ECOLOGICAL AND HUMAN HEALTH RISK ASSESSMENT IN A GOLD-MINING DISTRICT OF NICARAGUA

Picado Pavón. Francisco[1,2]

[1] CIRA-UNAN, Apartado Postal 4598, Managua, Nicaragua; francisco.picado@ekol.lu.se.

[2] Department of Ecology Lund University, 22362 Lund, Sweden

ABSTRACT

Risk assessment is the process by which the probability and magnitude of adverse effects is evaluated as a result of exposure to one or more stress factors. Risk assessment can be used to predict, compare, and manage environmental risk, and provide a quantitative basis for preventive or remedial action under uncertainty. This work attempts to integrate ecological, and human health risk assessments to mercury emissions in a small scale gold mining area. The relative risk of damages to stream biota, and local inhabitants, was calculated using hazard quotient (HQ) approaches. When comparing our results a relatively higher risk from Hg emission is found for human health followed by aquatic organisms.

INTRODUCTION

More than one century the Sucio River located in central Nicaragua has received wastes containing mercury, lead, and cyanide from the gold mining industry in Santo Domingo and La Libertad, but also from artisanal activity (Belt, 1874). Mercury concentrations in the Sucio River water are almost one order of magnitude higher than the permissible concentrations for human consumption (WHO, 1996), and the sediments are contaminated as far as 50 km downstream from the La Estrella plant (André et al., 1997). Metallic mercury is lost to the atmosphere through evaporation when gold particles in crushed ores are amalgamated with mercury, and when amalgam is burned. People from gold mining areas are repeatedly exposed to both inorganic and organic mercury. This pollution results in human exposure. For instance one of the exposure routes is through consumption of mercury-contaminated fish.

Here, the relative risk of mercury, released by gold mining in the Río Sucio basin, to stream biota and local inhabitants is calculated through a hazard quotients approaches. Those are essentially applicable to large as well as small areas, they assume that toxicity can be obtained relative to a reference substance, and they allow the comparison of risk from exposure to different stress factors (Zhang et al., 2001). The quotients are not measures of risk in a statistical sense, but when they are above 1.0, there are concerns about potential risks of adverse effects.

The aim of this work was to estimate and compare the risk in stream biota and local inhabitants.

Area description

Río Sucio is a small river historically impacted by the gold mining activity in the St Domingo district, where miners still use mercury in the gold enrichment process. The river basin area is about 28 km^2 and it is located in the central mountain region of Nicaragua (figure 1). The regimen of precipitation

is almost constant in the dry season and it varies in the rainy season. The mean precipitation is about 2400 mm yr-1 (Mendoza, 2006).

The annual temperature varies from 23 to 27 °C. The river flow increases downstream due to water inflow from several small streams and probably groundwater discharge. The amalgamation process discharges into the river approximately 21 kg of mercury per month (André et al., 1997).

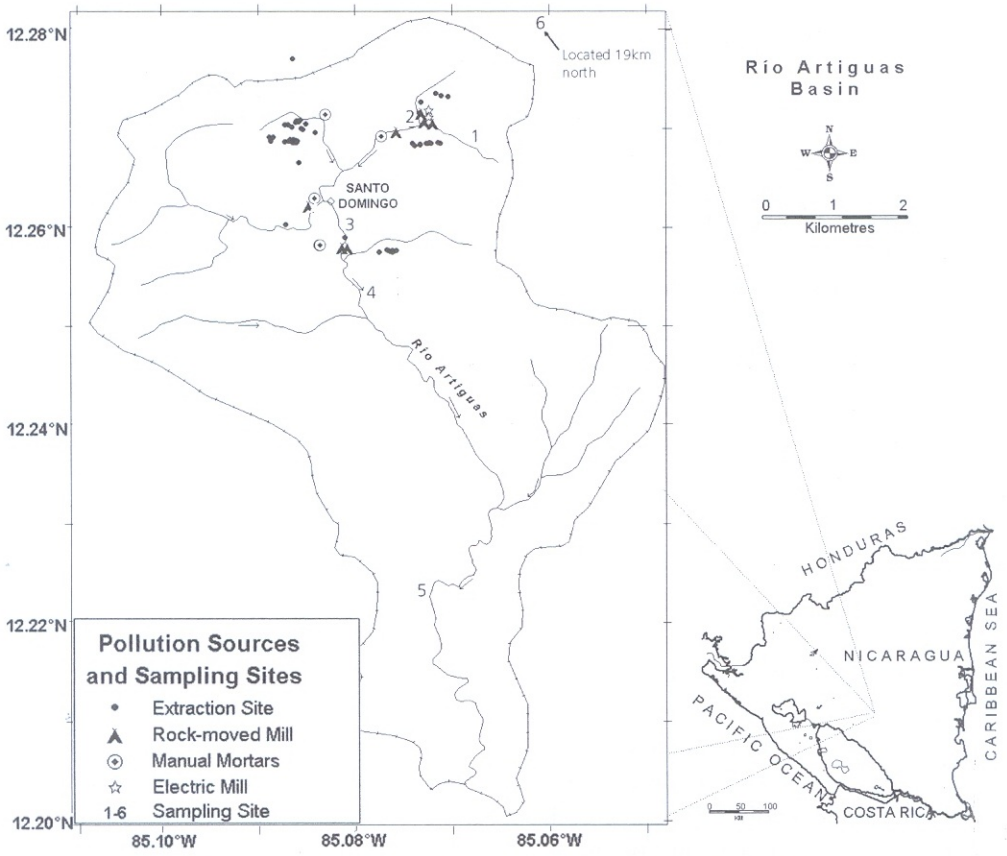

Figure 1. sampling sites and pollution sources in the Río Sucio basin

METHODOLOGY

Ecological and human health risk assessment:

Ecological and human health risk analyses were addressed through HQs. Observed mercury concentrations in river samples and data available in the literature were used to estimate the concentrations in benthic organisms. These concentrations were extrapolated to the fish and from the fish to human blood. The estimated concentrations of Hg in fish and in human blood were compared with toxicological criteria (LC_{50}) (EPA, 2006) and benchmark dose levels (BMDLs) (Rice, 2004) respectively.

The calculations of the HQs were conducted through Monte Carlo Simulations (MCS) with 10000 iterations using the @RISK 3.5.1 program (Palisade Inc.). The BestFit 2.0d (Palisade Inc.) was used to fit the probability distribution function (PDF) to the data. The PDFs were tested by the Chi-square method and p-value associated to them.

Frequency distributions of both the total dissolved Hg in the water (C_w) and the total Hg in the sediment (C_s) concentrations were obtained from hourly water sampling at six sites along the Sucio river and from the top 5 cm of sediment cores from the same sites (fig. 1). Mercury was determined by inductively coupled plasma mass spectroscopy (ICP-MS; Perkin Elmer, ELAN-6000). The detection limit of the instrument was 0.03 ng of total Hg/ml. It was calibrated against a single ^{202}Hg standard (1 ng/ml).

The human risk assessment is focused on general population of St Domingo. Mercury dietary intake, which is assumed the main route of exposure, as well as the concentration of mercury in human blood, are derived from MCS and compared with reference exposure limits. The estimations were also compared to the total blood mercury concentrations (S. Cuadra, unpublished data), which were analyzed by cold vapour atomic fluorescence spectrometry.

RESULTS

The highest mercury concentrations in both water (0.42-0.63 µg/l) and sediment (1.14-11.07 µg/g ww) samples were noted at the sampling sites 2, 3, 4, 5 located downstream to the gold-Hg amalgamation sites (fig. 1).

Normal probability distributions were best (chi-square ranking) describing the observations of Hg concentrations in river water, except in two cases when few data were available, uniform distributions were assumed. Because few data were available, the concentrations of total mercury in sediment are also assumed to have uniform distribution. Exponential probability distributions describe the BCF and LC_{50} data.

The mercury concentrations in fish were relatively low (0.04-0.35 µg/kg) when these are estimated from the waterborne mercury, but higher when these are calculated based on the mercury concentrations that where estimated in benthic organisms.

The probability that the Hg concentrations in river invertebrates would exceed the lethal concentrations varies from 0 to 7%. These concentrations were estimated based on the Hg concentrations observed in the sediments. High probabilities were found at those sites located near the gold amalgamation sites.

The probability that the Hg concentrations estimated in fish would exceed the LC_{50} varies from 0 to 10%. However, when mercury in the water is considered as unique mercury source to fish, the probability is 0% at all sampling sites.

The risk that human health would be adversely affected by the consumption of mercury contaminated fish was about 0.2%.

When both the estimated and the observed Hg concentrations in human blood are compared, it is found that they are in the same order of magnitude and the probability of exceeding the benchmark values are about 10 and 30% respectively .

CONCLUSIONS

The implicit risk for river biota and humans was addressed by the probabilistic exposure-effect relationship, which resulted to be relatively high. Therefore, in the case of aquatic organisms, fatal or sublethal effects on sensitive species (in the Río Sucio) are expected due to long term of waterborne mercury exposure.

Despite, both the reported and estimated mercury concentrations in fish are relatively high; the risk for humans related to consumption of fish can be considered negligible. However, when the mercury concentrations in blood are assumed to be due to the consumption of Hg-contaminated fish and compared with the exposure reference limits, the risk becomes higher.

Although, effects on human health due to mercury exposure are not studied yet in the St Domingo inhabitants, the probabilistic exposure-effect relationship, which was addressed on variability and uncertainties, indicates that the risk need to be quantified, and all possible sources of mercury exposure to be considered.

Despite, the worst scenario was assessed for aquatic organisms; the probabilities of exceeding the hazard endpoints were relatively high by themselves, suggesting that the aquatic life is been adversely affected by the pollution. However, when they are compared with those for human, these become the lowest.

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Cuadra S. UNAN-Managua, Apartado Postal 663, Managua, Nicaragua.

Department of Occupational and Environmental Medicine, 221 85 Lund , Sweden.