

GROUND-WATER CONTAMINATION BY PESTICIDES

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Introduction

Over one-half of the population of the United States relies on ground water for all or part of their potable water. Up to 95% of rural residents obtain their water supplies from wells. However, domestic uses account for only 18% of the ground water used in this country. Almost two-thirds of the ground water withdrawn in the U.S. is used for irrigation. In California, up to 20 billion gallons of ground water are used every day. The heavy dependence on ground water for both domestic and agricultural uses makes ground water a very valuable resource, which must be protected from contamination.

As a result of the large agricultural industry in the state, widespread use of pesticides has been made during the past 40 years. California alone accounts for 25% of the pesticides applied in the United States. Prior to 1979, little monitoring of ground water for the presence of pesticides was practiced because it was assumed that they were not sufficiently long-lived and mobile to pose a threat to ground water. However, the discovery of a soil fumigant, 1,2-dibromo-3-chloropropane (DBCP) in well water in Lathrop, California triggered widespread ground-water sampling programs. As a result, approximately 10,000 wells in the state have been analyzed for pesticide residues. The monitoring program detected more than 50 different pesticides in 23 California counties. The most commonly detected pesticide was DBCP, which was found in approximately 2500 of the wells.

California Legislation Related to Pesticides in Ground Water

Public concerns over exposure to toxic chemicals in the environment led to the passage of two pieces of legislation in California that impact ground water: Proposition 65 and Assembly Bill 2021 (AB2021). Proposition 65 requires that the governor publish (and update yearly) a list of chemicals known to the State to cause cancer or reproductive toxicity. One of the provisions prohibits a person in the course of doing business from knowingly discharging a chemical on the list into water or onto or into land where the chemical may pass into a source or potential source of drinking water. Thus, any pesticides which are known to cause cancer or reproductive toxicity will be subject to the provisions of Proposition 65.

AB2021, the Pesticide Contamination Prevention Act, was passed specifically to try to prevent or minimize future ground-water contamination by pesticides. This act states that the use of a pesticide will be restricted if it is detected in the ground water or found in the soil at or below the deepest of the following three depths: 8 feet below the soil surface, below the root zone of the crop, or below the soil microbial zone. Only pesticides that the California Department of Food and Agriculture (CDFA) is satisfied are in ground water as a result of

normal, legal agricultural use are subject to AB2021.

The act also provides for the establishment of Pesticide Management Zones (PMZs). PMZs are 1 mi² areas around a well where a pesticide has been detected, and thus the ground water is considered to be vulnerable to contamination. To date, five pesticides have been placed on the list of "detected leachers" and some or all of their uses have been restricted in their respective PMZs (see Table 1).

Table 1. Restricted Uses of Detected Leachers

<u>Pesticide</u>	<u>Restriction</u>
Atrazine	all outdoor agricultural, outdoor industrial and outdoor institutional uses prohibited in atrazine PMZs
Bromacil (Hyvar®) Diuron (Karmex®) Simazine (Princep®)	all non-crop uses prohibited in the respective PMZs
Prometon (Pramitol®)	all agricultural, outdoor industrial and outdoor institutional uses prohibited in prometon PMZs
Aldicarb	fall applications will be prohibited and rates allowed per acre reduced by 50%

In addition to the pesticides which have been detected in ground water, AB2021 requires that CDFA establish a list of suspected leachers. These are pesticides that, by virtue of their chemical and/or physical properties, may contaminate ground water even when used according to label directions. To identify suspected leachers, CDFA has established Specific Numerical Values (see Table 2). In order for a pesticide to be placed on the list, it must meet criteria for both mobility and persistence. In other words, it must meet EITHER the water solubility OR the soil adsorption coefficient AND the hydrolysis half-life OR aerobic soil metabolism half-life criteria. To date, 11 pesticides have been placed on the suspected leachers list (see Table 3).

Table 2. Specific Numerical Values

<u>Property</u>	<u>Value</u>
Water solubility	> 3 ppm
Soil adsorption coefficient	< 1900 cm ³ g ⁻¹
Hydrolysis half-life	> 14 days
Aerobic soil metabolism half-life	> 730 days

Table 3. Suspected Leachers (June, 1989)

Cyanazine (Fortrol®)	Metolachlor (Dual®)
Fenamiphos (Nemacur®)	Metribuzin
Fluometuron (Cotoran®)	Naptalam (Rescue®)
Linuron (Lorox®)	Pebulate (Tillam®)
Methiocarb (Mesurol®, Draza®)	Vernolate (Surpass®, Vernam®)
Methomyl (Lannate®)	

An important fact to note about AB2021 is that it applies to all pesticides, regardless of whether or not they have any effects on health. In addition, the act does not prescribe a minimum concentration where action must be taken. This means that any pesticide found in ground water or in the soil at the depth described above at any concentration will be subject to restricted use under AB2021. The severity of the use restrictions imposed by CDFA will, however, take into consideration health effects, site conditions, and the availability of alternative materials.

