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Mercury in Plants, Soil, and Water from a Caustic Chlorine Industry

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The use of elemental mercury in caustic-chlorine industries and subsequent discharge of waste on leaching to waterbodies, create widespread environmental problems (Rath et al. 1983). In addition to waterborne mercury, atmospheric emissions of mercury and its transport to biological systems, have received much attention of the environmental scientists. Works of Wallin (1976), Panigrahi & Misra (1978, 79) and Jernelov and Wallin (1973) pertaining to the studies of residual mercury level in water bodies, soil, vegetation around the chlor-alkali industries, and aquatic animals present near the discharge sites, added a lot to the galaxy of literature of environmental mercury pollution. Huckabee et al. (1983) reported an ecological survey of the distribution of mercury in vegetation in the vicinity of the mercury mine at Almaden, Spain and opined that study of mercury cycling and transport in the environment was most important due to the fact that mercury release to the environment was continuous, long term and effluents were from a restricted source. High residual level in plants around the industry (Wallin, 1976 and Huckabee et al. 1983) dragged our attention to survey the vegetation of the contaminated area and the residual mercury level in different plants, as the grazers of the area depend entirely on the vegetation of the contaminated area.

The present piece of work was designed to study the residual mercury level in the vegetation, and mercury concentration in the effluent and solid waste of a caustic-chlorine industry situated near Ganjam, Orissa, India (30 kms away from Berhampur). The industry is situated on the bank of the Rushikulya river estuary and discharges the effluent to the same estuary joining the Bay of Bengal (Fig. 1).

Mainly mercury is being discharged from the industry through the washings as effluent and sedimented mud

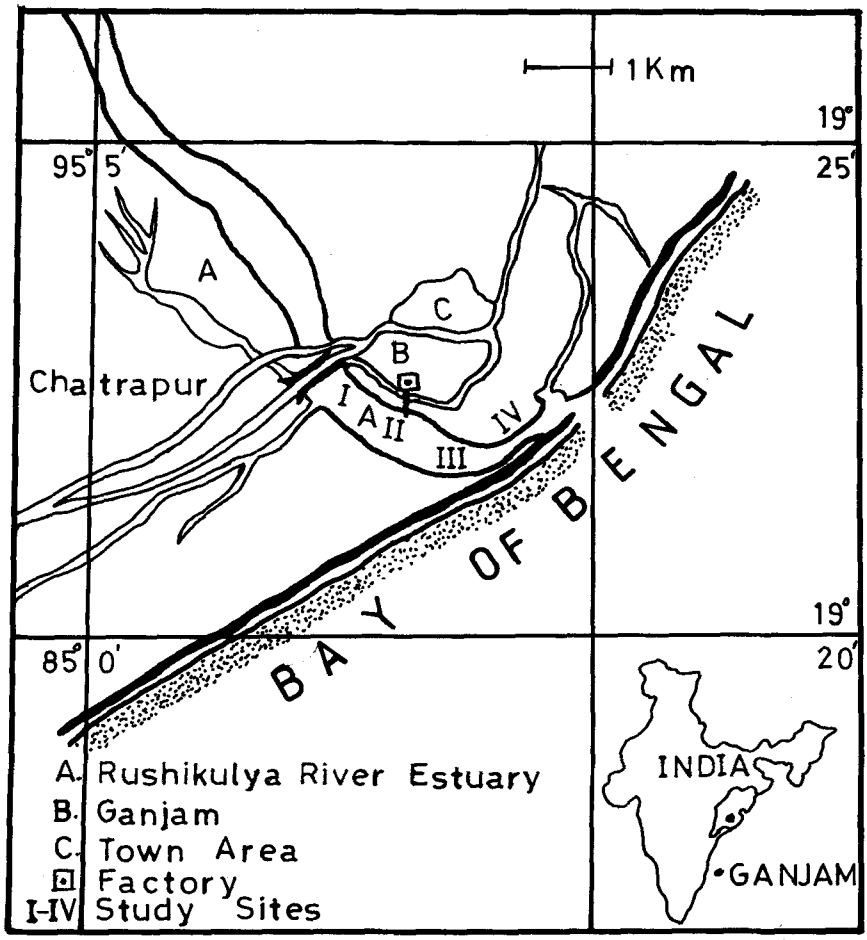

Figure.1. Location of ganjam area and study sites

inside the brine chamber as solid waste or brine mud which comes out along with the effluent. The brine mud gets deposited in the effluent channel which is being removed from time to time and dumped in the nearby field, thus being subjected to aerial dispersion after getting dried. In the rainy season, leached mercury from the solid waste enters into water bodies. In the Caustic-chlorine industries, the other sources of mercury discharge to the atmosphere is the ventilation air outlets from cell rooms and the hydrogen gas outlets (Wallin, 1976).

