



# Wastewater Spill into the Upper Gallatin River Watershed

## Part 3. Pharmaceuticals

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## REPORT SUMMARY

On March 3, 2016 there was a mechanical failure in a storage pond for tertiary treated waste water used for golf course irrigation near Big Sky, Montana. Over the next four days approximately 30 million gallons of the treated effluent discharged into and affected downstream waterbodies (Second Yellow Mule Creek, South Fork West Fork Gallatin River, West Fork Gallatin River, and the Gallatin River). DEQ began monitoring water quality in the spill affected area on March 5, 2016. DEQ sampled and analyzed for 46 pharmaceutical chemicals and breakdown products. Of these, 18 were detected in the water spilling directly from the pond, while 11 were detected in the tributaries. A single chemical (sulfamethoxazole, an antibiotic) was detected in all affected tributaries and all sites in the Gallatin River affected by the spill, and its presence could be attributed directly to the spill. The pond spill site is not a state water and is not subject to the Montana Water Quality Act or the national Clean Water Act, however the tributaries and the river are subject to those laws. There are no federal water quality criteria for pharmaceuticals, nor does Montana have any adopted pharmaceutical water quality standards. However Minnesota has several pharmaceutical water quality standards and a number of screening values, all for human health, and these were compared to concentrations DEQ measured during the spill. None of Minnesota's values were exceeded; therefore, human health effects from any individual chemical tested in this study are unlikely. This does not rule out human health effects from chemicals not analyzed for or combined effects of chemicals or metabolites. Pharmaceuticals may have detrimental impacts on aquatic life at very low concentrations (low microgram to nanogram per liter concentrations). At least one chemical (carbamazepine) achieved levels in the tributaries which exceeded levels shown to affect an aquatic invertebrate in laboratory studies. However, there is much uncertainty regarding impacts to aquatic life via low-concentration pharmaceuticals, or combinations of pharmaceuticals, so DEQ's ability to assess this impact is limited at this time. There was a large concentration decline in detected pharmaceuticals between the pond spill site and the first affected tributary (Second Yellow Mule Creek). This is likely due to sorption of the chemicals on to sediment particles, which were extremely high due to hillslope erosion during the spill. Most pharmaceuticals (about 75%) enter the aquatic environment via usage by individual people, whose waste is routed to wastewater treatment facilities and then a fraction (which varies by treatment level and chemical) of the pharmaceuticals are released in the treated wastewater to streams and rivers. Other sources include hospitals and disposal of expired or unwanted pharmaceuticals down the toilet. To prevent the latter, many communities offer take-back programs for expired/unwanted prescriptions; Bozeman has such a program (as do other Montana communities). Otherwise, it is advisable to dispose of unwanted pharmaceuticals in the trash where they can be better handled at a sanitary landfill, as these are carefully monitored and designed to handle chemical wastes.

## 1.0 INTRODUCTION AND OBJECTIVES

Sometime on March 3, 2016 there was a mechanical failure in a storage pond for tertiary treated waste water used for golf course irrigation near Big Sky, Montana. The pond was located high in the watershed (8,148 feet elevation) and over the next four days approximately 30 million gallons of the treated effluent discharged into and affected downstream waterbodies (Second Yellow Mule Creek, South Fork West Fork Gallatin River, West Fork Gallatin River, and the Gallatin River). DEQ began monitoring water quality in the spill affected area on March 5, 2016.

The effected waterbodies are all classified by the state of Montana as B-1. This means their water quality is to be maintained suitable for drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.

DEQ identified pharmaceuticals as an issue of public concern during the public meeting held in Big Sky on March 4<sup>th</sup>. The objective of this report (Part 3) is to address the effect of the spill on human health and aquatic life narrative standards (ARM 17.30.637(1)(d))<sup>1</sup> as related to pharmaceuticals. **Figure 1-1** (next page) shows DEQ's ten sampling locations. Three sites (9, 6, and 4) are located in parts of the drainage not affected by the spill and were used to characterize background conditions.

