Idaho State Department of Agriculture
Division of Agricultural Resources

Results of Testing for Pesticides in Ground Water, Including Pesticides Previously Untested 2008 and 2009

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ISDA Technical Summary #44 June 2009

Introduction

In 2008, the Idaho State Department of Agriculture (ISDA) Ground Water Program was awarded a grant by the Environmental Protection Agency (EPA) to test ground water for currently registered pesticides. The goal of the project was to test ground water for pesticides in agricultural areas that are most vulnerable to contamination, and to test for recently registered active ingredients that have never been evaluated before by ISDA. This project also involved testing for the normal analytical screen of pesticides used by ISDA. The grant provided resources to conduct testing of pesticides at privately owned domestic wells in southwest and south central Idaho (Figure 1). The testing was undertaken to develop a better understanding of impacts from registered active ingredients that have significant use in Idaho that have not been previously tested. Laboratory results indicated that all wells sampled had pesticide concentrations that are below any associated health standard.

Background

ISDA is responsible for a variety of programs, laws, and rules for protection of ground water from pesticides. The division of Agricultural Resources has a cooperative agreement with EPA to implement the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). ISDA staff implement Idaho Pesticide Laws and Rules and conduct monitoring duties to fulfill this cooperative agreement. Additionally, the Idaho Pesticide Management Plan (PMP), and the Rules Governing Pesticide Management Plans For Ground Water Protection (PMP Rule) require the state to respond to pesticide detections in Idaho ground water. The state response as outlined in these two documents is based on four distinct levels established by pesticide detection concentrations as they relate to a percentage of a reference point. A reference point is based on a health standard, such as a maximum contaminant level (MCL), lifetime health advisory level (HAL), or reference dose (RfD). ISDA response actions increase and become more stringent as the detection level increases. The PMP Rule divides the pesticide detections into the following levels:

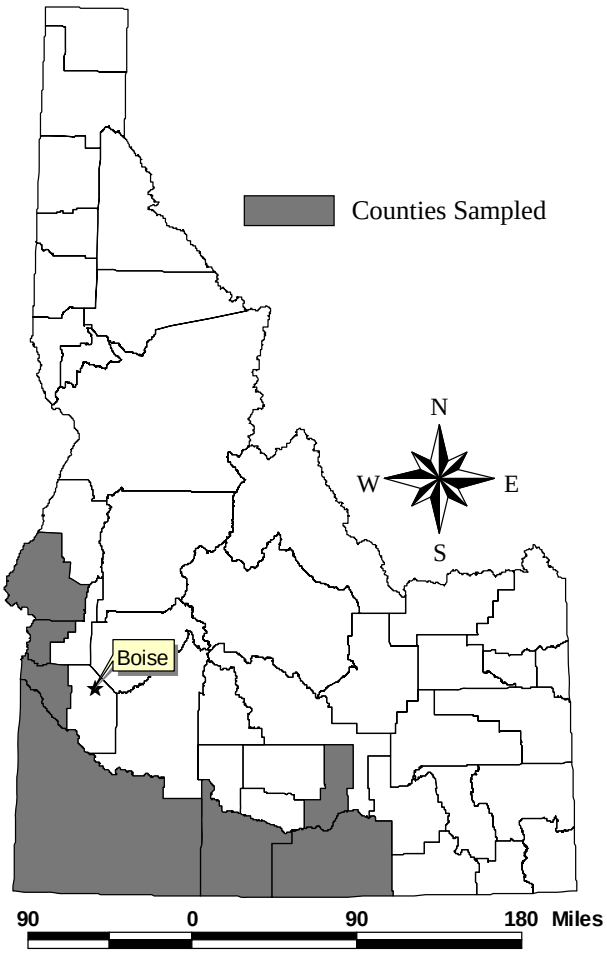

Figure 1. Map of Idaho and location of project.

Level 1: Detection above the laboratory detection limit to less than 20% of the reference point.
Level 2: Detection at 20% to less than 50% of the reference point.
Level 3: Detection at 50% to less than 100% of the reference point.
Level 4: Detection at or greater than 100% of the reference point.

