Historical Impact of Industrial Development on Groundwater and Surface Water Quality in the American Bottoms

Progress Report

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Abstract

Industrial development over the last 110 years has contaminated many parts of the American Bottoms, an extensive floodplain of the Mississippi just east of St. Louis. Groundwater resources have been especially severely impacted by long-term mismanagement of hazardous waste disposal by local industries. Toxic refuse from metal smelting, steel-making and wood-treatment industries has been released on site to percolate into the ground or to run off to local streams. Although there is no remaining direct record of groundwater pollution, there still remains a record of metals contamination in Horseshoe Lake, a natural lake in the most industrialized portion of the American Bottoms. We examined a sediment core from the lake to reconstruct the input of heavy metals and isotopes of carbon and nitrogen to the lake. We found an increase in $\delta^{15}N$ and $\delta^{13}C$ in the early-1900's indicating increasing pollution of the lake from sewage which caused an increase in primary production in the lake. Lead, tin, cadmium, and zinc concentrations increase in the sediment after 1947. This increase in heavy metals may be related to activities as NL Industries, a lead smelter located adjacent to the lake in Granite City, Illinois.

Introduction

The American Bottoms is a large area of the Mississippi Flood Plain in Southwestern Illinois that is located just across the river from the city of St. Louis. The floodplain contains a number of large, highly industrialized cities including East St. Louis and Granite City. Because of its proximity to Illinois coal deposits and abundant water supplies, the American Bottoms became a prime location for heavy industry during the 19th century. Another reason for locating in the American Bottoms was the abundance of water for industrial processes and for waste removal in lakes, streams and shallow, easy to reach, sandy aquifers (Colten 1988)

Development after 1890 turned the American Bottoms into a major industrial center. An unanticipated consequence of this early development is widespread contamination of land and water by hazardous wastes. Colten (1988) examined the historical record of hazardous waste management in the American Bottoms and found large areas of contamination in locations likely to affect groundwater quality. He argued that existing data bases may underestimate the extent of contamination because hazardous waste sources were much more widespread in the past. Colten's (1988) research was based on a study of historical documents and court records. He emphasized that "Factories dumped all manner of liquid waste into water courses for natural purification and dilution treatment while they heaped solids on site. This created numerous water sinks including most of the lakes and stream channels on the American Bottoms, where sediments were allowed to accumulate over the years." The potential for severe contamination of groundwater from these practices is clear.

History of Industrialization in the American Bottoms

The history of heavy industry began in the American Bottoms with the establishment of St. Louis Stamping Company in Granite City in 1866 (Crayne 1999). Granite City Steel Company which still occupies the northwest shore of Horseshoe Lake was established in 1895. Two lead smelters, National Lead (NL Industries) and Hoyt Metal were established in 1910. Midland Creosote (later Jennison-Wright) used coal tar from coking to treat railroad ties. Both National Lead and Jennison-Wright are now superfund sites located in Granite City. The National Lead site contained a 3-acre pile of lead-contaminated waste estimated at 200,000 tons.

Horseshoe Lake

Horseshoe Lake is a shallow (2m deep) oxbow located in Madison County adjacent to Granite City. Ollendorf (1993) cites unpublished radiocarbon dates indicating that the lake is 3,300 years old. She notes that the lake formerly received drainage from numerous small streams descending the bluffs to the east. Because of stream diversion, the lake now receives only urban runoff though Nameoki ditch, agricultural runoff through Elm Slough, and treated effluent (25mgd) from Granite City Steel (Hill *et al*. 1981). The water level of the lake is maintained by the Metro East Sanitary District.

Horseshoe Lake is very eutrophic (Hill *et al* 1981). Between 1959 and 1981 there were 14 fish kills. The likely cause of these fish kills is deoxygenation under ice during the winter rather than toxic contamination.

The sedimentary record of the lake should be a proxy for the contamination of the American Bottoms groundwater because of the intimate connection between groundwater and surface water in the sandy alluvial sediments of the floodplain. There is no remaining physical record of past groundwater contamination that can be sampled now. However, the sediments of lakes do record the long-term history of environmental pollution (Pan and Brugam 1997). The sedimentary record of the lake can be viewed as an archive of environmental contamination that can be compared with Colten's (1988) compilation of the written historical record.