## 2.0 METHODS

Samples were collected as grabs after triple rinsing the HDPE sample bottles with site water (analytical details are in **Table 2-1**). Field blanks (for evidence of inadvertent sample contamination) and duplicates (to assess repeatability) were collected. DEQ collects blanks and duplicates at the end of sampling trips; trips range from one to many days (here, the longest trip was three days). Pharmaceutical samples were collected once at each site (March 5<sup>th</sup>) and twice at the wastewater pond spill site (March 5<sup>th</sup> and March 6<sup>th</sup>). Samples were analyzed by AXYS Analytical Services (2045 Mills Road West, Sydney, British Columbia, V8L 3S8) according to AXYS method MLA-075 (AXYS Analytical Services, 2014), which is a modification of the United States Environmental Protection Agency Method 1694 (United States Environmental Protection Agency, 2007). Sample extraction was performed by a combination of liquid chromatography and mass spectrophotometry (LC-MS/MS). Reporting units are in ng/L and a comparison of the different units discussed in this report is shown in **Table 2-2** (next page).

**Table 2-1. Analytical details for water quality parameters in this report.**

Analyte	Preservation and Storage	Holding Time	Method	Lower Reporting Limit (LRL)
Pharmaceutical (refer to Table 2-3 for a complete list of analytes)	Cool to <6°C (on ice)	7 days	MLA-075	Refer to Table 2-3 for each LRL

<sup>1</sup> See page 17-2747 at: <http://deq.mt.gov/Portals/112/DEQAdmin/DIR/Documents/legal/Chapters/CH30-06.pdf>

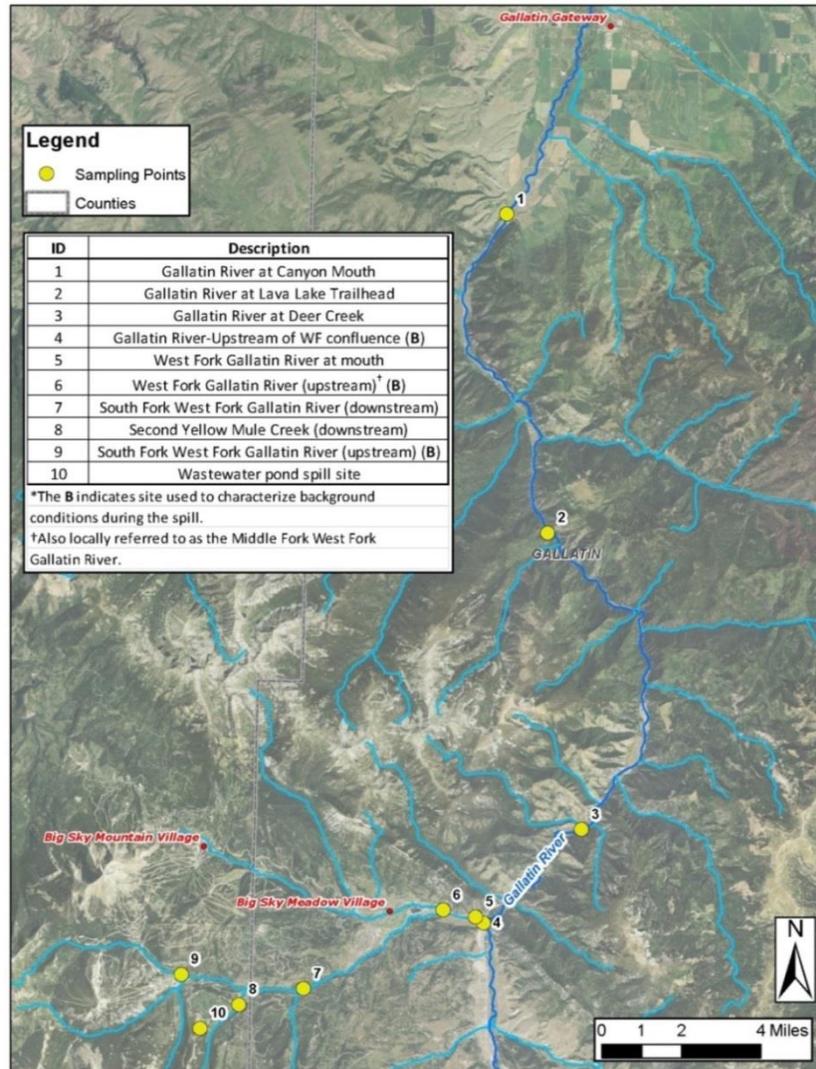


Figure 1-1. Map showing the ten sampling locations.

Table 2-2. Comparison of units of measurement discussed in this report.

