Bull. Environ. Contam. Toxicol. (2004) 73:506–510

DOI: 10.1007/s00128-004-0458-1

Bulletin of Environmental Contamination and Toxicology

Mercury Concentrations in the Community Drinking Water Sources Around Manado City, North Sulawesi, Indonesia

D. Limbong,[1,2,3] J. Kumampung,[1] I. F. M. Rumengan,[2] T. Arai,[3] N. Miyazaki[3]

[1] Faculty of Fisheries and Marine Science, Sam Ratulangi University, Manado 95115, Indonesia
[2] Yayasan Bina Cipta Aquatech, JL, Krida IX, Malalayang I Timur, Manado 95115, Indonesia
[3] International Coastal Research Center, Ocean Research Institute, The University of Tokyo, 2-106-1 Akahama, Otsuchi, Iwate 028-1102, Japan

Received: 14 November 2003/Accepted: 14 July 2004

Economic expansion through production activity causes various types of pollution that threaten the environment and human health. A relatively large gold deposit has been discovered in North Sulawesi Province in Indonesia. Large amounts of metallic mercury are used to amalgamate the fine gold particles of broken ore at the artisanal gold mining processing plants in the Talawaan Watershed. The metallic mercury used in amalgamation processing and leaked into the watercourses will be scattered irregularly throughout the river system. As pointed by Carmouze et al. (2001), because it is a high-density liquid, mercury tends to rapidly settle and enters into the anoxic layer of sediment. On the other hand, mercury also tends to be absorbed into clayey materials and organic substances, thus raising the possibility of its transport and dispersal particularly in rivers having strong flow. The accumulated mercury in sediment has reached acute levels according to WHO (1989) in some places within the Talawaan Watershed, and has led to increasing levels of mercury in biological samples (Limbong et al. 2003).

The location of the gold mining area is very close to Manado City, the capital of North Sulawesi Province. The artisanal gold processing plants are dispersed far from the mining area due to a lack of clear local government regulations regarding their construction in any given area. The drinking water supply for the city is provided mostly by a public drinking water company. The company's water source installations are scattered around the city. Three of those installations are located within the Talawaan Watershed (Fig. 1); one of them is a deep well and the other two use surface streams. This fact elevates concern over the potential for mercury contamination of those water sources.

Little information is available regarding the effects of mercury pollution on water supply installations. The company does perform quality control tests on the input water, but not on a regular basis, and mercury has not been included in the test parameters. Accordingly, the present study examined the potential mercury contamination of those drinking water sources that may affect as many as five thousand people in Manado City.

Correspondence to: T. Arai

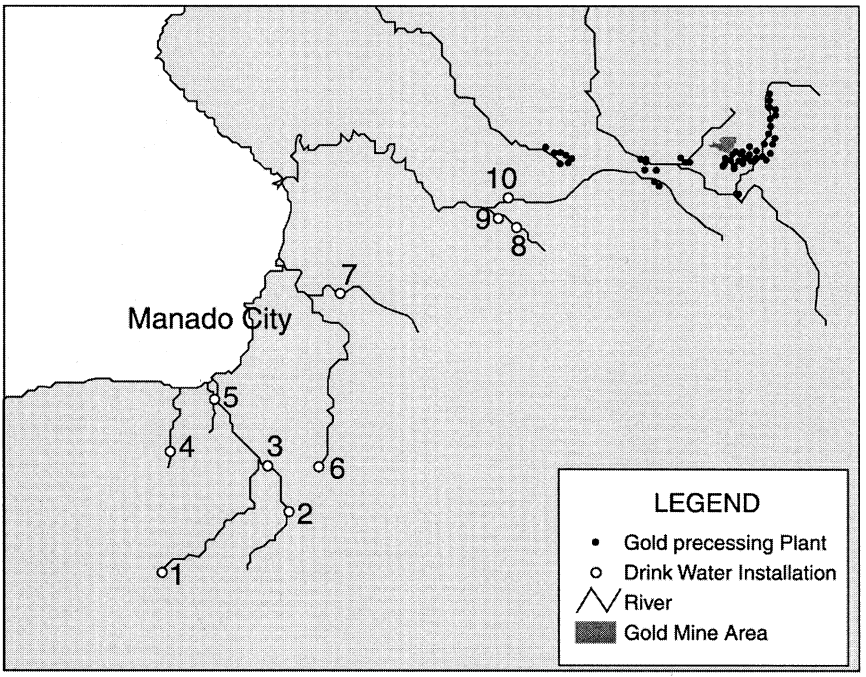

Figure 1. Sampling sites in the Talawaan Watershed, North Sulawesi Island, Indonesia.

