of D.N.O.C. in the blood following application of D.N.O.C. to the skin. This change has not been demonstrated after administration of D.N.O.C. by mouth. Study of the fatal cases of D.N.O.C. poisoning described by Bidstrup and Payne (1951) support the hypothesis advanced in this paper, that in human beings D.N.O.C. acts as a cumulative poison.

Summary

Five volunteers received 75 mg. of D.N.O.C. by mouth daily for five or seven days. It is absorbed through the alimentary canal, and its presence can be demonstrated in the blood. Doses of the order of 1 mg. per kg. result in concentrations of from 15 to 20 μ g. per g. of blood after three to five days.

After this concentration has been attained additional doses appear to cause temporary high concentrations associated with symptoms.

Forty days after the last dose of D.N.O.C. by mouth 1 to 1.5 μ g. per g. D.N.O.C. was still present in the blood.

D.N.O.C. is excreted slowly, the amount appearing unchanged in the urine being of the order of 1 to 2% of that given.

Symptoms of lassitude, headache, and malaise may appear after 350 to 500 mg. of D.N.O.C. has been administered and when the concentration in the blood is of the order of 20 μ g. per g. of blood.

Exercise has the effect of increasing the blood level, but large quantities of liquid cause no apparent changes.

Small quantities of D.N.O.C. were absorbed from the skin and caused an increase in the concentration of D.N.O.C. in the blood.

The relationship of blood concentrations of D.N.O.C. to physiological effects is discussed.

D.N.O.C. is shown to act as a cumulative poison in human beings.

We wish to thank Dr. Donald Hunter for many helpful suggestions, Dr. H. H. May for making the blood counts, and Miss Jean Peal, Messrs. R. G. Drew, K. E. Carling, A. J. Hobbs, and B. J. Biles for valuable technical assistance.

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The *Annual Report of the National Assistance Board* (H.M.S.O., price 1s. 9d.) for the year ended December 31, 1950, was published on June 28. The new regulations, which came into operation on June 12, 1950, brought increases in the allowances paid to all but a small minority of the 1,133,000 persons then receiving assistance from the Board. The new regulations were partly responsible also for the increase in the number of allowances to 1,349,902 at the end of the year. Including their dependent wives and children, the recipients of these allowances represented about two million persons dependent wholly or partly on assistance. The expenditure on national assistance grants during 1950 was £56,430,000, and in less than two and a half years the number of people receiving assistance has increased by more than 60%. An analysis of those receiving assistance in September, 1950, showed that they were mostly old, sick, or otherwise incapable of work. Men over 65 and women over 60 living at home formed 61.8% of the total, while sick or incapacitated persons under those ages accounted for 17%. The report gives particulars of the amounts paid to those receiving assistance, the rents paid by those persons (for which allowance is made separately in the assistance), the resources which they own, and the extent to which the assistance granted was increased by the use of the Board's discretionary powers to provide for special expenses.

POISONING BY DINITRO-ORTHO-CRESOL

REPORT OF EIGHT FATAL CASES OCCURRING IN GREAT BRITAIN

BY

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The use of dinitro-ortho-cresol (D.N.O.C.) as a selective weed-killer in cereal crops has resulted in the death from D.N.O.C. poisoning of seven agricultural workers in Great Britain since 1945. In the manufacture of D.N.O.C. one man has died from D.N.O.C. poisoning and many cases of intoxication are known to have occurred (Merewether, 1943). Death from D.N.O.C. poisoning has been reported also from Germany (Nordmann and Weber, 1936) and Holland (van Luijt, 1947), and cases of severe intoxication have occurred among agricultural and industrial workers in Hungary, France, U.S.A., India, and Africa.

