tendency to hilarity and, particularly in women, fits of uncontrollable hysterical laughter or crying. Men often become irritable and prone to quarrel. Those who have gained tolerance through repeated exposure may fail to show such emotional changes, and suffer simply from slight tremor of the hands, which makes fine work difficult (Hamilton, 1925; Kulkow, 1926).

From higher concentrations there is in addition irritation of the respiratory mucous membranes, resulting in a dry tickly cough and a sense of constriction in the throat. If exposure is continued the victim becomes ataxic, drowsy, and dull, and may complain of headache, vertigo, nausea, weakness, and irritation of the skin. The vision is blurred, and a burning pain is felt in the chest and abdomen and a feeling of pressure over the heart. In addition there may be tonic contraction of the flexors of the hands and twitching of the muscles of trunk and limbs (Rudd, 1944).

When still greater concentrations are present there is disorientation. The victim shouts abuse at those around and adopts a pugnacious attitude, so that his rescue is fraught with danger both for himself and for rescuers, who may forfeit their lives in the attempt. Hallucinations may be present. If exposure continues, delirium and coma supervene, and there are tonic and clonic convulsions—sometimes in one limb at first, later generalized. Convulsions may not appear till the victim has been removed to the fresh air (Machle, 1941).

If removed to a normal atmosphere the patient may recover quickly if exposure has been short, but later he falls into a deep sleep, from which, however, he can be roused. If exposure has been more prolonged coma may continue for several days and terminate even then in respiratory arrest. As the coma lightens, twitching of the arms and legs may occur, so that the limbs beat against the floor and the teeth chatter violently as though in a rigor. As consciousness returns vomiting sets in, headache is severe, and there is throbbing pain in the abdomen and in the extremities. The patient remains confused for many hours, however, and may relapse into coma from time to time. He is emotionally unstable, and may become pugnacious, throw himself about, or burst into hysterical laughter. When recovery finally ensues it is usually rapid, though vomiting, abdominal pain, and headache may persist for several days and stupefaction and inertia for a week or more.

If the concentration of the vapour is very high the victim falls to the ground unconscious almost immediately, and if not promptly rescued dies of respiratory arrest (Rambousek, 1913).

Physical Signs

Cyanosis is usually present during the stage of coma, and may be deep; the breathing is laboured and stertorous, and the skin cold and clammy. The pulse in the early stages is rapid and weak and may be irregular, but when motor unrest is present it becomes full and bounding. Later, pulse and respirations are slow and feeble and the temperature subnormal. The blood pressure falls as peripheral failure supervenes. Acrocyanosis may be marked. The pupils are dilated and may be unequal, and conjugate deviation, strabismus, or nystagmus is often found. The tendon reflexes are diminished or absent in

quiet coma, but when convulsions and motor unrest are present they are often exaggerated, the plantar responses extensor, and clonus present. There may be neck rigidity (Machle, 1941; Plummer, 1913).

The urine sometimes contains traces of albumin and sugar. Unlike benzol, petrol and benzine are not excreted in the urine in conjugation with sulphates (Wichern, 1909). A blood count often shows a moderate reduction of haemoglobin and erythrocytes, and an increase of bilirubin in the serum, but there may be haemoconcentration. A polymorph leucocytosis is frequent and the percentage of eosinophils may be increased. Blood changes are, however, not prominent as in benzol poisoning. Sometimes there is a rise of blood urea, but not sufficient to cause confusion with uraemia. The cerebrospinal fluid is not altered.

Prophylaxis and Treatment

Prophylaxis.—Where petrol is handled in enclosed places adequate ventilation must be assured, so that, when exposure is likely to be prolonged, concentrations of 1 part per 1,000 are not exceeded. Too much faith should not be placed in an oxygen-breathing apparatus, especially when the concentration of petrol vapour is likely to be high, as the fumes have great penetrative power.

Treatment.—The victim should be removed at once to the fresh air. If breathing has ceased, artificial respiration will be required, and oxygen, if available, should be given, preferably with 5% of carbon dioxide. The clothes, as they are saturated with petrol vapour and may be contaminated by the liquid, must be removed and the skin cleansed. Sedatives are required if there is much restlessness, paraldehyde or chloral hydrate generally sufficing. In very violent patients intravenous pentothal may have to be used. A dose of 0.5 g. dissolved in 10 c.cm. of distilled water is injected slowly till a quiet sleep has been procured. The remainder of the dose is then injected intramuscularly to prolong the action of the intravenous dose. Careful supervision must be exercised during the first four days lest respiratory arrest, circulatory failure, or convulsions supervene. In circulatory failure adrenaline should be avoided, as it tends to cause pulmonary oedema (Machle, 1941).

