Pesticides in Groundwater: The Aldicarb Story in Suffolk County, NY

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Abstract: Aldicarb, a carbamate pesticide, was detected for the first time in groundwater in Suffolk County, New York, in August 1979. Although all laboratory and field studies indicated that the pesticide could not reach groundwater, a combination of circumstances allowed its residues not only to reach groundwater but also to be ingested by humans. Inquiries in hospitals and poison control centers did not reveal any cases of carbamate poisoning.

The extensive monitoring program, conducted by the County in cooperation with the federal and state agencies and the Union Carbide Corporation, showed that 1,121 (13.5 per cent) of the 8,404 wells examined exceeded the state recommended guidelines of 7 ppb. Of the contaminated wells 52 per cent contained aldicarb between 8 and 30 ppb, 32 per cent between 31 and 75 ppb, and 16 per cent more that 75 ppb. Residents whose wells exceeded the guideline were advised not to use the water for drinking or cooking purposes and to obtain an alternate source of potable water. The Union Carbide Corporation provided those residents with activated carbon filtration units.

The incident raises several serious issues, such as the testing of pesticides under field conditions prior to registration and during their use, the validity of the recommended actionable levels, and the paucity of long-term epidemiologic studies of the health effects resulting from consumption of pesticides in trace concentrations. (*Am J Public Health* 1982; 72:1391–1395.)

Introduction

The application of pesticides to agricultural areas constitutes a potential source of water contamination. The extent of the contamination depends on the dose applied, the degradability of the pesticide, the soil conditions, and other ecological determinants. The use of pesticides is regulated predominantly by the federal government through the United States Environmental Protection Agency (EPA) and, to some extent, by the corresponding state agencies. After scientific laboratory and field investigations demonstrate that a pesticide is effective and does not have significant deleterious effects on human health or the environment, a label is approved. Additional testing is undertaken when residue tolerances in food crops are requested.

Unfortunately, in spite of the exhaustive testing performed to meet the rules and regulations required for registration, the existence of a combination of circumstances has allowed pesticide residues to reach the groundwater and to be ingested by humans. This report describes such an incident and addresses the means by which the regulatory authorities and the chemical industry handled the problem.

The Incident

On August 24, 1979, the EPA informed the Suffolk County (New York) Department of Health Services that water samples collected from a well in eastern Suffolk County contained traces of a pesticide, aldicarb, and that additional water samples would be collected for confirmatory purposes. Initial testing had been performed by the Union Carbide Corporation at the request of Cornell University's Long Island Horticultural Research Laboratory.

The Pesticide—Aldicarb is a highly toxic carbamate ester manufactured by the Union Carbide Corporation and marketed under the trade name of Temik for insect and nematode control. Aldicarb and other carbamate esters exert their insecticidal activity through reversible inhibition of the enzyme acetylcholinesterase, a major component of the nervous system. It is rapidly metabolized to aldicarb sulfoxide and to aldicarb sulfone, both of which retain insecticidal activity. It is further degraded to nonbiologically active ingredients.

Temik is registered in this country as a soil pesticide for systemic use in a variety of agricultural commodities. The pesticide was found to be very effective against two pests, the Colorado potato beetle and the golden nematode, which led to its extensive use in Long Island.

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Studies have shown that the persistence of aldicarb and its degradation products varies considerably according to the type of soil, plant presence, field conditions, moisture and pH.[1,2] Metabolic studies have shown that the carbamate pesticide is rapidly converted to the sulfoxide and more slowly to the sulfone antilog. In addition, the molecule undergoes hydrolytic transformation to a variety of products. In mammals, these products are rapidly excreted, primarily in the urine.[3]

Toxicological studies in a wide variety of animal species have shown that aldicarb and its carbamate metabolites, aldicarb sulfoxide and aldicarb sulfone, are not carcinogenic, mutagenic, or teratogenic.[4] Cholinesterase depression seems to be the most significant activity that can be evaluated with respect to its toxicology.[4]

A single-dose human feeding study was conducted by the Union Carbide Corporation using three groups of four adult males. The three groups received different doses of aldicarb of 0.1, 0.05, and 0.025 mg/kg body weight and were monitored for signs and symptoms of cholinergic activity and for acetylcholinesterase levels. Cholinergic signs and symptoms appeared only at the highest dose. Within six hours, all cholinesterase activity was found to have returned to normal in all groups where depression occurred. The rapid and transient reversibility of all signs and symptoms of cholinergic depression are normal with this and other carbamate esters of this class. It was concluded from the study that humans could tolerate acute doses of 0.025 mg/kg body weight with no ill effects noted.[4]

In spite of its high acute oral toxicity (the LD_{50} approximates one mg/kg body weight), accidental poisoning is rare. During 1977, nine individuals who ate cucumbers contaminated with 8,000–10,000 ppb of aldicarb experienced one or more of the following symptoms: nausea, vomiting, blurred vision, dyspnea, perspiration, headache, and temporary paralysis of the extremities which lasted only 4–12 hours with no residual effects.[5] This incident could be attributed to the illegal use of the pesticide in such a crop.

