

Effect of gold-mine related operations on the physical and chemical characteristics of sediment texture

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Abstract

The gold-mining process is unique as it not only has effects on the water quality and related environmental impacts, but also on the physical characteristics of the sediment in the area of the mining activities. The texture of the sediment in streams inside the mining area differs from the sediment texture in streams outside the mining area. The impact on the sediment in the gold-mining area is not uniform but area specific. It became clear that certain sections of the gold-mine environment might be common to most gold mines in South Africa. Internal recirculated waterways/streams which are not diverted into wetland areas, and also do not discharge to the outside boundaries of the mine, normally have fine graded sediment particles ($\leq 63 \mu\text{m}$). These streams are also close to the actual gold-mining activities. On the other hand, the sediment texture of the streams which do discharge to the outside boundaries of the gold mine and which, in some instances, also flow through wetland areas, is coarser closer to the mining activities than the texture some distance away. This suggests a deposition of coarse sand in the area closest to the mining activities and that fine sand, as a result of a fairly strong stream velocity, is transported through the wetland areas to the outside boundaries of the mine. Wetland vegetation (e.g. *Typha latifolia* and *Phragmites australis*) may also act as a physical barrier to the transport of coarse sand. Each section has its own characteristics regarding the metal concentrations in the various grain fractions; however, certain similarities exist. In the sections represented by streams, all metals, except iron, have the highest concentration in the size fractions $< 63 \mu\text{m}$. The lowest concentrations were found in the coarser fractions, which can possibly be ascribed to the presence of quartz in these fractions.

Introduction

The use of heavy metals for industrial purposes and their subsequent occurrence as trace contaminants have resulted in increased metal loading in the aquatic environment. Natural processes may also contribute some trace elements to the environment but the majority originate from mining and industrial processing (Horowitz and Elrick, 1992). The most concentrated pool of trace metals in aquatic ecosystems occurs in suspended and bed sediments. A wide variety of characteristics affect the way metals bind to sediments, and thus the potential biological availability of sediment-bound metals (Luoma and Davis, 1983). Firstly, concentrations of sediment-bound metals are strongly dependent on the surface area of sedimentary particles. Thus, fine-grained sediments bind metals more efficiently than do coarse-grained, sandy sediments. Secondly, several sedimentary components are involved in metal binding of which the most important include iron and manganese hydroxides, organic material and, to a lesser extent, clays and carbonates (US Geological Survey, 1982).

In the past, information on particle size has been used primarily in the study of sediment transport, and the commonly used methods for determination of particle-size distributions are presumably geared to that purpose (Lai, 1982). During the milling process gold-bearing ore is crushed and sediment of various grain sizes is released, to be deposited either on rock-

dumps or slimes dams (Funke, 1990). As a result of normal surface run-off from these man-made structures, the soil in the main effluent streams from gold mines consists of bottom sediments, the texture of which differs from other normal, non-mine streams (Funke, 1990).

The purpose of this paper is two-fold: firstly, to identify different sediment textures which can be related to different areas at a gold mine and, secondly to determine the extent to which the sediment texture can play a role in determining the sediment-trace element concentrations in the surface water within the boundaries of a gold mine's property in South Africa.

Material and methods

For a period of 15 months (March 1992 to July 1993) a study at two South African gold mines situated in the Witwatersrand and Transvaal geological sequences was conducted where core bottom-sediment samples were collected on a monthly basis. A total of 23 localities were sampled on a monthly basis and each of these was, in some way, in direct contact with effluent water pumped from underground or run-off water from both slimes dams and rock-dumps. The sediment samples were collected from 9 similar sections at both mines, selected according to habitat and geographical features, in the streams and impoundments affected by mining activities and outside the mine property. Sediment samples were collected with a stainless steel core sampler to a maximum depth of 30 cm. The core samples were placed in glass beakers and oven-dried at 60°C for 24 h. This drying temperature ensures that no chemical or textural characteristics of clay particles that may occur in the sediment will be altered. From each sediment sample a 80 g subsample was placed in an Endecott mechanical sieve with a sieve rack consisting of sieves at

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