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Early Warning Pesticide Monitoring in Nevada's Surface Waters

Introduction

A pesticide is a substance, or mixture of substances, used to kill or control insects, weeds, plant diseases, and other pest organisms (Nevada Department of Agriculture, 2019). Commercial pesticide applicators, farmers, and homeowners apply about 1.1 billion pounds of pesticides annually to agricultural land, non-crop land, and urban areas throughout the United States (Atwood and Paisley-Jones, 2017). Although intended for beneficial uses, there are also risks associated with pesticide applications, including contamination of groundwater and surface-water resources, which can adversely affect aquatic life and water supplies. Pesticides can contaminate groundwater and surface water directly through point sources (spills, disposal sites, or pesticide drift during an application). The main avenue of contamination, however, is indirect by non-point sources, which include agricultural and urban runoff, erosion, leaching from application sites, and precipitation that has become contaminated by upwind applications (fig. 1, Thodal and others, 2009).

Nevada Pesticide Monitoring and Early Warning Program

To reduce exposure to pesticide compounds, the U.S. Environmental Protection Agency (EPA), through the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), requires that all states establish a pesticide management program. The Nevada Department of Agriculture (NDA), with assistance from the EPA, has developed a program of education (Hefner and Donaldson, 2006), regulation (http://agri.nv.gov/Resources/Regulations/Pest/), and monitoring (Thodal and others, 2009) in the State of Nevada. In a cooperative effort, the NDA and the U.S. Geological Survey (USGS) began drilling boreholes and sampling water from a network of shallow wells in 1997 to characterize pesticide concentrations in groundwater (Thodal and others, 2009). In 2007, the NDA and USGS began collecting samples from a surface-water network. This fact sheet describes the pesticide monitoring of Nevada's surface waters.

There are several pesticides of particular concern to the NDA. This is based on widespread use and chemical characteristics that make these pesticides, or their degradation products, vulnerable to leaching into groundwater and surface-water resources. Once transported into water, there is significant potential for pesticide concentrations to approach or exceed human health or environmental reference levels. The NDA monitors pesticides of concern in coordination with the EPA to further understand annual pesticide usage, pesticide incidents, and potential contamination of water resources. A pesticide is added to NDA's list of pesticides of concern according to the following criteria: (1) frequency of detection, (2) upward trend in the frequency of detection, (3) widespread detections (across multiple counties), and (4) if the highest concentration is above 10 percent of its health and environmental threshold levels (U.S. Environmental Protection Agency, 2018). Pesticides on the list are reevaluated every 5 years and can be removed from the list with continued decreases in the number and severity of detections.

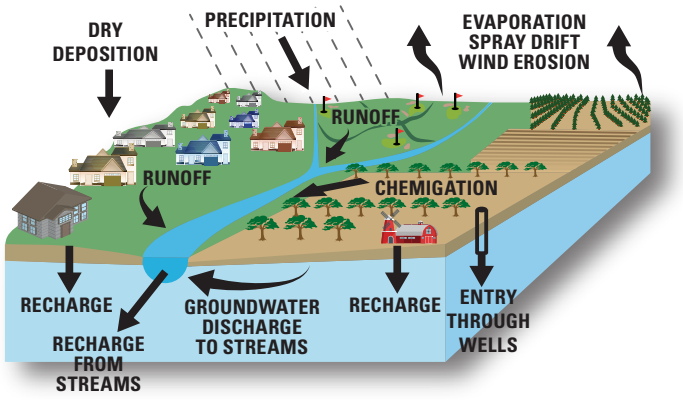

Figure 1. Routes pesticides can travel from the land surface to surface water and groundwater. Chemigation is a process by which pesticides are applied to the land through irrigation systems.

The NDA has developed a pesticide early warning system and best management practices (BMP) tool. The low-level pesticide concentrations collected from surface waters during this study are characterized and synthesized with associated information regarding crop types and land use. Using this as a tool, the NDA educates pesticide applicators, farmers, and the public about how to prevent or reduce pesticide loading early, when the concentrations are low, thereby protecting groundwater and surface-water resources.