Historical Monitoring (ISDA)

Since the 1990s, the ISDA Ground Water Program has conducted pesticide testing through local and regional-scale ground water monitoring in agricultural areas around the state. ISDA expanded pesticide sampling

efforts to urban areas beginning with the 2007 - 2008 Boise urban area in response to urban ground water pesticide detections reported by the United States Geological Survey (USGS) National Water Quality Assessment (NAWQA) project (Gilliom et al., 2006). Sampling projects conducted by USGS and other state FIFRA lead agencies have also identified that some newly registered pesticides have leachability concerns and have been found in ground water. With the funding provided ISDA determined, in addition to the normal analytical screen of pesticides, it was timely to test vulnerable wells in the existing ISDA network for the pesticides listed in Table 1 that have not been previously tested for in Idaho.

The goal of this project is to provide the ISDA Water Program with ground water monitoring data for 13 pesticides that ISDA has not analyzed for in agricultural land use areas (Table 1). The primary objective is to determine if any of the 13 pesticides have contaminated ground water and evaluate the need to add these extra pesticides to ISDA's ground water pesticide monitoring program. The information will be used to make regulatory and/or voluntary practice changes related to applications of pesticides. ISDA will also provide landowners and pesticide applicators education relative to this project. The information can also be used for educational purposes and to advance technical knowledge relative to ground water quality protection and the application of Best Management Practices (BMP). Ultimately, this effort should help ensure prevention of future ground water contamination. Tasks to meet these objectives were to:

- Collect ground water samples from approximately 17 domestic wells to be analyzed for 13 new pesticides, along with other pesticides and herbicides.
- Notify homeowner of results for their domestic well.
- Prepare data summary sheets at the completion of each sampling event and a technical report at the completion of all sampling summarizing significant findings.
- Meet with BMP and PMP Advisory Committees to determine what regulatory and/or voluntary practice changes will be recommended.
- Educate homeowners and pesticide applicators within project area on findings and recommendations from BMP and PMP Advisory Committees.

Pesticides Tested

ISDA water staff have sampled approximately 300 wells annually for 110 different pesticides using the University of Idaho Analytical Sciences Laboratory (UIASL) scan. New chemistries and pesticides have been developed recently that are not included in the UIASL scan. UIASL was able to develop methodologies to analyze for the 13 new pesticides (Table 1) that have not previously been tested for in agricultural land use areas, in addition to the 110 chemicals that are included in ISDA's regular pesticide screen.

Description of Project Area

The project covers numerous southern Idaho counties including Washington, Payette, Canyon, Owyhee, and Minidoka (Figure 1). The study area is located in

Table 1. Thirteen new pesticides added to ISDA's analytical screen, along with uses and common trade names.

Pesticide	Crops	Common Trade Name
Acephate	beans	Avatar, Cheminova, Executioner, Orthene
Azoxystrobin	alfalfa, barley, beans, corn, onions, potatoes, sugar beets, triticale	Abound, Amistar, Cruiser Extreme, Dynasty, Heritage, Quadris
Chlorsulfuron	barley, triticale, wheat	Chisum, Cimarron, Telar, Finesse, Glean, Landmark, Report, Throttle
Clopyralid	corn, barley, wheat	Accent, Commando, Curtail, Cutback, Redeem, Surestart
Cyfluthrin	alfalfa, beans, corn, peas, potatoes	Aztec, Baythroid, Defcon, Leverage, Power Force Multi-Insect Killer RTS, Renounce, Tombstone
Cypermethrin	non-crop areas, onions	Cypermethrin, Demon, Holster, Prevail, Up-Cyde
Glyphosate	corn, barley, beans, non-crop areas	Fireball, Halex, Roundup, Sequence, Touchdown, Traxion
Imazapyr	field corn, non-crop areas	Imazuron E Pro, Lightning, Lineage, Sahara, SSI Maxim Arsenal, Topsite
Imidacloprid	barley, beans, peas, potatoes, corn, wheat	Admire, Agri Star Impulse, Agri Star Macho, Advise, Nitro, Alenza, Alias, Areca, Attendant, Aura, Brigadier, Concur, Couraze, Dyna-Shield, Gaucho, Hawk-I N/O 2L, Imida E AG, Imidamax 4F, Imigold, Lada, Mana Alias, Marathon, Midash, Montana, Nitro Shield, Nuprid, Pasada, Prey, Provado, Quali-Pro Imidacloprid, Raxil, Senator, Sherpa, Torrent, Widow
Iprodione	beans, potatoes, onions	Iprodione 4L AG, Nevado, Rovral
Oryzalin	grapes, berries, orchards	Surflan
Propiconazole	corn, wheat, barley, onions	Bumper, Concert, Propiconazole E AG, Propimax EC, Quilt, Stratego, Tilt
Trifluralin	wheat, alfalfa, barley, dry beans, onions	Agri Star Trifluralin, Agrisolutions Trust, American Brand Herbicide Granules Containing Treflan, Buckle, Treflan, Triap, Triflurex, Trust