Pathology

The macroscopic changes are found for the most part in the lungs, which are hyperaemic and oedematous and show petechial haemorrhages and extravasations of blood. The bronchi are inflamed. There may also be haemorrhage into the serous cavities and the subserous tissues, and into the mucosa of trachea, gastro-intestinal tract, and bladder. The meninges, brain, and spinal cord are hyperaemic and oedematous, and show petechial haemorrhages. The kidneys are oedematous. Histologically, cloudy swelling and fatty degeneration are found in the liver and in the proximal convoluted tubules of the kidneys. The cerebrum is congested, and there are perivascular extravasations of blood. The nerve cells of the brain and spinal cord show chromatolysis, loss of lipoid, and dendritic degeneration. There is swelling or disappearance of myelin (Jansen, 1937; Machle, 1941).

Sequelae

Mild neurasthenic symptoms, such as headache, sleeplessness, and anorexia, are common after petrol poisoning. Evidence of organic change in the nervous system is, however, not infrequent, particularly epilepsy (Floret, 1927), but also lesions of the pyramidal, cerebellar, or sensory tract simulating disseminated sclerosis or other organic nervous disease (Potts, 1915). The signs may be of scattered lesions or be hemiplegic or of more local distribution. Memory and intellect may be impaired. Sometimes the peripheral nerves are involved, often only a single nerve, such as the sciatic nerve (Jansen, 1937) or one of the cranial nerves, such as the hypoglossal. Retrobulbar neuritis has been recorded. These symptoms and signs may not become evident for several months after the accident, and recovery may take many years, or the disability be permanent. An early and fatal complication described by Floret (1927) is necrosis of the skin of the face and of the mucous membrane of the mouth and throat, following an erysipelas-like eruption. Pneu-

monia may occur, but is more common after the inhalation of liquid petrol—as when it is drunk—than of vapour.

Summary

Two cases of acute poisoning due to petrol vapour are described. The aetiology, clinical features, and pathology are reviewed.

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MONO-ARTICULAR OSTEO-ARTHRITIS OF THE HIP

TREATMENT BY ACID INJECTION

BY

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During the past nine years I have treated over 1,200 cases of arthritis by intra-articular acid injection, comprising chiefly those of osteo-arthritis, of traumatic arthritis, of so-called "menopausal" arthritis, and of rheumatoid arthritis in the residual deformity stage. Owing to war conditions, effective statistical analysis of results has been impossible; it may, however, be legitimate to gauge the value of the treatment from the increase in the number of patients referred to my two hospital clinics annually—from 56 in 1940 to 186 in 1944. I estimate that over 70% of cases of all types have been rendered free from pain and with sufficient restoration of function to allow of a return to their normal occupation.

Mono-articular arthritis of the hip-joint, however, occupies an unenviable pedestal of intractability among joint affections. According to MacMurray (1943), "local treatment of the affected joint by hot packs, hot mud packs, radiant heat, etc., results in a more or less temporary relief of pain, but produces little interruption in the progress of the disease. Electrical treatment by ionization has proved to be of little or no value, and its use is followed in some instances by a considerable increase in the pain and tenderness." Manipulation has its advocates for early cases; fixation by plaster or other support will give relief from pain; deep x-ray therapy is said to effect improvement in about 10% of cases—the Freiburg authorities claimed that 33% of their cases were relieved by deep therapy. As none of these measures has in my experience arrested the disease process and has rarely returned the patient to economic circulation, it seemed that an analysis of the condition of the cases treated by joint acidification in one year might afford some indication of its usefulness or otherwise in this baffling disorder.

The rationale of acidification of arthritic joints is based on my observations on the pH of synovial fluid in various conditions (Waugh, 1936, 1938): in chronic osteo-arthritis of the hip this appeared to be consistently on the alkaline side—even as high as 8.8. It has been shown by Smith-Petersen that the use of the vitallium cap after excision of the head of the femur