Amount in a liter of water (grams)	Unit Name	Unit	Other Names Commonly Used
0.001	milligrams per liter	mg/L	parts per million (ppm)
0.000001	micrograms per liter	µg/L	parts per billion (ppb)
0.000000001	nanograms per liter	ng/L	parts per trillion (ppt)

**Table 2-3** (next page) lists the pharmaceutical chemicals analyzed. The lower reporting limit (LRL) refers to the concentration equivalent to the lowest calibration standard analyzed or the sample specific detection limit (SDL), whichever was greater. The analyte list includes many of the chemicals that have frequently been detected in surface waters and/or are considered priorities (World Health Organization, 2012; Ferrey, et al., 2015). However, this list does not cover all the possible pharmaceutical chemicals that might be found in surface waters. Of the 46 chemicals analyzed, 18 chemicals were detected (**Table 3.1**, page 5); the remaining 28 were non-detects.

**Table 2-3. Lower reporting limits for pharmaceutical chemicals DEQ analyzed for during the spill.**

Drug Class (shaded area) and Chemical Name	LRL (ng/L) based on 1 L sample	Drug Class (shaded area) and Chemical Name	LRL (ng/L) based on 1 L sample
<b>Non-prescription analgesic (OTC)</b>		<b>Antibiotic (cont.)</b>	
Acetaminophen	15.0	Sulfamethazine	0.6
<b>Antiarrhythmic and blood pressure support</b>		Sulfamethizole	0.6
Digoxin	6.0	Sulfamethoxazole	0.6
<b>Antidepressant -selective serotonin reuptake inhibitor (SSRI)</b>		Sulfanilamide	15.0
Fluoxetine	1.5	Sulfathiazole	1.5
<b>Antibiotic</b>		Trimethoprim	1.5
Azithromycin	1.5	Virginiamycin	3.0
Cefotaxime	6.0	<b>Anticonvulsant and Mood Stabilizer</b>	
Ciprofloxacin	6.0	Carbamazepine	1.5
Clarithromycin	1.5	<b>Antihistamine</b>	
Clinafloxacin	6.0	Diphenhydramine	0.6
Cloxacillin <sup>1</sup>	3.0	<b>Anti-worm (fungicide and parasiticide)</b>	
Enrofloxacin	3.0	Thiabendazole	1.5
Erythromycin-H2O <sup>2</sup>	0.3	<b>Fungicide</b>	
Flumequine	1.5	Miconazole	1.5
Lincomycin	3.0	<b>Cardiac Drug</b>	
Lomefloxacin	3.0	Diltiazem	0.3
Norfloxacin	15.0	Dehydro Nifedipine (metabolite)	0.6
Ofloxacin	1.5	<b>Oral contraceptive</b>	
Ormetoprim	0.6	Norgestimate	3.0
Oxacillin <sup>1</sup>	3.0	<b>Steroid (molecular application)</b>	
Oxolinic acid	0.6	Digoxigenin	6.0
Penicillin G (mainly intravenous) <sup>1</sup>	3.0	<b>Stimulant</b>	
Penicillin V	3.0	Caffeine	15.0
Roxithromycin	0.3	1,7-Dimethylxanthine <sup>2</sup>	60.0
Sarafloxacin	15.0	<b>Veterinary Drug</b>	
Sulfachloropyridazine	1.5	Carbadox	1.5
Sulfadiazine	1.5	Tylosin	6.0
Sulfadimethoxine	0.3		
Sulfamerazine	0.6		

<sup>1</sup>Concentration is estimated. <sup>2</sup>Caffeine metabolite.

### 3.0 RESULTS

Chemicals that were measured above their LRL are shown in **Table 3-1** (next page; all values in ng/L). In the table, drug classes are given in the left-most column, the chemical name is to the right of the drug class, and the measured concentrations are listed from the pond spill site (site 10) going downstream to site 1 (left to right). Background site 6 is in the furthest right column of the table and was not affected by the spill. The pond spill site values are the average of samples collected on two days, March 5<sup>th</sup> and March 6<sup>th</sup>. On March 6<sup>th</sup>, two samples (a primary and a duplicate) were taken and the average of their values was used in calculating the final average value. There were no detections in the field blank and the duplicate results were fair to good.