Passive Monitoring of Pesticides in Nevada Surface Waters

Passive methodologies are used to detect low level organic compound concentrations by accumulating and integrating them over time. Passive sampling devices, such as the polar organic chemical integrative sampler (POCIS), trap polar-organic compounds, including some pesticides and their degradates, from the water. As water flows through the POCIS, compounds are trapped and accumulate through time until concentrations are high enough to be detected using standard laboratory analyses (fig. 2; https://www.est-lab.com/pocis.php). The POCIS provides a measure of the absence, presence, or relative abundance of pesticides in the vicinity of the deployed passive sampler (Alvarez, 2010).

From 2012 to 2019, the NDA and USGS monitored pesticides in Nevada surface waters using POCIS at 26 sites, in 5 hydrographic basins, (table 1; fig. 3). Each sampling event typically consisted of up to six sites in the same watershed. Sites were chosen to be downgradient from agricultural and urban areas and adjacent to existing USGS streamflow gages, which were used to determine streamflow changes during the time POCIS were deployed. POCIS were deployed and retrieved after about 30 days according to the field methods described by Alvarez (2010). With multiple sampling sites on the same river, relative concentration is used to document pesticide presence. It is assumed that pesticide detections are from possible sources in the upstream vicinity of deployed passive samplers. Pesticide concentrations are compared to available drinking-water criteria and human-health advisories (U.S. Environmental Protection Agency, 2018).

Figure 2. Deployment canister containing three polar organic integrative samplers mounted on a center bracket.

Discrete Monitoring of Pesticides in Nevada Streams

Discrete samples (collected at a single point in time) of surface waters do not adequately reflect presence or absence of pesticides because pesticide concentrations are typically below analytical reporting levels because of the temporal and spatial variability in pesticide use, runoff, and streamflow (Keith, 1991; Alvarez, 2010). The discrete data provide pesticide concentrations for a "snapshot in time" as opposed to an accumulation of pesticides through a longer period. Although not the preferred collection method for monitoring low level pesticides in this project, discrete samples were collected from the Virgin and Muddy Rivers and the Las Vegas Wash in 2017 because the NDA laboratory was unable to analyze POCIS samples because of mechanical issues with analytical equipment. The discrete samples were analyzed at the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado for 225 pesticide compounds (table 1).

Table 1. Areas of pesticide monitoring in Nevada.

Surface-water feature	Hydrographic basin	Principal land use	Year sampled	Number of sites sampled
Walker River	Walker	Agriculture, range	2012, 2019	[2]4,6
Truckee River	Truckee	Urban	2012	2
Stillwater agricultural ditches and drains	Carson	12	2014	6
Humboldt River	Humboldt	9	2015	6
Virgin River[1]	Lower Colorado-Lake Mead	70	2017	2
Muddy River[1]	Lower Colorado-Lake Mead	235	2017	1
Las Vegas Wash[1]	Lower Colorado-Lake Mead	24	2017	1
Carson River	Carson	25	2018	4

[1]Pesticide sample collected discretely.

[2]Two sites sampled in 2012 were resampled in 2019.

