A Better Way to Protect Ground Water

John Troiano, Sr. Environmental Research Scientist, Department of Pesticide Regulation, California Environmental Protection Agency, 1001 I St., Sacramento, CA 95812
Phone (916) 324-4115, FAX (916) 324-4088, jtroiano@cdpr.ca.gov

Mark Pepple, Sr. Environmental Research Scientist, Department of Pesticide Regulation, California Environmental Protection Agency, 1001 I St., Sacramento, CA 95812
Phone (916) 324-4086, FAX (916) 324-4088, mpepple@cdpr.ca.gov

Joe Marade, Assc. Environmental Research Scientist, Department of Pesticide Regulation, California Environmental Protection Agency, 1001 I St., Sacramento, CA 95812
Phone (916) 324-4119, FAX (916) 324-4088, jmarade@cdpr.ca.gov

Introduction

Detections of residues of 1,2-dibromo-3-chloropropane (DBCP) in 1979 were the first indications of potential contamination of California's ground water supply by pesticides (Peoples et al., 1980). Subsequent well surveys conducted by the Department of Pesticide Regulation (DPR, formerly the Division of Pest Management in the California Department of Food and Agriculture) indicated that the contamination was more prevalent than originally anticipated. In response to a report from the State Water Resources Control Board, the legislature passed the Pesticide Contamination Prevention Act (PCPA) (Pesticide Contamination Prevention Act,1985). The purpose of the act was to prevent further pesticide pollution of ground water aquifers that may be used for drinking water supplies. The PCPA required DPR to:

1. Maintain a database of well sampling for pesticides. All state and local agencies were required to report any well sampling for pesticides. DPR asked federal agencies, such as the USGS to report on their well sampling voluntarily.
2. Develop a list of active ingredients with the potential to pollute ground water (the "Ground Water Protection List"- GWPL) and adopt that list in regulation (section 6800(b) of Title 3 of the California Code of Regulations (3CCR)). As part of that process, the law also required DPR to develop and adopt by regulation numerical benchmarks for physical/chemical properties of pesticides used to identify pesticides on the GWPL.
3. Monitor to determine whether pesticides on the GWPL were moving to ground water. The DPR Environmental Monitoring Branch conducts ongoing well sampling to determine whether pesticides on the list are contaminating ground water.
4. Review pesticides determined to move to ground water as a result of legal agricultural use to decide whether continued use can be allowed. Currently registered active ingredients that have been found in ground water due to legal agricultural use and that have modifications of use are listed in 3CCR section 6800(a).

In order to fulfill these requirements, DPR developed a ground water program that included sampling from wells located in rural, agricultural areas. In contrast to data obtained from the Department of Health Services, which requires sampling from wells that supply public water connected to 25 or more households, wells sampled by DPR serve mainly single-family households, drawing water from relatively shallow ground water aquifers. Generally, these wells are most susceptible to contamination from chemicals applied to the soil surface because they are located near sources of pesticide applications with a relatively short travel time of solutes from the surface to the shallow aquifer.

Prior to the PCPA, certain soil fumigants (DBCP, 1,2-D, and EDB) were detected in many California wells at concentrations that exceeded health levels (Troiano et al., 2001). Since the mechanism of movement to ground water was poorly understood, there were no known mitigation measures that could be implemented to protect ground water. Eventually it was determined that these pesticides "demonstrated serious uncontrollable adverse effects," which is one of the conditions specified in the California Food and Agricultural Code under which pesticides can be quickly suspended and subject to cancellation. Registration of these soil fumigants was eventually cancelled because of worker safety and general human exposure concerns, and lack of management practices to prevent further ground water contamination. As the well sampling program expanded, other pesticides were detected in California ground water but at levels that did not initially exceed health levels. Under these conditions, there was time to review these pesticides under the specified PCPA process, and to begin to understand how these chemicals were moving to ground water. Studies were conducted to determine pathways for movement of residues to ground water and, upon identification, additional studies were conducted to determine specific mitigation measures. With the development of mitigation measures, prohibition of use was no longer the only regulatory option and was necessary only when management options were not available.