To evaluate potential human-health impacts of the spill, DEQ compared the sample results to drinking-water health risk limits (HRLs), screening values (SVs), and risk assessment advice (RAA) from the Minnesota Department of Health (MDH). In terms of the level of confidence in HRLs, SVs, and RAAs, HRLs are the best understood/highest confidence, followed by SVs and then RAAs. Among the chemicals DEQ detected (**Table 3-1**) there were HRLs, SVs, or RAAs available for most of them.

HRLs were available for acetaminophen and carbamazepine, meaning there were more data on these active pharmaceutical ingredients, therefore, it can be stated with more certainty that the HRL level of active pharmaceutical ingredient in drinking water is not likely to cause an effect on humans. Accordingly, acetaminophen and carbamazepine have been adopted into Minnesota law as water quality standards (Minnesota Department of Health, 2011; Minnesota Department of Health, 2013; Minnesota Department of Health, 2014; Minnesota Department of Health, 2015).

MDH defines a SV as a “concentration of an active pharmaceutical ingredient that can be consumed daily with no anticipated health risk to humans”. Most chemicals in **Table 3-1** are compared to SVs. MDH states that this value is meant to be more protective (i.e., at a lower concentration) than a more in-depth evaluation would yield. The SVs were developed from the lowest therapeutic doses of the active pharmaceutical ingredient (amount of medication necessary to elicit a clinically relevant effect), uncertainty and adjustment factors (to account for uncertainty and data gaps), a relative source contribution (portion of reference dose expected to be from water), and drinking water intake rate. Multiple calculations go into each of the above factors, and for a more detailed explanation of the derivation see Suchomel et al. (2015).

One chemical had an RAA (sulfamethoxazole). This chemical has not been directly evaluated by MDH, but its RAA value was based on the health based value for sulfamethazine (another sulfonamide antibiotic).

Penicillin G is known to yield inconsistent results using the analytical method employed. Therefore, the result of Penicillin G, which was only found at the West Fork Gallatin River at the mouth (site 5), should be interpreted with a higher degree of uncertainty than the other chemicals.

All chemical detections decreased in concentration going downstream from the pond spill site (10) to the most downstream site (1). There was one exception; the veterinary drug carbadox was detected at low levels (2.5 ng/L) at the pond spill site and at slightly *higher* concentrations in two immediate downstream sites (Second Yellow Mule Creek (8) and the South Fork West Fork Gallatin River (7)).

**Table 3-1. Concentration of pharmaceutical chemicals detected in this study. Human health screening values from the Minnesota Department of Health are provided for comparison.**

			Sampling Site Number and Name (all concentrations are ng/L)							
Drug Class	Chemical Name	Screen Value (SV) <sup>1</sup> (ng/L)	(10) Pond spill site	(8) 2 <sup>nd</sup> Yel. Mule Cr.	(7) SFWF Gallatin R.	(5) WF Gallatin R. - mouth	(3) Gallatin R. @-Deer Creek	(2) Gallatin R @ Lava Lake trlhd	(1) Gallatin R. @ Canyon Mouth	(6) WF Gallatin R. (B)
Non-prescription analgesic (OTC)	Acetaminophen <sup>2</sup>	20,000	31.05	23.4						
Anti-depressant -selective serotonin reuptake inhibitor (SSRI)	Fluoxetine	200	9.37							
Antibiotic	Azithromycin	3,000	660.25							
	Clarithromycin	6,000	76.08							
	Erythromycin-H2O	40,000	18.15	5.54	3.78	2.79				4.44
	Ofloxacin	5,000	22.05							
	Penicillin G (mainly intravenous) <sup>4</sup>	9,000				6.03				
	Roxithromycin		2.74							
	Sulfa-methoxazole <sup>3</sup>	100,000	240.5	218	113	82.8	7.78	6.47	5.91	3.3
	Sulfanilamide		41.15							
	Trimethoprim	4,000	123.25	17.8	6.32	3.88				1.74
Anticonvulsant and Mood Stabilizer	Carbamazepine <sup>2</sup>	40,000	52.55	33.9	16.6	10.6				
Antihistamine	Diphenhydramine		71.15							
Anti-worm (fungicide and parasiticide)	Thiabendazole		10.78	2.19						
Cardiac Drug	Diltiazem	4,000	12.25	1.39	0.42					
Stimulant	Caffeine		1242.5	124	61.3	38.4				
	1,7-Dimethyl-xanthine (caffeine metabolite)		503.25	162	84.9					
Veterinary Drug	Carbadox		2.5	3.08	2.7					

<sup>1</sup>SVs are given unless otherwise noted in the Chemical Name column. <sup>2</sup>HRL. <sup>3</sup>RAA. <sup>4</sup>Penicillin G screening value was used for Penicillin V.

