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Effects on Tropical Fish of Soil Sediments from Kafue River, Zambia

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Kafue river, an important tributary of the Zambezi river is located in a highly exploited area in the Copperbelt region of northern Zambia. Mining and other industrial activities are highly concentrated in this part of the river. Copper and cobalt production is important especially at the city of Kitwe and in surrounding areas. Other minerals mined are zinc, lead and gold, although in small quantities. River sediments may serve as a trap for various anthropogenic pollutants including metals and some metals i.e. copper and cobalt are present in high concentration in feral fish caught in the Copperbelt area (Mwase et al masters thesis, 1984).

In reproduction, early life stages are sensitive steps in the animal life cycle. Many studies examining sensitivities of early life stages have revealed that larval stages are the most sensitive to copper (Hazel and Meith, 1970; McKim 1977; Rice et al., 1980)

In the present study, sediment from environmentally different localities of the Kafue river were toxicologically evaluated by a microtoxicity bioassay and by different tests systems of three species of tropical fish.

MATERIALS AND METHODS

Three different localities along Kafue river were selected for this study, extending from Kitwe in the north, Itezhi-tezhi in the central, to Kafue town in the south (Fig. 1). Sediment samples were collected using Ekman sediment sampler and stored in plastic containers at 4 degrees centigrade. In order to determine the toxicity of sediments collected along the Kafue river, three different tests were conducted.

The microtoxicity (MICROTOX TM) test was used to measure the acute toxicity of the different sediment samples i.e. Kafue river near Kitwe, Lake itezhitezhi, and near Kafue town. The method is based on the light generating process of the bacteria, which is related to their metabolic activity. The EC-50 value, i.e. the concentration that causes 50% light reduction was determined and the measured effect recalculated into toxic units (TU).

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Figure 1. Map of Zambia showing the Kafue river and the localities where samples were taken.

Adult zebra fish were either placed in special spawning aquaria for production of eggs to experiment 2:1 or placed in aquaria with different sediments for experiment 2:2.

In experiment 2:1 newly fertilized zebrafish eggs (n=20) were incubated in petri-dishes containing 50 ml of artificial fresh water and 0, 0.1, 0.3, 0.5 or 1.0 grams of sediment from Kafue river near Kitwe and Kafue town. Hatching frequency, median hatching time and median survival time were measured.

In experiment 2:2, adult zebrafish were exposed to 2, 20 or 200 grams of sediment collected in Kafue river near Kitwe, Lake Itezhi-tezhi and Kafue town. Each aquaria contained 5 lifers of artificial fresh water and 10 zebra fish. The artificial fresh water was prepared by salts added to tap water which had been treated by reversed osmosis ion exchange according to the Swedish standard ss028162. The water temperature was 25 degrees centigrade; the fish were fed with mosquito larvae daily and given a photo period of 12 hours light: 12 hours dark. The water was aerated and oxygen, pH, nitrite and ammonium levels were measured regularly according to OECD guidelines throughout the exposure period. The experiment was terminated after 28 days when the concentration of copper was measured in water and in surviving fish.

Adult *Tilapia rendalli* and *Tilapia mariae* were kept in separate aquarium, one male and one female together. Each aquarium contained approximately 150 litres of artificial fresh water at temperature of 26 degrees centigrade. The fish were fed mosquito larvae and since both *T. redalli* and *T. mariae* are substrate spawners, pieces of clay-pots were placed on the bottom of each aquarium.

Table 1. Toxicity response in bacteria exposed to sediments from three different localities along the Kafue river

Place of Sampling	Toxic Units (TU)
Kitwe town	13300
Itezhi-tezhi dam	145
Kafue town	1200

One day post-hatched yolk-sac fry (n=20) of *T rendalli* and *T. mariae* were transferred to glass crystalline jars containing 2.0 grams of sediment, from Kitwe, Itezhi-tezhi and Kafue town, and 40 ml artificial fresh water was added to each jar. The water was aerated and oxygen, pH, nitrite and ammonium levels were measured regularly throughout the exposure period of 28 days. The fry were fed *Artemia salina* daily. Mortalities were recorded during the exposure period of 28 days. Livers and gills of dead and surviving fish were processed accordingly for light microscopy (LM) and electron microscopy (EM).

