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INHIBITION OF PRIMARY PRODUCTION AS INDUCED BY HEAVY METAL IONS ON PHYTOPLANKTON POPULATION OFF COCHIN

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ABSTRACT

The effect of five metals (Cd, Ni, Cr, Pb and Hg) at different concentrations below and above tolerance limits, in the primary productivity off Cochin was investigated. It was observed that cadmium, nickel, lead, chromium and mercury even at low concentrations were found inhibiting the primary productivity. Among the metals tested, nickel appeared to be the least toxic and mercury the most toxic in their inhibitory effect. It was evident that the synergistic effect of inhibition was more acute when the metals were present in combination than each metal individually.

INTRODUCTION

Phytoplankters are often regarded as indicators of toxic substances including metals in natural waters (Chiaudani and Vighi, 1978; Bringman and Kuhn, 1978; Whitton, 1970). While toxic effects of metals on uni-algal cultures have been well understood (Davies, 1978; Sorentio, 1979; Bottino *et al.*, 1978; Break *et al.*, 1980; Rai *et al.*, 1981), information on the effect of heavy metals on natural marine phytoplankton is scanty. The extrapolation of data obtained using unialgal cultures to evaluate the effects of metals on phytoplankton under controlled environmental conditions poses some practical difficulties. As these cultures would have got adapted to the nutrient rich media in which they are maintained they may no longer be true representatives of natural strains of the same organism. Besides, the presence of high concentrations of chelating substances in the media and the larger population of cells in the culture could have an influence on the toxic effects of the metals. In this paper we report the effect of five heavy metal ions (Cd^{++}, Ni^{++}, Cr^{++}, Pb^{++} and Hg^{++}) at different concentrations below and above the tolerance limits for industrial effluents into coastal areas recommended by the Indian Standards Institution (now known as Bureau of Indian Standards) as evidenced in the primary productivity of populations of phytoplankton off Cochin.

MATERIAL AND METHODS

The experiments were carried out using water samples from the inshore waters, 5 nautical miles off Cochin. Stock solutions of Cd, Ni, Pb, Cr and Hg (mg/ml) were prepared with double distilled water from the respective inorganic salts 135 mg of $HgCl_2$, 192 mg of CrO_3,160 mg of $Pb(NO_3)_2$, 163 mg of $CdCl_2$ and 446 mg of $NiSO_4 . 6H_2O$ by dissolving in 100ml of double distilled water to get mg/ml solution. 1 ml of this solution of mercury was diluted to 100 ml to get a working solution of 10 μg/ml solution. The concentrations of various heavy metals used in the study are given in Table 1.

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TABLE 1. *Concentrations of metals used*

Metals	Source	Concentrations used (in ppm)			
		C_1	C_2	C_3	C_4
Cd	$CdCl_2$	0.5	1.0	2.0	4.0
Ni	$NiSO_4.6H_2O$	1.0	5.0	5.0	8.0
Pb	$Pb(NO_3)_2$	0.25	0.5	1.0	2.0
Cr	CrO_3	0.5	1.0	2.0	4.0
Hg	$HgCl_2$	0.0025	0.005	0.0075	0.01

The experimental conditions are as listed below:

E-1 - Each of the five metals individually added at C1, C2, C3 and C4 concentrations to sea water.

E-2 - All metals in combination at C1, C2, C3, and C4 concentrations to the seawater.

E-3 - Combination of all metals at C4 concentration except one to the sea water such as

i) Cd+Ni+Pb+Cr (-Hg); ii) Cd+Ni+Pb+Hg (-Cr);iii)Cd+Ni+Hg+Cr(-PB);iv) Cd+Hg+Cr+Pb (-Ni) and v) Hg+Cr+Pb+Ni (-Cd)

E-4 - Each of the five metals individually at C4 concentrations to filtered sea water (0.45µ).

The desired concentration of each metal was pipetted out from the stock solution (usually 0.025 to 0. 8 ml) to the incubation bottles so as to contain a final volume of 100 ml of seawater. Addition of these solutions caused no significant change in pH. These bottles were incubated with 1 ml of 5 µCi of $NaH^{14}CO_3$ supplied by BARC, Bombay along with suitable controls. The bottles (light and dark) were incubated on the deck of the vessel in duplicate for 2 hrs and filtered through membrane filters (C. N. O. 45 µ, Sartorius). The primary productivity at different concentrations and various combinations of metals was measured with a liquid scintillation counter (LSS 20 ECIL) having an efficiency of 82% according to the method of Steemann Nielsen (1952).

Seawater filtered through a 0.45 µ filter paper was used to measure the blank productivity at similar conditions and the blank corrections were made.

RESULTS AND DISCUSSION

During the period of experimentation, the inshore waters off Cochin recorded dominant populations of *Rhizosolenia calcar-avis;* besides less dominant forms of *Biddulphia mobiliensis, Ceratium* sp. and *Asterionella japonica.* No attempt was made to quantify them except chlorophyll - *a* (Lorenzen, 1967) recorded during each set of experiments. Cholorophyll - *a* at the site showed an average of 4.005 mg/m^3 and the phaeophytins was at 2.670 mg/m^3. The blank productivity of filtered sea water (might be due to nano and pico plankton) in highest concentration of metals, in mg C. m^3. h^{-1}, was 0.120 for mercury, 0.099 for cadmium, 0.082 for nickel, 0.080 for chromium and 0.167 for lead. These values were deducted from the respective productivity values to obtain net values of phytoplankton production.

