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Prepared as part of the
U.S. GEOLOGICAL SURVEY
TOXIC SUBSTANCES HYDROLOGY PROGRAM

Occurrence of Antibiotics in Water from Fish Hatcheries

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"Recently, pharmaceuticals, hormones, and other organic wastewater contaminants were reported in United States streams." (feature article, Environmental Science and Technology, March 15, 2002)

Introduction

The recent discovery of pharmceuticals in streams across the United States (Kolpin and others, 2002) has raised the visibility and need for monitoring of antibiotics in the environment. Possible sources of antibiotics and other pharmaceuticals in streams may include fish hatcheries. This fact sheet presents the results from a preliminary study of fish hatcheries across the United States for the occurrence and concentration of antibiotics present in fish hatchery water. The study examines both sulfonamides and tetracyclines. Sulfonamides are synthetic compounds, and tetracyclines are naturally occurring compounds.

The use of antibiotics added to specially formulated feed is a common practice in fish hatcheries to affect reproduction and growth, treat and prevent disease, and control parasites. The U.S. Food and Drug Administration (FDA) has approved several antibiotics for such purposes. They are oxytetracycline-HCl, sulfamerazine and a combination drug containing ormetoprim and sulfadimethoxine (Benbrook, 2002).

During January 2001–June 2002, the U.S. Geological Survey (USGS) Organic Geochemistry Research Laboratory (OGRL), Lawrence, Kansas, cooperatively collected water samples from 13 fish hatcheries across the United States (fig. 1) with the assistance of hatchery operators. A method for the analysis of antibiotics was developed and used to identify and quantify these compounds in fish hatchery water (Lindsey and others, 2001). This study was completed to determine if trace levels of antibiotics [approximately 1 microgram per liter (µg/L) or 1 part per billion or greater] occurred in water associated with fish hatcheries, which are a potential source of these compounds in surface water.

