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Acute Toxicity of the Synthetic Pyrethroid Deltamethrin to Fingerling European Catfish, *Silurus glanis* L.

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The wide use of synthetic pesticides is increasing worldwide pollution risks. The synthetic pyrethroids are among the most potent and effective insecticides available (Moore and Waring 2001), accounting for more than 30% of the world market in insecticides. The low toxicity of pyrethroid insecticides to mammals and birds and their limited soil persistence has encouraged the widespread and increasing use of pyrethroids in agriculture, as they are very potent agents against pests (Delistraty 2000; Milam et al. 2000; Köprücü and Aydın 2004).

Use of pyrethroids leads to the exposure of manufacturing workers, field applicators, the ecosystem, and the public to the possible toxic effects of these pesticides. Pesticides applied to the land may be washed into surface waters and may kill or at least adversely influence the life of aquatic organisms (Datta and Kaviraj 2003). The toxicity of synthetic pyrethroids in birds and domestic animals is low. However, fish are extremely sensitive to the neurotoxic effects of these pesticides. Pyrethroids have been shown to be neurotoxic and lethal to fish at concentrations 10-1000 times lower than corresponding values for mammals and birds (Bradbury and Coats 1989; Eells et al. 1993).

Pyrethroid toxicity is highly dependent on stereochemical structure (Milam et al. 2000). Deltamethrin, which is a synthetic type two pyrethroid insecticide and acaricide, was synthesized in 1974, and first marketed in 1977. Synthetic pyrethroids have been found to be highly toxic to fish (URL 1; Svobodova et al. 2003; Viran et al. 2003; Calta and Ural 2004; Köprücü and Aydın 2004), zooplankton communities (Tidou et al. 1992) and some beneficial aquatic arthropods (Srivastav et al. 1997). Effects of deltamethrin on nervous, hematological and respiratory systems in fishes have been reported (Golow and Godzi 1994). The environmental fate and effects of synthetic pyrethroid insecticides have been summarized by Hill (1989).

The World Health Organization published a report of acute toxicity data for deltamethrin in fish and classified it as highly toxic to fish; with the 96 h LC_{50} values ranging between 0.4-2.0 μg L^{-1} (WHO 1990). The Environmental Protection Agency states deltamethrin's bioconcentration factor is 698 for whole fish (URL 2).

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The European catfish (wells or sheatfish), *Silurus glanis* Linneaus 1758, is Europe's largest freshwater fish and is found in the Rhine River in Germany eastwards to the Black and Caspian Seas. It is presently cultured in ponds all over Asia, central and eastern Europe, with carp (URL 3; Linhart et al. 2002).

In Turkey, larvae of European catfish are artificially reared and then introduced to their natural freshwater reservoirs when they have reached the fingerling stage. At the same time, deltamethrin is a commonly used pesticide for pest control in the agricultural fields around these freshwater reservoirs. Therefore, the present study has aimed to determine the acute toxicity of deltamethrin on fingerling European catfish at the size attained just before introduction into reservoirs. In addition, in the present study lethal concentrations of deltamethrin have been firstly determined on the fingerling European catfish as a model species. Finally, our findings would be a useful tool for the control of regional reservoirs and their effective management with respect to the input of deltamethrin from agricultural areas.

MATERIALS AND METHODS

In this study, a static acute toxicity bioassay was performed according to the standard method (APHA 1985) to determine the 1, 12, 24, 48, 72 and 96 h lethal concentration values (LC_{10-90}) of deltamethrin (purity 2.5%, dissolved in 97.5% acetone), (S)-alpha-cyano-3-phenoxybenzyl (1R, 3R)-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropancarboxylate, (Roussel Uclaf DECIS 2.5 EC) for fingerling European catfish.

Fish, weighing 15-18 g and total length 13-15 cm, were obtained from the Keban Fish Breeding Unit of DSI IX., Region Directorate. They were brought to the laboratory and acclimatized to laboratory conditions for 7 days. Water temperature in the aquaria was maintained at 17±1 °C using a heater and the fish were subjected to a 12 h photoperiod using fluorescent lights. Fishes were fed with pellet feeds during adaptation, but they were not fed during the last 24 h of adaptation and throughout the duration of the test. Before starting the test, all experimental aquaria (280 L) were cleaned and filled with 270 L of dechlorinated tap water. The experimental water was kept in the tank for 24 h before deltamethrin was added. Water quality characteristics in the control units were determined according to APHA (1985). Dissolved oxygen, pH and conductivity were determined by a digital oxygen meter and a pH meter. The mean quality parameters of water used for preparation of test solutions were as follows; dissolved oxygen 7.2±0.4 mg L^{-1}, pH 8.4±0.1, electrical conductivity 227±9.5 μS cm^{-1}, alkalinity 148±24 mg L^{-1} and total hardness 196±15 mg L^{-1} as $CaCO_3$.