The chemical that came closest to the SV is azithromycin, an antibiotic commonly used in humans (e.g., Z-Pak) and occasionally in animals. It was detected at approximately 22% of the SV in the pond but was not detected at any of the other locations, potentially due to sorption with sediment. All other chemicals fell below 5% of the HRL, SV or RAA numbers.

Seven chemicals without SVs were detected (**Table 3-1**). Caffeine and its metabolite 1, 7-dimethylxanthine were found in the pond spill site (10), Second Yellow Mule Creek (8), and the South Fork West Fork Gallatin River (7); caffeine was found downstream all the way to the West Fork Gallatin River at the mouth (5). The antihistamine diphenhydramine was detected at the pond spill site (10) but not in the tributaries, as was also the case for roxithromycin and sulfanilamide (antibiotics). Thiabendazole (anti-worm fungicide and parasiticide) was detected in the pond spill site (10) and in Second Yellow Mule Creek (8). Carbadox (discussed above) was found in sites 10, 8, and 7.

Three antibiotics (**Table 3-1**) were detected in one of the background sites, West Fork Gallatin River (6). These were erythromycin-H<sub>2</sub>O, sulfamethoxazole, and trimethoprim; sulfamethoxazole and trimethoprim are components of Bactrim, a commonly prescribed antibiotic. Sulfamethoxazole was found in very low concentrations (3.3 ng/L) at this site.

Sulfamethoxazole was the only chemical detected in the Gallatin River downstream of its confluence with the West Fork Gallatin River; this chemical was detected to our most downstream site (Gallatin R @ Canyon Mouth (1); **Figure 1-1**). Sulfamethoxazole had the highest concentration (82.8 ng/L) among detected chemicals in the West Fork Gallatin River near the mouth (5; **Table 3-1**), while upstream of the West Fork confluence there was no sulfamethoxazole detected in the Gallatin River. Sulfamethoxazole presence in the mainstem Gallatin River can be directly attributed to the spill. Based on Gallatin River flow (USGS gage 06043500) and estimated West Fork Gallatin River flow on March 5<sup>th</sup>, the concentration of sulfamethoxazole resulting from the mixing of the two waterbodies would be about 11 ng/L, close to the measured value of 7.8 ng/L at the first downstream site (Gallatin R @ Deer Cr (3)) on the Gallatin River. Concentration then diminished, progressively, with increasing downstream distance (**Table 3-1**).

## 4.0 DISCUSSION

Montana has no water quality standards for pharmaceuticals. Similarly, the U.S. Environmental Protection Agency (EPA) has no drinking water criteria or 304(a) criteria<sup>2</sup> for pharmaceuticals. However, there are a few pharmaceutical chemicals on EPA's candidate contaminant lists 3 and 4 (list 4 is draft). The candidate contaminant list documents chemicals that are known or anticipated to occur in public water systems, but currently are not subject to any proposed or promulgated national drinking water regulations. The draft list 4 can be found at: <https://www.epa.gov/ccl/draft-contaminant-candidate-list-4-ccl-4>. Due to the lack of federal or Montana water quality standards for pharmaceuticals, DEQ compared its findings to Minnesota's criteria for human health and to the scientific literature for aquatic life. Each is discussed below. Readers should note that the pond spill site itself is not a state water and is not subject to the Montana Water Quality Act or the national Clean Water Act, however the tributaries

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<sup>2</sup> 304(a) criteria are EPA's nationally recommended values for ambient surface water to protect human health and aquatic life.

and the river are subject to those laws. Also, there are no surface water drinking-water intakes in the monitored area.

## 4.1 PHARMACEUTICALS AND HUMAN HEALTH

The scientific literature generally shows that measured concentrations of pharmaceuticals in surface waters are well below concentrations that may directly pose a threat to human health via drinking (World Health Organization, 2012; Batt, et al., 2016). Consistent with this, concentrations of the chemicals DEQ measured during the spill were below Minnesota's human health drinking water SVs (or HRLs, or RAAs), which were used for comparison (**Table 3-1**).

