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Acute Toxic Effects of Deltamethrin on Tilapia, *Oreochromis niloticus* (Linnaeus, 1758)

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Abstract

The effect of toxic compounds are variable among living organisms in different habitats. Toxicity tests are conducted to measure the effects of different pollutants on one or more species of organisms and in the form of LC_{50s}, assist in the development and application of water quality criteria for the protection of the aquatic environment. Active tilapia, *Oreochromis niloticus*, samples with size ranging between 4 and 6 cm standard length were exposed to different concentrations (between 0 and 30 µg/l) of Deltamethrin for 96 h in 50 l glass aquaria. This was to assess the dose-response of *O. niloticus* to different concentrations of the pesticide, and to estimate the LC_{50} using Probit analysis. The very low LC_{50} value of 15.47 µg/l obtained indicates that Deltamethrin is highly toxic to *O. niloticus*. This LC_{50} value should serve as a guide for the application of Deltamethrin in agriculture. Further study into the processes and mechanism by which Deltamethrin adversely affects the physiology of fishes have been recommended.

Introduction

In Ghana, modernization of agricultural practices has led to an increased use of pesticides some of which are known to be highly toxic to non–target organisms (Gordon & Odei, 1999). For instance, the use of pesticides has contributed significantly to improved national earnings from cocoa production in 2003 and 2004, as well as a reduction in the incidence of malaria in Accra (Anon., 2004). However, this positive trend in increased food production and improved health from the use of pesticides has negative ramifications for fish and other aquatic life inhabiting ponds, lakes, rivers, streams and other similar water bodies which is of great concern to the wider public.

Pesticides are meant to kill a very narrow range of undesirable organisms but they are capable of harming non-target organisms inhabiting treated ecosystems. They reach and remain in aquatic ecosystems through run-off and trophic transfers. On reaching aquatic ecosystems, such chemicals can cause serious harm to man dependent on water bodies. Deltamethrin is one of the pesticides widely used in many countries worldwide including Ghana (Extoxnet, 1995). It is a pyrethroid insecticide that kills insects on contact and through digestion. It has very broad spectrum control and is considered the most powerful of the synthetic pyrethroids because it is relatively stable and non persistent in the environment. It is used in many countries for agricultural, public health and livestock applications such as in the control of mosquitoes, fleas, cockroaches and tsetse flies (PAN Pesticide Database, 1996). In fact, pyrethroids were used during various periods in the recently-ended Onchocerciasis Control Programme in Ghana (Environmental Protection Agency, Ghana, personal communication).

Toxicity tests are conducted to measure the effects of one or more pollutants on one or more species of organisms (Reish & Oshida, 1987). In freshwater, the presence or absence of fish has been widely used as a biological indicator of the degree of pollution. Data obtained on the concentration of selected individual pollutants which are lethal to fish provide very necessary information, apart from identifying a boundary limit above which fish are likely to be killed (Lockwood, 1976). One of the commonly used measures of toxicity is the LC_{50}, i.e. the lethal median concentration that causes mortality in 50% of test organisms. A chemical with an LC_{50}, value of 5 µg/l is very highly toxic compared to one with 1000 mg/l which is practically non-toxic (Stephan, 1977). The knowledge gained from dose-response studies in animals is used to set standards for human exposure and the amount of chemical residue that is allowed in the environment.

Fisheries have provided humanity with food and economic benefits to many countries worldwide and in Ghana fish is an important source of protein, generally contributing about 60% of animal protein to diets (Directorate of Fisheries, 2003; Koranteng *et al*., 2004). Many communities living along rivers and lakes depend on fishing as a source of livelihood. Tilapia, especially *Oreochromis niloticus* was chosen for the study because it is abundant in Ghanaian fresh waters and widely utilized in aquaculture because of its hardy nature (Brummett & Noble, 1995; Prein *et al*., 1996). However, some practices of fishers and farmers during the lean season of the year, such as fishing with DDT, cause a lot of harm to many fish as well as other aquatic life. The fishes and crustaceans may subsequently be harvested and inadvertently consumed by residents. This has public health implications; some of the chemicals have carcinogenic and mutagenic effects (Mclyntyre & Mills, 1975).

