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Toxicity of Dimethoate on Primary Productivity of a Lentic Aquatic Ecosystem: A Microcosm Approach

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Primary productivity of phytoplankton and macrophytes forms the basis of the metabolic cycle in a natural aquatic ecosystem and it regulates energy flow and nutrient cycling. Indiscriminate application of pesticides and agrochemicals in modern agricultural practices leads to contamination of water bodies. Currently, annual global consumption of pesticides is 5 billion tones (Wright and Welbourn 2002). Pesticide contamination of water bodies has created toxicity stress on aquatic biota. Effects of pesticides in the ecosystem do not remain restricted to target organisms but rather extend to non-target organisms like phytoplankton and microorganisms (Mohapatra and Mohanty 1992). Phytoplankton play a key role in the freshwater ecosystem. Planktonic organisms have a short life cycle with high metabolic activity, which facilitates response to any pollution stress quickly and significantly compared to benthic or nektonic organisms (Perkins 1976). Various workers (Hussainy 1967; Karunakaran 1970; Sumitra 1971; Khatri 1984; Sharma and Sarang 2004) have made investigations on the primary productivity of freshwater ecosystems in India. Variation in chlorophyll content and phytoplankton productivity was observed in man made ponds (Guruswamy and Ramdoss 2000).

The primary productivity of a particular aquatic environment provides quantitative information about the amount of energy available. This is called the bioactivity of the system (Ohle 1956). The standing crop of phytoplankton is a good index of productivity status of any body of water (Wetzel 1975). Currently, there is a considerable interest in the use of microcosms as predictors for transport, transformation and fate of potentially toxic organic substances in aquatic systems. Microcosm tests have the advantage of providing data on the response of many organisms, including the effects of toxicants on interactions between species and their environment. In the natural environment it is difficult to handle such a study because of the complexity of the water body and its dimension too. Hence a microcosm study, with a laboratory environment proves to be more effective and useful for the evaluation of toxicity of pesticides. Moreover, the microcosm system with discrete boundaries can be manipulated and replicated well (Odum 1992). Dimethoate is commonly used as an organophosphorous pesticide in this part of Northern Karnataka, India. Hence the present investigation evaluates dimethoate toxicity on phytoplankton primary productivity of a lentic ecosystem using a microcosm approach.

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MATERIALS AND METHODS

The organophosphorus pesticide dimethoate [O,O-dimethyl-S(-N-methyl-carbamoylethyl) –dithiophosphate, Technical grade (90.05%)], was obtained from Rallies India Ltd., Bombay. Pure dimethoate is a colourless crystalline solid. The molecular formula is $C_5H_{12}NO_3PS_2$.

The present investigation was conducted on a constructed freshwater pond located within Karnatak University, Dharwad, India. Water samples were collected from different sites of the pond during morning hours (6AM to 7AM). The standard light and dark bottle method (Gaarder and Gran 1917; Vollenweider 1976) was employed for the measurement of dimethoate toxicity on primary productivity. The water samples were collected in two 300 ml BOD bottles. Untreated and treated samples taken in BOD bottles with different concentrations (5 ppm to 40 ppm) of dimethoate in triplicate were suspended in the experimental pond water at uniform depth of 30 cm from the surface. One of the bottles was white and the remaining one was covered by black aluminum foil to exclude the light at each site. The initial dissolved oxygen of water was immediately determined by an azide modification method (APHA 1998) from the same depth of each sampling site. The light and dark bottles were attached with a metal stand to allow uniform immersion at the same depth. The metal stand was held firmly in the soil with it lower end stuck on the bank of the experimental pond. The bottles were withdrawn from the water after four hours and their dissolved oxygen content was estimated. Photosynthetic evolution and respiratory consumption of oxygen in light and dark bottles respectively was determined at 4 hr intervals for 12 hrs.

