

A Method for Determining Suspended-Sediment and Trace-Metals Transpiration in the Clark Fork River, Western Montana

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Abstract

Suspended sediments are thought to be an important transport mechanism for toxic trace metals that have been identified in the Clark Fork. Hydrologic data from a network of water-quality stations combined with data simulation will be used to calculate suspended-sediment and trace-metals transport. An ultimate goal of such an investigation might be the development of a predictive model.

Introduction

Previous and current studies within the Clark Fork River drainage of western Montana (fig. 1) have documented the existence of toxic trace metals that have been released to the riverine system from mines and associated metals-extraction processes in headwaters areas. Investigations to date have focused on such problems as source areas, chemical sinks and effects on biota and ultimate fate of the metals. Although commonly studied independently, these problems are linked by the movement of the constituents through the Clark Fork system. Until conclusive studies have documented the transport mechanisms and quantified trace-metals movement, solutions to many of the trace-metals problems may be elusive. The methods described herein provide a means for determining the transport of suspended sediment and trace metals in the Clark Fork.

The Role of Sediment in the Trace-Metals Transport

Historically, many of the analyses for trace metals were performed on filtered samples and, thus, only the concentration of the dissolved phase was determined. Studies on such rivers as the Amazon and Yukon, as described by Gibbs (1), have indicated that the dissolved phase commonly accounts for a small fraction of all the trace metals in transport. In most aquatic systems, the suspended sediment has a trace-metals concentration that is much greater than the concentration dissolved in the water column. Therefore, an assessment of trace-metals transport in a riverine system needs to consider the fraction carried in suspension as well as the dissolved fraction.

Although suspended sediment as a whole can be examined as a transport mechanism for trace metals, additional insight can be gained from a knowledge of the particle-size distribution. The most significant factor controlling sediment capacity for retaining trace metals is grain size, according to Jenne and others (4). The correlation between decreasing grain size and increasing trace-metals concentrations is significant. This correlation is a result of factors, both physical and chemical, that most notably are related to the large surface area per unit weight of fine particles (such as clays) compared to larger particles. According to Horowitz (2) the increase commonly is more than a hundredfold.

A recent view of the role of clays as metals concentrators implies that clays function as substrates for the precipitation and flocculation of organic matter and secondary minerals such as hydrous iron and manganese oxides. Those secondary minerals, in turn, become substrates for the accumulation of trace metals rather than the clays themselves, according to Jenne (3). There is some debate whether accumulation takes place by organics and secondary minerals or whether there is direct physical and

chemical interaction with the clays. However, there is general agreement that the largest concentrations of metals are present with the clays and that the following clay minerals have a decreasing order of association with trace metals: (1) montmorillonite; (2) vermiculite; and (3) illite, chlorite and kaolinite.

Investigators recognize that sediments in suspension and fine sediments present in bed material readily revert from one medium to the other in response to stream flow dynamics. Accordingly, analytical techniques that measure trace-metals concentrations from sediment, either in suspension or in bed material need to be the same. The use of similar analytical techniques would lend compatibility to a variety of independent studies being undertaken throughout the Clark Fork basin. Recent analytical techniques developed by Horowitz (2) provide for direct measurement of trace metals from suspended sediment after extraction of sediment from the water-sediment mixture. The technique uses a traditional approach in analyses of trace metals from bottom sediments.

Measurement of Sediment and Trace-Metals Transport

A strategy has been devised to quantify the transport of trace metals in the Clark Fork, based on the association between sediment and trace metals in stream environments. The strategy involves establishing a monitoring program in which the actual transport of suspended sediment will be measured. The transport of trace metals will be accomplished through a combination of direct measurements and indirect estimates based on correlations between selected measurements. Hydrologic data will be collected from a network of fixed stations on the Clark Fork mainstem and at the mouths of major tributaries. Cost constraints require that the Clark Fork study be divided into specific stream reaches and that data be collected one reach at a time from the headwaters to the mouth. The logical first reach is from the confluence of Silver Bow and Warm Springs Creeks to the Turah Bridge, just upstream from Milltown Reservoir.

Suspended-sediment stations have been established on the Clark Fork at Deer Lodge and Turah (fig. 1). Sampling at these two sites will enable the direct measurement of suspended-sediment loads into and out of the most up- stream reach of the Clark Fork. Continuous-record stream flow data from existing gages will allow quantification of sediment on an annual basis as well as for short-term hydrologic events.

Sampling frequencies for these two mainstem sediment stations will range from two to three times a week during low flow to daily throughout medium to seasonal high flows. During periods of storm runoff, sampling will be intensified further to better characterize suspended-sediment concentrations during rising, peak, and falling stages of stream flow. Methods of sampling are described in the report of the U. S. Government (5).

The most accurate way to quantify trace-metals transport at the mainstem stations would be to independently analyze each set of sediment samples for the desired trace metals (arsenic, cadmium, copper, iron, lead, manganese, and zinc) and to couple these concentrations with daily stream flow to determine loads. Laboratory costs, however, make this approach prohibitive. Therefore, samples for trace metals will be collected less frequently and trace-metals loads will be determined by indirect methods.

