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Concentration levels of potentially harmful elements from gold mining in Lake Victoria Region, Kenya: Environmental and health implications

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ABSTRACT

Second only to the agricultural industry, mining is often considered to be the largest source of pollution in most mineral-rich countries. Mine wastes and tailings commonly generate large concentrations of effluents containing high levels of potentially harmful elements (PHEs) which migrate into various compartments of the ecosystem with obvious undesirable health consequences. In this study, the concentrations of As Cd, Hg and Pb were determined on samples of soil, stream water and fish (*Rastrineobola argentea*) collected from the Migori Gold Belt (MGB) in Kenya. Maximum total concentrations of Cd, Pb, As and Hg recorded in some samples in the study area were found to be far above the World Health Organization (WHO) and the Food and Agriculture Organisation (FAO) maximum allowable concentrations (MAC), respectively, including some from the control site, 150 km away from the MGB. The calculated geometric means showed that the PHE concentrations were significantly above MAC levels ($p < 0.05$) in the three sample types.

The PHE concentrations were as follows: in water, Cd: 1.5–10.5 $\mu g\ l^{-1}$, Pb: 0.4–13.1 $\mu g\ l^{-1}$, As: 0.06–23.0 $\mu g\ l^{-1}$, and Hg: 0.36–52.1 $\mu g\ l^{-1}$; in soil, Cd: 4.5–570 mg kg^{-1}, Pb: 5.9–619 mg kg^{-1}, As: 0.08–86.0 mg kg^{-1}, and Hg: 0.51–1830 mg kg^{-1}; and in fish; Cd, 1.9–10.1 mg kg^{-1}, Pb: 2.0–13.1 mg kg^{-1}, As: 0.02–1.92 mg kg^{-1}, and Hg: 0.26–355 mg kg^{-1}.

Concentrations of PHEs were much higher in the area affected by gold mining than at point S4 which was sampled for comparison and was 70 km away from the gold mining area. We conclude that gold mining and other human activities in the MGB have led to the release of toxic levels of Cd, Pb, As and Hg, which may lead to serious environmental health consequences in humans. We recommend that the public health sector addresses in a timely fashion, these sources of contamination (gold mining and associated human activities), in order to obviate impending health problems.

1. Introduction

The distribution of potentially harmful elements (PHEs) in the geological environment is governed by many geogenic factors including the chemical composition of bedrock, intensity of bedrock weathering, chemistry of the regolith, soil type and the intrinsic chemical properties of the PHEs themselves. Today, as a result of rapid urbanisation in some mining centres, the role of anthropogenic factors has also become important in controlling the distribution of PHEs (Davies and Mundalamo, 2010; Khalifi and Hamza-Chaffai, 2010). Human activities may drastically alter dynamics in the biochemical and geochemical cycles of PHEs in the environment. The study of PHEs in the environment is a subject of increasing interest to ecologists, biologists, farmers and environmentalists.

An assessment of the environmental risks due to soil pollution by PHEs, is of particular importance in studying the fecundity of agricultural areas (Orisakwe et al., 2012; Oyoo-Okoth et al., 2013). Potentially harmful elements can persist in soils for a very long time (regardless of their associated land use), and may enter the food chain in significantly elevated amounts under certain circumstances (Christensen and Moller, 1975; Davies, 2013; Khairiah et al., 2009; Liu et al., 2005; Oyoo-Okoth et al., 2013; Uwah et al., 2009).

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In Kenya, mining is known to provide a variety of socio-economic benefits, but it is also regarded as the single largest source of pollution after agriculture. Gold mining is a process that generates large volumes of mine waste, tailings and effluents, with considerable amounts of PHEs (AMAP/UNEP, 2013; Ogola et al., 2002; Telmer and Stapper, 2012; Telmer and Veiga, 2009). This causes a great deal of environmental and human health concerns, which may include land degradation, habitat alteration, and both soil and water contamination (Mol and Ouboter, 2004; Veiga and Baker, 2004; Webb et al., 2004). There is evidence that the concentrations of PHEs continue to increase in Lake Victoria (Oyoo-Okoth et al., 2013). In this paper, we examine the distribution of As, Cd, Hg, and Pb in soil, stream water and fish in gold mining areas of the Lake Victoria basin in Kenya (Fig. 1), and review the implications of elevated levels of PHE's to human health when these elements are incorporated into the food chain, and propose tangible measures for obviating any health risks.