Sulfamethoxazole (an antibiotic) was the most frequently detected chemical in the present study, and was detected at all monitoring sites, including one background site. In a study by EPA, sulfamethoxazole was the most frequently detected chemical and was found in 77% of the surface water examined across the U.S. in close proximity to urban areas (Batt, et al., 2016). High detection rates of sulfamethoxazole may be a result of its modest water solubility and a long half-life in water. Human health impacts from sulfamethoxazole are predicted to be very low. Even at its highest concentration in the pond spill water (240.5 ng/L), sulfamethoxazole only came to 0.24% of Minnesota's RAA value.

The highest detection of an antibiotic occurred in the pond spill site and was for azithromycin (660 ng/L). In contrast to sulfamethoxazole, azithromycin was not detected at any other site. This may be due to its low water solubility. The concentration of azithromycin in the pond spill site came to 22% of the SV, but due to lower water solubility and likely higher sorption to sediment (Kummerer, 2009), azithromycin was not detected downstream. Other commonly detected antibiotics in this study were erythromycin-H2O, which has also been detected in other surface and ground water studies (Focazio, et al., 2008) and trimethoprim and carbamazepine, which were detected in the EPA study of surface waters in 37% and 41% of the sites examined, respectively (Batt, et al., 2016).

Carbadox was detected in the pond spill site and two downstream sites at very low levels. The U.S. Food and Drug Administration's Center for Veterinary Medicine is taking legal action to remove carbadox from the market because the manufacturer has not demonstrated the safety of the drug. A notice of opportunity for hearing was filed on April 8<sup>th</sup>, 2016 and if the manufacturer does not respond, the drug will be removed from market (<http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm494934.htm>). Carbadox was detected in 28% of the lakes sampled in Minnesota and the authors state that it was unclear how it got into the lakes but that it may involve atmospheric transport (Ferrey, et al., 2015).

Of the chemicals detected at one background site (site 6), all three are common antibiotics that have been detected in other studies of surface and ground water (Focazio, et al., 2008; Batt, et al., 2016). Two of the antibiotics, sulfamethoxazole and trimethoprim, are often prescribed together as Bactrim. There are no permitted surface water or groundwater discharge permits upstream of this site. The source of the antibiotics is unclear; there may be septic systems somewhere in the drainage upstream.

No individual SVs, HRLs or RRVs were exceeded, and human health effects from any individual chemical tested in this study are unlikely. This does not rule out human health effects from chemicals not analyzed for or combined effects of chemicals or metabolites. This study was undertaken to determine the extent of effects from the spill by looking at a snapshot of chemicals in the pond spill water,

tributaries, and the mainstem Gallatin River. We conclude that human health effects are predicted to be minimal from this event and from the chemicals examined. Nevertheless, if you are concerned about contaminants, including pharmaceuticals in your drinking water, many inexpensive filters purchased in the store for the refrigerator or for the tap will filter out a large portion of pharmaceuticals. Filters need to be replaced on a regular basis for maximal performance. In addition, reverse osmosis systems have been found to be effective at filtering out pharmaceuticals and other chemicals from your water and are available as in-home filtration units (World Health Organization, 2012).

## 4.2 PHARMACEUTICALS AND AQUATIC LIFE

Research on fish, invertebrates, algae, and other aquatic organisms shows that ng/L to low µg/L concentrations of pharmaceuticals are potentially harmful to aquatic life, and these concentrations are commonly found in the aquatic environment (Daughton and Ternes, 1999; Santos, et al., 2010). During the spill, carbamazepine ranged from 11-34 ng/L in the affected tributaries, and studies of acute (short-term) effects of this chemical find a lowest observable effect concentration (LOEC) for aquatic life to be as low as 10 ng/L<sup>3</sup> (De Lange, et al., 2006; Santos, et al., 2010). Carbamazepine is widely found in rivers and streams at concentrations ranging from 325 to 6,300 ng/L. It has very low removal rates in wastewater treatment (7%), and takes months to degrade in the open aquatic environment (Daughton and Ternes, 1999; Santos, et al., 2010; Lamichhane, et al., 2013; Li, 2014).