portions of the western and eastern portion of the Snake River Plain.

This is a statewide monitoring project with different geology and hydrogeology across the state. In general, there are two general types of aquifers that will be sampled in this project: alluvial and basalt aquifers.

The first group of projects described are in Southwest Idaho were the geology is dominated by the blue clay layer deposited by Lake Idaho that separates the shallow unconfined systems from deeper confined systems.

Washington and Payette Counties Regional Project Area

The project area lies within the western Snake River Plain, a basin filled with sedimentary and volcanic rocks. The sedimentary rocks make up the major portion of the shallow aquifer in the project area. The shallow aquifer is composed of unconsolidated to poorly consolidated clay, silt, sand, volcanic ash, diatomite, freshwater limestone and conglomerates mostly deposited in a fluvial environment (Newton, 1991). A thick layer of blue clay underlies the shallow aquifer in the project area, which separates the shallow alluvial aquifer from the deeper sedimentary aquifer (Newton, 1991).

Payette and Gem Counties Regional Project Area

The project area overlies an aquifer system limited to the Payette River Valley composed of unconsolidated sands and gravels. There are two sources of ground water in the project area, a shallow water table aquifer and a deeper Payette Valley blue clay aquifer. Wells chosen for this project are completed in the shallow water table aquifer. Well yields in the valley range from 1 to 3,300 gallons per minute (Whitehead, 1994). Ground water depths range from 14 to 314 feet below land surface in wells tested as part of the project. Typical depth to ground water is less than 64 feet below land surface. All project wells are completed in unconsolidated sands and gravels. Locally, shallow ground water flow is likely towards the Payette and Snake Rivers. Overall, regional flow is to the south and west towards the Snake River.

Northern Owyhee County Regional Project Area

The sediments in the project area are classified as the Idaho Group geologic formation (U.S. Geological Society, 2000). The sediments are believed to be deposited by prehistoric Lake Idaho and recent deposition from the Snake River. A “blue clay” layer is found on well drillers’ reports on file at IDWR for many of the project wells. The blue clay layer is part of the Glenns Ferry Formation and the low permeability of the clay produces a confined aquifer under the layer (Othberg, 1994). Ground water used for domestic purposes in the project area appears to come from two sources: (1) a shallow system of coarse grained sands and gravels, and (2) a deeper confined system of black sand under the blue clay layer (Carlson et al., 2001). Well drillers’ reports indicate the shallow aquifer to be approximately 50 feet below the ground surface and the deeper aquifer to be located at varying depths, generally less than 300 feet. Based on well driller’s reports from domestic wells, typical depth to ground water is less than 40 feet. The shallow aquifer is composed of alluvial deposits, mainly sand and gravel, with a few thin interbedded clay layers. The general ground water movement appears to be toward the Snake River, which is an area of probable ground water discharge (Carlson et al., 2001).

Lower Boise Basin Regional Project Area

The hydrogeology throughout much of the project area can be characterized by two aquifers: a deep and shallow ground water zone that are separated by a blue clay layer. The shallow aquifer occurs in older terrace gravels, basalts of the Snake River Group, younger terrace gravels, and Quaternary alluvium. Recharge to the shallow aquifer is mainly from leakage of irrigation canals and laterals, downward percolation of applied irrigation water and precipitation, and downward percolation of domestic wastewater from septic tanks (Thomas and Dion, 1974). Most of the recharge occurs during April through October, which corresponds with the irrigation season (Dion, 1972). The deep aquifer is found in the blue or gray sand directly beneath the blue clay layer (Wood and Anderson, 1981). The blue clay is believed to be found throughout the project area between the depths of 300 to 700 feet below the ground surface and varies from a thickness of a few feet to a few hundred feet (Petrich et al., 1999). The direction of ground water movement is controlled largely by topography and surface drainage. Overall, regional ground water flow is towards the Boise River.