MATERIALS AND METHODS

Plants were collected within 3 kms radius from the industry. Samples were collected very close to the effluent channel

and also from the localities, where the solid wastes of the industry (brine mud from the effluent channel) were dumped. 45 different plants with different sample sizes were collected from the entire area for residual mercury analysis.

Fig.1 shows the location of the industry, effluent channel anddischarge sites. Basing on the localization of the place and areas contaminated, 5 areas were earmarked as study sites. Water and soil samples were collected periodically to analyse the mercury concentration level in each site.

All the samples were brought to the laboratory in sealed containers. All samples of plant tissue were washed thoroughly with distilled water twice, dried overnight at35^{o}C and ground to powder in a grinder. The samples were weighed in a single pan balance and digested in Bethge's apparatus with an acid mixture (1:3 conc.H_2SO_4 and conc. HNO_3). Residual mercury concentration measurements were made in a 'Mercury Analyser' (ECIL, MA5800A). Water and soil samples were also digested and analysed following the same procedure. Total mercury levels were expressed as mg/kg dry wt. in plant and soil samples and as mg/l in liquid samples.

All the data were statistically analysed (mean and standard deviation).

RESULTS AND DISCUSSION

The effluent of the industry showed the highest mercury concentration level (0.1756 $\pm$ 0.0027 mg/l) when compared to other sites (Table 1). Similarly, the soil (brine mud) of the effluent channel showed a strikingly high mercury content (596.67 $\pm$ 25.17 mg/kg dry wt.) when compared to other sites (Table 1). Site-I, being in the upstream; showed the presence of mercury at lower concentration. This may be due to high tides in the estuary, the water column swells and a thorough mixing of the effluent occurs throughout the estuary.

Table 2 shows the residual mercury level in different plant species. Higher amounts of mercury were recorded in plants collected from the effluent channel and solid waste area. With the increase in distance from the industry, the mercury level declines. Lippia nodiflora and Cyperus rotundus collected from the effluent channel area showed the highest residual mercury level, 40.17 $\pm$ 0.58 and 25.17 $\pm$ 1.26 mg of mercury per kg dry weight of the plant tissue,respectively. Jatropha gossypifolia & Justicia simplex collected around the industry accumulated mercury to the tune of 19.07 $\pm$ 0.06 & 13.83 $\pm$ 0.45 mg of mercury per kg dry wt.,

Table.1. Mercury concentration in soil and water samples collected from different sites.

Site	Concentration of mercury in mg/kg dry wt. (Soil)	Concentration of mercury in mg/l (Water)
I	00.42 ± 0.07*	0.0348 ± 0.0012
II	44.33 ± 1.15	0.1035 ± 0.0046
III	00.71 ± 0.07	0.0323 ± 0.0021
IV	00.46 ± 0.07	0.0311 ± 0.0021
V	596.67 ±25.17	0.1756 ± 0.0027

* Data mean of five samples with standard deviation.

Table. 2. Residual mercury level (mg/kg dry wt.) in plants

		Mercury level
Plants from the effluent channel		
Lippia nodiflora	(18)*	40.17 ± 0.58**
Cyperus rotundus	(17)	25.17 ± 1.26
Eragrostis ciliata	(17)	15.77 ± 0.51
Cynodon dactylon	(11)	14.83 ± 0.58
Ipomoea digitata	(14)	7.9 ± 0.26
Pandanus odoratissimus	(7)	3.57 ± 0.20
Plants around the solid waste deposit		
Jatropha gossypifolia	(10)	19.07 ± 0.06
Justicia simplex	(15)	13.83 ± 0.45
Calotropis procera	(12)	9.73 ± 0.32
Acalypha indica	(14)	5.33 ± 0.14
Amarantus spinosus	(18)	4.08 ± 0.25
Mimosa pudica	(17)	4.00 ± 0.47
Croton sparsiflorus	(25)	2.17 ± 0.14
Amarantus viridis	(11)	2.13 ± 0.13
Azadirachta indica	(17)	1.87 ± 0.06
Argemone mexicana	(21)	1.32 ± 0.19
Boerhaavia repens	(18)	1.23 ± 0.15
Plants from the nearby populated localities		
Amarantus spinosus	(18)	2.12 ± 0.32

Table 2 (contd.)