The study aimed to assess the dose-response of *O. niloticus* to different concentrations of Deltamethrin and to determine the LC_{50} of Deltamethrin to tilapia, *O. niloticus.*

Materials and methods

The tests were performed in a laboratory equipped with concrete holding tanks, glass aquaria, constant supply of water and good lighting system. The indoor tanks were filled with tap water and aerated for 3 days to help reduce the chlorine content. About 300 active test specimens ranging between 4 and 6 cm standard length were transported to the laboratory from a farm about 5 km away. The specimens were acclimatized to laboratory conditions for 7 days in the indoor holding tanks. The *p*H, dissolved oxygen concentration and temperature of water in the tanks were monitored daily using a standardized digital meter.

Preliminary tests were conducted to provide guidance on range of concentration of pesticide to use in the bioassay. A stock solution of 25 mg/l was prepared from the original product concentration of 12.5 g/l. From the stock solution, the test solutions were prepared using distilled water. The specimens were not fed a day prior to and during toxicity tests to reduce faecal and excess food contaminating the test solution. The nominal test concentrations were 0.0 µg/l, 10.0 µg/l, 15.0 µg/l, 20.0 µg/l, 25.0 µg/l and 30.0 µg/l with three replicates each. Ten specimens were placed in each 75 × 45 cm glass aquarium located indoors, filled with 50 l of test solution and aerated using tubed motorized pumps. Monofilament netting was used to cover the tanks to prevent the specimens from jumping out of test solutions. The behaviour of specimens was observed and death was recorded for the 96-h test period. Death was defined as complete immobility with no flexion of the abdomen upon forced extensions (Lockwood, 1976).

The results from the toxicity tests were analyzed, using a World Health Organisation (WHO) Computer Pro-gramme, Probit (1982). The concen-trations used were converted by the programme to log dose and the number of dead fishes to mortality Probit values. A plot of these two parameters was made from which the LC_{50} was estimated.

Results and discussion

Temperature, dissolved oxygen and *p*H of the test solutions recorded did not fluctuate significantly over the test period (Table 1). When the fishes were exposed to Deltamethrin, mortalities recorded increased with increasing concentrations and death occurred faster in the higher concentrations (Table 2). On initial contact, the test fishes became inactive, about 80% of fishes in the 15–30 µg/l test solutions laid down on their sides or remained in a vertical position for up to 4-6 h. Swimming began after this period but fishes were not as active as those in the control tanks. A similar observation was also made in previous studies using *Tilapia mossambica* and *Saratherodon mossambica* in South Africa (INCHEM, 1990).

TABLE 1

Mean ± s.e. daily p*H, temperature and dissolved oxygen of test solutions*

Concentration µg/l	p*H*	*Temperature °C*	*Dissolved oxygen mg/l*
Control	6.60 ± 0.04	26.7 ± 0.05	3.98 ± 0.06
10.0	6.69 ± 0.03	26.8 ± 0.05	4.12 ± 0.07
15.0	6.80 ± 0.04	26.6 ± 0.04	3.93 ± 0.05

20.0	6.71 ± 0.05	26.7 ± 0.05	3.75 ± 0.06
25.0	6.56 ± 0.04	26.7 ± 0.05	3.78 ± 0.06
30.0	6.58 ± 0.04	26.5 ± 0.04	3.55 ± 0.05

TABLE 2

Summary of number of fish deaths and survivors after 96 h in test solutions (number in each test solution, n = 10)

Conc.mg/l	*Replicate 1*		*Replicate 2*		*Replicate 3*	
	Dead	*Alive*	*Dead*	*Alive*	*Dead*	*Alive*
Control	0	10	0	10	0	10
10.0	2	8	2	8	2	8
15.0	5	5	5	5	5	5
20.0	7	3	7	3	6	4
25.5	8	2	8	2	9	1
30.0	10	0	9	1	10	0

The successive physiological disturbances induced by pesticides which include hyperactivity, loss of equilibrium, tremors and convulsions are capable of producing an avoidance mechanism causing population movement (Schimmel *et al*., 1983; Murty, 1986). Some species such as the rainbow trout, *Salmo gairdneri*, tend to remain motionless for several minutes. This observation is comparable to the findings of this study, i.e. fishes remained motionless after exposure to high concentrations of Deltamethrin.