RESULTS AND DISCUSSION

The microtoxicity test on the sediments was conducted in order to evaluate the toxicity of sediments from different areas of the Kafue river. The sediment collected near Kitwe was approximately 90-fold and 10-fold more toxic than those from Lake Itezhi-tezhi and Kafue town, respectively (Table 1). Newly fertilized zebra fish eggs had a prolonged median hatching time of 11.8 days after exposure to sediments collected near the city of Kitwe compared with the median hatching time of 4.2 days in the group exposed to the same amount of sediments collected near Kafue town. The prolonged hatching time may be as a result of effects of various metals or other components contained in the sediments, which may retard the normal maturation processes. Similarly, exposure of juvenile Tilapia species to sediments from the three sampling points caused high mortalities as compared with the control group (Figure 2). Sediments collected near Kitwe caused particularly dramatic mortalities and by the thirteenth day no fish survived.

Many studies examining sensitivities of early life stages have revealed that larval stages are the most sensitive to copper (Hazel and Meith, 1970; McKim 1977; Rice et al., 1980). Other studies have linked development of biological and pathological reactions to the high levels of anthropogenic substances in the sediments. Pathological reactions have been described in the gills (Daust et al., 1984), the liver (Fantin et al., 1992; Khangarot et al., 1992), olfactory organ (Julliard et al., 1993) and reproductive organs (Wester, 1991) after exposure to copper of different

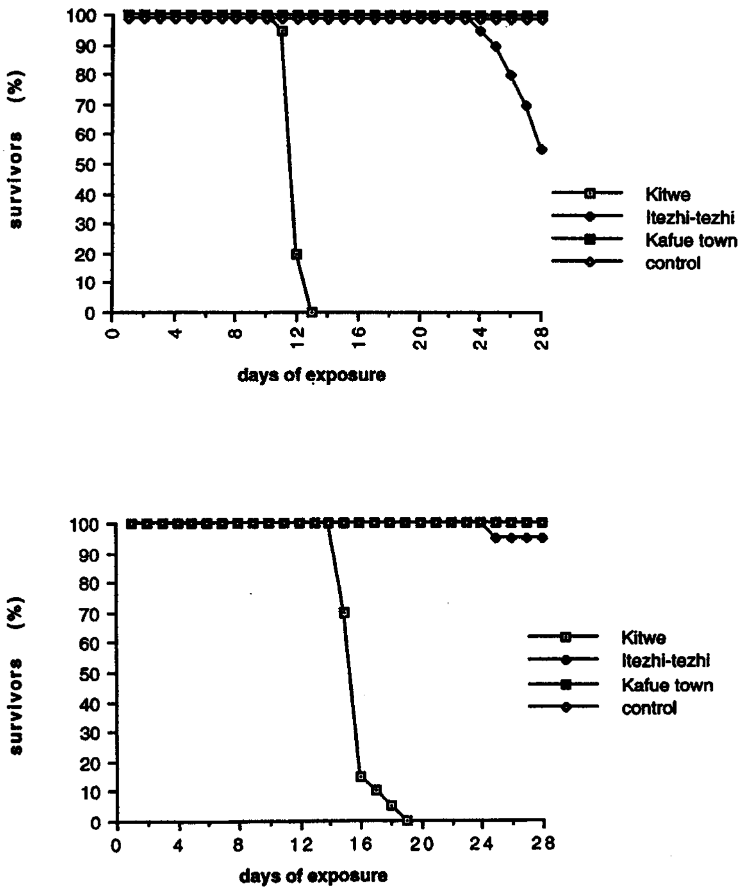

Figure 2. Survival rates of juvenile *T mariea* and *T rendalli* during exposure to sediments from different localities along the Kafue river.

species of fish. In the present study the pathological findings are consistent with those seen by other investigators. Hypertrophy and hyperplasia of the secondary lamellae epithelia (figure 3) resulted in an increase in the respiratory distance between the blood and the oxygen. The fusion of the adjacent secondary lamellae resulted in the reduction of the water flow over the gill epithelia. The increase in the number of chloride cells in the epithelia of secondary lamellae may be a reflection of a compensatory mechanism for ionic loss. Proliferation of the mucous cells may also be seen as a physical defensive mechanisms against the external stimuli. The pathological alterations singly or in combination caused an over all impairment in oxygen diffusion.

