CAST ISSN 0194-4096

COMMENTS from CAST

1983-1

April 1983

THE MISSOURI DIOXIN CONTROVERSY: SCIENTIFIC OVERVIEW

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Headquarters Office: 250 Memorial Union, Ames, Iowa 50011
Telephones: 515-294-2036 and 294-2903

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Introduction

The current controversy over dioxin in Missouri results principally from the presence of this substance in certain roads in Times Beach and other areas in the vicinity, and from a flood that caused some soil movement. Although there are 75 dioxins, the one to which the term "dioxin" is popularly applied is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, sometimes called TCDD. This dioxin is considered the most toxic of the ones that have been studied (Kociba and Schwetz, 1982). Moore (1973) chaired a comprehensive symposium on dioxin, and Hayes (1982) recently reviewed the medical effects.

Dioxin in the Environment

In the spring of 1971, a salvage oil company sprayed three horse arenas in eastern Missouri with waste oil that was contaminated with dioxin derived from oily waste produced in a chemical plant that had manufactured trichlorophenol (Shea and Lindler, 1975). Dioxin is a trace by-product of this chemical process. All three arenas were toxic to horses. Several people who frequented one of the arenas became ill, particularly one small girl who played there daily. A special study was made of the arena where the human sicknesses occurred (the medical results are discussed in the next section of these comments), and concentrations of 31,800 to 33,000 parts of dioxin per billion of soil were found (Carter et al., 1975).

Contaminated oil from the same source was used to spray certain of the roads in Times Beach, Missouri, and other areas in the vicinity. The spraying was done in 1971 according to BeVier (1983) and in 1972 and 1973 according to Bukro (1983). Concentrations of dioxin found currently are reported to range from 1 to 5 parts per billion in yards and homes and up to 300 parts per billion in road shoulders and ditches (Garmon, 1983).

Whether the oil applied to the roads had the same original concentration of dioxin as that applied to the horse arena studied by Carter et al. (1975) is not known. The lower concentration of dioxin in the road samples than in the horse arena samples, however, is consistent with the finding that dioxin is degraded in soil. The rate of degradation appears to range from about 50% in a year (Kearney et al., 1972) to 50% in more than 10 years (Fanelli et al., 1982). Although the concentrations of dioxin reported in the road samples still exceed those found in the environment in general, the two ranges overlap.

Dioxin is widely distributed in the environment. Indications are that fire may be an important source. Dioxin is formed when certain substances are burned. Bumb et al. (1980) found 0.3 to 100 parts of dioxin per billion of soil from the Dow Chemical Plant area in Midland, Michigan, 0.1 part per billion of home fireplace soot, 0.003 part per billion of the contents of a diesel truck muffler, and 0.004 part per billion of the contents of an automobile muffler. Most of the environmental samples they analyzed contained less than one part of dioxin per billion. Similarly low concentrations of dioxin were found by Nestrick et al. (1981) in "particulates" in chimneys from wood-burning furnaces in rural areas in eastern, central, and western United States.

The Environmental Protection Agency has been concerned about the formation of various toxic substances from combustion of municipal wastes, a disposal method that has been advocated by that Agency and the Department of Energy in recent years. In a review paper presented in January of this year (Barnes, 1983), the cochairman of EPA's "Chlorinated Dioxins Work Group," while verifying that various dioxins, including 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, and other toxic substances are produced in trace amounts during combustion of municipal wastes and are emitted to the atmosphere, concluded that "it appears that certainly the worst fears about adverse effects on public health will not be realized and that more likely a significant health concern does not exist." A similar conclusion was reached by Olie et al. (1983) from studies in The Netherlands.

Rau (1983) reported that the ash from the Mt. St. Helens eruption that fell over industrial areas contained dioxins, whereas ash that fell on areas without industry or other combustion sources did not, indicating that the ash picked up the dioxins from the air over industrial areas as it fell. A sample of dried sewage sludge that had been sealed in glass in 1933 before the widespread production of chlorophenols, also was found to contain dioxins, including 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, here called dioxin.