Factors Controlling Pesticide Fate in the Subsurface

Pesticide properties

As mentioned above, for a pesticide to be placed on CDFA's list of suspected leachers, it must meet criteria for both mobility and persistence. These factors must be considered jointly when assessing a pesticide's potential to contaminate ground water. If a pesticide is very mobile, and persists for a long period of time, it has a high potential to contaminate ground water. On the other hand, if it is not mobile, and only persists for a short period of time, the potential for ground-water contamination is low (although it may be a candidate to contaminate surface water through runoff).

One of the most important factors determining the mobility of a pesticide is its solubility in water. When a pesticide enters the soil, some of it will stick to the soil particles through a process called adsorption, and some will mix with the water that is present in the pores between the soil particles. The solubility of the pesticide determines the amount that will be present in the soil water, and thus be available for leaching. Solubility and adsorption are inversely related, therefore, pesticides that have a high solubility will be present in the soil water at a relatively high concentration compared to the amount that is adsorbed onto the soil particles. The affinity of a pesticide to adsorb to the soil can be expressed using the soil adsorption coefficient, K_{oc} . The smaller the K_{oc} value, the smaller the amount of pesticide adsorbed to the soil and the larger the amount in the water. Pesticides with small K_{oc} values are more likely to be leached through the soil than those with large K_{oc} values.

The persistence of a pesticide is generally expressed in terms of its half-life, sometimes written $t_{1/2}$. One half-life is the amount of time required for

one-half of the mass of the pesticide to be degraded. After 2 half-lives, $\frac{1}{4}$ of the pesticide will have been degraded; after 3 half-lives, $\frac{1}{8}$ will have been degraded, and so on. Pesticides can be degraded by several means, including chemical, physical, and biological processes. The half-life of a pesticide is reported in such a way as to reflect the process used to calculate that half-life. Examples include hydrolysis half-life (degradation by the chemical process of splitting the pesticide with water) and aerobic soil metabolism half-life (degradation by oxygen-requiring soil bacteria). The larger the half-life value, the greater the possibility that the pesticide can persist long enough to leach through the entire soil profile and reach the ground water.

Soil properties

In addition to the characteristics of the pesticide, soil properties are very important when determining the vulnerability of a site to ground-water contamination by a pesticide. The soil texture (i.e., the percent sand, silt and clay) affects pesticide leaching in two ways. Water, and any materials it contains, moves more slowly through clay soil than through soils with a high sand content. Clay particles also act to slow the movement of some pesticides by providing adsorption sites. Therefore, all other factors being equal, there tend to be less of a concern for ground-water contamination at sites with clayey soils than sandy soils.

Soil permeability is a measure of the rate at which water moves through soil. Soils with a high permeability lose applied water quickly through leaching. Pesticides applied to very permeable soils have a greater potential to contaminate ground water than if they are applied to less permeable soils. However, soils with low permeabilities have more problems with surface runoff that can lead to surface-water contamination by pesticides.

The organic matter content of soil is positively correlated with the adsorption of pesticides. Soils with high organic matter content would be less vulnerable to leaching than would soils with low organic matter content. Another benefit associated with high organic matter soils is that organic matter is required for microbial growth. Soil microorganisms are important in the degradation of many pesticides.

Non-uniformities in the soil such as worm holes, root-hair channels and fractures also influence how pesticides travel through the soil. If a fracture is present in a clayey soil, a pesticide will be able to move through the soil at a much faster rate than would be expected if the fracture were absent. Non-uniformities may help to explain why pesticides are found in the ground water at some sites where the overlying soil was felt to be "non-leaching".

Site conditions

One of the most important site conditions contributing to its vulnerability is the depth to ground water. The deeper the ground water, the longer it will take for the pesticide to reach the water table, and the smaller the mass of the pesticide that will be present to enter the ground water (because the pesticide is degrading with time). The temperature at the site can influence the rate of pesticide degradation, with colder temperatures generally resulting in slower

degradation rates.

Management practices

The practices of the pesticide applicator and the irrigation practices at the site are very important in determining the potential for pesticide contamination of ground water. Pesticides that would not be considered to be leachers by virtue of their chemical and physical properties may leach to ground water if the proper management techniques are not used. Conversely, good management practices may result in preventing ground-water contamination by pesticides that are considered leachers. Following the label directions and using common sense when applying pesticides can help to minimize the potential for ground water contamination. Irrigation management is also very important, because in general, the more water applied, the more the pesticide will move into the soil. Only the amount of water required by the plants should be applied; over-watering is costly and could contribute to pesticide contamination of surface or ground water.

Preventing pesticide contamination of ground water is less expensive and much easier than trying to remediate contaminated sites or closing wells because they exceed standards and drilling new ones. Additionally, in California, preventing pesticides from entering ground water will decrease the number of pesticides whose use has to be restricted as a result of AB2021.