From 1977 to 1979, 133 cases of over exposure to aldicarb formulations have been reported. Of these, only 40 cases were confirmed aldicarb poisoning. The acute signs and symptoms indicative of cholinesterase inhibition disappeared with the cessation of exposure. No deaths attributable to aldicarb were reported among those exposed.[4]

Health Department Action

Because of its universal use in the estimated 22,000 acres of potato farms and because of Suffolk County's unique position as an area with a sole source aquifer, an extensive monitoring program was initiated by the Suffolk County Department of Health Services. In undertaking the monitoring program, two problems were encountered relating to the scarcity of laboratories which were capable of testing for the pesticide in water, and the lack of agreement on an acceptable level of aldicarb in drinking water.

The laboratory problem was resolved through extensive assistance from the Union Carbide Corporation, the Environmental Protection Agency, and the New York State Department of Health.

The National Academy of Sciences recommended a level of seven parts per billion of aldicarb in drinking water as the safe level for human consumption. Several factors were considered and assumptions made in calculating this no-adverse-effect level in drinking water.[6] These included:

- That the no-adverse-effect dose—based on animal and human studies—is 0.1 mg/kg body wt/day;
- That when an uncertainty factor of 100 is utilized, the acceptable daily intake would be reduced to 0.001 mg/kg/day;
- That the average adult weighs 70 kilograms;
- That the average adult drinks two liters of water per day; and
- That the aldicarb intake from water represents only 20 per cent of the total aldicarb intake.

The recommended level was calculated as follows:

$$\frac{0.001 \text{ mg/kg/day} \times 70 \text{ kg} \times 0.2}{2 \text{ liters/day}}$$

$$= .007 \text{ mg/l} = 7 \text{ ug/l or } 7 \text{ ppb}$$

This 7 ppb level has been challenged by Union Carbide which questioned the validity of some of the aforementioned assumptions. Issues raised included:

- That the EPA acceptable daily intake of aldicarb is .003 mg/kg body weight;*
- That the no-adverse-effect level in animals is 0.125 mg/kg body weight;*
- That a tenfold margin of safety has been recommended by EPA in situations where cholinesterase inhibition is the major and/or only effect noted in animal studies;** and
- That limiting the aldicarb intake from aqueous sources to 20 per cent cannot be substantiated on any grounds.

Several no-adverse-effect levels in groundwater were consequently proposed using different methods of computation and acceptable daily intake. These ranged from 21 ppb to 100 ppb.** The New York State Department of Health adopted the National Academy of Sciences recommended level of 7 ppb. As a responsible health agency, the Suffolk County Department of Health Services had no alternative but to accept the State recommendations, assume that concentrations of aldicarb exceeding 7 ppb are potentially hazardous, and act accordingly.

The initial survey concentrated mainly on private wells within farming areas and those in close proximity. Of the 330 wells selected for testing, 76 (23 per cent) had aldicarb above the recommended guideline of 7 ppb. This number would have been reduced substantially had a different acceptable level been utilized. Although it was made clear that these

*Personal Communication from Edwin Johnson, EPA, to Robert Oldford, Union Carbide, March 1981.

**Personal Communication from Ronald Baron, Union Carbide, November 1981.

wells were selected because of their presence in potato farms or in the direction of groundwater movement, the erroneous assumption was made by some officials and the news media that one-fourth of the wells in eastern Suffolk County were contaminated with aldicarb.

Contact was made with the local hospitals and poison control centers to inquire whether they received or treated any cases of carbamate poisoning during the past few years. Our investigation revealed that no cases were known to these agencies.

In order to reduce further contamination of groundwater with aldicarb, the County asked the State of New York to reduce the allowable dose of the pesticide from 7 pounds per acre to 3 or 4 pounds per acre as an interim solution. While this recommendation was being considered, Union Carbide requested from EPA an amendment of the aldicarb label to ban its use in Suffolk County, which was granted.

The County Department of Health Services also requested assistance from several pesticide manufacturers to test water samples for the possible presence of their products in groundwater. Some manufacturers responded positively to the request and a rather limited survey was initiated. Such a survey revealed the presence of other pesticides such as carbofuran, dinoseb, 1,2 dichloropropane, and naled.

The Mass Survey

In the meantime, negotiations between the State and County health departments and the Union Carbide Corporation culminated in a mutual agreement between Union Carbide and Suffolk County whereby the corporation agreed to provide laboratory assistance to the county in what is considered to be the most extensive survey ever conducted for a pesticide in groundwater in this country.