Grandview Regional Project Area

Water level data from the Idaho Department of Water Resources indicate the regional ground water flow direction in the area is to the north-northwest (Hagan, 2000). The predominate hydrogeologic environment in the Grandview area is Quaternary alluvium (Hagan, 2000). Most domestic wells in the Grandview area draw water from sand and gravel zones within the unconfined alluvial aquifer. A thick sequence of blue clay and shale of the Idaho Formation underlies the alluvium and acts as a base for the alluvial aquifer (Hagan, 2000).

The following projects are located in south central Idaho and are characterized predominately by basalt aquifers, except the alluvial perched aquifer in Minidoka County and the upper alluvial aquifer of Cassia County.

Twin Falls County Regional Project Area

The Twin Falls County project area is composed of surface or near surface fractured basalt flows. Based on well drillers' reports from wells sampled as part of the project, depth to first encountered ground water is variable ranging from about 10 feet to 300 feet below land surface. Drillers' reports indicate that the ground water aquifer is situated in fractured basaltic rocks with intercalated sands and gravels.

Cassia County Regional Project Area

The hydrogeology of Cassia County consists of an upper aquifer within sedimentary alluvial deposits overlying a lower aquifer of fractured basalt. The majority of wells evaluated within the study area draw ground water from the upper sedimentary alluvial aquifer. Based on well drillers' reports from domestic wells in the project area, typical depth to ground water is less than 50 feet below ground level in the upper aquifer and over 150 feet below ground level in the lower aquifer. The shallow aquifer is composed of alluvial deposits, mainly sand and gravel, with interbedded clay layers. Major sources of recharge to the underlying ground water system include applied irrigation water, canal leakage, surface water leakage, and precipitation. Ground water flow direction in the study area is variable (Tesch, et. al., 2003).

Minidoka County Shallow Aquifer Regional Project Area

The geologic cross section from Carlson (1999) suggests the alluvial aquifer, in part, may be perched on top of clay layers that separate the shallow alluvial aquifer from the deeper regional basalt aquifer. Water elevation contouring of the deep system suggests an area of mixing at the northern most extent of the shallow system. The majority of the alluvial aquifer is composed of sands and gravels deposited by streams and the Snake River (Rupert, 1997).

The aquifer is recharged mainly from infiltration of irrigation water, with some shallow wells going dry after the end of the irrigation season (Rupert, 1997). Based on well driller's reports from domestic wells in the project area, typical depth to ground water is less than 100 feet and is as little as four feet below land surface in some areas. Well logs indicate that unconsolidated deposits of sand and gravel extend to a depth of 200 to 250 feet below land surface and are underlain by basalt. In addition, analysis of well logs suggests that the unconsolidated deposits and basalt are fairly continuous laterally with a very slight dip to the west (Atlakson and Carlson, 2008). Data collected from the area suggests a relatively low gradient for the shallow system with direction of ground water flow to the north (Carlson, 1999). However, in a study done by the USGS, water flow direction of the shallow system was determined to be south towards the Snake River (Mitchell, 1998).

Methods

Well sites for ground water pesticide testing were selected based on a geographic review of existing pesticide data in ISDA databases. Existing ground water quality data were overlain on landuse data using GIS software and visually evaluated for agricultural areas and previous pesticide detections.

In addition to land use, well depth was used as a criteria. All wells chosen were located in vulnerable aquifer areas and were considered shallow in nature. Wells with a depth of less than 100 feet and with previous pesticide detections were given preference.

All sample collections followed established ISDA ground water monitoring standard operating procedures for sampling, handling, storage, and shipping. Samples were sent to the UIASL in Moscow, Idaho for analysis. UIASL used liquid chromatography/mass spectrometry analysis for pesticides utilizing modified EPA Methods. Duplicates, blanks, and matrix spikes/matrix spike duplicates were collected and submitted as a part of the quality assurance project plan.