MATERIALS AND METHODS

Water samples were collected from ten public drinking water installations around Manado City. Based on their water sources, these installations can be categorized into water springs, deep wells, and surface streams. Locations of the installations are mapped in Figure 1. In installation number 5, the water comes from two sources; a surface stream and a water spring. Therefore, in total 11 water samples were collected (3 from water springs, 1 from a deep well, and 7 from surface streams).

Sample collections were conducted twice; the first was in November 6 – 9, 2000 and the last in May 4 – 12, 2001. Water samples were taken from the upper layer (about 10 cm from surface) of the water source pool. A pre-labeled 500 ml plastic bottle sample was used. About 2 ml of HNO_3 was added into the sample bottle before its cap was inserted in order to stabilize the mercury content, because trace mercury in water samples is relatively stable at lower pH (Anonymous 2001). In the year 2001, water sample collection was also conducted for the measurement of suspended solids. All water samples were keep in a cool box to maintain low temperature (5 – 10^{o} C) until mercury analysis. At the same time as the sample collection, direct measurement of water temperature and pH were performed at every sampling site using a water thermometer and pH test kit.

In the present study, the determination of total mercury was made by means of sensitive and reliable methods employed during the course of mercury analysis in laboratory. The analytical procedures for mercury in water samples followed those described by Limbong et al. (2003). This procedure involves cold-oxidation of the acidified sample using bromine monochloride before reduction of the sample by means of stannous chloride. The mercury vapor released is then measured in a modified cold vapor atomic absorption spectrophotometer (CVAAS). The detection limit for water samples was 10^{-2} µg/l. Quality control was monitored for all chemical analyses. Instrument calibration was verified by analyzing certified calibration solutions during each instrumental run. These external reference standards were generally within 94 to 101 % of the nominal concentrations. All of the sample spikes for water were within 93 to 106 % recovery. Preparation blanks were prepared to detect potential contamination during the digestion procedure. These preparation blanks generally measured below the detection limit.

Total suspended solids are a water parameter that measures the portion of solid matter trapped by a filter. Suspended solids include anything from silt and plankton, to industrial waste and sewage. A 500 ml water sample from each sampling site was filtered through a preweighed 0.45 µm filter paper by using a filtration apparatus equipped with an aspirator. The residue retained on the filter was dried at 70° C for about 6 hours to a constant weight. The increase in the weight of the filter represents the total suspended solid.

RESULTS AND DISCUSSION

The results of the analyses of the water samples are given in Table 1. For a better interpretation, values of total suspended solids and total mercury contents in water samples are plotted in Figure 2 according to location. The fluctuation of values of

Table 1. Total mercury concentration and other parameters of water samples from source pools of public drinking water installations.

No	Site Name	Type	Year 2000			Year 2001			
			°C	pH	Hg(µg/l)	°C	pH	Hg(µg/l)	SS (10^{-5} g/ml)
1	Kumahukur	Water spring	25	6	0.13	25	6	0.05	0.00
2	Lotta	Surface stream	27	7	NA	28	7	0.06	1.75
3	Pancuran IX	Surface stream	29	6	0.10	28	7	0.05	1.25
4	Sea	Surface stream	28	6	0.09	28	6	0.09	1.25
5a	Malalayang	Water spring	27	6	0.09	27	6	0.05	0.25
5b	Malalayang	Surface stream	28	6	0.10	27	6	0.05	1.00
6	Koka	Water spring	26	6	0.13	27	6	0.05	0.25
7	Paal II	Surface stream	28	6	0.07	28	7	0.11	3.50
8	Perumnas	Surface stream	28	7	0.10	28	6	0.56	1.25
9	Paniki	Deep well	36	7	0.10	35	7	0.09	1.50
10	Kilu	Surface stream	27	6	0.05	28	6	0.92	1.75

NA = Under Repair; SS = Suspended solid.

