

## Mercury pollution from artisanal gold mines

## A hazard to human health?

by Don Appleton, Keyworth

ercury is a potent toxin that can have adverse effects on physiological and neurological processes, of which the degeneration of the central nervous system is the most pronounced. The human and ecotoxicological hazards associated with mercury contamination of terrestrial and aquatic systems have been recognised since the 1950s following the Minamata poisoning episode in Japan, which arose from human exposure to methylmercury in fish. Whereas most mercury contamination previously resulted from hydrocarbon combustion and manufacturing processes in industrialised regions, small-scale gold producers now release significant quantities of mercury into the environment as a result of its use for amalgamation. The amalgamation process requires the use of about two tonnes of mercury for each tonne of gold recovered. Small-scale gold miners



Temporal changes in the amount of mercury dissolved in river water downstream of the Diwalwal gold mining area demonstrate the importance of continuous or frequent monitoring of water quality. (The red line indicates the level above which water is not suitable for drinking or for aquatic organisms used for human consumption, such as shellfish).

produce thousands of tonnes of gold each year so environmental contamination by mercury release is a major concern in many countries. The discovery in 1983 of several alluvial and bedrock gold occurrences by artisanal miners on the island of Mindanao, in the Philippines, resulted in a series of largely uncontrolled gold rushes and the development of several mining communities, of which the most important is Diwalwal. At its peak in the mid-1980s the Diwalwal community numbered over 100 000 although the population has declined progressively to its present level of approximately 40 000 inhabitants. Much of the mineral processing activity during the 1980s involved amalgamation of gold ore with mercury in ball and rod mills, and it is estimated that about 50 tonnes of mercury were discharged into the local river system each year. Whereas most of the gold is now extracted with cyanide, amalgamation with mercury is still used to process up to a quarter of the gold ore.

The lack of appropriate technology and proper health and safety procedures in the informal gold mining sector in Mindanao has led to severe environmental degradation and mercury pollution of river systems as well as of paddy fields irrigated with mercury-polluted river water. The 50% decline in rice yields from the 1980s to the 1990s, together with unexplained skin disease in the local population and the death of a significant number of oxen have been attributed to mercury and cyanide pollution from the Diwalwal mining centre.

The United Nations Industrial **Development Organisation (UNIDO)** has been working to address these issues and to reduce mercury emissions from small-scale mining centres in the Philippines. In 1999, as part of this programme, it commissioned a multidisciplinary team to determine the extent and consequences of mercury and related chemical pollution of the Naboc river system downstream of Diwalwal. The team comprised an environmental geochemist from the BGS, a NERC ecotoxicologist, and medical toxicologists from the Institute of Forensic Medicine in Munich, working in conjunction with local scientists and community workers.

Environmental surveys carried out by the BGS in collaboration with the Philippine Mines and Geosciences Bureau showed





Mercury contaminated, silt-laden water in an irrigation canal and adjacent rice paddy field, Naboc Irrigation Scheme, island of Mindanao, the Philippines.

that the Naboc river is characterised by very high levels of mercury dissolved in the water. Mercury in solution was 40 to nearly 3000 times higher than the maximum recommended concentrations for drinking-water and waters from which shellfish are taken for human consumption. Mercury is also extremely high in the sediment suspended in the water and deposited on the river bottom, being 10 to 150 times higher than the level currently accepted as being hazardous to aquatic life. Whereas the local farmers and their families obtain all their drinking-water from wells, which do not appear to be contaminated with mercury, some people eat mercury-contaminated fish and mussels from the Naboc River and this may pose a risk to their health. Marked temporal variations in the amount of dissolved mercury in the river water reflect changes in the amount of mercury-contaminated, mineral processing waste being discharged into the river from the gold processing plants (see graph, left). This illustrates the importance of continuous or frequent monitoring of water quality in rivers polluted by mining activities if transient pollution events are to be detected.

The survey also indicated serious pollution of paddy-fields, where the siltladen, mercury-contaminated water from the River Naboc has been used over the last decade to irrigate rice. Multiple influxes of irrigation water have deposited silt containing up to 90 milligrams of mercury per kilogram of sediment and this is ploughed into the soil profile twice a year. Mercury in soil samples taken from rice paddy-fields averages 24, and reaches a maximum of 96, milligrams of mercury per kilogram. Whereas there appear to be no Philippine national guideline values for mercury in agricultural soils, the maximum permissible concentration of mercury in UK agricultural soils (one milligram per kilogram) is clearly exceeded in many of the soil samples. Much lower mercury concentrations within the range expected for uncontaminated soils (less than 0.3 milligrams of mercury per kilogram) characterise the non-irrigated soils on which corn is cultivated.

Studies by the NERC ecotoxicologist, Dr Jason Weeks, indicated that little mercury is taken up into the rice grain consumed by 600 local farmers and their families. Adsorption of mercury on to secondary iron hydroxides and organic matter in the soil, together with the formation of mercury sulphide in the oxygen-deficient layers of the waterlogged soil profile, appears to render mercury relatively unavailable to the rice plants. It is fortunate for the local farmers and their families that natural soil processes seem to prevent the adsorption of mercury by the rice, thereby reducing the health risk from the contaminated soils. This is confirmed by the fact that the concentrations of mercury in the blood, urine, and hair of the people eating rice from the mercury-contaminated rice fields are no greater than in people living in a 'control' area not affected by gold mining activities. The main mercury health hazard is undoubtedly to people in the mining settlement of Diwalwal who are directly exposed to mercury used for gold amalgamation. Toxicological studies indicate that their hair and blood mercury levels are a cause for concern.



View of the Diwalwal gold mining centre on the island of Mindanao, Philippines.