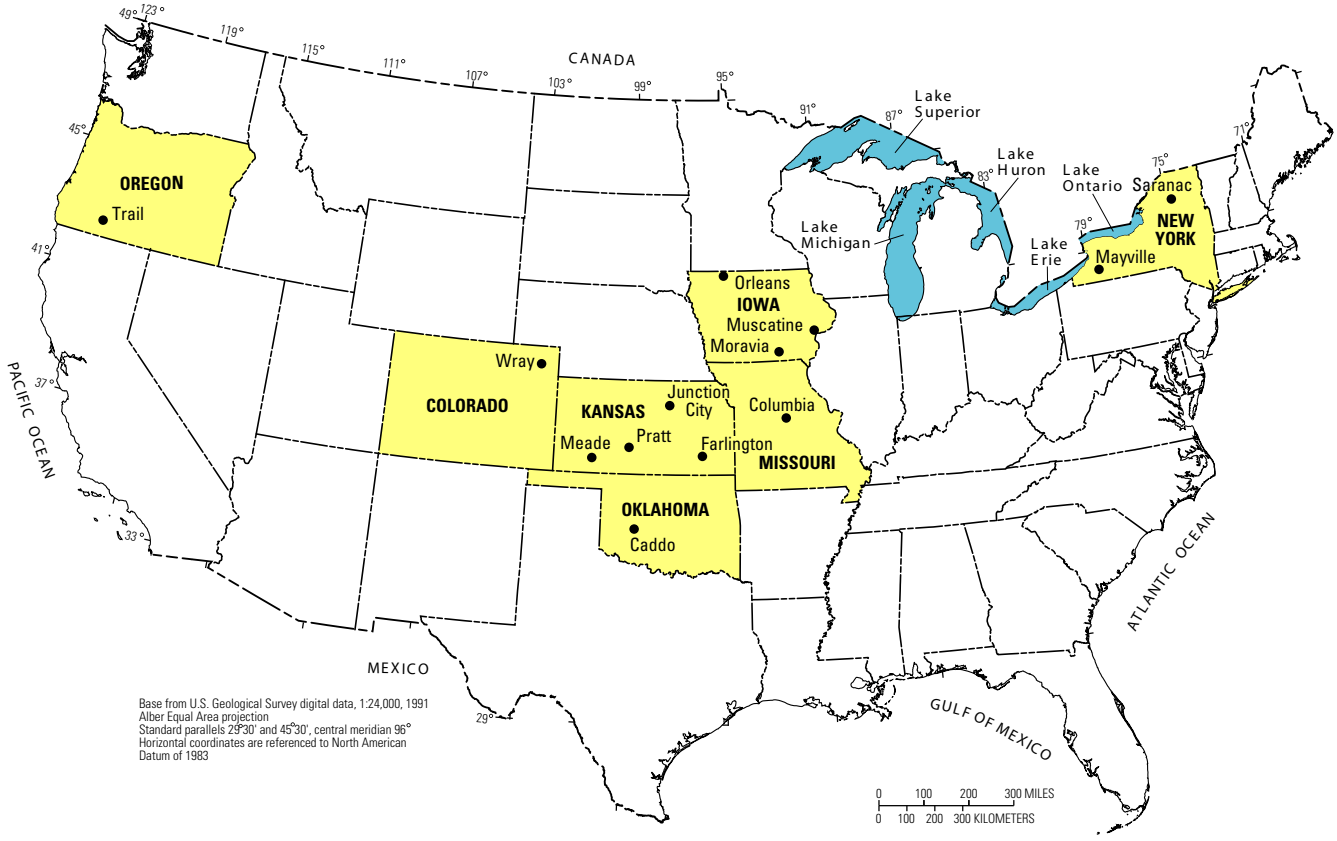

Figure 1. Location of 13 fish hatcheries sampled across the United States, January 2001–June 2002.

Types of Fish Hatcheries

There are three kinds of fish hatcheries in the United States-Federal, State, and private or commercial hatcheries. The Federal government operates approximately 110 fish hatcheries, States operate about 500 fish hatcheries, and private and commercial enterprises operate about 2,000 fish hatcheries (Willoughby, 2002). The fish hatcheries described in this report are State operated with the exception of the research ponds at the USGS Environmental Research Center in Columbia, Missouri. Freshwater fish hatcheries have become a popular and fast-growing industry. Fish raised at the hatcheries are released in public and private waters to augment depleted natural stock, maintain sport and commercial fishing, and supply food. The hatcheries produce numerous species of fish.

The study described in this fact sheet representatively sampled water from both extensive and intensive fish hatcheries. By tradition, extensive fish hatcheries have an earthen, farm-pond appearance; whereas, intensive hatcheries raise the fish in concrete ponds and raceways. Extensive fish hatcheries (fig. 2) naturally supply both the nutritional and environmental needs of the fish. Normally, extensive fish hatcheries raise both warm-water and cool-water fish (15 to 27 C). An undetermined number of fish are placed in the earthen ponds, then counted at the time of transfer to release locations from the fish hatchery. The ponds typically are drained at the end of the hatchery season in late fall (Willoughby, 2002).

Intensive fish hatcheries (fig. 3) are operated under a more controlled environment. Hand feeding or mechanical fish feeders meet the nutritional needs of the fish. Oxygen, ammonia, and nitrate levels are maintained by the use of filters or rapid exchanges of water in the system to help meet the environmental needs of the fish. In the past, intensive fish hatcheries have been used only to raise cold-water fish (10 to 16 C); however, with improved technology, it has become practical to raise warmwater fish at an intensive fish hatchery (Willoughby, 2002).

