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Influence of Water Quality Parameters on the Phytotoxicity of DDT

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Water quality parameters have been found to influence the phytotoxicity of DDT to green alga *Scenedesmus dimorphus*. Among these factors, physico-chemical nature of the pesticide in water, algal cell density, salt content, nutrients and their interactions are found to significantly modify the response of alga to pesticidal toxicity. However, salinity is not found to alter the response of alga to the pesticide. Consideration of environmental factors in the phytotoxicological study of pesticidal pollution will be useful in its practical application.

Key Words: Water quality, Pesticide, Phytotoxicity

Introduction

Inhibition of algal growth by DDT even at very low concentrations has been reported (Södergren 1968, Bowes 1972, Subramanyan et al. 1979). However, literature survey reveals many inconsistent results on toxicity range of DDT and algal tolerance (Goulding & Ellis 1981). Experimental conditions and environmental factors adopted by various workers have important bearing on the phytotoxicity of pesticide. This aspect has been ignored. Little information is available on the extent to which pesticidal toxicity is influenced by physical and chemical characteristics of pesticide and environmental conditions. This makes it difficult to draw any conclusion of ecological significance, based on laboratory data. This widens the gap between the practical application of laboratory data to natural ecosystem and reliability of such data. Present work is thus, undertaken to study the effect of these environmental factors on the phytotoxicity of DDT to *Scenedesmus dimorphus*, a local bloom forming green alga.

Materials and Methods

Green alga *S. dimorphus* is isolated from the local eutrophic waters of stabilization pond and fish pond. The unialgal culture is maintained in a basal medium (Becker & Venkataraman 1978). Details of algal bioassay procedure and application of DDT in bioassay are given in our previous communication (Chaudhari et al. 1985).

Algal bioassays are carried out to study the influence of environmental factors in aquatic environment such as *p*H, total salt content, salinity, algal cell density, nutrients (nitrate-N, ammonia-N, O-phosphate-P) and their interactions and dissolved inorganic and organic-carbon as carbon source. These are the fundamental water quality parameters which may influence the interaction of DDT with the primary producers—algae—in aquatic environment. Algal bioassays are carried out in the basal medium with slight modifications, while studying the effects of different components of nitrogen and phosphorus in the medium.

Results and Discussion

S. dimorphus is reported to be sensitive to DDT applications, the maximum algicidal effect being $72LC_{40}$ at 5 PPM DDT concentration (Chaudhari et al. 1985). Algal response towards pesticidal toxicity under varying water quality parameters is studied here and the results are given below:

Physico-chemical Nature of Pesticide

Because of low solubility of DDT in water (Frear 1955, ASA Publication No. 8, 1966) the physico-chemical nature of pesticide has remarkable influence over its biological availability and phytotoxicity to algal cells. Results of the experiments have shown that DDT is most toxic to algal cells when it is evenly distributed in water in the form of fine particles at 5–10 ppm concentrations when added after dissolving in acetone (1 ml l^{-1}). At higher concentrations, toxicity decreases as DDT gets precipitated and settles at the bottom. When DDT powder is directly added to the water at the same phytotoxic concentrations, DDT powder is not evenly distributed and remains at the bottom because of its very low solubility, thus reducing the interaction of algal cells with the pesticide and the resultant toxicity of pesticide (figure 1). In natural water bodies, excess DDT gets concentrated in the bottom layers and does not come in contact with algae. In general, the pesticide residue-trend in aquatic ecosystems appears to be as follows: water has the lowest average residue, bottom residue 18 times; zooplankton and benthic algae 37 times, fish 790 times and aquatic insects 7300 times that of water (Konar 1977). Even though the solubility of DDT and pesticides in general is low in water, suspended particles and bottom sludge on which pesticide is adsorbed in natural water bodies are now shown to play an important role in the interaction of pesticide with the phytoplankton. Suspended particles and bottom sludge which moves upward in water column during day time cause greater and more prolonged toxicity of PCB* to phytoplankton than PCB directly present in water (Nau-Ritter et al. 1982). Small suspended particles generally sorb more PCB than does the same weight of larger particles (Karickhoff et al. 1979) and may desorb significant amounts of PCB to phytoplankton (Harding & Phillips 1978). Concentrations lower than 10 μg of PCB per litre, desorbed from sediments, may change the productivity and biomass of natural phytoplankton communities (Nau-Ritter et al. 1982) and could alter the food web within an ecosystem thereby affecting the production of species beneficial to man (O'Connors et al. 1978). This aspect of pesticidal interaction in natural water bodies needs to be studied in detail.