Dinitro-ortho-cresol is a yellow crystalline solid manufactured for use as a weed-killer, insecticide, ovicide, and fungicide. It was introduced in 1892 as the active principle of a preparation called "antinonin" for use against the Nun moth. In 1925 the work of Tattersfield, Grimingham, and Morris led to the use of D.N.O.C. in agriculture and horticulture. For the control of weeds in cereal crops D.N.O.C. is applied as an aqueous spray at the rate of from 5 to 8 lb. (2.3 to 3.6 kg.) per acre (0.4 hectare) in 100 gallons (455 litres) of water. Commercial preparations contain up to 50% D.N.O.C. in the form of a paste, which is diluted with water immediately before use. D.N.O.C. is a constituent of the oily wash used for the late winter spraying on fruit trees, and is used as a dust or in suspension in oil for the control of locusts. No fatalities or cases of poisoning have been reported among persons using D.N.O.C. as a winter wash on fruit trees. The concentration of D.N.O.C. in sprays for this purpose is much less than that in the aqueous suspension applied to cereal crops for the control of weeds.

D.N.O.C. is applied to cereal crops from spraying machines drawn by tractor. The spraying equipment consists of a tank connected to a long spray boom on which are arranged a number of nozzles. Two types of machine are in use. In one the spray from the tank is forced through the nozzles by the action of a simple reciprocating pump working at a pressure of approximately 27 lb. per square inch (1.9 kg. per cm.²). This results in a spray of coarse droplets from which there is little drift. The D.N.O.C. is maintained in suspension by means of an agitator fitted to the spray tank. The other type of equipment works on an atomizer principle. The suspension of D.N.O.C. is delivered by gravity to the nozzles on the spray boom and is forced through by an air blast provided by a centrifugal fan. The liquid is broken up into a fine spray, which drifts readily and dries on the machine as a fine dust. It is usual for two men to work together as a team. The spray operator dilutes the concentrated D.N.O.C. with water in an open container, from which it is conveyed to a tank in the spraying machine. As the spray operator rides on the

machine to control the spray and to attend to faults, such as blockage of nozzles, which may arise during spraying, both he and the tractor driver are at risk. Men who have worked with both types of equipment consider that symptoms are more likely to occur when the atomizing type of machine is used to disperse the spray. Blockage of nozzles occurs more often with this machine because no agitator is fitted in the spraying-tank and the D.N.O.C. tends to settle out.

In Great Britain spraying of cereal crops with D.N.O.C. for the control of weeds takes place in the late spring and early summer. In normal seasons spraying begins in April and continues for a period of from six to eight weeks. In order to complete the spraying while conditions of weather and crop growth are most favourable it has been the custom in the past for spray operators to work long hours. Both in Great Britain and in other countries all cases of fatal poisoning have occurred during unusually hot weather.

Clinical Features

The early symptoms of D.N.O.C. poisoning include fatigue, excessive sweating, unusual thirst, and loss of weight; they are often ignored or are attributed to the climatic conditions and long hours of work. These early symptoms were present as long as 48 hours before death in all the fatal cases which have occurred in Great Britain. Except for anxiety and restlessness there may be no additional symptoms to suggest poisoning; but from these early symptoms to the time when the patient becomes acutely ill, with an increased rate and depth of respiration, tachycardia, and rise of temperature, the interval may be less than one hour. Death in coma follows rapidly.

Parsons (1948, personal communication) saw three cases of severe D.N.O.C. intoxication among men manufacturing D.N.O.C. dust. One of these cases was that of a man aged 37 who had been employed for only 17 days in this occupation. He poured D.N.O.C. powder from kegs into a grinding mill. Although he wore a dust mask it did not fit well, and he inhaled dust coming from the keg and the mill. His skin was stained yellow within a few days of beginning work with D.N.O.C., but he remained well until two days before his admission to hospital. His first symptom was sweating at night. Next day he felt suffocated, and became weak and dyspnoeic. On examination the most striking feature was the profuse sweating. Parsons states that "the suprasternal notch filled with sweat as one stood and watched." His temperature was 100° F. (37.8° C.), the pulse rate 130, and respiratory rate 30 a minute. The basal metabolic rate determined after 24 hours was +80%. The patient recovered completely in 48 hours. McDonald (1943) reported the case of a negro factory worker suffering from D.N.O.C. poisoning in whom the basal metabolic rate rose to 400%. He had recently lost 20 lb. (9.1 kg.) in weight. Most spray operators lose weight during the D.N.O.C. spraying season, and weight loss is rapid in cases of poisoning. One man lost 2 stone (12.7 kg.) in weight in one week (Bidstrup, 1949).