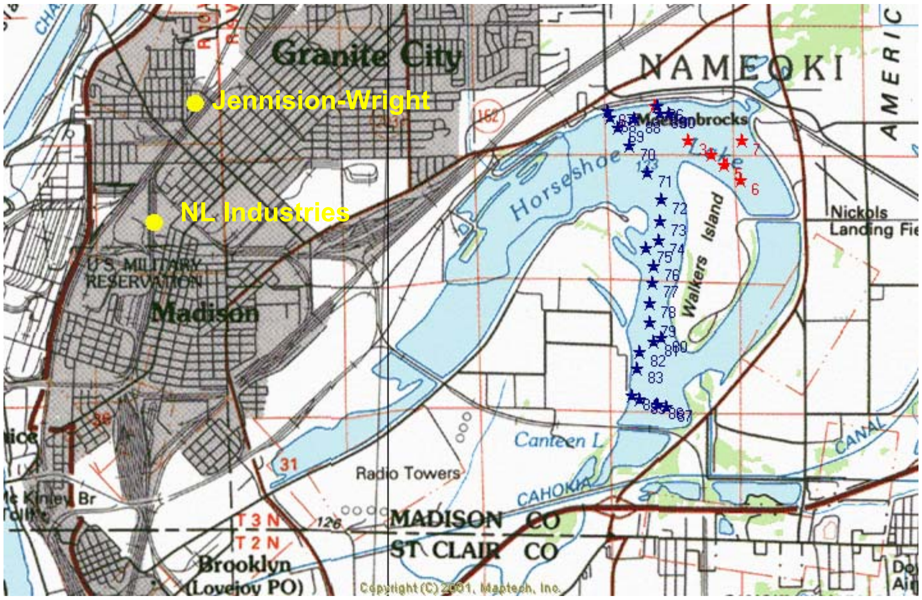

Fig. 1 Map of Horseshoe Lake. Blue stars show locations of the preliminary sediment survey. Red stars show core locations. Yellow dots show superfund sites.

Objective

We are using the physical record of contamination stored in the sediment of Horseshoe Lake, Madison County, to reconstruct the impact of urbanization and industrialization on groundwater resources. We expect the sedimentary record to show increasing levels of contaminants as industrialization has increased. We also expect reductions of contamination as hazardous sites have been cleaned up in recent years.

Approach/Fieldwork

The lake was first surveyed to determine the best locations to take sediment cores. Each survey point was located using a Geographical Positioning System (Fig. 1). Seven cores were taken by pushing a 7.5 cm wide clear plastic tube into the sediment on a rod. The top an bottom of the tube were sealed with rubber stoppers and the tube was held in a vertical position and taken to the laboratory. There the cores were extruded into plastic Whirl-Pak bags. The bags were stored at 4^{o}C until analysis.

The sediment was processed using acetolysis to reveal pollen grains (Faegri and Iversen 1975). Pollen was counted under a microscope at 40x. The sediment level from the time of the first colonization of the lakeshore by European/American farmers was determined by searching for the first increase in pollen from agricultural weeds.

Lead-210 and carbon-14 were also used to date the sediment. Carbon-14 analysis was done by Geochron Laboratories, Boston, MA. Lead-210 dating was performed by the St. Croix Watershed Research Center in Marine-on-St. Croix, MN.

Stable isotopes of carbon and nitrogen were analyzed at the Boyce Thompson Institute, Cornell University, Ithaca, NY. Metals analysis was done using X-ray Fluorescence Analysis at the Department of Earth and Planetary Sciences, Washington University, St. Louis, MO.

Principal Components Analysis was completed using the computer program, PCord.

Results and Progress

Although we have some data for most chemical variables from all 7 cores that we took from the lake, only core 3 has been dated. The information in this paper will be based on our analysis of this core.

Dating

The average sedimentation rate for core 3 is .26 cm/yr as calculated from the lead-210 data. The ragweed rise that indicates the arrival of European/American farmers at the lake is 53 cm. This event is dated at 1809 from historical records of Madison County (Anonymous 1882).

Sediment Chemistry

Both $\delta^{13}C$ and $\delta^{15}N$ increase since 1900 in the core (Fig. 2). These increases in stable isotopes have been seen in other locations and are indicative of eutrophication of the lake by the input of human and/or animal waste (Brenner et al. 1998). The nitrogen isotopic signature at the top of the core is consistent with contamination by sewage (Roadcap et al. 2001). Percent carbon and percent nitrogen decline in recent years (Fig,2).

