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The Effects of Cadmium on Plankton Populations under Different Manurial Treatments

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ABSTRAK

Pemulihan populasi plankton daripada dedahan 1 mg/l kadmium telah dikaji dalam bioassai luar yang menggunakan baja tak organik, tahi lembu atau keringan tahi ayam sebagai nutrien tambahan. Walaupun 99% populasi plankton dimusnahkan serta merta selepas didedahkan kepada kadmium, kedua-dua ketumpatan zooplankton dan fitoplankton pulih semula pada kadar perlahan mulai hari ke-15 rawatan. Populasi zooplankton yang dirawat dalam tangki menjadi hampir sama berbanding dengan kawalan dalam masa 55 hari rawatan. Kerinan tahi ayam adalah lebih berkesan terhadap pemulihan populasi zooplankton. Walau bagaimanapun, populasi fitoplankton tidak pulih daripada tegangan (tegasan) kadmium dalam mana-mana rawatan nutrien walaupun selepas 55 hari. Kadmium terlarut berada dalam larutan sehingga hari ke-15, sementara pada rawatan yang lain ia berterusan hingga 25 hari.

ABSTRACT

Recovery of plankton populations from exposure to 1 mg/l of cadmium was studied in an outdoor bioassay using inorganic fertilizers, cow dung or poultry litter as nutrient additions. Although 99% of the plankton populations were eliminated immediately after exposure to cadmium, both zoo- and phytoplankton densities began reappearing at a slow rate from Day 15 of treatment. Zooplankton populations of the treated vats became numerically comparable to the control within 55 days of treatment. Poultry litter effected a quicker recovery of zooplankton populations. However, phytoplankton populations did not recover from the cadmium stress in any of the nutrient treatments even after 55 days. Dissolved cadmium was present in solution up to Day 15, while in the other treatments it persisted up to 25 days.

INTRODUCTION

Cadmium stress on the microfauna of aquatic ecosystems has been widely studied by the use of artificial enclosures (Marshall, 1978, 1979; Wong *et al.*, 1978; Marshall and Mellinger, 1980; Cairns *et al.*, 1986). Ecosystems having a low level of nutrients have been found to be more sensitive to cadmium compared with highly enriched water bodies (Hendrix *et al.*, 1981). Nutrient-rich organic and inorganic fertilizers are frequently used in pisciculture ponds to increase productivity of plankton. Little is known about the influence of these fertilizers on the stress effect of cadmium. In the present investigation, attempts were made to evaluate the efficacy of cow dung, poultry litter or a mixed inorganic fertilizer to expedite the recovery of plankton populations from the stress of cadmium.

MATERIALS AND METHODS

Experiments were conducted in 400 l outdoor culture tanks with an average depth of 0.5 m and a 3 cm thick soil layer at the bottom. The culture tanks were divided into three blocks, each block with four sets of tanks arranged as per RCB design (Gomez and Gomez, 1984). Tanks were filled with unchlorinated tap water and were treated with 200 kg/ha of lime 15 days prior to any manuring. Four tanks, at random, were manured with cow-dung (4000 kg/ha), four tanks were treated with poultry litter (2000 kg/ha) and four tanks with mixed inorganic fertilizers (200 kg/ha) containing urea, single super phosphate and murate of potash with an N:P:K ratio of 4:2:1. Each tank was then innoculated with an equal volume of a plankton population, which was grown in a separate tank for this purpose. Plankton populations were allowed to grow for one month and then each block was again manured as previously described. Counting of plankton densities commenced after the second installment of fertilizers and continued at intervals of 10 days, up to 80 days. On the 25th day, two tanks in each block were treated with 1 mg/l cadmium making duplicate sets of cadmium treatment and control for each manurial treatment.

For the estimation of cadmium in water, duplicate samples were collected from each tank at an interval of 5 days after the introduction of cadmium. After separation of the suspended matter from the water by filtration using Whatmann filter paper, the concentration of filterable cadmium was estimated using an atomic absorption spectrophotometer following the method of APHA (1975). Physico-chemical parameters of the water were also made at 10 day intervals during the entire period of investigation (APHA, 1975)

RESULTS AND DISCUSSION

None of the tanks showed any sign of algal bloom during the period of investigation. Single factor analysis of variance showed significant variation in total zooplankton and phytoplankton densities among the various manuring treatments with or without cadmium (Table 1). LSD test with mean zooplankton and phytoplankton densities in control groups showed that zooplankton grew better with poultry litter as compared with the other two months, while phytoplankton grew better with inorganic fertilizers compared with cow dung (Table 2). Mean phytoplankton densities in tanks with poultry litter and inorganic fertilizers were comparable to each other. Within 5 days of treatment almost 99% of the zooplankton and phytoplankton populations were eliminated from the treated waters (Figs. 1 & 2).