Dose response of fish to chemical

The high LC_{50} value of 15.47 µg/l for Deltamethrin to *O. niloticus* (Table 3, Fig. 1) indicates the potency of the chemical. Golow & Godzi (1994) had LC_{50} value of 14.90 µg/l using the same chemical of concentration 2.5 g/l and fish of size ranging between 2 and 4 cm in tests at the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. It was a re-newal test in which the test solution was changed periodically. This value is comparable to the 15.47 µg/l that was estimated in the present study. In India, the LC_{50} of technical grade Deltamethrin on 37-day-old African catfishes, *Clarias gariepinus* was 0.63 µg/l (Lamai *et al*., 1999). This suggests that the fry are more susceptible, and different species respond differently to concentrations of chemicals.

TABLE 3

LC_{50} values and summary statistics from the Probit plots

Replicates	*LC_{50} (mg/l)*	*95% Confidence limits*
1	15.37	10.86 – 18.92
2	15.50	10.49 – 19.32
3	15.55	11.36 – 19.06
Average	15.47	10.90 – 19.10

Statistical summary

Degrees of freedom	Chi^2	probability	t-value	heterogeneity	No. of iterations
3	3.316	0.3454	1.96	1.00	7

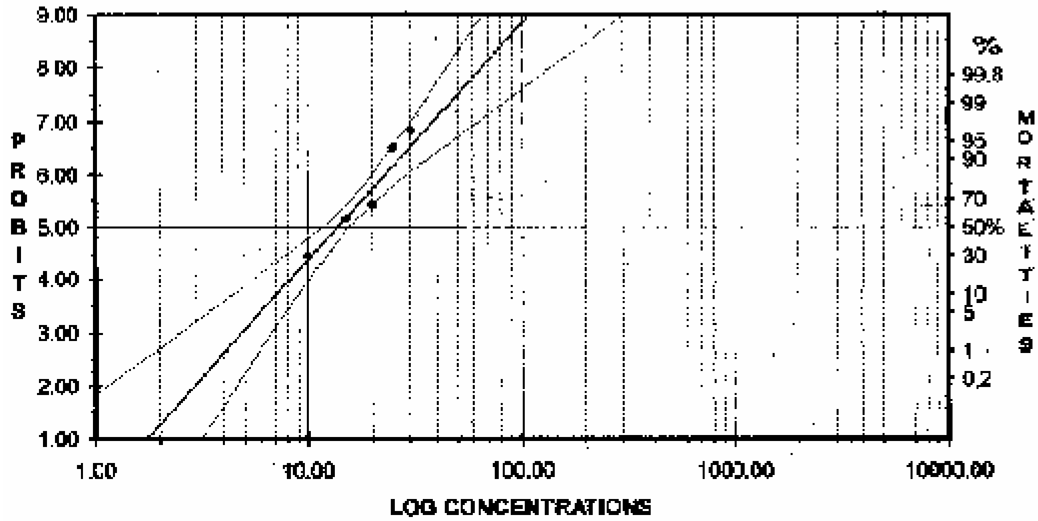

Fig. 1. A typical Probit plot showing LC_{50} value

There are others that did not die in the test solutions even after the 96 h; there is, however, a probability that they had accumulated some amount of toxins. When such fishes are consumed by man, implications may include respiratory malfunctions, hypersensitivity and genetic mutations. There are also problems that can arise as a result of mishandling and wrong applications of chemicals. Some have corrosive effects and produce a burning sensation when used without protective gloves.

It must not be forgotten, however, that agents of toxicity, only very exceptionally, possess selective toxicity toward their target organisms; they can exercise harmful effects on other categories of living creatures, particularly on man himself (Bell & Megillivray, 2000). High values of chemicals in water bodies that serve as source of drinking water reduces its quality and can pose serious health problems such as diarrhoea and vomiting.

Conclusion and recommendations

When fishes were exposed to Deltamethrin, they became inactive for between 4–6 h depending on the concentration. In their natural environment such as in ponds or lakes, this will make them vulnerable to their predators and diseases unless they escape early enough. The study showed that Deltamethrin is highly toxic to *O. niloticus* with a very low LC_{50} of 15.47 mg/l. Given the high toxicity of Deltamethrin to fishes, it is clear that a certain degree of environmental education is needed to ensure the right application of pesticides. The desire to improve food production from crops should be tempered with a consideration for other food sources such as fish, as well as conserving aquatic biodiversity.

It is recommended that expanded toxicity tests are conducted using different chemicals and organisms to document LC_{50} values and other relevant data to help environmental authorities such as the Environmental Protection Agency (EPA) in Ghana come up with dosage requirements. With adequate information, informed decisions can be made about the use of chemicals to minimize the risk to human health and the environment.

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