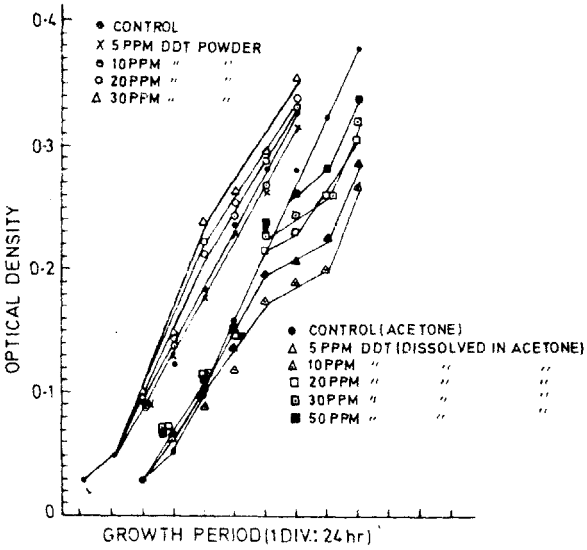

Figure 1 Toxic effects of DDT on *Scenedesmus* culture when added as powder/after dissolving in acetone as a carrier solvent

Algal Cell Density

Influence of algal cell density on the persticidal toxicity was studied by varying the Initial Algal Inoculum (IAI) size in the algal bioassay (table 1). Toxicity of DDT to *Scenedesmus* is found to be inversely related to the size of IAI. More the size of IAI, lesser is the toxic effect of DDT on the growth rate and growth potential of alga. At more IAI growth potential of DDT treated algal culture was the same as that of untreated control except that final algal yield at 96 and 120 hours are slightly less than the control.

Growth potentials of alga in untreated controls are found to be more or less identical when IAI is within 0.45–0.1 OD. However at low IAI i.e. 0.005–0.015 there is a lag phase of 48 hours. This shows that at lower size of IAI, algal cells require more time to acquire exponential growth phase.

Maximum inhibition of algal growth potential at the end of experiment i.e. 62.9% is observed at lowest size of IAI (OD—0.005) (table 1). Per cent inhibition is decreased quickly with the increase in IAI being 30.7, 12.1, 12.5 and 8.4% at IAI of OD 0.015, 0.045, 0.070 & 0.10 respectively equivalent to algal dry weights (ppm) 4, 19, 35, 51 respectively.

Possible explanation for increased toxicity at low IAI may be due to availability of more pesticide per cell of alga. This quantity goes on decreasing with the increase in total number of cells. Corresponding dry weights of alga against the Optical Densities are shown in table 1, and the relationship

*PCB-Polychlorinated biphenyls

Table 1 *Size of initial algal inoculum and DDT toxicity to* Scenedesmus

Initial Algal Inoculum (IAI) (in OD)	Dry wt. of Inoculum (g/l)*	DDT dose (5 ppm) as % dry weight of alga	Inhibition (%) of algal growth after 120 hrs	Ultimate algal yield (in OD)	Period of first exponential growth phase (hr)	Period of second exponential growth phase (hr)	Total of F & G
A	B	C	D	E	F	G	H
0.005	**	—	62.9	0.330	24	24	48
0.015	0.004	125.0	30.7	0.280	24	72	96
0.045	0.019	25.0	12.1	0.255	72	24	96
0.070	0.035	14.3	12.5	0.170	72	24	96
0.100	0.051	9.8	08.4	0.065	72	24	96

* Dry wt. calculated from the standard graph
** Beyond detection limit

between relative concentrations of alga and DDT (W/W) and algal growth inhibition is shown in figure 2. It appears that algal growth inhibition is very less when DDT dose is below 25% of algal dry weight. When DDT dose is increased beyond 25% of algal dry weight, algal growth inhibition becomes more and more acute. Algal cells thus can tolerate DDT concentration upto 25% of its dry weight with slight inhibition in the algal growth potential. This observation may be made use of in treatment of pesticidal waste.

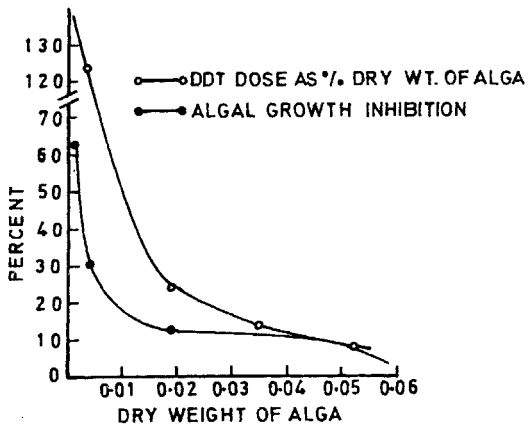

Figure 2 Relationship between relative concentrations of alga and DDT (w/w) and algal growth inhibition

At low IAI, control untreated cultures show initial lag phase of 48 hours which is absent in treated cultures (table 1). The characteristic lag phase of *Scenedesmus* in between two exponential growth phases (Chaudhari et al. 1985) is after 72 hours at dense IAI (OD—0.045–0.1) but is after 24 hours in low IAI (OD 0.005–0.015). At lowest IAI algal growth shows decline after 72 hours while in other cultures, algal growth revives after second exponential growth phase.