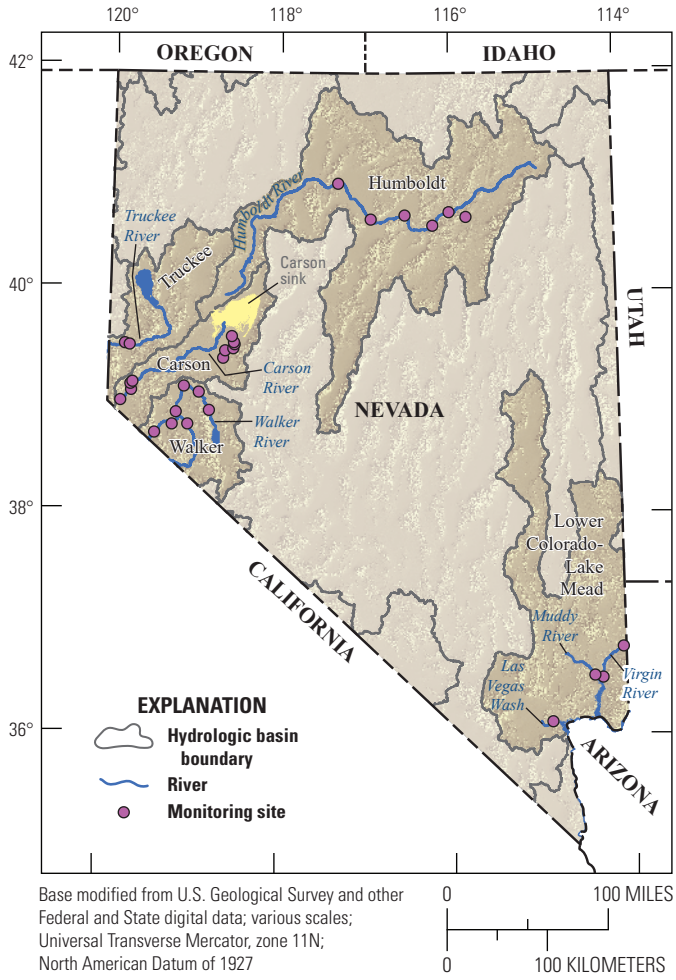

Figure 3. Pesticide monitoring areas in Nevada. Access site information and available data here. https://maps.waterdata.usgs.gov/mapper/nwisquery.html?URL=https://waterdata.usgs.

Glyphosate is a common and widely used herbicide for weed control both in residential areas and croplands. (U.S. Environmental Protection Agency, 2019). The EPA has set a maximum contamination level (MCL) of 700 micrograms per liter (µg/L) of glyphosate in drinking water. Kidney and reproductive damage have been documented as a couple of the possible health effects that could result from long-term exposure to drinking water with concentrations above the MCL (U.S. Environmental Protection Agency, 1995). In 2018, glyphosate was added to the monitoring effort to help the NDA understand glyphosate application practices by homeowners and farmers. Because POCIS samples can not be analyzed for glyphosate, discrete samples were collected from the Carson (2018) and Walker Rivers (2019) and analyzed for glyphosate at the USGS Pesticide Laboratory in Kansas.

Results and Discussion

Pesticide Results from Passive Monitoring

Each POCIS was analyzed for nearly 80 pesticides by the NDA chemistry laboratory in Sparks, Nevada. Results of selected passively collected pesticides are summarized in table 2. Analytical results received from the NDA laboratory were reported in nanograms/POCIS (ng/POCIS), however a conversion calculation (Alvarez, 2010) was performed to

Table 2. Summary of Nevada Department of Agriculture's pesticide monitoring program analytical results from POCIS samples. All pesticides listed are on NDA's pesticides of concern list.

[herb, herbicide; insect, insecticide; µg/L, micrograms per liter; U, analyzed for but not detected; NA, not available]