2. Study area

2.1. General information

The study area of Macalder is within the Migori Gold Belt (MGB) and covers part of the Lake Victoria Basin. This region is the centre of many human activities, including agriculture, fishing and gold mining. Lake

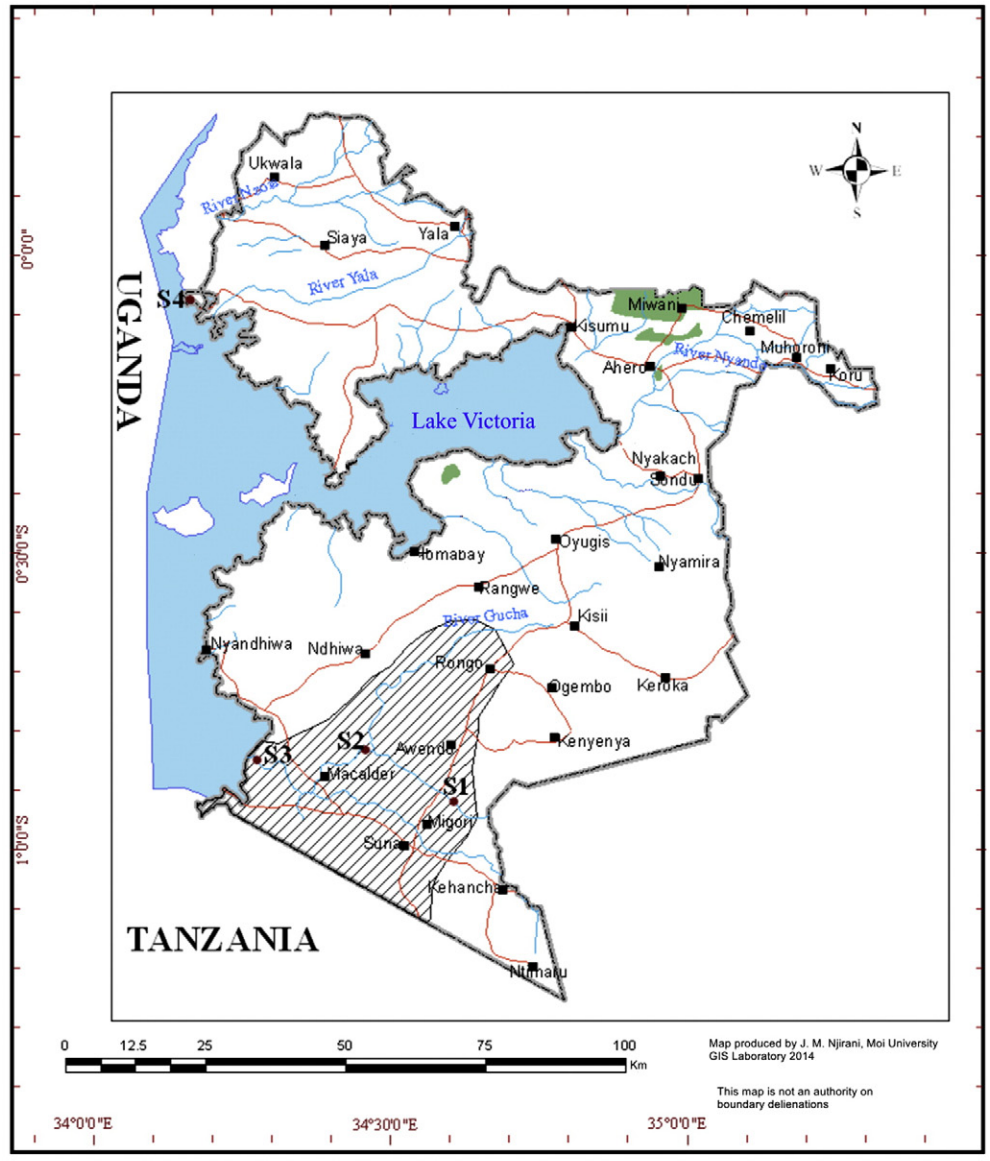

Fig. 1. Map of the study area showing the four sampling sites (S1, S2, S3 and S4) along Gucha, Migori and Nzoia Rivers.