Phosphorus amendment reduces bioavailability of lead to mallards

Gary H. Heinz[1], David J.Hoffman[1], Shannon L. Kondrad[1], and Daniel J. Audet[2]

[1]USGS Patuxent Wildlife Research Center, Laurel, MD 20708 and [2]U.S. Fish and Wildlife Service, Spokane, WA 99206

The Problem

Lead levels in sediment over broad areas of the Coeur d'Alene River Basin in Idaho have been measured in thousands of µg/g on a dry-weight basis. Waterfowl sometimes consume large amounts of sediment in the course of feeding (Connor 1993, Beyer et al. 1994), and since the early 1900s, have been dying from lead poisoning along the Coeur d'Alene River (Chupp and Dalke 1964; Benson et al. 1976; Blus et al. 1991). One idea for reducing the hazard of such highly contaminated sediments to waterfowl is to add a material such as phosphoric acid (H_3PO_4) to the sediment in order to bind the lead into biologically unavailable forms.

Abstract

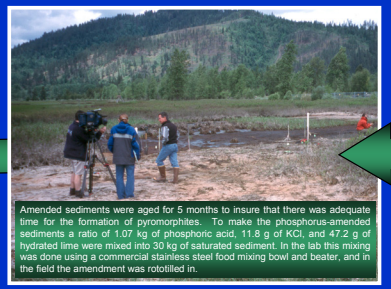
Lead poisoning of waterfowl has been reported for decades in the Coeur d'Alene River Basin in Idaho as a result of the ingestion of lead-contaminated sediments. We conducted a study to determine whether the addition of phosphoric acid to sediments would reduce the bioavailability of lead to mallards (Anas platyrhynchos). When sediments were amended with 1% phosphorus under laboratory conditions, and diets containing 12% amended sediment were fed to mallards, reductions in tissue lead were 43% in blood, 41% in liver, and 59% in kidney with sediment containing about 4,520 µg/g lead on a dry-weight basis and 41%, 30%, and 57% with sediment containing about 6,990 µg/g lead. Although the phosphorus amendment substantially reduced the bioavailability of lead, lead concentrations in the tissues of mallards fed the amended sediments were still above those believed to be harmful to waterfowl. The addition of phosphoric acid as we used it might only significantly benefit waterfowl where sediments or soils contain less than 1,000-2,000 µg/g lead.

Methods

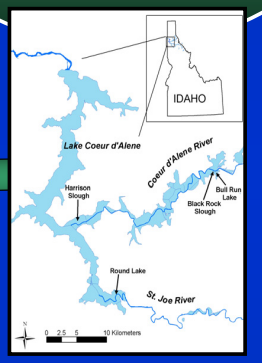
Ten male mallards were randomized to each of 8 different diets containing sediment from either the St. Joe River (a river that is relatively uncontaminated by lead) or one of three locations within the Coeur d'Alene River Basin in Idaho. Each diet contained 12% sediment, but some of the sediments had been amended with 1% phosphorus as phosphoric acid. After 8 weeks on the experimental diets, a sample of blood was taken from each bird for lead analysis, the birds were euthanized with CO_2, and a sample of liver and kidney was saved from each bird for lead analysis.

Lead-poisoned tundra swans

Mallards were fed a diet that contained 12% sediment. The sediments had been aged, dried to a moisture content of about 10%, thoroughly homogenized, and then sieved through a 1-mm stainless steel sieve to remove debris and any lead shotgun pellets that might have been present.



Amended sediments were aged for 5 months to insure that there was adequate time for the formation of pyromorphites. To make the phosphorus-amended sediments a ratio of 1.07 kg of phosphoric acid, 11.8 g of KCl, and 47.2 g of hydrated lime were mixed into 30 kg of saturated sediment. In the lab this mixing was done using a commercial stainless steel food mixing bowl and beater, and in the field the amendment was rototilled in.



Results

Table 1.

Lead in the sediments used to make the experimental diets

Source of sediment	Lead (µg/g, dry wt.)
Round Lake	21
Harrison Slough	4,520
Black Rock Slough	5,390
Bull Run Lake	6,990

Table 2.