Sample Collection

Samples were collected from fish hatcheries in seven States-Colorado, Iowa, Kansas, Missouri, New York, Oklahoma, and Oregon. Seven extensive fish hatcheries were sampled as follows: Wray Fish Hatchery, Wray, Colorado, established as a warmwater fish hatchery in 1930; Fairport Fish Hatchery, Muscatine, Iowa, located on the Mississippi River; three Kansas fish hatcheries located at Farlington, Meade, and Pratt; USGS Environmental Research Center, Columbia, Missouri; and Durant Fish Hatchery, Caddo, Oklahoma.

Figure 2. Example of an extensive fish hatchery used to raise warmwater and cool-water fish near Meade, Kansas.

Six intensive hatcheries were sampled as follows: Rathbun Fish Hatchery, Moravia, Iowa, built in 1977; Spirit Lake Fish Hatchery, Orleans, Iowa, established in 1880; Milford Fish Hatchery, Junction City, the newest hatchery in Kansas; two New York fish hatcheries Chautauqua at Mayville and Adirondack at Saranac Lake; and Cole M. Rivers Fish Hatchery, Trail, Oregon, the largest hatchery on the West Coast.

Water samples were collected from the 13 fish hatcheries during January 2001 through June 2002 using methods described by Wilde and others (1999). A total of 189 random samples were collected for this study. Of the 189 random samples, 14 were collected from source water for the hatcheries. The water samples were collected in 250-millimeter baked amber-glass bottles, immediately chilled, and sent by overnight air express to the USGS OGRL in Lawrence, Kansas.

Figure 3. Example of an intensive fish hatchery used to raise cold-water fish near Trail, Oregon.

Analytical Methods

Prior to analysis, the water samples were filtered through a 0.7-micron glass-fiber filter into 125-milliliter amber-glass bottles. A newly developed method of solid-phase extraction with liquid chromatography/mass spectrometry positive-ion electrospray analysis and selected-ion monitoring was used to analyze the samples (Lindsey and others, 2001; Kolpin and others, 2002). The method was used to analyze three classes of antibiotics that include six sulfonamides-sulfachlorpyridazine, sulfadimethoxine, sulfamerazine, sulfamethazine, sulfamethoxazole, and sulfathiazole; five tetracyclines-chlortetracycline,doxycycline, minocycline, oxytetracycline, and tetracycline; three tetracycline degradates-anhydrochlortetracycline, anhydrotetracycline, and demeclocycline; and five quinolines-carbadox, flumequine, norfloxacin, oxolinix acid, and sarafloxacin.

Occurrence of Antibiotics in Fish Hatchery Water

Of the 189 water samples collected and analyzed from the 13 fish hatcheries, antibiotics were detected in 27 samples collected from five fish hatcheries. As shown in figure 4, oxytetracycline and sulfadimethoxine were detected most frequently in the samples at detection frequencies of 4 and 12 percent, respectively. It is not surprising that these two antibiotics were detected in the water samples as they are FDA approved for aquaculture. Tetracycline was present at a detection frequency of 1 percent. Overall, these three antibiotics were detected in 14 percent of the samples. The other antibiotics and their degradates that were analyzed were not detected.

Measurable concentrations of antibiotics are listed in table 1. These concentrations did not exceed 2.3 µg/L, except in two samples. The range in detected concentrations of oxytetracycline was 0.17 to 10 µg/L. However, the median concentration for oxytetracycline detections was less than 0.05 µg/L. Generally, the range of detected concentrations of sulfadimethoxine was 0.10 to 1.2 µg/L, with one sample containing greater than 15 µg/L. This sample came from the hatchery at Junction City, Kansas. The concentration reported as greater than 15 µg/L resulted from using a secondary peak of that compound. Due to the limited volume of submitted samples, appropriate dilutions to fit within the working range of the method were not available. The median concentration for sulfadimethoxine detections was less than 0.05 µg/L. The two detections of tetracycline may represent trace impurities present in the oxytetracycline, or the tetracycline may be a possible transformation product of oxytetracycline.