Results

ISDA sampled a total of 16 wells with previous pesticide detections for 13 new pesticides (Table 1) throughout southern Idaho (Figure 1) in the fall of 2008 and spring of 2009. New methodologies for these 13 pesticides were established through the 2007/2008 Boise Urban Discretionary Project, making it possible to test for these compounds in wells with previous pesticide detections. None of the 13 new pesticides were detected. All detections were for pesticides previously tested for and commonly detected in Idaho's ground water.

Sampling results indicate some pesticide impacts have occurred to the shallow aquifers within each area sampled. Results are summarized and presented in the following sections.

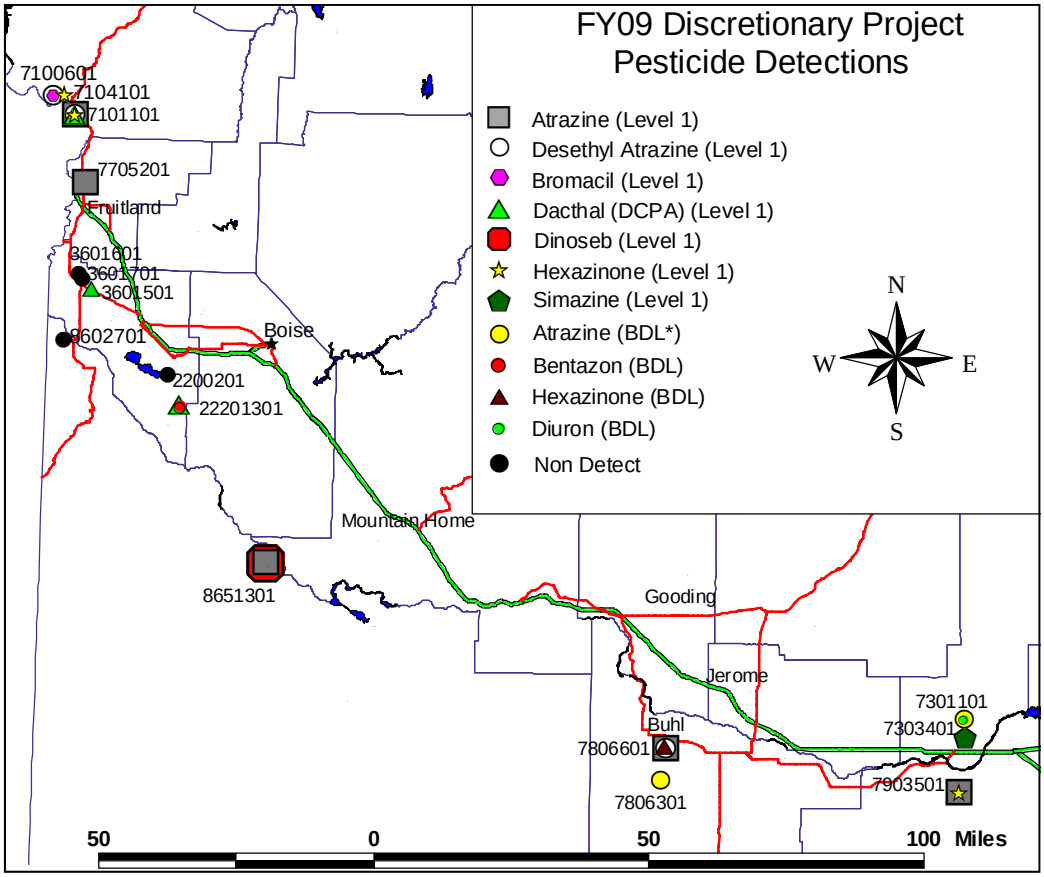

Figure 2. Pesticide results from ISDA 2008/2009 sampling of the Statewide Ground Water Monitoring. *BDL - Below Detection Limit.

Table 2. Pesticide Results from the Statewide Ground Water Monitoring for 13 New Pesticides Discretionary Project.

Pesticide	No. of Detections	Range (µg/L)	Reference Point (µg/L)
Atrazine	5	0.04 – 0.09	3 (MCL)[1]
Bromacil	1	0.32	90 (HAL)[2]
Dacthal	3	0.2 – 1.3	70 (HAL)[2]
Desethyl Atrazine	4	0.04 – 0.07	….[3]
Dinoseb	1	1.3	7 (MCL)[1]
Hexazinone	3	0.05 – 0.15	400 (HAL)[2]
Simazine	1	0.16	4 (MCL)[1]

[1]MCL – EPA Maximum Contaminant Level
[2]HAL – EPA Lifetime Health Advisory Level
[3]Breakdown product of Atrazine, MCL of 3 mg/L for atrazine is used.

