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.

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).

**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   | 4,6                     |
| Truckee River         | Truckee            | Urban              | 2012         | 2                       |
| Stillwater agricultural ditches and drains | Carson | 12 | 2014 | 6 |
| Humboldt River        | Humboldt           |                    | 9            | 2015                    | 6 |
| Virgin River¹         | Lower Colorado-Lake Mead | 70 | 2017 | 2 |
| Muddy River¹          | Lower Colorado-Lake Mead | 235 | 2017 | 1 |
| Las Vegas Wash¹       | Lower Colorado-Lake Mead | 24 | 2017 | 1 |
| Carson River          | Carson             |                    | 25           | 2018                    | 4 |

¹Pesticide sample collected discretely.
²Two sites sampled in 2012 were resampled in 2019.

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) |
|-----------------------------------|--------------|--------------|-----------------|-----------------|--------------|-------------------|----------------------|----------------|
| EPA Maximum contaminant level¹ | 70           | 3            | NA²             | NA²             | NA²         | 200               |                      |                |
| EPA Health advisory level¹       | 200          | 700          | 3,500           | 100             | 2,000       | NA²               | 35                   |                |
| USGS Noncancer Health-based screening level¹ | NA | NA | 100 | 20 | 300 | NA | NA | |

Walker and Truckee River (2012)

| USGS station identification number | Station name | 2,4-D (herb) | Atrazine (herb) | Bromacil (herb) | Diuron (herb) | Hexazinone (herb) | Imidacloprid (insect) | Oxamyl (insect) |
|-----------------------------------|--------------|--------------|-----------------|-----------------|--------------|-------------------|----------------------|----------------|
| 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)

| USGS station identification number | Station name | 2,4-D (herb) | Atrazine (herb) | Bromacil (herb) | Diuron (herb) | Hexazinone (herb) | Imidacloprid (insect) | Oxamyl (insect) |
|-----------------------------------|--------------|--------------|-----------------|-----------------|--------------|-------------------|----------------------|----------------|
| 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              |
| 103122220                       | 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)

| USGS station identification number | Station name | 2,4-D (herb) | Atrazine (herb) | Bromacil (herb) | Diuron (herb) | Hexazinone (herb) | Imidacloprid (insect) | Oxamyl (insect) |
|-----------------------------------|--------------|--------------|-----------------|-----------------|--------------|-------------------|----------------------|----------------|
| 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)

| USGS station identification number | Station name | 2,4-D (herb) | Atrazine (herb) | Bromacil (herb) | Diuron (herb) | Hexazinone (herb) | Imidacloprid (insect) | Oxamyl (insect) |
|-----------------------------------|--------------|--------------|-----------------|-----------------|--------------|-------------------|----------------------|----------------|
| 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              |
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 applicator’s 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).
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 the 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 (terbumylazine) were found in Las Vegas Wash surface water. Generally, the concentrations of these pesticides (0.0045 to 0.0834 µg/L) were within the same range as other pesticides (0.00005 to 0.0627 µg/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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