Phytoplankton populations began reappearing in the treated tanks within 15 days of treatment but at a slow rate. Although zooplankton densities in the treated and control tanks were comparable at the end of the experiment, phytoplankton densities in the treated tanks were less than those of the control treatments throughout the experiment, indicating continuation of cadmium stress. The initial recovery of zooplankton populations was better in tanks treated with poultry litter where the mean zooplankton densities in this group were higher

TABLE 1
Significance of variance of zooplankton and phytoplankton densities among several manuring groups

Test animal	d.f.	F	P
Zooplankton:			
Control	2, 14	4.48	<0.05
Treated	2, 10	8.13	<0.01
Phytoplankton:			
Control	2, 14	6.65	<0.01
Treated	2, 10	5.10	<0.05

TABLE 2
LSD of mean zooplankton and phytoplankton densities among various manuring groups (T_1 = Cow dung, T_2 = Poultry Litter and T_3 = Inorganic fertilizers)

Test organism	Source of variation	Control LSD	Control Mean diff.	Treated LSD	Treated Mean diff.
Zooplankton	T_1 vs T_2	5% = 62.67	63.5	5% = 23.15	29.17
	T_1 vs T_3	0.1% = 123.30	20.37	0.1% = 47.67	11.50
	T_2 vs T_3	1% = 86.98	83.87	1% = 32.93	40.67
Phytoplankton	T_1 vs T_2	5% = 574.36	476.63	5% = 102.42	43.33
	T_1 vs T_3	0.1% = 1108.50	976.50	0.1% = 210.86	143.16
	T_2 vs T_3	1% = 797.15	499.87	1% = 145.67	99.83

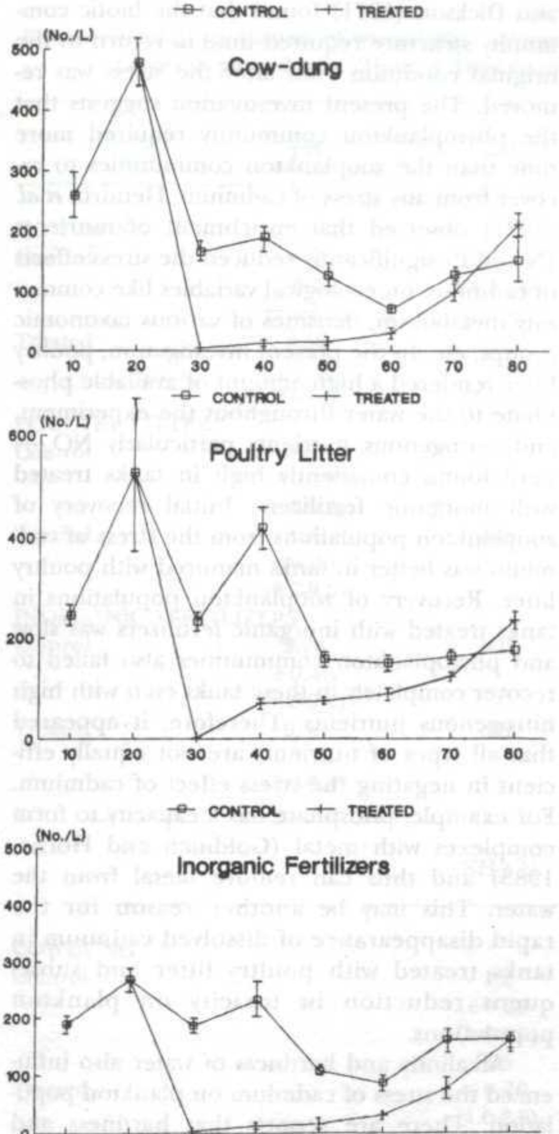

Fig. 1 : Influence of cow dung, poultry litter and inorganic fertilizers on the recovery of zooplankton populations from the stress of cadmium (1 mg/l) Bar = S.D.

than those of the two groups during the recovery period. Recovery of phytoplankton populations based on all densities was very slow.

Initial (1 day) concentration of filterable (dissolved) cadmium in the water was highest in tanks manured by inorganic fertilizers (0.47 mg/l) followed by those manured by poultry litter (0.32 mg/l) and cow dung (0.28 mg/l). Dissolved cadmium gradually decreased in all culture tanks but the rate of reduction was faster in tanks receiving poultry litter as a fertilizer. A detectable amount of cadmium was in solution up to 15 days after treatment in tanks manured with poultry litter (Fig. 3) while in other groups it persisted up to 25 days.

Concentration of filterable (dissolved) cadmium in water in the treated tanks varied from 0.47– 0.02 mg/l up to 25 days after treatment.