The survey area comprised about 100 square miles covering most of the towns of Riverhead, Southold, Southampton, East Hampton, and part of the town of Brookhaven. The area was divided into grids approximately 1,500 × 1,500 feet. All accessible wells within 2,500 feet of potato farms were sampled. In view of the number of variables and the size of the sample, computer analysis was undertaken. During an 8-week period between April and June of 1980, more than 8,000 water samples were collected and shipped to the Union Carbide laboratory in Charleston, West Virginia for testing.

Quality control was provided by the New York State Department of Health Laboratory. The procedures utilized included the use of blanks, duplicates, and spiked samples. This quality assurance component demonstrated the reliability of the overall performance of the Union Carbide Corporation Laboratory.

Table 1 shows the results of testing of private wells, non-community water supplies, and community water systems during and prior to the mass survey. As is evident, 13.5 per cent of the private wells exceeded the guideline, while 8 per cent of the non-community water supplies and 7.4 per cent of the community water systems did so.

Of the 8,051 private wells tested, marked variation occurred in the extent of contamination in different areas within the same townships and within 2,500 feet of potato farms. This variation is attributed to the hydrology of the area, the soil conditions, the movement of groundwater, and the dose and time of application of the pesticide.

Table 2 illustrates the variation in aldicarb concentrations detected in the private wells. The mean concentration of aldicarb of all samples was 6.2 ppb with a standard deviation of 14.5 ppb, indicating the wide scatter in the contamination level of the individual samples from the mean.

The maximum concentrations of aldicarb detected by the type of water supply are given in Table 3. High levels of contamination, such as the 515 ppb detected in one private well, were encountered on rare occasions only.

The proximity of a well to a potato farm was one of the determinant factors in water contamination with aldicarb. Table 4 illustrates this point in a subsample of private wells. The pesticide concentration was highest in the wells located within 1,000 feet and decreased gradually as the distance increased. A cumulative frequency distribution shows that 94.4 per cent of all wells with detectable traces of aldicarb occurred within a distance of 1,000 feet from farming activities.

Corrective Action

For those residents whose wells exceeded the 7 ppb level, the homeowner was advised not to use the water for drinking or cooking purposes and to obtain an alternate

TABLE 1—Groundwater Contamination by Type of Well

Source	Number of Wells	Exceeding the Guideline	Showing Traces	Non-Detectable
Private Wells	8051	1087 (13.5)	1068 (13.3)	5896 (73.2)
Non-Community Water Supplies	274	22 (8.0)	45 (16.4)	207 (75.5)
Community Water Supplies	68	5 (7.4)	5 (7.4)	58 (85.3)
Others	11	7	1	3
TOTAL	8404*	1121 (13.3)	1119 (13.3)	6164 (73.3)

*Includes the wells tested in the initial survey. Figures in parentheses indicate percentages.

TABLE 2—Aldicarb Concentrations Detected in Private Wells in Parts Per Billion

Concentration in ppb	Number of Wells	Per Cent
None detected	5896	73.2
1–7	1068	13.3
8–30	565	7.0
31–75	345	4.3
More than 75	177	2.2
TOTAL	8051	

TABLE 3—Maximum Aldicarb Concentrations by Type of Water Supply

Water Supply	Parts per Billion
Community Water Supplies	27
Non-Community Water Supplies	59
Private Wells	515
Others	493

supply of potable water. In the case of community water systems, a recommendation was made to the purveyor to suspend the use of the contaminated well, and to switch to other uncontaminated wells. This was not always possible and, in one situation, the purveyor had to resort to treatment through the use of activated carbon filtration.

Because of the hardship encountered in obtaining alternate sources of potable water in many areas of the county, treatment of existing sources was considered. A cooperative study with Union Carbide was initiated in December 1979 to test the efficacy of activated carbon filters. This study demonstrated that large activated carbon filters (which contain about 17–22 pounds of activated carbon) were effective in removing most of the aldicarb and its metabolites for extended periods depending on usage, presence of other contaminants, and water quality.

These preliminary findings, coupled with Union Carbide's interest in alleviating the hardship imposed on the residents with contaminated wells, prompted the signing of an agreement between Union Carbide and Suffolk County. Under the terms of this agreement, Union Carbide provided an activated carbon filtration system, free of charge, to those residents whose wells exceeded the 7 ppb level.

It should be emphasized that the activated carbon filters are not the optimum solution to the problem of groundwater contamination with aldicarb, other pesticides, and synthetic organics. They should be viewed only as an interim solution to a rather complex, multi-faceted, and long-term problem.