Sulfamethoxazole was the most widely distributed antibiotic due to the spill, but notable concentrations of trimethoprim (which is often prescribed along with sulfamethoxazole) and erythromycin were also detected in the tributaries (**Table 3-1**). In a statistically-rigorous national survey, sulfamethoxazole was the most frequently detected chemical in urban-influenced rivers and streams in the U.S., and was found in 82.7% of stream miles<sup>4</sup> (Batt, et al., 2016). Sulfamethoxazole concentrations in the upper-most tributaries in the present study (113-218 ng/L; **Table 3-1**) were, compared to the national study, quite high; 92-98% of the surveyed urban-influenced streams had concentrations *lower* than what we measured (Batt, et al., 2016). However, in general, studies show that impacts to fish and aquatic invertebrates from antibiotics occur at much higher concentrations (in the mg/L range) than were observed during the spill (Santos, et al., 2010; Batt, et al., 2016). Algae tend to be sensitive at lower concentrations, in the low µg/L range (Ferrari, et al., 2004). Antibiotics can have significantly enhanced impacts on aquatic life when present in combination with other antibiotics (Eguchi, et al., 2004), and these additive/synergistic effects tend to lower the concentrations that cause aquatic life impacts.

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

None of the pharmaceutical chemicals measured by DEQ during the spill reached concentrations that are likely to cause human health effects. Most chemicals were at concentrations which are a fraction of the human health benchmarks DEQ used as comparison. One chemical (azithromycin) came to 22% of the human health benchmark, but was not detected in any stream or river (only at the pond spill site).

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<sup>3</sup> The tested organism was a freshwater crustacean *Gammarus pulex*.

<sup>4</sup> One site from Montana was included in the study.

Research on fish, invertebrates, algae, and other aquatic organisms shows that ng/L to low µg/L concentrations of pharmaceuticals are potentially harmful to aquatic life. At least one chemical (carbamazepine) achieved concentrations in the tributaries that exceed levels shown to affect an aquatic invertebrate in laboratory studies (De Lange, et al., 2006). Pharmaceuticals are among a number of contaminants of emerging concern that may have detrimental impacts on aquatic life at very low concentrations (Daughton and Ternes, 1999; Santos, et al., 2010). However, very few of these chemicals have undergone an environmental assessment because the U.S. Food and Drug Administration (FDA) only requires such an assessment if the expected concentration at the point of entry into the environment is expected to be  $\geq 1$  µg/L (Daughton and Ternes, 1999; Santos, et al., 2010). For this reason, the effect of low-concentration pharmaceuticals (and combinations of pharmaceuticals) on fish and other aquatic life remains an area with limited information and additional study is necessary (Corcoran, et al., 2010; Batt, et al., 2016).

Many of the chemicals DEQ analyzed interact with/sorb to sediments (Kummerer 2009). A very large volume of erosional sediment was introduced into the streams as a result of the down cutting of the spill into the hillside (Montana Department of Environmental Quality and Fish Wildlife and Parks, 2016). The large reduction in the concentration of pharmaceuticals observed between the water at the pond spill site and the first receiving stream (Second Yellow Mule Creek) is probably due to sorption on these suspended sediments.

Most pharmaceuticals (about 75%) enter the aquatic environment via usage by individual people, whose waste is routed to wastewater treatment facilities and then a fraction of the pharmaceuticals are released in the treated wastewater to streams and rivers (Kummerer, 2009). Other sources include hospitals and disposal of expired or unwanted pharmaceuticals down the toilet. Guidelines to dispose of prescription and over-the-counter drugs based on FDA guidelines can be found at:

<http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm101653.htm>

- 1) Do not flush medicines down the sink or toilet unless disposal instructions on the prescription information indicate that this is the right mechanism.
- 2) Transfer unused medicine to authorized collectors for disposal.
  - a) Contact the local waste management office to learn about options and guidelines in your area. There is a pharmaceutical take-back program in Bozeman, information may be found at <http://healthygallatin.org/blog/safe-drug-disposal/>.
  - b) Check the U.S. Drug Enforcement Agency authorized collectors in your area or major DEA events at: <https://www.deadiversion.usdoj.gov/pubdispsearch/spring/main?execution=e1s1>
- 3) If you don't have any of the above options, dispose medicines by taking them from their original container and mix them with used coffee grounds, dirt or kitty litter. Place the mixture in a sealable bag, empty can or other container to prevent the drug from leaking or breaking out of a garbage bag, and dispose of it in the trash for regular pick up.

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