Solanum melongena	(8)	1.58 ± 0.12
Hibiscus sabdariffa	(7)	1.13 ± 0.12
Luffa cylindrica	(8)	0.90 ± 0.09
Zizyphus jujuba	(13)	0.82 ± 0.06
Vigna sinensis	(11)	0.82 ± 0.06
Azadirachta indica	(6)	0.76 ± 0.12
Ocimum basillicum	(8)	0.74 ± 0.11
Justicia simplex	(9)	0.71 ± 0.06
Phaseolus vulgaris	(5)	0.58 ± 0.14
Dolichos lablab	(8)	0.58 ± 0.07
Phaseolus mungo	(12)	0.58 ± 0.07
Acalypha indica	(8)	0.58 ± 0.18
Ephorbia prostrata	(10)	0.56 ± 0.15
Psidium guayava	(14)	0.54 ± 0.07
Momordica charantia	(5)	0.54 ± 0.07
Cucurbita maxima	(5)	0.42 ± 0.07
Oryza sativa	(9)	0.42 ± 0.07
Croton sparsiflorus	(12)	0.38 ± 0.15
Cynodon dactylon (from the other sites of the study)		
Site - I	(5)	2.02 ± 0.13
Site - II	(5)	11.67 ± 0.58
Site - III	(5)	4.67 ± 0.21
Site - IV	(5)	1.87 ± 0.13

*Value in parentheses indicates sample size
**Data presented, mean ± standard deviation

respectively. Plants collected from the populated localities showed lower residual mercury concentration; A. spinosus, Solanum melongena and Hibiscus sabdariffa showed 2.12 ± 0.32, 1.58 ± 0.12 and 1.13± 0.12 mg of mercury per kg dry wt. of the plant tissue, respectively.

Plants (Table 2) collected from contaminated area showed heavy accumulation of residual mercury. These plants may accumulate mercury by three routes of uptake; through the roots from the soil, through the stomata from the atmosphere and by the retention of particulate mercury, with atmospheric uptake predominating in the above ground

parts of herbaceous plants (Lindberg et al. 1979 and Huckabee et al. 1983). The increased mercury level recorded in plants near the industry strongly indicate an increasingly high deposition of mercury in the vicinity of the industry. Wallin (1976) reported the gradual decline of mercury concentration in plants with the increase in distance. Similar tendency was marked in this study even, confirming the idea that the origin of this deposition was only the Caustic-chlorine industry. Huckabee et al. (1983) reported higher levels of mercury in plants collected from the nearby places of the mine(mercury ore/smelter), when compared to the plants collected from a long distance.

Plants collected from the nearby localities also showed higher level of residual mercury. The grazers of that particular locality solely depends upon the grasses and other plants available in the nearby areas around the industry. It can pretty well be presumed that grazers might be accumulating higher levels of mercury in different tissues. Mercury compounds may be able to pass through a food chain without any change in chemical form (Smart and Lloyd, 1963). Mercury enters into the body of the terrestrial organisms from the mercury contaminated soil and atmosphere.

Neurological disorders caused by mercury and the secondary poisoning as demonstrated by Borg et al. (1975), Panigrahi and Misra (1980) and Panigrahi (1980) may have important ecological consequences. Mercury accumulation by the biota were probably at steady state in Ganjam area. Higher concentrations of mercury in the effluent channel (Table 1) and mud collected from the effluent channel (Table 1) and lower concentrations of mercury at the other sites studied (mostly due to dilution by the river and estuarine water) can well be correlated with the residual mercury level in plants (Table 2) and in animals (Panigrahi, 1980). Mercurial compounds are toxic to humans (as demonstrated in animals) and its occurence in fishes and plants (grazed by economically important grazers) is of more toxicological significance. Residual mercury level in organisms and its build up in the food chain is of more ecological significance.

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