USE OF CLUSTER AND PRINCIPAL COMPONENT ANALYSES TO PROFILE AREAS IN CALIFORNIA WHERE GROUND WATER HAS BEEN CONTAMINATED BY PESTICIDES

JOHN TROIANO, BRUCE R. JOHNSON and SALLY POWELL
Environmental Monitoring and Pest Management Program California Department of Pesticide Regulation, California Environmental Protection Agency, Sacramento, CA, 95814, U.S.A.

and

STEVE SCHOENIG
Biological Control Program, California Department of Food and Agriculture, Sacramento, CA, 95832, U.S.A.

(Received: 22 August 1994)

Abstract. An empirical approach to profiling areas of ground water contamination by pesticides was devised that did not rely upon determining the level of vulnerability between land areas and that did not assume any particular pathway for ground water contamination. Climatic and soil data were obtained for 1-square mile sections of land in California where pesticide residues had been found in well water samples and the detection was attributed to legal agricultural applications. These sections were designated as known contaminated (KC) sections. Climate and soil data were also obtained for sections which lacked either well sampling data or a positive pesticide detection. These sections were designated as candidate sections. Statistical procedures were used to cluster groups of KC sections first with respect to climate characteristics and then with respect to soil characteristics. Principal components analysis (PCA) was used to construct a statistical profile of soil variables for each cluster of KC sections. A method based on the PCA was developed to compare the similarity of soil profiles derived for each KC section cluster to individual candidate sections. Since the profiling scheme was based only on data from KC sections, candidate sections that did not match any KC cluster profile could only be considered dissimilar to contaminated sections, receiving a status of not-classified. This profiling method is flexible and it can be revised to incorporate updated well sampling information.

1. Introduction

Delineation of land areas where pesticide residues could contaminate ground water is desirable from a regulatory perspective because it would enable a regional approach to the development and implementation of best management practices (BMPs). Modeling approaches to determine spatial vulnerability to contamination have been recently reviewed (EPA, 1993; National Research Council, 1993). The underlying assumptions for these approaches are that an index can be developed to reflect the susceptibility of a given area of land to ground water contamination by pesticides, and that the variables chosen to construct the index apply to all land areas. In these approaches there are usually a priori assumptions about the route by which pesticides contaminate ground water and about the importance of certain variables to include in the model. Most models of vulnerability have been developed to identify areas that are susceptible to leaching of pesticides to ground water, so climatic, hydrogeologic, or soil variables are included that maximize the discrimination in leaching potential between land areas.

To date, only a few well monitoring studies have been conducted to test the correlation of vulnerability indices generated by models with incidence of pesticide residues in well water samples. The use of DRASTIC indices as indicators of vulnerability has been statistically tested in three studies (EPA, 1992; Balu and Paulsen, 1991; Holden et al., 1992). DRASTIC indices of vulnerability were developed for county-wide areas and were constructed from weighted ratings of seven hydrogeologic variables which experts agreed were important determinants in leaching of pesticides to ground water (Aller et al., 1985). None of the well monitoring studies found a good correspondence between occurrence of pesticide residues in well water and the DRASTIC scores because pesticide residues were detected in areas designated as relatively non-vulnerable. Estimates produced by the indices may be affected by the spatial scale used to construct the index or by error associated with model variables (National Research Council, 1993). On the other hand, problems related to interpretation of well sampling results could cause unfavorable correlation.

Roux et al. (1991) conducted a survey for the presence of simazine residues in well water sampled in the states of California, Delaware, Florida, Illinois, Indiana, Michigan and West Virginia. A vulnerability index that was a multiplicative product of aquifer and soil sensitivities was developed to rank 22 counties selected from the 7 states. Even though Fresno and Tulare counties in California had the lowest vulnerability rankings, simazine was consistently detected in well water sampled from these two counties. Movement of residues to ground water by pathways other than leaching was suspected.

Monitoring studies conducted by the California Department of Pesticide Regulation (CDPR) staff support this result. In Tulare county, California, residues of herbicides that had been applied for pre-emergence weed control in citrus were measured in runoff water entering suspected dry wells (Braun and Hawkins, 1991). One purpose of a dry well is to aid drainage of soil by providing a fast route for water flow to subsurface layers of soil. Owing to the large number of dry wells in Tulare county, movement of residues into dry wells must be considered an important avenue for ground water contamination from legal agricultural applications of pre-emergent herbicides. Examples of other alternative avenues for ground water contamination from legal agricultural applications are movement of surface water into Karst formations (Hallberg, 1989) or into cracks in clay soils (Graham et al., 1992). In our experience, identifying leaching as a cause of positive detections in large retrospective well surveys has been problematic because of the strong possibility for other avenues of pesticide movement to ground water.

Other problems with using well sampling results to detect ground water contamination or to validate vulnerability assessments are potential inconsistencies in pesticide detections over time or the possibility of lateral transport of contaminants with ground water. For example, Wilkersen et al. (1985) used an empirical discriminant analysis approach to produce a classification equation for vulnerability of sections of land to well contamination by DBCP, a soil fumigant. A section of