Pesticides

Ten wells, or 62.5% of the wells sampled, had one or more pesticide detected above the laboratory detection limit. All detections were Level 1 category established by the Idaho PMP Rule and below any Idaho or EPA health standards (Figure 2 and Table 2). Four wells had detections below the laboratory detection limit in the ground water (Figure 2).

Pesticides positively detected above the laboratory detection limit (in order of number of detections) were atrazine (5), desethyl atrazine (DEA) (4), Dacthal (DCPA) (3), hexazinone (3), bromacil (1), dinoseb (1), and simazine (1) (Table 2).

Pesticide Descriptions

The following information summarizes the chemical characteristics and the labeled use of each pesticide that was detected in this project.

Atrazine is a systemic triazine herbicide used to control broadleaf weeds and some grassy weeds (EPA, 2003a). Laboratory studies have shown that atrazine is mobile and persistent and has had widespread detections in ground water and surface water (EPA, 2003a). There are numerous products that contain atrazine as an active ingredient and are labeled for agricultural uses in Idaho.

Desethyl atrazine, or DEA, is a breakdown product of atrazine.

DCPA, or dimethyl tetrachloroterephthalate, is a pre-emergent herbicide used to control annual grasses and broadleaf weeds. DCPA is commonly known by the trade name "Dacthal." DCPA is a general use product

used on turf, ornamentals, strawberries, certain vegetables, onions, beans, and cotton. Two products are currently registered in Idaho that have DCPA as an active ingredient. They include Dacthal® Flowable Herbicide and Dacthal® W-75 Herbicide.

Hexazinone is a triazine herbicide used against many annual, biennial, and perennial weeds, as well as some woody plants. It is mostly used on non-crop areas. Hexazinone is a systemic herbicide that works by inhibiting photosynthesis in the target plants. Rainfall or irrigation water is needed before it becomes activated. It is available in soluble concentrate, water-soluble powder, or granular formulations (EXTOXNET, 2009). Hexazinone is a general use product. There are currently eight products registered in Idaho with hexazinone as an active ingredient.

Bromacil is a herbicide used for control of annual and perennial weeds (broadleaf and grasses), brush, and woody plants and vines (EPA, 1996). Lab studies have shown that bromacil is very mobile in sand, sandy loam, clay loam, and silt loam soils (EPA, 1996). There is extensive data that shows that bromacil leaches to the ground water as a result of normal agricultural use.

Dinoseb is a phenolic herbicide used in soybeans, vegetables, fruits and nuts, citrus, and other field crops for the selective control of grass and broadleaf weeds (e.g., in corn). It is also used as an insecticide in grapes, and as a seed crop drying agent. It is produced in emulsifiable concentrates or as water soluble ammonium or amine salts. The use of dinoseb was cancelled in the U.S. in 1986. This action was based on the potential risk of birth defects and other adverse health effects for applicators and other persons with substantial dinoseb exposure (EXTOXNET, 2009).

Bentazon is a post-emergence herbicide used for selective control of broadleaf weeds and sedges (a weed) in beans, rice, corn, peanuts, mint, and others. Bentazon is a contact herbicide, which means that it causes injury only to the parts of the plant to which it is applied. It interferes with the ability of susceptible plants to use sunlight for photosynthesis (EXTOXNET, 2009). Bentazon is a general use product. There are currently four products registered in Idaho with bentazon as an active ingredient .

Diuron is a pre- and post-emergent herbicide used to control a wide variety of annual and perennial broadleaf and grassy weeds (EPA, 2003b). Diuron is mobile and has the potential to leach to the ground water (EPA, 2003b). There are numerous products currently registered in Idaho with diuron as an active ingredient.

Simazine is a chlorinated triazine selective herbicide used to control most annual grasses and broadleaf weeds (EPA, 2006). Laboratory studies have shown that simazine is persistant and highly mobile, and has a strong potential to leach into the ground water, especially in low organic matter soils such as sandy soils (EPA, 2006).