Case Reports

Case 1.—An industrial worker aged 31 was employed for three weeks before his death on March 21, 1946, on the manufacture of D.N.O.C. He carried bucketfuls of molten D.N.O.C. to a hydroextractor and removed in buckets the final product, a granular form of D.N.O.C. containing up to 10% moisture. He wore no protective clothing except overalls. Four days before his death he complained of headache and profuse sweating. He was away from work for two

days, but returned to his job on the day of his death and worked for eight hours. He appeared well when the works manager saw him during the morning. He became ill during the afternoon and was taken to hospital, where he died shortly after admission. No details of the clinical condition during his final illness are available. At necropsy there was deep yellow staining of the palms of the hands, soles of the feet, scalp, beard, and pubic hair. The skin of the thighs and chest and around the mouth was stained a paler yellow. A specimen of cerebrospinal fluid obtained before death was also yellow in colour. The lungs showed intense congestion with some oedema, and petechial haemorrhages were present towards the bases. There were a few petechial haemorrhages in the brain beneath the pia mater. Multiple haemorrhagic erosions were seen in the mucosa of the stomach. The liver was congested and the kidneys showed cloudy swelling.

Case 2.—An agricultural worker aged 29 was employed as a tractor driver for one year by a firm of contract sprayers. For two months before his death on May 28, 1946, he had been spraying corn with D.N.O.C. On the evening before his death he complained of feeling unwell, but did not appear to be seriously ill. During the night he became much worse and was gravely ill by 6 a.m. He died in hospital less than four hours later. Cyanosis of the lips and ears and a rapid rate of respiration were observed at the time of his admission to hospital. Necropsy findings were similar to those described in Case 1.

Case 3.—An agricultural worker aged 29 was employed as a spray operator using D.N.O.C. as a weed-killer for less than one month before his death on May 14, 1947. Although his wife had noticed that he was unwell and had been perspiring excessively for a few days before his death, the man himself did not complain of symptoms until shortly before his admission to hospital, where he died. He had completed a full day's work on the day of his death.

Case 4.—An agricultural worker aged 31 was employed as a spray operator for two weeks before his death on May 14, 1947. At the time of his death he had sprayed 153 acres (61 hectares) of corn with D.N.O.C. weed-killer, applying 6 lb. (2.7 kg.) of D.N.O.C. in 30 gallons (136 litres) of water to each acre. On the day of his death he sprayed only one acre (0.4 hectare). During the evening preceding his final illness he complained of thirst, but went as usual to the fields next day. His machine broke down when he had sprayed only one acre (0.4 hectare) and he rested in the shade of a tree until the evening. When he returned to his home at 5.15 p.m. he was obviously very ill. Breathing was difficult and he was sweating profusely. He was admitted to hospital, where he died eleven hours after the onset of acute symptoms. Necropsy findings were similar to those described in Case 1.

Although death occurred on the same day in Cases 3 and 4, the men were working in different areas and were employed by different firms.

Case 5.—An agricultural worker aged 38 had been employed as a spray operator for six weeks. He had used D.N.O.C. for three weeks before his death on May 21, 1948. On the day before his death his landlady had observed that he was perspiring freely and was unusually thirsty. In spite of these symptoms, he went to work and returned at 8 p.m. looking ill. At 8.30 p.m. he was much worse and died in hospital a short time later. Necropsy findings were similar to those described in Case 1. At the inquest in this case evidence was given that the man had quenched his thirst with water from the trailer tank. Although this should contain fresh water for making up the spray solution, analysis showed that in fact this water contained slightly more D.N.O.C. than was found in the spraying-tank.

Case 6.—An agricultural worker aged 40 was spraying D.N.O.C. for six weeks prior to his death on June 22, 1949. He was well until two days before his death, when he complained of profuse sweating and thirst. He was able to work on the next day, but as his symptoms persisted, he was admitted to hospital on the third day of his illness. At this time his face was flushed, he was sweating profusely, and

both the rate and the depth of respirations were increased. His hair was observed to be bright yellow in colour, and his eyebrows a yellowish green. The palms of the hands, the forearms, and the toenails were stained a bright yellow, the skin of the neck and the exposed part of the chest was paler, and the skin over the rest of the body had only a faint yellow tinge. The conjunctivae were not stained.