USGS station identification number	Station name	2,4-D (herb)	Atrazine (herb)	Bromacil (herb)	Diuron (herb)	Hexazinone (herb)	Imidacloprid (insect)	Oxamyl (insect)
				µg/L				
EPA Maximum contaminant level[1]		70	3	NA[2]	NA[2]	NA[2]	NA[2]	200
EPA Health advisory level[1]		200	700	3,500	100	2,000	NA[2]	35
USGS Noncancer Health-based screening level[3]		NA	NA	100	20	300	NA	NA
				Walker and Truckee River (2012)				
10297500	W Walker Rv blw Smith Vly Div nr Wellington, NV	0.0011	0.0003	U	0.0017	U	U	U
10300000	W Walker Rv nr Hudson, NV	0.0033	0.0004	U	0.0019	0.0137	U	U
10300600	Walker Rv at Snyder Ln nr Mason, NV	0.0035	0.0006	U	0.0122	0.0122	U	U
10301500	Walker Rv nr Wabuska, NV	0.0030	0.0061	U	0.0068	0.0068	0.0052	U
10348000	Truckee Rv at Reno, NV	U	0.0002	0.0034	U	U	U	U
10348200	Truckee Rv nr Sparks, NV	U	U	U	U	U	U	U
				Stillwater agricultural ditches and drains (2014)				
10312190	Lower Diagonal Drain at HWY 50 nr Fallon, NV	0.0121	U	0.0627	0.0108	U	U	U
1031220130	Harmon Reservoir Outflow nr Fallon, NV	0.0143	U	0.0107	0.0083	0.0005	U	U
103122155	Stillwater Pt Res Bypass Canal nr Stillwater, NV	0.0143	U	0.0352	0.0118	0.0006	U	U
1031221902	S-Line Diversion Canal near Stillwater, NV	0.0187	U	0.0122	0.0069	0.0007	U	U
10312220	Stillwater Slough Cutoff Drain nr Stillwater, NV	0.0231	U	U	0.0020	0.0008	U	U
10312270	Paiute Drain at Wildlife Ent nr Stillwater, NV	0.0593	U	U	0.0024	U	U	U
				Humboldt River (2015)				
10320000	S Fk Humboldt Rv abv Dixie Ck nr Elko, NV	U	U	U	U	U	U	U
10321000	Humboldt Rv nr Carlin, NV	0.0242	U	U	0.0007	U	U	U
10322500	Humboldt Rv at Palisade, NV	0.0113	U	U	0.0113	U	U	U
10323425	Humboldt Rv at Old US 40 Brg at Dunphy, NV	0.0344	U	U	0.0008	U	U	U
10325000	Humboldt Rv at Battle Mountain, NV	0.0265	U	U	0.0006	U	U	U
10327500	Humboldt Rv at Comus, NV	0.0053	U	U	0.0005	U	U	U
				Carson River (2018)				
10310407	Carson Rv nr Genoa, NV	0.0151	U	U	U	U	U	U
10311000	Carson Rv nr Carson City, NV	0.0056	U	U	0.0001	0.0003	U	U
10311300	Eagle Valley Ck at Carson City, NV	0.0047	0.00005	0.0058	0.0139	0.0007	0.0001	U
10311400	Carson Rv at Deer Run Rd nr Carson City, NV	0.0081	U	U	0.0004	0.0003	0.0006	U

Table 2. Summary of Nevada Department of Agriculture's pesticide monitoring program analytical results from POCIS samples. All pesticides listed are on NDA's pesticides of concern list.—Continued

[herb, herbicide; insect, insecticide; µg/L, micrograms per liter; NV, Nevada; U, analyzed for but not detected; NA, not available]

USGS station identification number	Station name	2,4-D (herb)	Atrazine (herb)	Bromacil (herb)	Diuron (herb)	Hexazinone (herb)	Imidacloprid (insect)	Oxamyl (insect)
				Walker River (2019)				
10293500	E Walker Rv abv Strosnider Ditch nr Mason, NV	0.0036	U	U	U	U	U	U
10297500	W Walker Rv at Hoye Brg nr Wellington, NV	0.0003	U	U	U	U	U	U
10300600	Walker Rv at Snyder Ln nr Mason, NV[4]	0.0021	0.0041	U	U	0.0001	0.0001	0.0001
10301500	Walker Rv nr Wabuska, NV[4]	0.0273	0.0052	U	U	0.0001	0.0106	0.0050
10302002	Walker Rv at Lateral 2-A Siphon nr Schurz, NV	0.0044	0.0046	U	U	0.00005	0.0044	0.0001
10301600	Walker Rv abv Weber Res nr Schurz, NV	0.0107	0.0038	U	U	0.0001	0.0064	0.0009
	Number of detections[5]:	23	10	6	18	12	6	4
	Minimum concentration:	0.0003	0.00005	0.0011	0.0001	0.00005	0.0001	0.0001
	Maximum concentration:	0.0593	0.0052	0.0627	0.0139	0.0068	0.0106	0.0050

[1]U.S. Environmental Protection Agency, 2018.

[2]Maximum contaminant level not yet developed by EPA.

[3]Norman and others, 2018.

[4]Sampled in 2012 and 2019.

[5]Out of 26 sites.

convert the pesticide results to concentrations for comparison to EPA maximum contaminant and health advisory levels (table 2). The USGS noncancer health-based screening levels are also provided for comparison (Norman and others, 2018).