Depth-integrated, cross-sectional samples analyzed for dissolved and suspended trace metals will be collected at the two mainstem sites and near the mouths of four major tributaries: Little Blackfoot River,

Flint Creek, Rock Creek, and Blackfoot River (fig. 1). Samples from the mainstem sites will be collected approximately bimonthly during low flows (August through March) and twice monthly during high flows (April through July). Samples from the tributary stations will be collected primarily during high flow periods. Attempts also will be made to collect additional samples at all mainstem and tributary sites during periods of runoff from major storms. Information from the tributaries can be used to determine if significant amounts of trace metals are being contributed to the mainstem. Should preliminary sampling show that they are, sampling at the tributaries can be increased for better quantification.

Based on the analyses of the suspended trace-metals samples, regression equations will be developed to determine the relation between concentrations of individual trace metals and sediment concentrations. Complete particle- size distribution of the sediment from the selected samples also will be determined to evaluate the size class of sediments to which the metals are commonly associated. More meaningful regression equations may be established using correlations with a specific size class of sediment. Metals concentrations for periods between selected samples will be estimated by simulating trace-metals concentrations using the regression equations and sediment concentrations from the daily sediment samples. The simulated trace-metals concentrations and stream flow data can be used to calculate trace-metals loads.

The dissolved fraction of trace-metals loads will also be calculated indirectly by relating measured metals concentrations to corresponding stream- flow discharges at the time of sampling and thus developing regression equations. The gaps in concentration data can then be simulated from the regression equations and mean daily stream flow discharges. After simulating the concentrations, loads can be calculated in the same manner as for the suspended trace metals.

Throughout many river systems and in selected reaches of most others, the movement of bed material along the bottom may account for a measurable amount of the total sediment load. These bottom sediments are not accounted for by standard suspended-sediment sampling techniques. Therefore, trace metals that may be transported with bed sediments are not included in load calculations.

To limit as much as possible the bed load fraction of sediment, cross-sections for sampling have been located at sites where stream velocities are sufficient to retain fine sediments in suspension, thus keeping the streambed relatively free of fine material.

Predictive Methods

Because aquatic systems are dynamic, the foregoing program will only describe existing conditions during the data-collection phase. An ultimate goal might be the development of a predictive model that would be used to determine sediment and metals transport in the Clark Fork in response to various hydrologic conditions and plans of resource management.

A primary requirement for developing such a model would be the acquisition of a database consisting of temporal and spatial input from the network stations. Any viable model needs to address both physical and chemical aspects of trace-metals transport. Several physical transport models presently exist. Research efforts may be required to identify chemical transformations that occur in the various stream environments of the Clark Fork. A general approach, then, might be to modify an existing physical transport model for application to the Clark Fork system and to incorporate the necessary chemical elements that are identified.

Literature Cited

1. Gibbs, R. 1977. Transport phases of transition metals in the Amazon and Yukon Rivers. U.S. Geological Society of America Bulletin 88: 829-843.
2. Horowitz, A. 1984. A primer on trace metal-sediment chemistry. Geological Survey Open-File Report 84-709.
3. Jenne, E. 1976. Trace metals sorption by sediments and soils-sites and processes. In: Chappell, W.; and Peterson, K., eds., Symposium on molybdenum. Marcel-Dekker, New York. 2: 425-553.
4. Jenne, E.; Kennedy, V.; Burchard, J.; and Ball, J. 1980. Sediment collection and processing for selective extraction and for total metals analysis. In: Baker, R., Contaminants and sediments. Ann Arbor Science Publishers, Ann Arbor, MI. 2: 169-189.
5. U.S. Government (agencies of). 1978. National handbook of recommended methods for water-data acquisition, Chapter 3- Sediment.

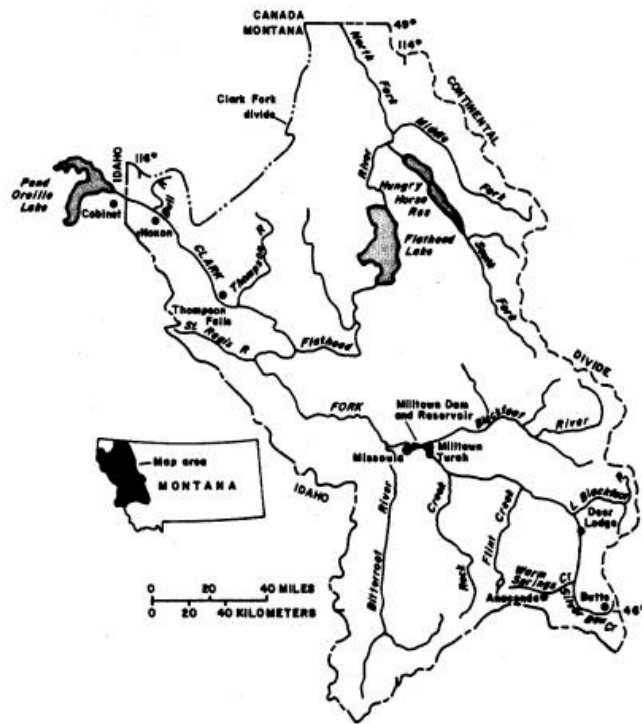


Figure 1. Clark Fork drainage of western Montana.