Behavioural Toxicology
The fish serves as bio-indicator of water quality and this can be easily testified by morphological, physiological and behavioural changes in an altered environment. Since pesticides irrespective of their concentration are known to alter the aquatic environment, this certainly has profound effects on biochemical and physiological parameters, which in turn vary with the concentration of the pesticide and duration of exposure. Interestingly, physiological and biochemical changes do influence behavioural patterns and this is more conspicuous in fish, particularly with reference to aquatic pollution. So far literature on behavioural responses in fish under pesticide toxicity is rather limited. More recently, this line of work is also gaining impetus as observed from the works of Koundinya and Ramamurthy, (1978); David et al., (2004) and Narasimha et al., (1983).

In the laboratory, fish behaviour can be a sensitive marker of toxicant-induced stress as reported by Atchison et al., 1987; Little et al., 1985; Westlake, 1984. Toxic substance entering aquatic ecosystem can have a wide range of adverse effects on faunal communities, not all of which can be learned from standard toxicity tests (Henry and Atchison, 1986). The principle biological variables examined in the standard tests according to some authors are changes in survival, growth and reproduction rate. Studies have documented alteration in respiration, locomotion, social organization, reproduction tendency and predator avoidance. Behaviour is an organismal level of all the above mentioned parameters including biochemical, physiological state of the animal under the influence of the environment. Further, behavioural study should have objectives that should,
(1) Be easily observed in the laboratory or field,
(2) Be sensitive to the chemicals of interest,
(3) Be previously well-described,
(4) Be ecologically relevant to species survival,
(5) Integrate several sensory and/or mechanical modalities. In addition, the
method should be routinely available and simple to employ.

The extensive use of pesticides in agriculture, public health and forestry
ultimately leads to the contamination of aquatic biotopes, posing a great threat to
the environment (Visweswaraiah et al., 1975). Elucidation of the action of
pesticides on non-target organisms forms a thrust area in the field of toxicology due
to the serious effects and residue-leaving (Persistent) nature of these pesticides.
Metabolic and pathologic derangements on exposure to pesticides are well
documented (Kohli et al., 1975). The uptake of the toxic compounds in aquatic
invertebrates has recently been reviewed by Holden, (1973). Kerr and Vass, (1973)
reviewed the uptake of the toxic compounds in aquatic invertebrates.

Behavioural patterns are known to be highly sensitive to changes in the
steady state of an organism. Animal behaviour is a neurotropically regulated
phenomenon, which is mediated by neurotransmitters (Bull and Inerney, 1974).
The organophosphorus and carbamate compounds are known to inhibit
acetylcholinesterase, the enzyme that is present in synaptic regions and mediates
transmission of impulse by breaking acetylcholine to acetic acid and choline
(O'Brien, 1967). Several reviews, however, have demonstrated the sensitivity of
fish behavioural toxicity tests and have suggested that these tests be added to the
current hazardous evaluation process (Olla et al., 1980; Westlake, 1984; Little et al., 1985). Various behavioural changes that have been associated with organophosphorus and organochlorine insecticides in a number of species of fish include loss of locomotor control (Raind, 1977), avoidance (Kynard, 1974), decreased feeding, increased aggression, elevated number of comfort movements and respiratory disruptions (Bull and Mc Inerney, 1974). In view of this, the effect of lethal and sub lethal concentrations of dimethoate (EC35%) on the general behavioural pattern of the fish, *Cyprinus carpio* are investigated in the present study.

**RESULTS**

**Normal fish**

Control fishes maintained a fairly compact school, covering about one third of the bottom during the first 5th day of the 15th days experiment. By 6th day, the school became less compact covering up to two-third of the tank area. Fishes were observed to scrap the bottom surface. When startled, they instantly formed a tight school that was maintained briefly. They were sensitive to light and moved to the bottom of the tank when light was passed into the tank. Except a less response to form a dense school towards the end of the study, no other extraordinary behaviour was observed.

**Treated fish**

Fish exposed to the lethal concentration of dimethoate, migrated immediately to the bottom of tank. The schooling behaviour was observed to be disrupted in the first day itself. Fish occupied twice the area than that of the control
group. They were spread out and appeared to be swimming independent of one another. This was followed by irregular, erratic and darting movements with imbalanced swimming activity. The swimming behaviour was in a cork crew pattern rotating along horizontal axis and followed by ‘s’ jerk, partial jerk, sudden, rapid, non-directed spurt of forward movement (burst swimming). The frequency of surfacing phenomenon was greater on the second day of exposure wherein the fish frequently came to the water surface. On day 3 the fish were continuing in the surface area in a horizontal axis without showing escaping phenomenon (jumping). On the 4th day they lost their equilibrium and response, to external stimuli such as touch and light followed by drowning to the bottom. The fish eventually died with their mouth and operculum wide opened. A change in colour of the gill lamellae form reddish to light brown with coagulation of mucus on gill lamellae was seen in dead fish.

In sublethal treatment, the schooling behaviour of the fish was slowly disrupted during the first day. The ventilation rate was increased, hyperactivity, excitement, hyperventilation etc, were not much influenced on exposure to the sublethal concentration of dimethoate at 5 and 10 days. Further, the fish at 15 days of exposure exhibited balanced swimming and active feeding. The fish behaved in normal way.