Herbicides, used to control weeds, were the most detected form of pesticide in Nevada's surface waters. The three herbicides detected most often were the general use (can be applied without a license) herbicides 2,4-D (88 percent of the sites sampled), diuron (69 percent of the sites sampled), and hexazinone (46 percent of the sites sampled), which are applied by farmers, commercial pest control operators, and homeowners to kill unwanted weeds (table 2). 2,4-D is a widely used selective herbicide, meaning it only kills unwanted broadleaf plants while most grasses and crops remain unharmed (U.S. Environmental Protection Agency, 2005). Although 2,4-D was detected in every watershed sampled except the Truckee River, the concentrations were at least three orders of magnitude less than the EPA's MCL for the herbicide. Similar to 2,4-D, diuron was present in every watershed except the Truckee River; however, diuron was typically found in main-stem river channels downstream from agricultural areas (75 percent of the river sites sampled (9 of 12), excluding the six Stillwater agricultural ditches and drains). Diuron was detected in each of the four Walker River sites sampled in 2012 (range of 0.0017–0.0122 µg/L); however, diuron was not present in the Walker River when resampled in 2019. All measured concentrations of diuron were at least four orders of magnitude below the EPA's health advisory level (table 2). The third most detected pesticide, hexazinone, was detected in all rivers sampled, except for the Truckee and Humboldt Rivers, at concentrations far below the EPA's health advisory level of 2,000 µg/L (table 2). The remaining two herbicides, atrazine and bromacil, were detected less frequently than 2,4-D, diuron, and hexazinone. Atrazine, a restricted-use (requires an applicators license) herbicide, was detected in most Walker River sites; concentrations were at least two orders of magnitude below the established 3 µg/L MCL (table 2). Bromacil, another general use herbicide, was detected in four of the six agricultural canals and drainage ditches near Fallon, Nevada, which included the highest pesticide concentration (0.0627 µg/L) obtained from POCIS samplers. The only pesticides detected in the Truckee River were atrazine and bromacil at concentrations at least four orders of magnitude less than EPA's health advisory levels.

Imidacloprid and oxamyl, two insecticides on NDA's pesticides of concern list, had comparatively fewer detections than herbicides during this study. Imidacloprid is a general use insecticide that was found in the main channels of the Walker and Carson Rivers, downstream from urban areas, at concentrations from 0.0001 to 0.0106 µg/L (table 2). In 2019, oxamyl (a restricted-use insecticide) was only detected in the four main-stem Walker River samples downstream from Mason, Nevada. Measured oxamyl concentrations were low, with the highest concentration four orders of magnitude less than the EPA's health advisory level of 35 µg/L (table 2).

Table 3. Summary of Nevada Department of Agriculture's pesticide monitoring program from discrete samples analyzed by the USGS National Water Quality Laboratory. Glyphosate samples were collected from the Carson and Walker Rivers only in 2018 and 2019, respectively.

[herb, herbicide; insect, insecticide; <, less than; µg/L, micrograms per liter; —, not sampled for; NV, Nevada; EPA, U.S. Environmental Protection Agency; USGS, U.S. Geological Survey; NA, not available]

USGS station identification number	Station name	Acephate (insect)	Fipronil (insect)	Imidacloprid (insect)	Terbuthylazine (herb)	Glyphosate (herb)
		µg/L				
EPA maximum contaminant level[1]		NA[3]	NA[3]	NA[3]	NA[3]	700
EPA health advisory level[1]		NA[3]	NA[3]	NA[3]	NA[3]	70,000
USGS health-based screening level[2]		—	—	—	2	40
09415090	Virgin Rv at Mesquite, NV	<0.01	<0.004	<0.016	<0.0036	—
09415250	Virgin Rv abv Lake Mead Nr Overton, NV	<0.01	<0.004	<0.016	<0.0036	—
09419507	Muddy Rv at Lewis Avenue at Overton, NV	<0.01	<0.004	<0.016	<0.0036	—
09419800	LV Wash Blw Lake Las Vegas Nr Boulder City, NV	0.0834	0.0045	0.0331	0.0118	—
10310407	Carson Rv nr Genoa, NV	—	—	—	—	<0.02
10311000	Carson Rv nr Carson City, NV	—	—	—	—	0.02
10311300	Eagle Valley Ck at Carson City, NV	—	—	—	—	2.9
10311400	Carson Rv at Deer Run Rd nr Carson City, NV	—	—	—	—	0.03
10293500	E Walker Rv abv Strosnider Ditch nr Mason, NV	—	—	—	—	<0.02
10297500	W Walker Rv at Hoye Brg nr Wellington, NV	—	—	—	—	<0.02
10300600	Walker Rv at Snyder Ln nr Mason, NV	—	—	—	—	<0.02
10301500	Walker Rv nr Wabuska, NV	—	—	—	—	0.1
10302002	Walker Rv at Lateral 2-A Siphon nr Schurz, NV	—	—	—	—	0.02
10301600	Walker Rv abv Weber Res nr Schurz, NV	—	—	—	—	0.05