One final piece tying the program together was the development of a geographical information system (GIS). The need for GIS development was initially driven by our desire to develop an efficient monitoring program. Since the goal of the monitoring program was to detect pesticides that were moving to ground water, there was a need to determine where pesticides were being applied, and what soil types and depth to ground water were associated with detections. This information was then incorporated into a GIS system, which is used to indicate areas of the state where detections are most likely. This approach has been incorporated into the recent update of the ground water regulations enacted in May of 2004 where vulnerable areas, denoted ground water protection areas (GWPA), are defined by soil properties and depth to ground water.

Identifying Vulnerable Areas and Pathways to Ground Water

One result of the ongoing ground water sampling program was the development of a relatively large data set of wells containing pesticide residues that originated from non-point source applications. This data set was used as the basis for an empirical approach to determining spatial vulnerability of pesticide movement to ground water (Troiano et al., 2000). A vulnerable unit was defined as a section of land where pesticide residue had been detected in at least one well and the detection determined to result from non-point source applications where a section is a 1-square mile area of land (Davis and Foote, 1966). Soil data were obtained for each contaminated section and a statistical clustering method was used to group sections of land that had similar soil properties. For the first cut, soil texture, which was identified as a combination of permeability and shrink-swell variables, formed groups. Additional sub-groups were identified based on the presence of a hardpan layer in the soil and on the presence of an annual water table (Troiano et al., 2000).

One benefit of this approach is flexibility whereby vulnerable clusters can be more accurately described and/or additional vulnerable conditions can be identified as more geographic information becomes available. For example, depth-to-ground water data were not available for the first statewide assessment, but it is now an integral variable for identifying vulnerable areas. The vulnerability analysis has been used to focus our well sampling studies in areas with the highest probability for detections and it also forms the basis for changes in DPR's ground water regulations where use of certain management practices are required in vulnerable areas.

Regulation of Pesticides Detected in California's Ground Water

Although the prevailing opinion regarding regulations is that they are an impediment to pesticide use, the goal of regulating ground water contaminants is to encourage their continued use but under management conditions that will prevent their movement to ground water, thereby assuring their presence in the grower's toolbox. This course of action attempts to balance economic considerations with environmental protection. If a 6800(a) listed pesticide is used in a designated GWPA, the user is required to obtain a permit from the local Agricultural Commissioner (Table 1). One objective of the permit is to notify users that the pesticide they are applying has the potential to move to ground water in a vulnerable area. But more importantly, the permit will be conditioned with a mitigation measure that, when adopted by the user, will minimize movement of the chemical to ground water. Furthermore, DPR has developed a list of management practice options to give users flexibility depending on the situation. Management practice options may be added to the list as additional information is developed by DPR, user groups, and others. The regulations also encourage development of additional management practices, especially if the current ones pose a hardship.

The mitigation measures are tailored to the specified pathway to ground water where GWPAs are indicated as either **leaching or runoff**. Figure 1 illustrates the location of GWPAs in the San Joaquin Valley. Studies conducted in coarse-textured soils indicated the importance of managing percolating water, especially during the irrigation season (Troiano et al., 1993). The following list of mitigation options is available in **leaching** GWPAs where the normal soil water infiltration process predominates over surface runoff:

Leaching GWPA Management Options – Choose one:

L-1. Do not irrigate for 6 months following application (usually applicable to noncrop uses);
L-2. Irrigate so water does not contact treated area for 6 months following application;
L-3. Irrigate efficiently for 6 months following application applying no more than 133 percent of water at each irrigation required to satisfy evapotranspiration losses;
L-4. Use a scientifically-based alternative management practice approved by the Director as specified by an enforcement letter;
L-5. Apply the pesticide with no use modification if none of the management practices are feasible, and the requestor submits and DPR approves a protocol for testing a new management practice