Conclusions

Results of testing indicate that pesticides have been found in the various aquifers tested as part of this project. Ten wells, or 62.5% of wells sampled, had one or more pesticide detected in the ground water above the laboratory detection limit.

The pesticides detected above the minimum LDL in this project were: atrazine, dacthal, hexazinone, desethyl atrazine, bromacil, dinoseb, and simazine. The pesticides were all at concentrations less than 20% of a reference point. None of the 13 new pesticides were detected in any of the wells tested. This project proved useful in providing ground water data on the 13 new pesticides that had not previously been tested in Idaho.

Overall, the ground water quality in the areas tested is good. There are minor impacts to the ground water quality from low level pesticide detections.

Recommendations

ISDA will respond to the pesticide detections from this project in accordance with the response section of IDAPA 02.03.01 Rules Governing Pesticide Management Plans For Ground Water Protection.

ISDA personnel will continue to educate the pesticide applicators on the importance of adhering to label requirements and to apply all pesticides according to federal and state laws.

ISDA Water Program staff recommend similar projects in the future to help identify areas of concern with respect to pesticides in ground water, including these 13 new pesticides.

Pesticide Management

ISDA recommends that measures to reduce pesticide and impacts on ground water be addressed and implemented. ISDA recommends that:

- Pesticide users and sellers evaluate pesticide storage, containment, mixing, loading, rinsing, disposal, and application practices in the project area.
- Pesticide users utilize the ISDA Pesticide Disposal

Program (PDP). The PDP is a free program in which ISDA will dispose of any unused pesticides that are no longer needed in an environmentally safe manner. Information regarding this program can be found on the ISDA's website: http://www.agri.idaho.gov/Categories/Pesticides/pdp/indexdisposalmain.php.

- Pesticide products that are least likely to leach be chosen for the soil type in the project areas. For a list of pesticide leachability rating, please refer to ISDA's website: http://www.agri.idaho.gov/Categories/Environment/water/waterPDF/factSheets/pesticides/Leachable_brochure.pdf. For assistance in determining your soil type, please contact your local County Extension Office or USDA NRCS Office.
- Pesticide applicators consider utilizing IPM techniques in this area.
- Pesticide applicators and homeowners assess lawn and garden practices, especially near wellheads.
- Home and garden retail stores establish outreach programs to illustrate proper application and management of pesticides.

Well Testing, Construction, and Management

Domestic wells within the project area should be protected to prevent contamination of the shallow aquifer. The ISDA suggests the following options:

- Activities near wellheads be done in a manner that does not impact well water quality.
- Homeowners consider using the Idaho Home*A*Syst program to conduct self assessments related to wellhead protection. The program is found at http://homeasyst.idahoag.us.
- Construction of new wells or deepening of existing wells in the area be completed with the appropriate planning and design considerations following Idaho's laws and rules.

Acknowledgments

ISDA Water Program staff thank EPA Region 10 for providing funding for this special sampling project. The authors would also like to thank the homeowners in the study area who allowed us to access and sample their wells. Without their participation and cooperation, this study would not be possible.

A very special thanks to Steven McGeehan, Ph.D, Brian Hart, Ph.D, Janet Snow, and all of the staff at the University of Idaho Analytical Sciences Laboratory (UIASL). Due to their technical advice and efforts, we were able to sample for pesticide compounds that ISDA had not previously analyzed. The success of this project is due, in large part, to the expertise of the employees of the UIASL.

ISDA staff would like to thank former ISDA employees Rick Carlson and Jessica Atlakson for their expertise and contributions to this project. In addition, the authors would like to thank Paula Chase, ISDA, for editorial review of this document.

References

Atlakson, J., and R. Carlson, 2008. Ground water quality of Minidoka County alluvial aquifer, 1997 – 2007. Idaho State Department of Agricultural Technical Summary #38.

Dion, N.P., 1972. Some effects of land-use changes on the shallow ground-water system in the Boise-Nampa area, Idaho. Water Information Bulletin No. 26, June 1972.

Carlson, Rick A., 1999. Geostatistical assessment and hydrogeologic implications of agricultural best management practices to reduce nonpoint source nitrate pollution southern Minidoka County, Idaho. Masters Thesis, Boise State University, Boise, Idaho 83725, 177 pp.