Gross primary productivity was calculated from differences in oxygen concentration in the light (Dl) and dark (Dd) bottle, the net primary productivity was calculated from difference in oxygen concentration in light (Dl) and initial (Di) bottle, while community respiration was calculated by the decrease in oxygen content in the dark (Dd) bottle as compared to initial reading (Di). The following formula was used for the calculation of primary productivity. Gross primary productivity (GPP): O_2 mg/L/hr = DL–Dd /hr, Net primary productivity (NPP): O_2 mg/hr =DL–Di/hr., Community respiration (CR): O_2 mg/L/hr =Di–Dd /hr. Data obtained was converted in terms of carbon (C) value using a conversion factor of 0.375 and values are expressed as mg C/m^3/hr, (Trivedy and Goel 1990).

An EC-TDS analyzer (Elico India) was used to measure conductivity and total dissolved solids. Physicochemical parameters viz., temperature, dissolved oxygen, salinity, free carbon dioxide, chloride, calcium, magnesium, carbonates, bicarbonates were assessed using standard procedures and expressed in mg/L (APHA 1998). Phytoplankton species enumeration was made (Adoni 1985). Pearson's co-efficient of correlation and two factor ANOVA was applied for statistical analysis (Gupta and Kapur 1983).

RESULTS AND DISCUSSION

Results are presented in Tables (1-3) and Figures (1-3). Data on physicochemical parameters of the experimental pond water are presented in Table 1. pH of water was slightly alkaline, physicochemical factors and occurrence of higher concentration of nitrates and phosphates influenced the phytotoxic effect of pesticides (Cairns et al. 1975). The phytoplankton of experimental ponds were identified. A total of 21 species were enlisted from the pond of which 6 species belong to Cyanophyceae, 7 species to Bacillariophyceae, 5 Chlorophyceae and 3 to Euglenophyceae (Table 2). Cyanophyceae and Bacillariophyceae were dominant, when compared to the other two families.

Table 1. Physicochemical parameters of experimental pond

No	Parameters	
1	Temperature	19° -28°C
2	pH	7.66
3	Conductivity (EC)	618 µs
4	Total Dissolved Solid (TDS)	311
5	Dissolved Oxygen (DO)	4.4
6	Salinity	0.3
7	Free Carbon Dioxide (CO_2)	33
8	Chloride (Cl)	72.42
9	Calcium (Ca)	41.6
10	Magnesium (Mg)	0.486
11	Carbonates (CO_3)	0
12	Bicarbonates(HCO^-_3)	260

No. 4 to 12 are expressed in mg/L

Table 2. Phytoplankton of experimental pond

No	Class	Phytoplankton
1	Cyanophyceae	*Microcystis* sp.
		Oscillatoria princeps
		Anabaena planctonica
		Anacystis cyanea
		Agmenellu quadriduplicatum
		Chlorococcum humicola
2	Bacillariophyceae	*Navicula graciloides*
		Gomphonema parvulum
		Fragillaria crotonensis
		Nitzschia palea
		Pinnularia nobilis
		Stauroneis phoenicenteron
		Meridion Criculare
3	Chlorophyceae	*Scytonema sp*
		Oedogonium sp
		Spirogyra sp
		Cosmarium sp
		Desmidium sp.
4	Euglenophyceae	*Euglena acus*
		Phacus sp.
		Rhodomonas