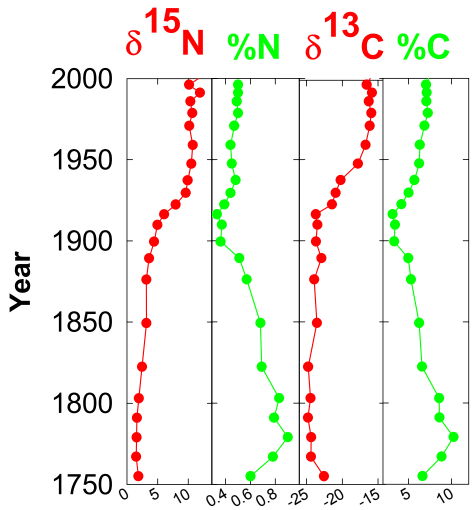

Fig. 2 Stable isotopes of carbon and nitrogen in core H5.

Most major chemical elements in the core decline after 1900 (Fig. 3). The exception is calcium which increases during this period. We interpret this increase in calcium as the precipitation of calcium carbonate from a eutrophic water column as a result of high uptake of carbon dioxide by algae. The accumulation of calcium carbonate seems to dilute other minerals in the core.

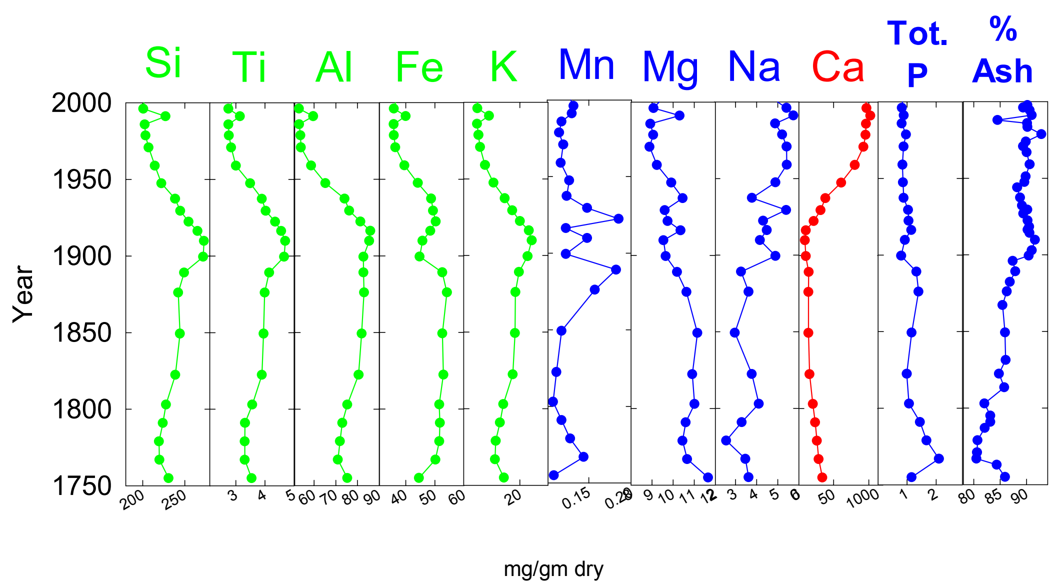

Figure 4: Major elements in core H5

Tin, cadmium, lead, strontium and zinc all increase dramatically after 1947 (Fig. 5). In particular lead concentrations increase from about 16 mg/gm dry weight to 195 mg/gm dry. Likewise zinc concentrations increase from 120 mg/gm to 2260 mg/gm. Similar increases have been noted in locations where there is significant pollution from industrial processes (von Gunten et al. 1997).