Rapid multiplication of algal cells is the initial response of algae to DDT application during the first 24 hours period. This may be a active phase of initial interaction between alga and DDT i.e. adsorption of DDT on to the algal cell and entry into the cell. Therefore, in the next phase of algal growth, toxic effects of DDT on the algal growth potential are observed. Maximum accumulation of DDT in algal cell is reported to take place within a short time i.e. 1 to 3 hr for *Ankistrodesmus amalloides* and *Tetraselmis chuii*, 15 seconds to 3 minutes for *Chlorella pyrenoidosa* (Sodergren 1968, Rice & Sikka 1973, Neudorf & Khan 1975).

Shifting of characteristic lag phase (SLgp) from 72 hr in dense IAI to 24 hr in low IAI must have some relation with the mechanism in algae to overcome the toxic effect of pesticide (Chaudhari et al. 1985). At low IAI earlier shifting may be needed to overcome the increased toxicity of DDT.

*p*H

*p*H of the aquatic basal medium is found to be a decisive factor in optimising the growth of *Scenedesmus* (table 2). Alkaline *p*H (i.e. 9) of the medium is found to be optimum for the growth of *Scenedesmus*. Growth potential of alga is found to be slightly low in the control where *p*H of medium is not controlled. In this control set, initial *p*H 9.5 of culture medium is found to be increased to 10.1. At low *p*H values, growth of algae decreases gradually with the decrease in *p*H as shown in the table 2. At *p*H 5 & 6, though the growth rate and potential is reduced, still alga steadily grows for a longer period. When DDT treated cultures are compared with respective control cultures, it

Table 2 *pH variation and DDT toxicity to* Scenedesmus

Treatment	Promotion/Inhibition (%) of algal growth after 120 hrs as compared to respective controls	Ultimate algal yield (after 120 hrs) (in OD)		period of exponential growth (hr)	
		Control	Treatment	Control	Treatment
(A) *p*H 5	Nil	0.130	0.130	96–24(120)	48–48(96)
(B) *p*H 6	+ 10.00	0.150	0.165	48–72(120)	120–0(120)
(C) *p*H 8	− 12.82	0.195	0.170	72–72(144)	48–24(72)
(D) *p*H 9	− 32.69	0.260	0.175	96–0(96)	48–24(72)
(E) No *p*H adjustment (maximum *p*H 10)	− 48.00	0.250	0.130	96–24(120)	24–72(96)

appears that DDT toxicity to algal cultures is more at higher *p*H and less at low *p*H (below 8). Deleterious effect of DDT on the growth potential of algae are minimised at low *p*H around 7 ± 1. Nevertheless, pesticide-treated algal cultures at *p*H 6 show enhancement over the control algal cultures. At *p*H 5 no inhibition of algal growth is observed.

Regular observations of *p*H of treated and untreated algal cultures before their daily adjustment to specific levels, also reveals the tendency of algal culture to change and stabilize *p*H between 8 & 9 which is the most optimum *p*H for algal growth.

Salinity

Salinity is the important characteristic of water bodies especially in the region of saline soils and at the confluence of sea and river or in marine estuaries. When the salinity of the basal medium was increased by addition of sea salt at the concentration range 0.01–2 g L^{-1} algal growth potential was very slightly affected. Growth potential of DDT treated cultures was not found to be altered with the increase in the salinity of the medium.

Total Salt Content

The composition of basal medium for *Scenedesmus* (Becker & Venkataraman) is considered as normal (N) (Total salt content — 167 ppm). This was modified as 2N, N, N/10, N/100 & N/1000 as given in the table 3.

Comparison of respective control cultures shows gradual reduction in the algal growth rate and growth potential with increasing dilution of the culture medium as the nutrients become more and more limiting. Whereas in pesticide treated cultures per cent inhibition increases with the increase in nutrient concentration in the basal medium i.e. N & 2N (table 3). In contrast to these results, DDT promotes the growth of algae in diluted medium over that of control. Maximum enhancement of algal growth is observed at N/10 concentration.