Lead in tissues

Types of sediment being compared	N	Lead (µg/g, wet-weight) Blood	Liver	Kidney
Round Lake, unamended (reference site)	10	0.68	0.14	0.34
Harrison Slough, unamended in lab	10	5.1	22	39
versus				
Harrison Slough, amended in lab	10	2.9*	13*	16*
Black Rock Slough, unamended in lab	10	5.2	20	32
versus				
Black Rock Slough, amended in field	10	2.3*	9.2*	11*
Bull Run Lake, unamended in lab	10	6.4 A*	23 A	56 A
versus				
Bull Run Lake, amended in lab	10	3.8 B	16 B	24 B
versus				
Bull Run Lake, amended in field	10	2.3 C	10 C	13 C

*Significantly lower than unamended sediment; two-tailed t-test ($\alpha = 0.05$).

* Means for Bull Run Lake that do not share a letter in common were significantly different by ANOVA and Tukey's tests ($\alpha = 0.05$).

Conclusions

Concentrations of lead in the tissues of mallards fed unamended sediments were similar to those reported for waterfowl feeding in the Coeur d'Alene River Basin (Chupp and Dalke 1964, Benson et al. 1976, Henny et al. 2000). The addition of 1% phosphorus to lead-contaminated sediments, whether in the lab or the field, reduced the bioavailability of the lead to mallards, but lead in mallard tissues still exceeded concentrations believed to be harmful to waterfowl (Pain 1996, Beyer et al. 2000). Thus, in highly contaminated environments, phosphorus amendments alone may not make lead-contaminated sediments safe.

Research Needs

Tests need to be done to determine the practical limitations of phosphoric acid in reducing the threat of lead poisoning in waterfowl when ingestion of contaminated sediments is the source of the lead. Additional work with phosphoric acid will need to include an assessment of any ecological risks widespread application might cause. For example, in the field plant growth was severely inhibited by the amendment. Finally, the long-term efficacy of sediment amendments must be measured if they are to represent a cost effective and viable means of reducing lead poisoning of waterfowl in contaminated habitats.

Acknowledgments

We thank Anne Dailey for overall support and coordination of this project. The planning and study design was a multi-agency effort, including the U.S. EPA (Anne Dailey, Mark Sprenger, and Mary Jane Nearman), Idaho Department of Environmental Quality (Nick Zilka and Kathy Johnson), U.S. Fish and Wildlife Service (Brad Frazier and Julie Campbell), Coeur d'Alene Indian Tribe (Phil Cernera), and many others who provided helpful suggestions. Mark Snyder, Nick Zilka, Julie Campbell, Brad Frazier, Stan Peterson, and Jon Munkers helped in the treatment of sediments in the field and the collection of sediments. Brad Frazier and Stan Peterson provided advice and assistance in adding the amendments in the lab. Carol Erwin, Dan Murray, Michael Hoffman, and Michael Hammond cared for the ducks; and Glen Olsen took blood samples from the ducks. Funding for the study came from the U.S. Environmental Protection Agency.

References

Benson WW, Brock DW, Gabica J, Loomis M (1976) Swan mortality due to certain heavy metals in the Mission Lake area, Idaho. Bull Environ Contam Toxicol 15:171-174

Beyer WN, Audet DJ, Heinz GH, Hoffman DJ, Day D (2000) Relation of waterfowl poisoning to sediment lead concentrations in the Coeur d'Alene River Basin. Ecotoxicol 9:207-218

Beyer WN, Connor EE, Gerould S (1994) Estimates of soil ingestion by wildlife. J Wildl Manage 58:375-382

Blus LJ, Henny CJ, Hoffman DJ, Grove RA (1991) Lead toxicosis in tundra swans near a mining and smelting complex in northern Idaho. Arch Environ Contam Toxicol 21:549-555

Chupp NR, Dalke PD (1964) Waterfowl mortality in the Coeur d'Alene River Valley, Idaho. J Wildl Manage 28:692-702

Connor EE (1993) Soil ingestion and lead concentration in wildlife species. MS Thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA

Henny CJ, Blus LJ, Hoffman DJ, Sileo L, Audet DJ, Snyder MR (2000) Field evaluation of lead effects on Canada geese and mallards in the Coeur d'Alene River Basin, Idaho. Arch Environ Contam Toxicol 39:97-112

Pain DJ (1996) Lead in waterfowl. In: Beyer WN, Heinz GH, Redmon-Norwood AW (eds) Environmental contaminants in wildlife: Interpreting tissue concentrations. Lewis, Boca Raton, FL, pp 251-264