Discussion and Recommendations

The detection of aldicarb in groundwater for the first time in this country brings into focus several issues and practices which have to be addressed:

Registration of pesticides by the federal government—The extensive laboratory and field trials which preceded the registration of aldicarb indicated that the pesticide would not reach groundwater. This indication was based on its fast degradation, short half-life, and its confinement to the upper two feet of soil during normal rainfall or irrigation. In Long Island, a combination of circumstances led to the downward leaching of the pesticide. The circumstances included the sandy soil, characteristic of many areas in eastern Suffolk County, a shallow water table, heavy rainfall during the preceding two years, and probably a larger than usual dose of application.

This unexpected detection of aldicarb in groundwater points to the urgent need for more comprehensive testing of pesticides under varying field conditions prior to their registration. In addition, groundwater should be monitored not only prior to, but during pesticide use in sensitive areas such as those with sole source aquifers and special soil conditions.

Actionable levels and acceptable risks—Tremendous achievements in laboratory technology during the past decade have enabled us to detect traces of many contaminants previously unidentified. Although the toxic effects of many contaminants are well documented in heavy industrial and acute exposure, very little is known about the long-term effects of exposure to low doses of these contaminants.

In order to establish actionable levels for many pesticides, reliance has been placed on extrapolation from animal experiments and on the few uncontrolled epidemiologic studies among human populations. In the process of deter-

TABLE 4—Aldicarb Concentration by Distance of the Well from a Potato Farm

Aldicarb Concentration*	Number of Wells within Stated Distances					
	<100 Feet	101–500′	501–1000′	1000–1500′	1501–2000′	2001–2500′
1–7 ppb	296 (42.5)	344 (46.5)	284 (57.1)	50 (75.7)	32 (82.0)	8 (100.0)
8–30 ppb	196 (28.1)	193 (26.1)	139 (27.9)	10 (15.2)	5 (12.8)	0 (0.0)
31–75 ppb	136 (19.5)	128 (17.3)	48 (9.6)	5 (7.6)	1 (2.6)	0 (0.0)
>75 ppb	69 (9.9)	75 (10.1)	27 (5.4)	1 (1.5)	1 (2.6)	0 (0.0)
Totals	697 (100.0)	740 (100.0)	498 (100.0)	66 (100.0)	39 (100.0)	8 (100.0)

*Figures in parentheses are column percentages.

mining these levels, several parameters were used including the no-adverse-effect level, acceptable daily intake, water consumption, expected exposure to other non-aqueous sources, etc. The limitations inherent in extrapolation from animal studies and from the crude uncontrolled epidemiologic studies, and the many stipulations and assumptions utilized, subject these proposed actionable levels to serious questions and challenges.

Probably the most important task at present is a reevaluation of the actionable levels of the frequently encountered environmental contaminants. This reevaluation should take into consideration realistic health effects, reasonable acceptable risks, and economic impact.

The lack of controlled epidemiologic studies to assess the health effects of long-term exposure to low concentrations of pesticides—Because of our inability to test for the various pesticides in these trace concentrations in the past, the prospective approach is the only one which could yield meaningful results. It is fully realized that it might be very difficult and perhaps impossible to design a study which could establish a cause and effect relationship between pesticides and the clinical manifestations characteristic of pesticide poisoning because of the various etiologic agents which could be incriminated, the variations in the degree of exposure to contaminants in water and other non-aqueous sources, and the long follow-up periods. Despite these anticipated difficulties, it is of paramount importance that studies be initiated to explore at least the presence or lack of association between pesticides and selected clinical conditions.

The lack of evidence to support or negate a causal relationship at present does not mean that we, as public health officials, can ignore the presence of these toxic contaminants in groundwater until further documented studies prove the presence or absence of such evidence. On the contrary, any responsible health agency should assume that these contaminants represent a potential hazard to public health and act accordingly. Such action should include proper planning, abatement of sources of pollution, connection to public water systems, and water treatment.

The past decade has witnessed a dramatic emphasis on environmental contaminants and their impact on human health. The wide publicity given incidents such as the Love Canal in New York State and the possible deleterious effects of exposure to Agent Orange have heightened public awareness and, in a sense, engendered a state of environmental paranoia.

We should do everything possible to identify and abate sources of pollution and find corrective solutions to existing sources whose effects are tangible. It would be most desirable, of course, to avoid exposure to all possible risks—the tangibles and intangibles. This requires tremendous resources which are not, and most probably will not, be available in the near future.

Our society seems to be willing to accept tangible and measurable risks in our daily activities as a result of cigarette smoking, excessive food and alcohol intake, and the use of the automobile. The same society, however, is unable to tolerate potential, intangible, and unmeasurable risks from food additives, pesticides, air pollutants, and water contaminants. As public health administrators, we have a responsibility not only to monitor and control these substances but also to help the public become fully aware of their risks and benefits without resort to rhetoric on either side of the issue.

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10th Annual Texas Human Nutrition Conference

The 10th Annual Texas Human Nutrition Conference will be held February 18, 1983 at Texas A&M University.

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