The liver is an important organ involved in metabolic processes and in detoxification of xenobiotics. In some situations, materials may accumulate in the liver to

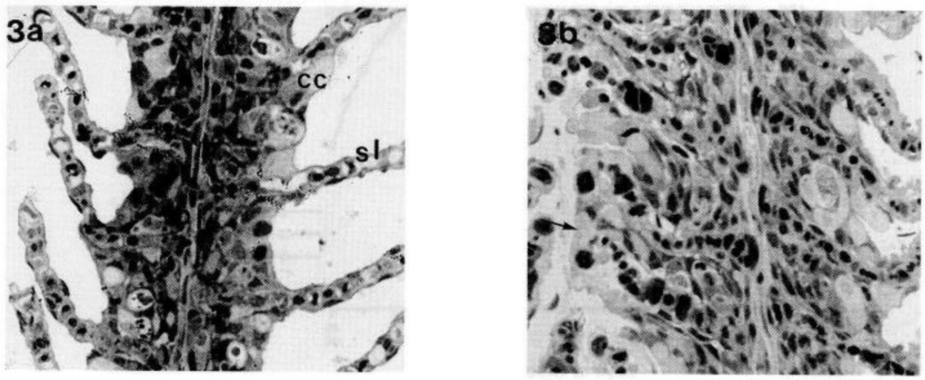

Figure 3. (a) 300x Morphology of gills from adult zebra fish kept in aquarium without sediment. (b) 400x Gill morphology of adult zebra fish exposed to sediments collected from Kafue river near the mining area. Note the increase in the cellularity and the resulting fusion of the adjacent secondary lamellae (arrow).

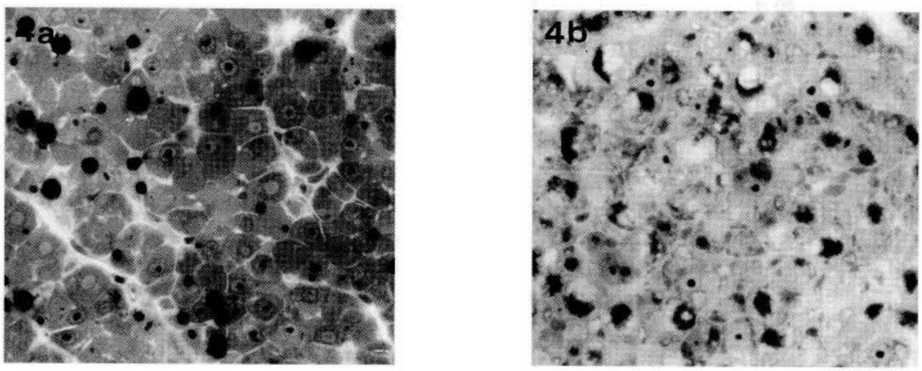

Figure 4 (a) Morphology of tilapia fry liver from aquarium without sediment. (b) hepatocytes from tilapia sacfry exposed to sediments collected near the mining area. Note the necroses of the cells.

toxic levels and cause pathological alterations. Diffusely distributed cytosolic copper is associated with cytotoxic changes including hepatocellular necrosis, fatty change and edema (Burton et al, 1989). High levels of copper inhibit enzymes involved in energy production and protein synthesis.

The higher mortalities and the associated pathological lesions in the gills and liver (Figure 4) indicates the magnitude of irreversible damage inflicted by metals and pollutants contained in the sediments.

The present investigation showed that the sediment collected upstream in Kafue river at Kitwe showed very high toxicity in all test systems. Advanced pathological lesions in the livers and gills were recorded and no early life stages survived during exposure to sediments collected in Kafue river near Kitwe. These observations may be explained and directly related to the contamination of sediments by the mining activities in the Copperbelt region.

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