DISCUSSION

The migration of the fish to the bottom of the tank following the addition of dimethoate, clearly indicates the avoidance behaviour of the fish as observed in the
carps which was reported by David et al., (2002); Murthy, (1987). Nisar Ahmed, (1989) have also observed the avoidance nature by *Labeo rohita* on exposure to three pollutants viz., endosulfan, malathion and sevin. Similar behaviour was reported by Belitginer and Freeman, (1983); Hartwell *et al.*, (1989) in various species of fish. It has been also reported by Folmar, (1976) that Rainbow trout can detect and avoid copper sulphate, dalapon, xylene and acrolein. The lethal concentration of herbicide glyphosate has been avoided by Rainbow trout (Hildebrand *et al.*, 1982). Similar observation was reported by Devi, (1991) on the *Oreochromis mossambicus* exposed to endosulfan.

Disruption of schooling behaviour of the fish, due to the lethal and sublethal stress of the toxicant, results in increased swimming activity, and entails increased expenditure of energy (Murty, 1987). A change in the normal physiological and biochemical aspects in the treated fish in the present study could be attributed to the disruption of the schooling behaviour of the fish, which in turn leads to higher activities as suggested by Murty, (1987). Weis and Weis, (1974) have reported that carbaryl has a marked effect on the schooling behaviour of the Atlantic silverside. Loss of such behaviour following pesticide exposures has been observed by Drummond *et al.*, (1986).

The treated fish resorts to erratic swimming indicating loss of equilibrium. It is likely that the region in the brain which is associated with the maintenance of equilibrium should have been affected (Sambasiva Rao *et al.*, 1984; Mehrle and Mayer, 1975; Drummond *et al.*, 1986). Loss of equilibrium and erratic swimming
are reported in blue gills exposed to dursban (Mehrle and Mayer, 1975). Excited and erratic movements were observed by Santhakumar et al., (2001) in *Anabas testudineus* exposed to monocrotophos. Similar observation was also reported by Sabita and Yadav, (1995) on the fish *Heteropneustes fossilis* exposed to rogor and endosulfan.

Fish can sometimes sense the presence of a xenobiotic chemical in water and tend to avoid it. The surfacing phenomenon exhibited by dimethoate exposure fish, might either be due to hypoxic condition of the fish as reported by Sambasiva Rao et al., (1984) for *Channa punctatus*. The increased surfacing phenomenon during the initial periods of exposure to dimethoate concentrations suggests an elevated rate of metabolism. Changes in ventilation rate and surfacing frequencies are the general symptoms noticed in the fish after exposure to the pesticide and these activities help the fish to avoid contact with poison and fight against stress (Ray and Munshi, 1987). This fact is clearly evidenced in the present study. Chronic exposure of finfish to aroclor was found to induce surfacing phenomenon of fish as pointed out by Hansen et al., (1972). Drummond et al., (1986), have recorded similar observation in fathead minnow treated with different chemical groups.

The increased ventilation rate by rapid, repeated opening and closing of the mouth and opercular coverings accompanied by partially extended fins (Coughing) was observed in the present study. This could be due to clearance of the accumulated mucus debris in the gill region for proper breathing as suggested by Carlson and Drummond, (1978), Cough and Yawns seem to be a more extreme
effort to do the same (Cairns et al., 1982). Similar situation was observed by Carlson et al., (1982) in bluegill. Like wise, monocrotophos exposure has been reported to cause increased opercular movements in Anabas testudineus (Santhakumar et al., 2000). Schaumburg et al., (1967) have noticed a direct relationship between the frequency of coughing and the time of exposure in Rainbow trout. Coughing frequency in Coho Salmon was observed to be increased with increasing concentration of fenitrothion (Bull and Mc Inerney, 1974).

The hyper excitability of the fish invariably in the lethal and sublethal exposure of dimethoate may probably be due to the hindrance in the functioning of the enzyme AChE in relation to nervous system as suggested by many authors (Moore, 1966; Narasimha et al., 1986; Shakul Hameed and Vadamalai, 1986; Agarwal and Balakrishanan, 1989). It leads to accumulation of acetylcholine, which is likely to cause prolonged excitatory postsynaptic potential. This may first lead to stimulation and later cause a block in the cholinergic system. David, (1995) has observed hyperactivity, in Labeo rohita exposed to fenvalerate to affect central nervous system. Mehrle and Mayer, (1975) and Venugopalan and Sasibhushana Rao, (1979) reported the state of neuromotor system in the exposed fish. Pesticide exposures manifest into hyperactivity of muscles in Blunt nose minnow (Mount, 1962); Gold fish (Grant and Mehrle, 1970); Cyprinus carpio (Toor and Kaur, 1974); Barbus stigma (Manoharan and Subbaiah, 1982); Tilapia mossambica (Deva Prakasa Raju, 2000) and Anabas testudinus (Madhab Prasad et al., 2002).

Pronounced secretion of mucus in the fishes exposed to pesticide may be an adoptive response perhaps for providing additional protection against corrosive
nature of the pesticides and to avoid the absorptions of the toxicant by the general body surface. This agrees to the earlier findings of Sadha, (1993); Sabita and Yadav, (1995); Santhakumar and Balaji, (2000). Loss of positive rheotaxis of the fish is a good indication of toxic response. Similar observation has also been made in *Tilapia renalli* exposed to 'bis' by Chliamovitch and Khun, (1977).

Behavioural characteristics are obviously sensitive indicators of toxicant effect. It is necessary, however, to select behavioural indices for monitoring that relation to the organism’s behaviour in the field in order to derive a more accurate assessment of the hazards that a contaminant may pose in natural systems. In the present study as evidenced by the results the abnormal changes in the fish exposed to lethal concentration of dimethoate are time dependent. However, the normal behaviour of the fish at 10 and 15 days on exposed to sub lethal concentrations indicates its adaptability to the sub lethal concentration due to long term exposure of dimethoate.