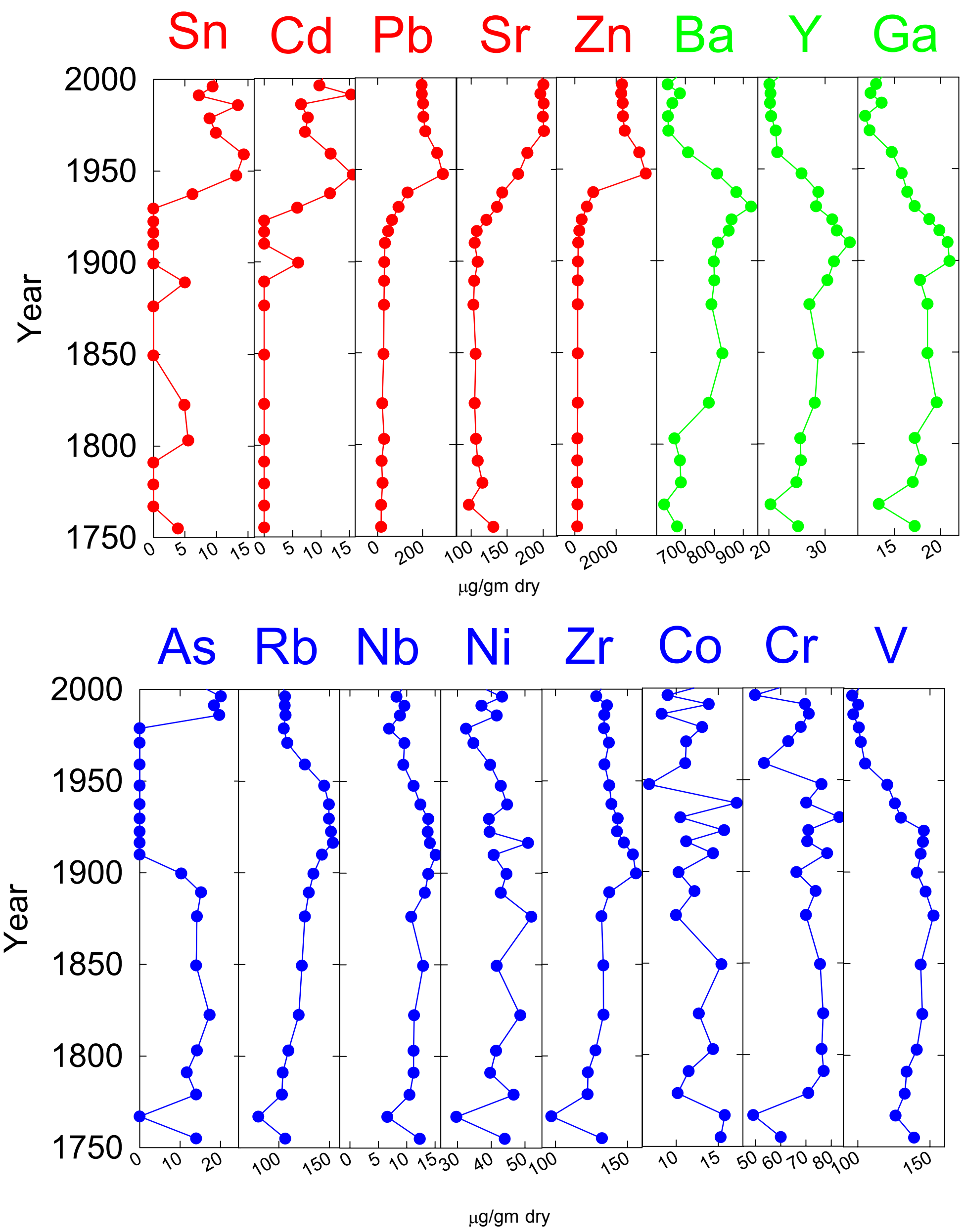

Figure 5: Trace and Heavy metals in Horseshoe Lake core 5

Statistical Analysis

Principal Components Analysis was applied to the data from core 3 (Fig. 6). Our goal was to summarize the widely varying chemical data-sets from the core in a manner that would reveal differences among core levels. The factor scores from the principal components analysis clearly reveal three separate core regions. The bottom of the core (1750 to 1890) has low concentrations of calcium, tin, lead, and zinc. The middle portion of the core (1890 to 1947) has high concentrations of silica, titanium, aluminum, iron and potassium, but low concentrations of calcium. The top of the core (from 1947 to the present) represents the period of maximum contamination by heavy metals. Lead, tin, cadmium and zinc have high concentrations. The changes in the factor scores in the principal components analysis correspond to the changes in land use in the watershed. They imply that the colonization of the site by pioneer farmers had little impact on the lake and the environment of the American Bottoms. The industrialization of the late 19th century changed the lake by increasing the input of chemical elements that are associated with erosion and siltation. Finally, the recent development of heavy industry in the lake watershed since the late 1940's has resulted in increased contamination with heavy metals.