This one-time survey indicated the presence of trace concentrations of antibiotics, typically in the 0.10- to 2.0-µg/L range, in water from 5 of the 13 fish hatch- eries sampled. There were no detections of antibiotics in the 14 samples of source water collected from the fish hatcheries, thus the presence of FDA-approved anti- biotics (oxytetracycline and sulfadimeth- oxine) is most likely due to the addition of specially formulated feed to fish hatchery water.

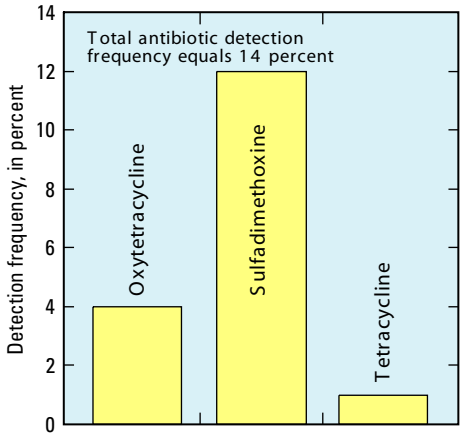

Figure 4. Detection frequency of antibiotics in water samples from 13 fish hatcheries, January 2001 through June 2002.

Table 1. Antibiotic concentrations detected in water samples from five United States fish hatcheries, January 2001 through June 2002

[The analytical reporting limit for all three antibiotics was 0.05 microgram per liter. --, not detected]

Fish hatchery (fig. 1) and sample location	Date of collection (month/day/year)	Oxytetracycline	Sulfadimethoxine	Tetracycline
Extensive fish hatcheries				
Meade, Kansas				
Pond 1 West	5/31/01	--	0.25	--
	5/31/01	--	.21	--
	5/31/01	0.23	.23	--
	7/11/01	--	.12	--
	7/11/01	--	.16	--
	7/11/01	--	.13	--
Pond 2B	5/31/01	--	.15	--
	5/31/01	--	.26	--
	5/31/01	--	.23	--
Pond 3B	5/31/01	--	.46	--
	5/31/01	--	.36	--
	5/31/01	--	.33	--
Pond 4B	5/31/01	--	1.0	--
	5/31/01	--	1.2	--
	5/31/01	--	.89	--
	7/11/01	--	.10	--
Caddo, Oklahoma				
Pond 20	10/18/01	.17	--	--
Small reservoir	10/18/01	.31	--	--
Intensive fish hatcheries				
Junction City, Kansas				
Raceway inlet	6/25/01	--	.24	--
	7/25/01	--	.69	--
	8/28/01	--	.28	--
Raceway outlet	6/25/01	.65	>15	--
	7/25/01	--	.57	--
	8/28/01	--	.30	--
Mayville, New York				
Settling pond	7/10/01	10	--	--
Saranac Lake, New York				
Raceway outlet	6/26/01	2.3	--	0.10
	10/23/01	1.7	--	.61

Conclusions

This study concluded that:

- The majority of water samples randomly collected (86 percent) did not contain detectable antibiotics, which indicates that the current practices at the majority of fish hatcheries do not commonly result in occurrence of antibiotic residuals in fish hatchery water.
- Fourteen percent of the samples did contain detectable concentrations of either oxytetracycline and sulfadimethoxine, which are FDA-approved antibiotics. Trace concentrations were most frequently detected in the 0.10- to 2.0-µg/L range, with two detections at 10 and greater than 15 µg/L.

- Five of the 13 hatcheries (38 percent) submitted samples with measurable concentrations of antibiotics; therefore, fish hatcheries do present a possible trace source of oxtetracycline and sulfadimethoxine in water should it be released to the environment.
- Results of this study can be used by fish-hatchery operators to consider management options to recycle water and (or) minimize the release of water containing trace levels of antibiotics to the aquatic environment.

Acknowledgments

The authors wish to thank the fish hatchery operators in Colorado, Iowa, Kansas, Missouri, New York, Oklahoma, and Oregon, as this data-collection effort could not have been accomplished without their assistance.

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