Nitrogen

Effect of nitrate-N and ammonia-N on the phytoxicity of pesticide under a wide range of concentration was studied by applying urea and potassium

Table 3 *Total salt content and DDT toxicity to* Scenedesmus

Treatment	Promotion or inhibition (%) of algal growth after 120 hrs as compared to respective controls	Ultimate algal yield (after 120 hrs) (in OD)		period of exponential growth (hr)	
		Control	Treatment	Control	Treatment
2N (334 ppm)	− 21.74	0.230	0.180	120+72 (192)	120+24(144)
N (167 ppm)	− 16.67	0.210	0.175	120+48(168)	48+48(96)
N/10 (16.7 ppm)	+31.82	0.110	0.145	160+0 (160)	48+48 (96)
N/100 (1.67 ppm)	+6.25	0.080	0.085	120+0 (120)	120+0 (120)
N/1000 (0.167ppm)	Nil	0.030	0.030	120+0 (120)	120+0 (120)

nitrate at a concentration range of 1.4 μgl^{-1}–55.4 mgl^{-1} of NO_3-N and 2.8 μgl^{-1}–28.0 mgl^{-1} of NH_3-N respectively. Both the types of nitrogen sources showed similar type of response on the toxicity of DDT. Toxicity of DDT is found to be considerably decreased at and below 0.28 and 0.14 ppm concentrations of NH_3-N and NO_3-N respectively. At higher concentrations, toxicity and algal growth inhibition become pronounced.

Ortho-phosphate – P

In contrast with the observation with nitrogen, decreasing concentrations of O-phosphate shows that toxic effect of DDT become more and more pronounced with the decrease in the O-phosphate concentration of the medium. Algal growth potential in the respective controls do not show any change with the logarithmic decrease in the O-phosphate concentration but the algal growth potential in the DDT treated cultures are considerably reduced. This shows that O-phosphate may have counter effect on the DDT toxicity.

Organic Matter as a Source of Carbon

Sodium citrate is used as a source of carbon in the bioassay experiment. In eutrophic waters the organic carbon plays an important role in eutrophication and algal bloom formation. Many eutrophic algae are found to be resistant to chemicals and are more efficient as scavengers of salts in eutrophic waters. *Scenedesmus dimorphus* is frequently observed in the eutrophic stabilization pond effluents. This alga is also reported to be facultative heterotrophic and can utilize organic carbon for its growth. Therefore, the interaction of pesticide with algae in presence of organic carbon is of great significance.

Toxic effects of DDT are found to be counteracted when sodium citrate was added to the cultures around 25 mg carbon l^{-1} (figure 2). At higher concentrations (98 mg carbon l^{-1}), algal growth in treated culture is found to be tremendously enhanced over that of control. Biological activity is so enhanced that within 24 hours, the level of algal growth in treated cultures (196 mg carbon l^{-1}) becomes equal to the level of algal growth after 120 hours in control cultures (figure 3). Organic

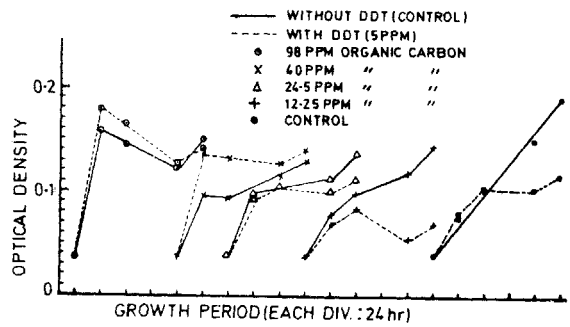

Figure 3 Effect of dissolved organic matter on the toxicity of DDT to *Scenedesmus*

carbon content in water thus plays an important role in modifying the DDT toxicity to algal cultures.

Inorganic Carbon

When sodium bicarbonate as a source of inorganic carbon was used, it was observed that low doses i.e. below 14 ppm show the same lethal effect as that of control whereas in higher concentrations of inorganic carbon lethal effect is found to be increased to 55–57% algal inhibition at about 14 ppm to 72 ppm of inorganic carbon. Thus in highly alkaline waters with bicarbonate alkalinity DDT is more toxic to this alga.

Water quality parameters, thus, have important bearing on phytotoxicity of pesticides. Pesticidal toxicity is mainly influenced by its physicochemical nature in the water because of its low solubility, the dispersion and distribution of pesticide is affected affecting its biological availability. *p*H, total salt content and nitrogen are directly related to the toxicity of pesticides while O-phosphate and organic carbon counteract the pesticidal toxicity. Toxicity is also found to be increased in alkaline water with bicarbonate alkalinity. Thus in a natural ecosystem C:N:P ratio is important in deciding the nature of pesticide-algal interaction.

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