When applied individually, Cd, Ni, Pb, Cr and Hg had similar inhibition on primary productivity though in different magnitudes. Gradual increase in the concentration of each metals from C1 to C4 decreased the productivity although overall addition of any of these metals registered a considerable drop in primary productivity as measured by ^{14}C fixation rate (Fig. 1). Similar trend was observed when all metals in combination at a particular level was added to the *in situ* phytoplankton population (Fig. 1). However, inhibition is more acute synergistically than each metal present individually.

In comparison to mercury, cadmium

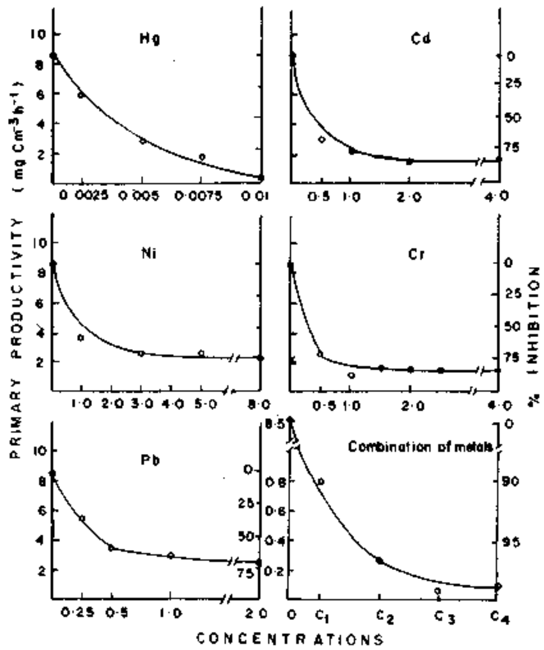

Fig. 1. Effect of heavy metals on the primary productivity.

In comparison to mercury, cadmium has proved to be relatively less toxic (Li, 1980; Kuiper, 1981). Hollibaugh *et al.* (1980) studied the response of Saanich Inlet population to 10 heavy metals. Of these mercury was the most toxic and influenced growth at low concentration. In the present study also mercury of all other metals had maximum inhibition (Fig. 1). When C_4 levels of all metals except one was added, the productivity values showed interesting results. When all metals were added in combination, the productivity obtained was 0.1 mg C. $m^{-3}.h^{-1}$. However all other metals except chromium or mercury was added, the productivity was increased to 0.26 and 0.33 mg C. m^{-3}. h^{-1} indicating acute toxic role of mercury and chromium (Table 2). When nickel was absent in the mixture of metals the productivity obtained was very low and accounted for 75% over the control (mixture of all metals). Based on the results obtained, it is known that these phytoplankton population have more affinity towards Ni ions than Hg and others. It is also evident that Ni ions act antagonistically to the influence of other four metals towards the primary productivity. It is presumed that nickel and other metals compete for the same binding sites, but nickel could bind easily with the cell membrane, and without allowing mercury or chromium to bind with cell as established by Break *et al.* (1976) and Cossa (1976). Thomas *et al.* (1980) concluded that growth inhibition upon Sannich Inlet population was due to copper and mercury than arsenic, cadmium, antimony, selenium and zinc. Quite parallel to this we also found mercury and chromium were more inhibitory to primary productivity of natural phytoplankton population off Cochin than lead, cadmium and nickel. It is likely that metal affinity to the natural phytoplankton populations off Cochin though inhibitory to productivity, can be drawn like Hg>Cr>Pb>Cd>Ni. Among the divalent transition metals, Bowen (1966) observed the following affinity rates for plankton: Zn>Pb>Cu>Mn>Co>Ni>Cd. The tolerance limits for industrial effluents let into a coastal water body as recommended by the Bureau of Indian Standards (I S, 1981) are shown to be 0.01 mg/l for Hg, 2 mg/l for Cd, 5 mg/l for Ni, 1 mg/l for Pb and 1 mg/l for chromium. Even at levels lower than these, it is apparent that primary productivity was affected considerably (Fig. 1).

It is evident that cadmium, nickel, lead, chromium and mercury even at the lowest (C1) concentrations are found inhibiting the primary productivity off Cochin waters. Nickel is the least toxic and mercury is the most toxic metal at either end of the scale inhibiting primary production. Moreover it is imperative that the presence of nickel can

TABLE 2. *Combined effect of all metals and all except one at C_4 concentrations on the primary productivity of phytoplankton populations off Cochin*

Metals	Primary production (mg C.m^{-3}.h^{-1})	% over the control
Mixture of all metals	0.10	100
Mixture without Hg	0.33	330
Mixture without Cr	0.26	260
Mixture without Pb	0.17	170
Mixture without Cd	0.16	160
Mixture without Ni	0.075	75

antagonize the total inhibition caused by mercury, chromium, lead and cadmium. It is also clear that synergistic effect of inhibition is more acute when the metals are present in combination than each metal individually.

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