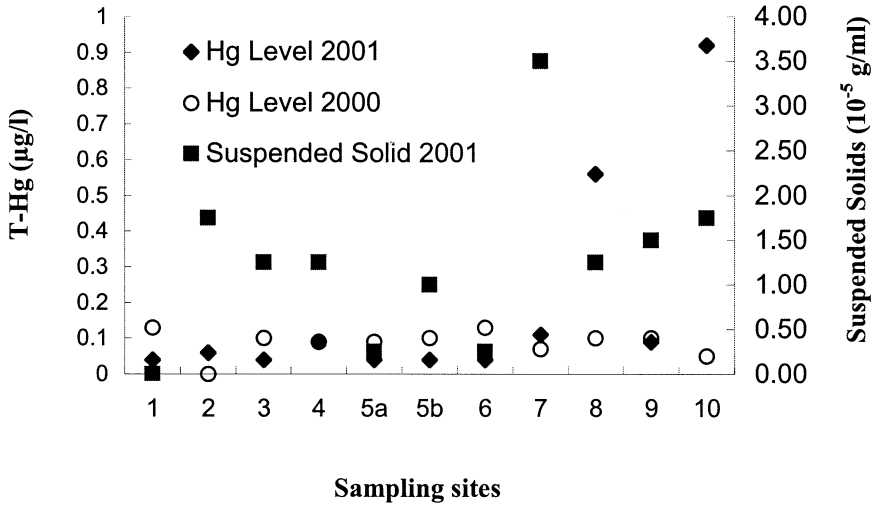

Figure 2. Total mercury concentration and total suspended solid in water samples from source pools of public drinking water installations. Sampling sites are indicated in Figure 1.

total suspended solids in water samples provides an insight that the sites use surface stream are generally deal with problem of high level suspended solids. The results of total mercury content for the year 2000 are generally low, indicating that there was no mercury contamination in any sampling site. All values are far below the standard level for drinking water of 1 µg/l as established by the World Health Organization and adopted by the Indonesian Government (WHO, 1989). The values indicate the background levels of mercury in the study area have a mean value of 0.096 µg/l.

In the year 2001, all values fluctuated around the expected background level except for the values of sites 8 and 10 (Fig. 2). Although the values of these two sites are still below the standard level for ensuring health, the drastic increase of mercury levels within a six month interval may signal significant problems to come. With a limited data, it is still difficult to predict with confidence the potential future increase of mercury levels in the two sites, but these divergences suggest the potential impact of gold mining activities to the water system within the Talawaan Watershed because these two sites are located within the watershed and use surface streams as their water source. The explanation for the low mercury level at another installation located in the watershed (site 9 in Fig. 1) would have to do with its water source, which comes from a deep well. This installation also has a unique characteristic in which its water temperature fluctuates in the range 35 - 36 ^{o} C, indicating that the water comes from a hot spring.

These results signal the urgent need for more thorough and regular quality control tests regarding mercury levels especially in the drinking water installations in the Talawaan Watershed. Special attention should consequently be given to this very active mining area, and solutions must be provided as soon as possible in order to avoid an epidemic resulting from the continuing discharge of mercury from the artisan gold mining activities.

Acknowledgments. We thank the US AID Natural Resource Management Program in North Sulawesi that sponsored a monitoring program in the study area implemented by a local nongovernmental organization, Yayasan Bina Cipta Aquatech with the help of staff members of Sam Ratulangi University.

REFERENCES

Anonymous (2001) Preventive measures against environmental mercury pollution and its health effects. Japan Public Health Assoc Tokyo, Japan, p 112.

Carmouze J.P., Lucotte M., and Boudou A. 2001. Mercury in the Amazon. Importance of human and environment health hazards. IRD editions. Institut De Recherche Pour Le Developpement. Paris, France, p 40.

Limbong, D., J. Kumampung, J. Rimper, T. Arai, and N. Miyazaki. 2003. Emission and environmental implications of mercury from artisanal gold mining in North Sulawesi, Indonesia. Sci Total Environ 302: 227-236.

WHO. 1989. Mercury – Environmental Aspects. Environ. Health Crit. 89, International Program on Chemical Safety, WHO, Geneva.

WHO. 1990. Methylmercury Environ Health Crit 101, International Program on Chemical Safety, WHO, Geneva.