In contrast to leaching GWPAs, runoff GWPAs are primarily characterized by soils that contain a hardpan layer located 2-3 feet below the soil surface where movement of residues to sensitive sites has been measured as a result of winter rain runoff (Braun and Hawkins, 1991). When agricultural practices are used that exacerbate compaction of soil, the resulting soil condition is characterized by low soil infiltration rates that favor runoff of water. A follow-up study indicated that incorporating herbicide residues by a mechanical method into soil prior to a precipitation event drastically reduced offsite movement of residues through a combination of reducing concentration in runoff water and reducing the amount of runoff water produced (Troiano and Garretson, 1998). The following list of mitigation options is available in **runoff** GWPAs where surface runoff predominates over the normal soil water infiltration process:

Runoff GWPA Management Options – Choose one:

R-1. Apply in a band not to exceed 33% of distance between crop rows, except in citrus where the band can extend to the dripline of the tree;
R-2. Disturb soil within 7 days before application (not an option for bentazon);
R-3. Incorporate the pesticide on 90% of the area treated within 48 hours after the day of application by mechanical means (disc, harrow, rotary tiller) or by pressurized irrigation (not an option for bentazon);
R-4. Apply between April 1 and July 31;
R-5. Keep runoff water onsite for 6 months. If kept in a storage basin, the basin should have a low percolation rate (<0.2 in/hr) unless the runoff water is recirculated within 24 hours;
R-6. Keep runoff water in an offsite low permeability (<0.2 in/hr) storage basin, under the control of the permittee, for 6 months.
R-7. Channel runoff onto an un-irrigated fallow field for 6 months after application, with full consideration of plantback restrictions.
R-8. Allow unchanneled runoff to move to an adjacent area equal in size to the area treated as long as the runoff does not move to sensitive sites, such as dry wells, ditches, or permeable retention areas.
R-9. Use a scientifically-based alternative management practice approved by the Director as specified by an enforcement letter.
R-10. Apply the pesticide with no use modification if none of the management practices are feasible, and the requestor submits and DPR approves a protocol for testing a new management practice.

The last two mitigation measures for both leaching and runoff conditions add flexibility to the regulations by promoting development of additional management practices.

In addition to the management practices for uses on agricultural crops, the regulations address use in recharge areas, canals and ditchbanks, roadside use, and wellhead protection. The structure is similar to the agricultural use in that, when feasible, a list of options is available to choose from. Complete information on the regulatory program is available at the DPR website at **http://www.cdpr.ca.gov/docs/gwp/index.htm**.

Summary
California regulations for protecting ground water from pesticide residues were revised in May 2004. At the heart of the regulations was the implementation of a spatial vulnerability assessment that identified areas of the state that are most vulnerable to pesticide contamination. Vulnerable areas are described by soil properties and depth to ground water data. Identification of specific soil properties lead to determination of pathways for movement of pesticides residues to ground water and a determination of whether they occur by either leaching or runoff processes. The 'Better Way to Protecting Ground Water' is allowing continued use of known ground water contaminants but under management practices that minimize their potential movement to ground water. In addition, a list of management options has been developed for each pathway to ground water, providing flexibility for the user to continue use in vulnerable areas.

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Table 1. Pesticide active ingredients known to contaminate ground water that are listed in Food and Agriculture section 6800(a). Some associated product names are indicated.

Active Ingredient	Product Name
Atrazine	Aatrex®
Simazine	Princep®
Bromacil	Hyvar®, Krovar®
Diuron	Karmex®, Krovar®
Prometon	Pramitol®
Bentazon	Basagran®
Norflurazon	Solicam®, Predict®, Zorial®

Figure 1. Location of leaching and runoff ground water protection areas (GWPAs) in the San Joaquin Valley. White sections with a gray outline are leaching GWPAs and solid gray colored section are runoff GWPAS.