On admission the pulse rate was 88, the temperature 101.5° F. (38.6° C.), and respirations 28 a minute. The blood pressure was 164/60. A curious chrome-yellow colour of the urine was observed. There were no other abnormal findings on clinical examination. Unusual thirst continued throughout the day, and the respiratory rate increased to 32 by the evening. The pulse rate varied between 80 and 90 and the temperature rose to 102.5° F. (39.15° C.). Next morning sweating and thirst were still marked, the temperature had risen to 103° F. (39.4° C.), pulse rate to 96, and respiratory rate to 36. Attempts to remove the yellow staining from the skin were unsuccessful. In addition to cold sponging every two hours, aspirin and phenacetin, 4 gr. (0.26 g.) of each, were given four-hourly and an attempt was made to administer oxygen. In spite of these measures the patient became rapidly worse. At 12.30 p.m. he was very restless; the pulse rate had risen to 126 and the respiratory rate to 52. He became confused and lapsed into coma at 1.30 p.m. The face remained flushed until a few moments before his death at 3.3 p.m. Death was preceded by pulmonary oedema and cyanosis, and a short convulsion.

Cases 7 and 8.—These patients were agricultural workers. Case 7 (aged 24) was employed as a tractor driver and Case 8 (aged 25) as a spray operator. They worked together as a team for one month before their death on June 6, 1950. During this time they had sprayed approximately 220 acres (89 hectares) of corn, applying 1-1½ gallons (4.5-6.8 litres) of 50% D.N.O.C. paste in 60 gallons (272 litres) of water to each acre (0.4 hectare) of crop. Although the men did not complain of symptoms until the day of their death, both were observed to be perspiring excessively on the preceding day. They ate a normal breakfast on the day of their death, but went rather later than usual to the fields. Spraying did not begin until noon, and at this time the spray operator complained of feeling ill. The tractor driver advised him to rest in the shade of a tree and offered to do both jobs. The latter stated before his death in hospital that his mate had not worked at all on this day.

During the afternoon the tractor driver also felt ill. Both men started towards the farm riding on the tractor. About 100 yds. (91 metres) from the farm gate the spray operator said that he could go no further, and asked his mate to get him some water. He got down from the tractor and must have died almost immediately, for he was found dead at the roadside by a passer-by before his mate had returned with the water. The doctor who examined the spray operator at the roadside soon after death stated that rigor mortis was already well advanced.

The farmer noticed that the tractor driver was not looking well and took him immediately to a doctor. He was sweating profusely and his skin was stained yellow, but there was little to suggest at this time that he was seriously poisoned. The doctor recommended his admission to hospital only because his mate had died. On admission to hospital he was sweating profusely and seemed to be extremely anxious. The pupils were widely dilated. His general appearance suggested recent strenuous exertion such as a five-mile (8-km.) cross-country run. Within an hour he was obviously gravely ill, his condition resembling that seen in thyroid crisis. A sedative, fluids by mouth, and cold sponging failed to alter the course of the illness, and the man died in coma less than three hours after he was first seen by a doctor. Before the onset of coma the respiratory rate was 60 a minute and the temperature 102.8° F. (39.3° C.).

Necropsy findings were similar in both cases. The hair in the frontal and temporal regions was golden-yellow in colour, and similar colouring was observed in the eyebrows, the hair of the beard area, and the pubic hair. The hands

were stained deep yellow, particularly on the palmar surfaces. The soles of the feet were more deeply yellow in colour than the dorsal aspect, although the yellow staining of the skin extended to the ankles. The skin of the remainder of the body had a slight yellow appearance. The lungs showed a few small subpleural haemorrhages over all surfaces. The cut surface of the lungs was deep red in colour from congestion and slight oedema. In the spray operator there was faint yellow staining of the peritracheal and peribronchial tissues. A small blood-stained pericardial effusion was present. Liver, spleen, and kidneys were congested; the thymus was glandular, and the brain oedematous, with flattening of the cerebral convolutions. There was a striking absence of subcutaneous and omental fat. The shaft of the femur was examined in one case and found to contain red marrow throughout. On microscopical examination this was shown to be the marrow characteristic of an anaemia.