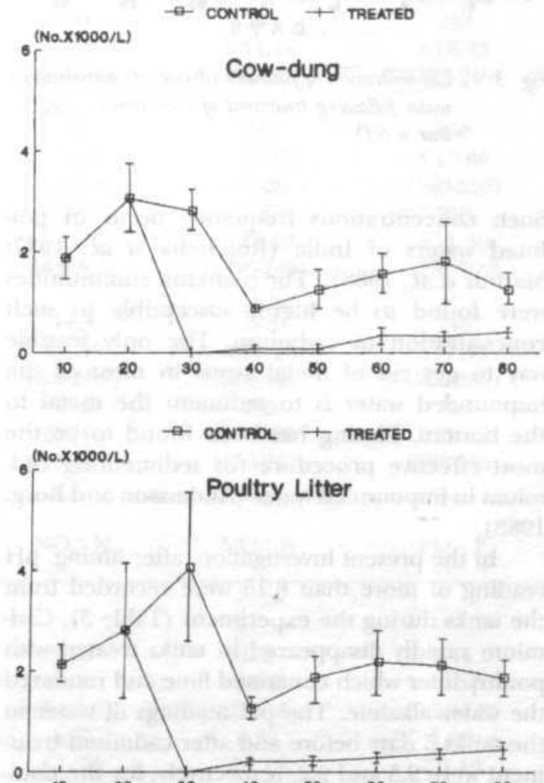

Fig. 2 : Influence of cow dung, poultry litter and inorganic fertilizers on the recovery of phytoplankton populations from the stress of cadmium (1 mg/l) Bar = S.D.

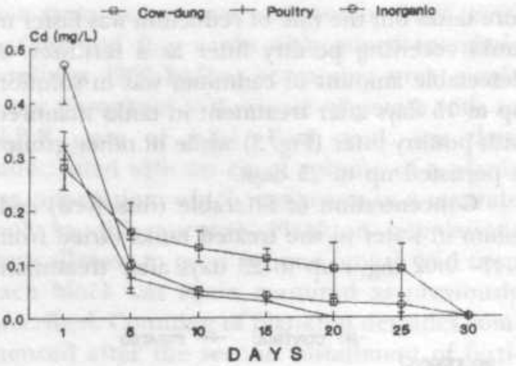

Fig. 3 : Concentration of filterable (dissolved) cadmium in water following treatment of cadmium (1 mg/1) Bar = S.D.

Such concentrations frequently occur in polluted waters of India (Ruparelia *et al.*, 1987; Mathur *el al.*, 1988). The plankton communities were found to be highly susceptible to such concentration of cadmium. The only feasible way to get rid of metal stress in most of the impounded water is to sediment the metal to the bottom. Liming has been found to be the most effective procedure for sedimenting cadmium in impounded water (Andersson and Borg, 1988).

In the present investigation, after liming, pH reading of more than 8.15 were recorded from the tanks during the experiment (Table 3). Cadmium rapidly disappeared in tanks treated with poultry litter which contained lime and rendered the water alkaline. The pH readings of water in the tanks 5 days before and after cadmium treatment were 9.3 and 9.2, respectively, for the poultry litter treatment, 8.9 and 8.8 for the inorganic fertilizer treatment, and 8.4 in both tanks for the cow dung treatment. Mean alkalinity of water was also recorded as 280 mg/l at both 20 and 30 days in treatment with inorganic fertilizers, and 220 and 245 in treatment with cow dung. This condition of high pH and alkalinity further expedited cadmium sedimentation in tanks manured with poultry litter. Rapid sedimentation of the metal was probably one of the reasons for more rapid recovery of the zooplankton population in these tanks.

Phytoplankton populations did not recover completely even after the partial disappearance of the metal from the water. This indicates the stress of cadmium continued even after the disappearance of the metal from the water. Cairns and Dickson (1971) found that the biotic community structure required time to return to the original condition even after the stress was removed. The present investigation suggests that the phytoplankton community required more time than the zooplankton communities to recover from any stress of cadmium. Hendrix *et al.* (1981) observed that enrichment of nutrients (N and P) significantly reduced the stress effects of cadmium on ecological variables like community metabolism, densities of various taxonomic groups, etc. In the present investigation, poultry litter rendered a high amount of available phosphate to the water throughout the experiment, and nitrogenous nutrients particularly NO_3–N were found consistently high in tanks treated with inorganic fertilizers. Initial recovery of zooplankton populations from the stress of cadmium was better in tanks manured with poultry litter. Recovery of zooplankton populations in tanks treated with inorganic fertilizers was slow and phytoplankton communities also failed to recover completely in these tanks even with high nitrogenous nutrients. Therefore, it appeared that all types of nutrients are not equally efficient in negating the stress effect of cadmium. For example, phosphate has a capacity to form complexes with metal (Goldman and Horne, 1983) and thus can remove metal from the water. This may be another reason for the rapid disappearance of dissolved cadmium in tanks treated with poultry litter and subsequent reduction in toxicity on plankton populations.