Concentrations of dioxin as great as 0.094 part per billion have been found in the tissue of fish from the Great Lakes, and 0.16 part per billion has been found in the tissue of a herring gull from Lake Huron (Stalling et al., 1982). According to Sedgwick (1983), concentrations of dioxin averaging 0.2 part per billion have been

[1]Prepared by Charles A. Black, Executive Vice President, CAST.

found in fish from rivers in the industrialized areas of Michigan, but none has been found in fish from rivers in nonindustrialized areas.

Effects on People

Toxicity of Dioxin

In comparisons of the relative toxicities of various substances to the most sensitive of the animal species tested, Reggiani (1978) noted that TCDD or dioxin is estimated to be 10,000 times more toxic than sodium cyanide, but only 0.0001 times as toxic as tetanus toxin and 0.00003 times as toxic as botulinum toxin (the latter two are natural bacterial poisons). Of the species tested for sensitivity to dioxin, the guinea pig is the most sensitive and the hamster the least (Kociba and Schwetz, 1982). Humans seem considerably less sensitive than guinea pigs.

Like all other poisons, dioxin cannot be shown to have any detrimental effects if the dose is small enough. Dioxin does not seem to have any known favorable effects at any dose, but the botulinum toxin, which is 33,000 times more potent than dioxin (Reggiani, 1978), has been used therapeutically in small amounts to relax the muscles of the human eye as an aid in straightening crossed eyes (Treichel, 1982).

Chloracne

As exposure of the human skin to dioxin (the usual mode of excessive exposure) increases into the range of observable unfavorable effects, the first symptom that appears is a disfiguration of the skin called chloracne (Kligman, 1968; Crow, 1981). In its mildest form, chloracne resembles "blackheads." Melvin (1978) testified that "the diagnosis of chloracne is central and essential in making the diagnosis of TCDD poisoning in man...." In humans, chloracne has been found to develop as soon as 3 weeks after a strong exposure (Kligman, 1968) and as long as 5 to 7 weeks after a lesser exposure, such as occurred in 1976 in a chemical plant accident in Seveso, Italy (Homberger et al., 1979). Mild chloracne due to dioxin is not accompanied by laboratory or clinical evidence of other manifestations of toxicity (Kligman, 1968; Crow, 1981).

The Horse Arena Incident

In an investigation of the 1971 horse arena incident in eastern Missouri, Carter et al. (1975) reported that four "children and one adult frequently exposed to the arena complained of skin lesions. In at least two of the children, the lesions described were consistent with chloracne." The mother and her two daughters who were involved in this incident were examined later to determine whether there were any observable lingering effects. In the report published on the results of this medical examination, Beale et al. (1977) said that "our experience demonstrates that people exposed to dioxin can recover completely with no apparent sequelae from the toxin." To be on the safe side, they qualified their findings with the additional statement that "It remains to be determined whether the exposure to dioxin in these children will result in abnormal pregnancies or affect their offspring." One cannot provide scientific proof that something that has not happened in the past will not happen in the future.

The Seveso Incident

The medical findings in the 1971 horse arena incident have been verified by medical studies made on a much larger scale in connection with the 1976 accident in Seveso, Italy, mentioned previously. In this incident, excessive pressure in a trichlorophenol reactor blew the safety valve and permitted the mixture to escape into the atmosphere. The reaction mixture, contaminated with dioxin, descended in a cloud on the vegetation, soil, and buildings of a heavily populated area adjacent to the factory containing the reactor.

According to Fanelli et al. (1982), 32% of the rabbits died in the first 52 days after the accident in a heavily contaminated zone in which the dioxin fallout was as great as 20,000 micrograms per square meter (equivalent to 1,500 parts per billion of soil with a bulk density of 1.3 to a depth of 1 centimeter). In a less heavily contaminated zone in which the dioxin fallout ranged from 5 to 50 micrograms per square meter (equivalent to 0.4 to 4 parts per billion of soil with a bulk density of 1.3 to a depth of 1 centimeter), 9% of the rabbits died in the first 52 days. Animals of other species died as well. These deaths were attributed primarily to consumption of vegetation contaminated directly by the fallout.