[1]U.S. Environmental Protection Agency, 2018.

[2]Norman and others, 2018.

[3]Maximum contaminant level not yet developed by the EPA.

The greatest number of pesticide detections in a single POCIS sample were found in Eagle Valley Creek, a tributary to the Carson River in Carson City receiving urban runoff. This site, sampled in 2018, had detections of six of the seven pesticides listed on NDA's pesticides of concern list: five herbicides and one insecticide (table 2). All pesticide concentrations were well below EPA MCLs and health advisories (table 2).

Pesticide Results from Discrete Monitoring

In 2017, discrete samples were collected from the Virgin River, Muddy River, and the Las Vegas Wash, a large urban return-flow channel discharging to Lake Mead. No pesticides were detected above laboratory reporting levels from the Virgin or Muddy Rivers; however, three insecticides and one herbicide were detected from the Las Vegas Wash: acephate, fipronil, imidacloprid, and terbuthylazine (table 3). None of these pesticides have established EPA MCLs or health advisories.

In 2018, discrete glyphosate samples were collected from the Carson River, and in 2019, from the Walker River. Glyphosate was detected at three sites on the Carson River and Walker River, each (ranging from 0.02 to 2.9 µg/L) far below the 700 µg/L MCL (table 3).

Summary

The Nevada Department of Agriculture (NDA), in cooperation with the U.S. Environmental Protection Agency (EPA), has created a pesticide management program for Nevada's groundwater and surface-water resources. During the past 8 years, the USGS has partnered with the NDA to monitor pesticides in groundwater and surface water as part of that program.

From 2012 to 2019, passive samplers have been used to monitor polar pesticides that possess chemical characteristics making them susceptible to partitioning into the State's water resources. To date, four Nevada rivers and various agricultural canals and drainage ditches near Fallon, Nevada, have been evaluated. Herbicides were the most frequently detected form of pesticide in Nevada's surface waters, including 2,4-D (23 of 26 sites), diuron (18 of 26 sites), and hexazinone (12 of 26 sites).The highest pesticide concentration detected using POCIS sampling technique was bromacil (0.0627 µg/L). This sample was collected from an agricultural drain near Fallon, Nevada, in 2014.

Using discrete sampling methods, three insecticides (acephate, fipronil, imidacloprid) and one herbicide (terbuthylazine) were found in Las Vegas Wash surface water. Generally, the concentrations of these pesticides (0.0045 to 0.0834 ug/L) were within the same range as other pesticides (0.00005 to 0.0627 ug/L) found in other Nevada surface waters using passive sampling. As of 2020, no established EPA drinking water criteria or health advisories have been established for these compounds. No pesticides were detected in either of the two tributaries to Lake Mead, the Virgin and Muddy rivers. In 2018 and 2019, samples from the Carson and Walker rivers, respectively, were analyzed for the very popular general-use herbicide glyphosate using discrete methods. Glyphosate was detected at three sites each on the Carson and Walker rivers; all concentrations were several orders of magnitude below the MCL. Pesticide concentrations typically are present at concentrations elusive to discrete sampling methods; therefore, monitoring of pesticides using discrete techniques is often ineffective at conclusively determining the presence or absence of pesticides. Overall, pesticides detected thus far in Nevada rivers have been at very low concentrations, orders of magnitude below established EPA MCLs and health advisories.

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By Jena M. Huntington[1], Derek C. Entz[2], and Carl E. Thodal[3]

[1]U.S. Geological Survey, Nevada Water Science Center

[2]Nevada Department of Agriculture

[3]Retired, U.S. Geological Survey, Nevada Water Science Center

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