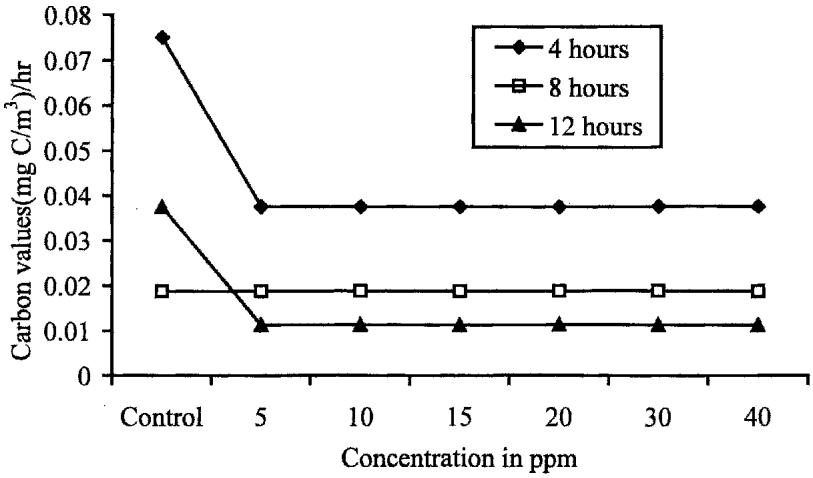

Figure 1. Effect of dimethoate on gross primary productivity (GPP)

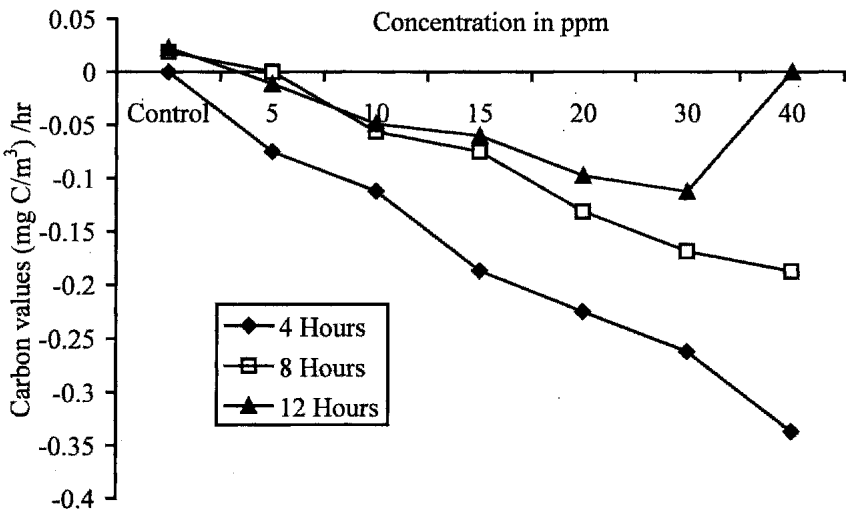

Figure 2. Effect of dimethoate on net primary productivity (NPP)

From the data it is evident that dimethoate toxicity on primary productivity increased with increase in the concentration of pesticide. A severe phytotoxic effect of dimethoate was evident on the primary productivity of the aquatic ecosystem. Gross primary productivity (GPP) remained the same at specific hours of treatment irrespective of the concentration of pesticides, however at each concentration there has been 50 percent decline in GPP at 8 hrs and 70% reduction at 12 hrs of exposure (Fig 1). Net primary productivity (NPP) continue to show declining trend in comparison to control value in all the treatments irrespective of exposure duration (Fig 2). The gradual reduction in NPP with respect to the

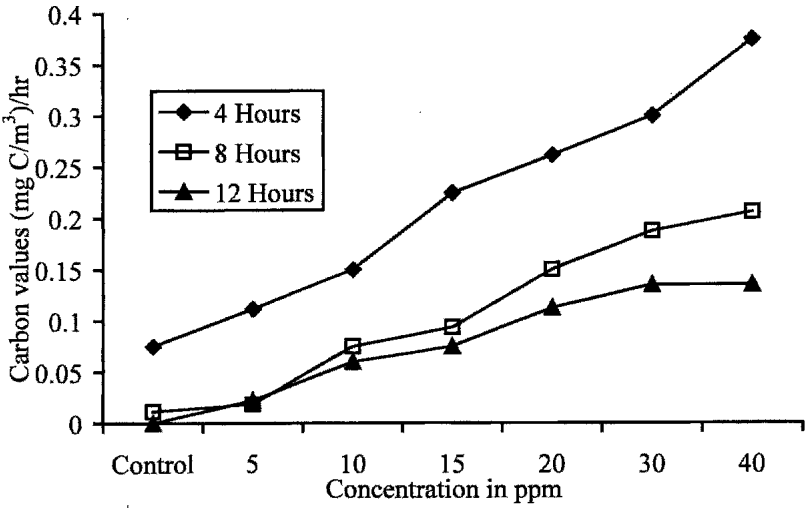

Figure 3. Effect of dimethoate on community respiration (CR)