Alkalinity and hardness of water also influenced the stress of cadmium on plankton population. There are reports that hardness and alkalinity of water reduce the toxicity of cadmium to aquatic organisms (Chapman and Steven 1978; Calamari *et al.*, 1980). Competition of cadmium ion with that of Ca and Mg (Nusch, 1977; Wright and Frain, 1981) and sedimentation of Cd ion under the above conditions (Andersson and Borg, 1988) were found to be the principal reasons behind the reduction of Cd toxicity. In the present investigation both alkalinity and hardness of water was relatively much higher, particularly in the first 30 days of the experiment in tanks manured with poultry litter. Hardness of water in these tanks at 20 and 30 days were 240 and 290 mg/l respectively in contrast to 200 and 215 for the inorganic fertilizer and cow dung treatments

TABLE 3

Physico-chemical parameters of water (mg/l) recorded during the experiment. Values are mean 6 S.D. with ranges in parentheses. (Hard. = Total hardness as $CaCO_3$, Alk. = Total alkalinity as $CaC0_3$)

	pH	CO_2	DO	Hard.	Alk.
COW DUNG					
Control	8.18	12.5	6.5	220	226
	60.42	68.66	61.91	616.33	683.81
	(7.8-8.5)	(0.0-20.0)	(4.0-8.5)	(200-245)	(200-242)
Treated	8.38	2.25	7.0	205	240
	60.49	62.06	62.0	634.16	616.33
	(8.0-8.7)	(0.0-8.5)	(4.2-9.0)	(190-220)	(220-245)
POULTRY LITTER					
Control	8.85	NIL	7.5	245	260
	60.89	-	61.00	637.86	640.00
	(8.6-9.4)	-	(6.0-8.5)	(200-280)	(240-320)
Treated	8.98	NIL	7.0	220	250
	60.05	-	61.15	628.28	611.50
	(8.7-9.5)	-	(6.0-8.5)	(200-245)	(220-300)
INORGANIC FERTILIZERS					
Control	9.28	NIL	14.5	278	245
	60.49	-	67.37	628.72	657.45
	(8.8-9.4)	-	(6.0-24.0)	(200-300)	(200-280)
Treated	9.38	NIL	15.5	215	220
	60.25	-	63.42	630.00	628.28
	(8.9-9.4)	-	(8.0-20.0)	(180-240)	(180-260)

	NH_3^- N	NO_3^- N	NO_2^- N	PO_4^- P
COWDUNG				
Control	1.2	3.75	0.2	0.44
	60.22	61.50	60.2	60.37
	(1.0-2.0)	(3.0-6.0)	(0.1-0.5)	(0.25-1.0)
Treated	1.5	4.50	0.23	1.00
	60.70	61.73	60.13	60.40
	(1.0-2.0)	(2.0-4.2)	(0.1-0.4)	(0.6-1.3)
POULTRY LITTER				
Control	0.7	2.75	0.28	3.25
	60.89	61.50	60.21	60.50
	(0.1-2.0)	(1.0-5.0)	(0.1-0.5)	(3.0-5.0)
Treated	0.33	3.50	0.1	4.00
	60.21	61.91	60.0	61.15
	(0.1-0.8)	(2.0-4.5)	(0.05-0.2)	(3.0-6.0)
INORGANIC FERTILIZERS				
Control	0.21	13.25	1.83	2.23
	60.21	61.26	60.78	60.21
	(0.1-1.0)	(11.0-15.0)	(0.6-2.5)	(1.2-2.0)
Treated	0.13	13.50	0.59	1.30
	60.05	61.91	60.24	60.14
	(0.05-0.5)	(12.0-16.0)	(0.2-1.0)	(1.0-2.5)

respectively. High alkalinity and hardness of water during treatment with cadmium helped to reduce the toxicity of cadmium rapidly in tanks treated with poultry litter. Alkalinity and hardness of water also increased in tanks treated with inorganic fertilizers from day 40 of the experiment. Mean alkalinity in these tanks ranged from 240 to 260 mg/l and mean hardness ranged from 200 to 240 mg/l during this period. Such high alkalinity perhaps resulted from intense photosynthesis which was also evident from high dissolved oxygen (DO) in these tanks (ranging from 15 to 20 mg/l). Concentrations of dissolved cadmium was relatively much higher in the initial period, and it also persisted for a longer period as compared with treatment of poultry litter. This resulted in the continuation of stress in the treatment with inorganic fertilizers.

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