Analysis of rabbit livers was a useful means of monitoring the dioxin contamination because much of the ingested dioxin is retained by the liver before it is eliminated. In 1978 and 1979, when rabbits were confined on test plots of dioxin-contaminated soil and their diet consisted of vegetation newly produced on the soil, no dioxin could be found in the livers of 99.5 and 99.8% of the animals, and only traces were found in the livers that gave a positive test.

According to the review by Hays (1982), "evacuation of children began 17 days after discharge of the vapor. By the end of a month, 730 people of all ages had been evacuated from the most heavily contaminated area ...." Fanelli et al. (1982) put the number at 733; they noted that the 4737 inhabitants of the less heavily contaminated zone were not evacuated.

Homberger et al. (1979) reported that the initial path-

ological effects of the accident on humans were burns suffered by children from exposure to chemicals other than dioxin in the fallout. The chloracne that appeared in 181 persons healed rapidly and completely in most instances. Toxicity to the liver, neurological abnormalities, and deranged porphyrin metabolism were not observed in the chloracne cases. Pregnancy, fetal development, growth of the newborn, immunoresponse, rate of chromosome aberrations, functions of the nervous system, blood and liver conditions, and rates of sickness and death remained within the range current for the nonexposed population of adjoining areas.

The Issue of Exposure

The concentrations of dioxin calculated on a part per billion basis to a depth of 1 centimeter in the Seveso incident would provide a greater hazard than an equal addition of dioxin in waste oil in the Missouri incidents. In Seveso, the dioxin was all on the surface initially, and part of it was on vegetation that was eaten by animals. In Missouri, the waste oil was applied to nonvegetated areas, and the volume added per unit area would have been great enough to carry some of the dioxin with it below the surface of the soil, thus reducing its availability to humans and animals.

The strong binding of dioxin to soil particles greatly reduces the uptake of dioxin by the body of test animals through both the skin and the digestive tract, according to experiments by Poiger and Schlatter (1980). The same investigators found that the availability of the dioxin for absorption by test animals decreases with increasing time of contact with the soil.

Humans ingest little soil, they have little direct external body exposure to dioxin in soil, and, in light of Poiger and Schlatter's (1980) data, the dioxin in soil to which they are exposed has much less effect than an equivalent amount of the pure compound. Thus, Bukro's (1983) implication that "dioxin, described by a respected health researcher as a 'doomsday chemical' that can be harmful to humans in microscopic amounts as low as one part per billion" can be equated to the effect of one part of dioxin per billion of soil is without substance.

In the meantime, the Centers for Disease Control have recommended that human exposure be limited to concentrations less than 1 part of dioxin per billion of soil for the conditions in a specific area in Imperial, Missouri. According to a private communication from Paul Stehr of the Centers for Disease Control, an attempt now is being made by the Environmental Protection Agency and the Centers for Disease Control to develop a standard for general use upon which the two agencies can agree. The 1 part per billion figure is a conservative estimate based upon risk of human cancer. As yet, it is not known whether dioxin is a human carcinogen. Studies with rats (Kociba et al., 1978) have shown that, when the level of dioxin in the diet during 2-year feeding studies was 2.2 parts per billion, the incidence of tumors of the liver, lung, and hard palate was increased, whereas the incidence of tumors of the pituitary, uterus, mammary glands, pancreas, and adrenal gland was reduced. This level of dioxin was high enough to cause severe toxicity. No increase in tumors was found in rats receiving amounts of dioxin that induced only slight or no indications of toxicity.