Carlson, R., G. Bahr, and L. Boyle, 2001. Ground Water Quality Monitoring Results for Northwest Owyhee County, Idaho. Idaho State Department of Agricultural Technical Summary #6.

EPA, 1996. Reregistration eligibility decision—bromacil. EPA Office of Prevention, Pesticides, and Toxic Substances, EPA 738-R96-013, August 1996.

EPA, 2003a. Interim reregistration eligibility decision—atrazine. EPA Office of Prevention, Pesticides, and Toxic Substances, January 2003.

EPA, 2003b. Reregistration eligibility decision—diuron. EPA Office of Prevention, Pesticides, and Toxic Substances, September 30, 2003.

EPA, 2006. Reregistration eligibility decision for simazine. EPA Office of Prevention, Pesticides, and Toxic Substances, EPA 738-R-06-008, April 6, 2006.

EXTOXNET, accessed 2009. http://extoxnet.orst.edu/pips/bentazon.htm

EXTOXNET, accessed 2009. http://ace.orst.edu/info//extoxnet/pips/dinoseb.htm

EXTOXNET, accessed 2009. http://extoxnet.orst.edu/pips/hexazin.htm

Gilliom, Robert J., Jack E. Barbash, Charles G. Crawford, Pixie A. Hamilton, Jeffrey D. Martin, Naomi Nakagaki, Lisa H. Nowell, Jonathan C. Scott, Paul E. Stackelberg, Gail P. Thelin, and David M. Wolock, 2006. The quality of our nation's waters—pesticides in the nation's streams and ground water, 1992–2001: U.S. Geological Survey Circular 1291,172 p.

Hagan, E., 2000. Ground water quality investigation and wellhead protection study Grand View, Idaho. Idaho Department of Environmental Quality Ground Water Quality Technical Report No. 16.

Mitchell, John C., 1998. Waste disposal wells as a factor in nitrate levels in ground water, A&B Irrigation District, Minidoka County, Idaho. Idaho Department of Water Resources, 2 p.

Neely, Kenneth W., and Janet K. Crockett, 1998. Ground water quality characterization and initial trend analysis for the Treasure Valley shallow and deep hydrogeologic subareas, Idaho Department of Water Resources Water Information Bulletin No. 50, Part 3.

Newton, G. D., 1991. Geohydrology of the regional aquifer system, western Snake River Plain, southwestern Idaho: U.S. Geological Survey Professional Paper 1408-G, 52 p.

Othberg, K.L., 1994. Geology and geomorphology of the Boise valley and adjoining areas, western Snake River plain, Idaho: U. S. Geological Survey, Idaho Geological Survey Bulletin 29.

Petrich, C. R., J. H. Hutchings, S. M. Urban, and R. A. Carlson, 1999. Progress report on the characterization of treasure valley ground water resources: Idaho Department of Water Resources and Idaho Water Resources Research Institute University of Idaho, Idaho Department of Water Resources Open File Report. Pp. 13 – 20.

Rupert, M.G., 1997. Nitrate (NO2+NO3-N) in ground water of the upper Snake River Basin, Idaho and Western Wyoming, 1991-95. U.S. Geological Survey, pp. 3-42.

Tesch, C. A., R.A. Carlson, and J. Fox, 2003. Ground water nitrate monitoring in Cassia County, Idaho. Idaho State Department of Agriculture Technical Results Summary #13, 7p.

Thomas, C. A., and N.P. Dion, 1974. Characteristics of Streamflow and Groundwater Conditions in the Boise River Valley, Idaho: U.S. Geological Survey Water Resources Investigation No. Pp. 38-78, 56.

U.S. Geological Survey, 2000, Owyhee County Observation Wells. http://www.idaho.usgs.gov/public/grwater/SWIDAHO/Owyhee.html, referenced May 2000.

Whitehead, R. L., 1994. Ground water atlas of the United States, Idaho, Oregon, and Washington. United States Geologic Survey Pub. HA 730-H.

Wood, S. H., and J. E. Anderson, 1981. Geology, Chapter 2. Idaho Department of Water Resources, Water Information Bulletin No. 30, Geothermal Investigations in Idaho Part II, ed. John C. Mitchell, pp 9 – 31.