Discussion

The pharmacological effects of D.N.O.C. are similar to those produced by the related compound dinitrophenol (D.N.P.). Both substances cause stimulation of general cellular metabolism, and this effect is accentuated by heat. Dodds and Robertson (1933) demonstrated that the effect of D.N.O.C. upon metabolism differed from that of thyroxine, although the ingestion of D.N.O.C. resulted in an increase of the basal metabolic rate similar to that caused by thyroxine. There is an increase in oxygen consumption and in aerobic glycolysis. Glycogen disappears from liver and muscles. The biochemical basis of the action of D.N.P. and D.N.O.C. is poorly understood. *In vitro* D.N.P. causes an interference with the formation of high-energy bonds during the oxidation of substrates, notably those of the Krebs cycle. As a result of this effect fatty acid oxidation is also abolished (Judah, 1950, personal communication).

The symptoms and signs of D.N.O.C. poisoning can be explained by the effects on cellular metabolism. If the mechanisms of the body which control heat loss are inadequate, the temperature rises and remains high until the metabolic rate begins to decline. The increase in metabolism is always greater than can be ascribed to the fever itself. The clinical picture in the terminal stages has been likened to that seen in thyroid crisis. Death results from heatstroke or cerebral oedema—respiration and the heart failing almost simultaneously. Rigor mortis sets in at once.

Many cases of poisoning and some deaths occurred among men engaged in the manufacture of D.N.P. as an explosive between 1914 and 1917 (Perkins, 1919). In spite of this experience Cutting, Mehrtens, and Tainter (1933) introduced D.N.P. for the treatment of obesity after animal experiments and clinical trial had failed to demonstrate the toxic effects of small doses continued over a long period of time. Dodds and Pope (1933) recommended D.N.O.C. in preference to D.N.P. as being less toxic and more effective in the treatment of obesity. By 1937, reports of deaths and cases of severe intoxication from all countries where D.N.P. and D.N.O.C. had been used for this purpose caused both drugs to fall into disrepute. In some cases death was due to accidental overdosage with D.N.P. or D.N.O.C. In others agranulocytosis followed the ingestion of D.N.P. Bilateral cataract occurred after the administration of both substances, but was recorded more often after the ingestion of D.N.P. This is presumably due to the less extensive and more cautious use of D.N.O.C. (Horner, 1941). No case of cataract due to D.N.O.C. has been reported in industrial or agricultural workers, but there can be no doubt that this potential hazard exists.

D.N.O.C. is absorbed through the skin as well as by ingestion and by inhalation. Experimental work in animals and human beings demonstrates that D.N.O.C. is a cumulative poison. The administration of 75 mg. of D.N.O.C. daily by mouth to human volunteers caused a steady rise in the concentration of D.N.O.C. in the blood until a level of from 15 to 20 μ g. per g. was reached after three to four days. At this stage a further dose of 75 mg. caused a considerable increase in the concentration of D.N.O.C. in the blood, a peak of at least 40 μ g. per g. being reached in two to four hours. Symptoms of lassitude, headache, and general malaise were associated with this sudden increase. The rate of excretion in human beings is remarkably slow. Five daily doses of 75 mg. of D.N.O.C. were given by mouth to human volunteers. Forty days later, after the final dose, concentrations of from 1 to 1.5 μ g. per g. could still be detected in the blood of four volunteers (Harvey, Bidstrup, and Bonnell, 1951).

Death from D.N.O.C. poisoning has not been recorded except during periods of unusually hot weather. On the days on which death from D.N.O.C. poisoning occurred in Great Britain, the maximum temperatures recorded in the areas were as shown in the Table. The effect of

Maximum and Minimum Temperatures Recorded in Places in Great Britain on the Days when Death from D.N.O.C. Poisoning Occurred

Case No.	Work	Date	Temperature			
			Max.		Min.	
			$^{\circ}$ F.	$^{\circ}$ C.	$^{\circ}$ F.	$^{\circ}$ C.
1	Industrial	21/3/46	56	13.3	42	5.6
2	Agricultural	28/5/46	66	18.9	48	8.9
3	"	14/5/47	78	25.6	46	7.8
4	"	14/5/47	79	26.1	48	8.9
5	"	21/5/48	70	21.1	40	4.4
6	" { ill	19/6/49	60	15.5	44	6.7
		20/6/49	64	17.8	45	7.2
		21/6/49	69	20.6	45	7.2
7	" { died	22/6/49	69	20.6	44	6.7
		6/6/50	86	30.0	52	11.1