The Buying of Times Beach

Many homes were destroyed in the flooding of Times Beach, and the added trauma of the dioxin issue has caused emotions to run high in the immediate area. The pressure on the Environmental Protection Agency as a consequence of this and other concerns related to toxic wastes has been extreme. Various Congressional Committees have been investigating the Agency and its performance. At one stage, EPA Administrator Anne Burford was cited for contempt of Congress for refusing to provide the Congress with certain information it requested. The continuing criticism from the Congress and the media no doubt was responsible for her eventual resignation.

The outcome of the Times Beach incident, announced before the resignation, has been a political decision to buy out the town. The amount mentioned is $33 million of Environmental Protection Agency money plus an additional 10% to be supplied by the state of Missouri (Garmon, 1983).

Scientific knowledge played a part in the political decision, but unfortunately it was used more to inflame the issue than to enlighten the public. Only soil analyses seem to have been used. The presence of dioxin in soil, however, does not provide acceptable evidence of the existence of significant human exposure. The decision was forced too quickly to allow the development of adequate scientific evidence.

Verifying the Existence of a Hazard to People

Because the presence of chloracne is the first indication of mild human exposure to dioxin, the occurrence of this symptom in the residents of the Times Beach area would indicate that their exposure to dioxin (or certain other substances that produce the same symptom) is sufficient to have an observable effect. Some medical examinations have been made, but they provided no evidence of chloracne or other health problems (Edgar, 1983). A more recent Associated Press (1983) story quoted a medical doctor involved in the physical examinations as saying that "More than 1200 people have been screened.... Of those, 112 at greatest risk were

selected for more extensive medical tests...." However, "There have been no positive findings in the physical exams of those tested so far." Another medical doctor is quoted as saying that "We have found no gross physical defects." The story notes, however, that "Preliminary health examinations of people exposed to some of the highest known concentrations of dioxin in Missouri have uncovered only minor skin rashes." Had these "rashes" been identifiable with chloracne, the first known symptom of mild poisoning by dioxin, the story no doubt would have brought this out.

Further evidence could be obtained by confining guinea pigs on the undisturbed surface of areas contaminated to different degrees. Guinea pigs are the most sensitive species known, and if they developed little or no indication of toxicity with such continuing direct exposure to the soil, there would be no reason to expect that the residues would present a significant toxic hazard to the local human population because humans are less sensitive than guinea pigs and have less exposure to the dioxin in the soil. Such a test, of course, would need to be made with due regard for the experimental method.

Another way to evaluate the significance of the human exposure was devised by Newton and Snyder (1978). These investigators based their technique upon observations by Kociba et al. (1978) that when rats were fed a diet containing 0.022 or 0.21 part of dioxin per billion "no irreversible toxic effects [were produced] during a lifetime of exposure," and that the concentrations of dioxin in the livers of the rats averaged 24.4 times as great as the concentrations in the diets. Using the traditional safety factor of 100 to 1 (an intake equal to 0.01 times the maximum no-effect level in the test species), Newton and Snyder suggested that a lifetime ingestion of a diet containing 0.00022 to 0.0021 part of dioxin per billion would be tolerated without adverse effects by a much larger array of mammals. Such dietary levels should be associated with 0.005 to 0.05 part of dioxin per billion of liver tissue on the basis of the 24.4 concentration factor. This technique leads to the suggestion that the livers of free-ranging dogs and cats in the vicinity of the dioxin-contaminated roads in Missouri be assayed for dioxin. If the concentration is 0.005 to 0.05 part of dioxin per billion of liver tissue or less, the indications would be that the animals had not been exposed to levels of dioxin that produce significant toxicity. The human population then could be considered safe because its exposure would be much less than that of the dogs and cats.

Conclusion

The presence of dioxin in soil does not provide acceptable evidence of the existence of significant exposure of human residents in eastern Missouri adjacent to roads treated years ago with dioxin-contaminated waste oil. As a basis for determining whether the current exposure to dioxin is sufficient to be of concern, the first logical step would appear to be to determine the incidence of the skin ailment known as chloracne in the human population. The examinations reported have disclosed no evidence of this or other acute dioxin-related health problems. Other tests based upon easily conducted studies with animals would provide further verification of the significance of the hazard.

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