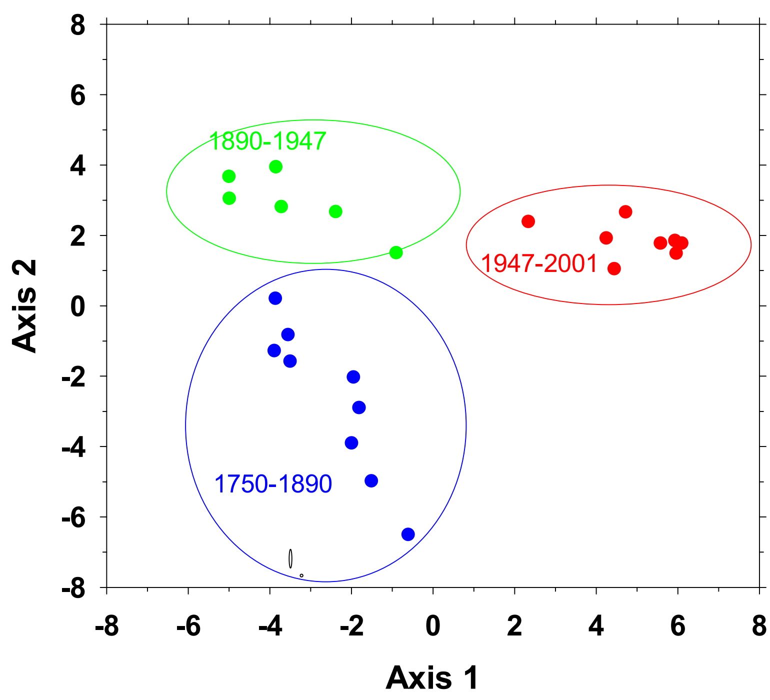

Figure 6: Principal Components Analysis of the chemical data from Horseshoe Lake Core 5. Blue markers represent samples from the lower part of the core (1750 to 1890). Green markers represent samples from the middle part of the core (1890-1947). Red markers represent samples from the top of the core (1947 - 2001)

Discussion

The sediment of Horseshoe Lake clearly shows a history of environmental pollution. Changes in stable isotopes indicate the beginning of contamination by sewage and the resultant increase in primary production at the lake. A result of this eutrophication of the lake was an increase in the precipitation of calcium carbonate - a natural consequence of high primary production in hard-water lakes.

The most recent changes in the lake sediment indicate increased inputs of heavy metals especially lead. We are not certain of the source of this contamination. It may be a result of operations at the NL Industries lead smelter. During the next year we will be taking more cores from sites near to the NL Industries site. We will also analyze the lead isotopes present in the sediment. It is possible to use the isotopic signature of the lead to determine its source. We hope to analyze the surface sediment of the lake to determine if the distribution pattern of metals and stable isotopes might indicate the source of contamination.

Non-Technical Summary

We took sediment cores from Horseshoe Lake, an oxbow lake in the American Bottoms across the Mississippi River from St. Louis, Missouri. Our goal was to reconstruct the history of contamination of the local groundwater by using the record of stable isotopes and heavy metals in the sediment. Our preliminary results show a contamination of the lake by human sewage starting in the beginning of the 20th century. In 1947 the sediment core shows an almost 10-fold increase in heavy metals concentrations. In particular lead and cadmium increase after that time. Although we are not yet certain of the source of this contamination, we suspect that it is from a lead smelter in Granite City. The smelter site has been remediated under the CERCLA (Superfund) starting in 1983. There is no evidence yet of a decline in heavy metal contamination in the lake sediment.

Impact of the Research

Our work shows that Horseshoe Lake contains an historical record of poor hazardous waste management in the American Bottoms. The sedimentary record of the lake documents increasing pollution of the local surface- and ground-water supplies. There is no evidence of reduced contamination of the lake as a result of superfund clean-up in the recent past. Elevated concentrations of heavy metals remain in the sediment even after contamination has ceased. The story of Horseshoe Lake is an object lesson for other pollution sites because it shows that environmental contamination may not be very reversible.

Publications

None yet, but we expect to publish our results in the near future.

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