Temperatures were taken from thermometers exposed in a louvered Stevenson Screen 4 feet (122 cm.) above short turf at meteorological stations nearest the places at which cases occurred.

heat has been demonstrated in animals given sublethal doses of D.N.O.C. Such animals die rapidly when subjected to a temperature of 40 $^{\circ}$ C. (Harvey, 1951, unpublished results).

Treatment and Prevention of Poisoning

The treatment of mild or moderately severe D.N.O.C. intoxication is expectant and symptomatic. Complete rest and relief from anxiety should be ensured by the use of barbiturates. Sedatives should be administered by the intramuscular route when restlessness and anxiety are pronounced. Oxygen, cold sponging, and replacement of fluids assist in relieving symptoms due to oxygen lack and excessive sweating. In seriously poisoned persons these measures have failed to alter the course of the illness. Credner and Siedek (1949) claim that the administration of 10 ml. of a 2.5% solution of sodium methyl thiouracil by intravenous injection rapidly reduces the basal metabolic rate in persons in whom the rate of metabolism has been increased by ingestion of D.N.O.C. Because D.N.O.C. is a cumulative poison, and is excreted very slowly by human beings, persons who have suffered any symptoms of poisoning should be removed from risk of further absorption for a period of at least six weeks.

Methods adopted for the safe handling of D.N.O.C. have been described by Hunter (1950), and the recommendations of the Zuckerman Working Party on the handling of toxic substances in agriculture include

instructions concerning types of protective clothing, washing facilities, working periods, supervision of workers, arrangements for meals, and methods of decontamination of machinery and equipment (*British Medical Journal*, 1951). If these precautions are strictly observed the risk of poisoning will be greatly reduced, but careless handling of D.N.O.C. by individual workmen, or accidents at work, may result in the absorption of dangerous amounts.

In the cases reported in this paper protective clothing was supplied, and some of the men had been instructed in the methods for the safe handling of D.N.O.C. In spite of these precautions the protective clothing was discarded because of the intense heat and discomfort. The early symptoms of D.N.O.C. poisoning are so unobtrusive that they will be detected in time to prevent serious poisoning only if regular inspection and careful questioning of men at risk is carried out before they begin to work each day. Yellow discoloration of the sclera indicates absorption of significant quantities and may precede the onset of symptoms. Fatigue, insomnia, sweating, thirst, and loss of weight must be regarded as manifestations of D.N.O.C. poisoning whatever other factors may appear to play a part in causing these symptoms.

Summary

Eight fatal cases of D.N.O.C. poisoning which have occurred in Great Britain since 1945 are described. In all except one of these the men were working less than 12 hours before their death.

Methods of treatment and prevention of poisoning are outlined.

The literature on D.N.P. and D.N.O.C. poisoning is reviewed, and the mode of action of these substances is discussed.

D.N.O.C. is absorbed by inhalation and ingestion and through the skin. It is a cumulative poison. It causes an increase in metabolism and may lead to death from heat-stroke. This explains why deaths from D.N.O.C. poisoning usually occur in hot weather and within a few hours of the appearance of symptoms.

In addition to the fatal cases described in this paper a further death from D.N.O.C. poisoning has occurred during the current spraying season (*Lancet*, 1951, 1, 1419), and there have been two severe cases of poisoning.

The information on the exposure to D.N.O.C. and the clinical and necropsy findings in the cases of poisoning described are gathered from many sources. We wish to thank particularly Drs. A. J. McCall, T. N. Morgan, A. F. T. Ord, and G. D. Owen, as well as Dr. W. E. Ripper, of Pest Control Ltd., and Mr. R. E. Longmate, of E. C. Longmate Ltd. The Director of the Meteorological Office, Air Ministry, Harrow, made available to us the temperature recordings which appear in the Table. Dr. Donald Hunter, Professor G. S. Wilson, and Dr. D. G. Harvey have assisted greatly with advice and criticism in the preparation of the paper.

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