increased concentration of toxicant may be due to inhibitory action of dimethoate on metabolic activities of autotrophs. Similar observations made on the phytotoxic effect of dimethoate on primary productivity were attributed to inhibition of chlorophyll synthesis in phytoplankton (Arunachalam and Pandiaraj 1994). The inhibition and degradation of chlorophyll by the treatment of Rogor on *Chlorella vulgaris* has been reported (Sureka Rani 1999).

The reduction in the rate of community respiration was inversely proportional to duration of exposure to dimethoate at each treatment. However, the rate of respiration increases at successive duration of exposure to the toxicant. Our observation confirms the findings of Jankiram and Jayaraj (1996) that there appears to be no direct inhibitory effect of dimethoate on the respiratory activity of microorganisms. The present respiratory response of phytoplankton in the presence of dimethoate was higher than that of the control. There was a linear increase in respiration along with the increase in the concentration. This may be due to the action of respiratory enzymes mediated by the cumulative effect of the pollutants (Prasad 1990). From the data, it is clear that 40 ppm dimethoate inhibit GPP and NPP completely but favours only community respiration (0.135 mg C values /m^3 /hr). The enhanced rate of community respiration is directly proportional to the concentration of toxicant (Fig 3).

The two-way analysis of variance (ANOVA) confirms the phytotoxic effect of dimethoate and is statistically significant to its concentration ($P<0.01$ and $P<0.05$ Table 3). Gross primary productivity is positively correlated with net primary productivity that was highly significant negatively with community respiration (Table 4). Frequent use of pesticides poses a serious threat to aquatic ecosystem.

Dimethoate is fairly stable in water having a half-life of twelve days which is sufficient to cause inhibition of productivity of the aquatic ecosystem.

Table 3. Average, variance and ANOVA of dimethoate toxicity on primary productivity and community respiration

Exposure time	GPP		NPP		CR	
	Average	Variance	Average	Variance	Average	Variance
4 hrs	0.043	0.00201	-0.171	0.013	0.214	0.012
8 hrs	0.019	0	-0.086	0.006	0.104	0.006
12 hrs	0.015	9.84E-05	-0.044	0.003	0.079	0.003
Between treatment cons.	F=30.24051 **		F=10.42593 **		F=38.89088 **	
Between treatment periods	F=3.658228 *		F=5.957444 **		F=20.15173 **	

* is significant at the 0.05 level
** is significant at the 0.01 level

Table 4. Correlation of dimethoate toxicity on primary productivity and community respiration

Exposure time	Correlation		
	GPP & NPP	GPP & CR	NPP & CR
4 hrs	0.650	-0.570	-0.995**
8 hrs	A	a	-1.000**
12 hrs	0.361	-0.689	-0.608

** Correlation is significant at the 0.01 level
a-Cannot be computed because at least one of the variables is constant.

A high rate of community respiration is indicative of increased break down of organic substances in the aquatic ecosystem. It is concluded that dimethoate is phytotoxic and inhibits the rate of primary productivity. The decreased photosynthetic release of oxygen coupled with increased respiratory consumption of oxygen results in the depletion of oxygen leading to anoxic conditions and causing serious threat to aquatic biota. The present microcosm test reveals the phytotoxicity of dimethoate on phytoplankton productivity. This will help to

understand the effect of this pesticide on phytoplankton and physicochemical environment of a lentic aquatic system at the macrocosm level.

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