Seven different concentrations of deltamethrin (0.25, 0.50, 0.75, 1, 2, 3 and 4 μg L^{-1}) and a control with five replicates were used in the test series. Exceeding aeration was applied to the aquarium for 2 h in order to obtain a homogeneous concentration of the toxic compound, and then 20 fish were transferred into each aquarium. Mortality was assessed at 1, 24, 48, 72 and 96 h after the start and dead fishes were removed immediately. Behavioral changes of test animals were closely followed and recorded.

Deltamethrin was prepared from a stock solution weighed in a glass boat and transferred to a volumetric flask containing experimental water. Dilutions of the defined stock solution were used for tests described below. The stock solutions were renewed every 12 h. Two control groups received acetone at a concentration used in the dilution of the maximum deltamethrin concentration.

All replicates were used for calculation of mean values. Statistical analyses were performed with the SPSS 10.1 computer program (SPSS Inc. Chicago, Illinois, USA). Data obtained from the deltamethrin acute toxicity tests were evaluated using the probit analysis method. The lethal concentrations with 95% confidence limits were calculated. The chi-square test was employed for comparing mean mortality values using a significance level of 0.05.

RESULTS AND DISCUSSION

The results show that deltamethrin is very toxic to fingerling European catfish, *Silurus glanis*. Its toxicity on fingerling European catfish increased with increasing concentration and exposure time. For example, when fish were exposed to 0.50 μg L^{-1} deltamethrin, only 20% died at 96 h whereas 94% died at 1 h when exposed to the 4 μg L^{-1} deltamethrin concentration ($p<0.05$, Table 1). In addition, the 1, 24, 48, 72 and 96 h LC_{50} values of water-soluble deltamethrin, using a static bioassay system to fingerling European catfish were determined as 2.497, 1.446, 1.215, 0.866 and 0.686 μg L^{-1}, respectively. There were significant differences in LC_{10-90} values obtained for different times of exposure ($p<0.05$, Table 2).

There are differences in the acute toxicity of deltamethrin for various fish species. The USDA National Agricultural Pesticide Impact Assessment Program's EXTOXNET document reports that deltamethrin has acute toxicity to fish in laboratory tests to be in the average range LC_{50} value of 1-10 μg L^{-1} (URL 1). Datta and Kaviraj (2003) found 24-96 h LC_{50} value for cathfish, *Clarias gariepinus*, as 0.004-0.015 μg L^{-1}. Mittal et al. (1994) reported deltamethrin toxicity to guppy, *Poecilia reticulata*, as the most toxic of the pyrethroids studied (96h LC_{50} value = 0.016 μg L^{-1}). Viran et al. (2003) estimated the 48 h LC_{50} value of deltamethrin for guppy as 5.13 μg L^{-1}. Svobodova et al. (2003), Calta and Ural (2004), Mestres and Mestres (1992) and Lakota et al. (1989) determined 96 h LC_{50} values for common carp, *Cyprinus carpio*, as 0.06 μg L^{-1}, 1.65 μg L^{-1}, 1.84 μg L^{-1} and 3.50 μg L^{-1}, respectively. Mestres and Mestres (1992) reported a 96 h LC_{50} value for rainbow trout, *Oncorhynchus mykiss*, as 0.39 μg L^{-1}. Köprücü and Aydın (2004) estimated 48 h LC_{50} values for common carp embryos and larvae as 0.213 μg L^{-1} and 0.074 μg L^{-1}, respectively. Bradbury and Coats (1989) have reviewed the toxicology of pyrethroids in fish, invertebrates, amphibians, mammals, and birds and cited deltamethrin toxicity to *Salmo salar*, *Gambussia affinis* and *Oncorhynchus mykiss* as 96 h LC_{50} values of between 0.50 μg L^{-1} and 1.97 μg L^{-1}. Golow and Godzi (1994) found 24-96 h LC_{50} values for fingerling Nile tilapia, *Oreochromis niloticus*, as 14.5 μg L^{-1} and 16.0 μg L^{-1}, respectively. They concluded that deltamethrin was two times more toxic to the fish species than dieldrin. Rao et al. (1983) determined 24-96 h LC_{50} value for *Esox lucius* and *Ctenopharyngodon idella* as 23-44 μg L^{-1} and 91-155 μg L^{-1}, respectively. WHO (1990) reports the acute toxicity of deltamethrin on *Oncorhynchus mykiss*, *Salmo salar* and *Salmo trutta* as 0.39-2.20 μg L^{-1}, 0.59-1.97 μg L^{-1} and 4.7 μg L^{-1}, respectively. Our results are in agreement with the reports of Bradbury and Coats (1989) and WHO (1990) for *Salmo salar*.

Some pesticides used in agriculture are known to be toxic to non-target aquatic biota (Ward et al. 1995), and deltamethrin belongs to this group. In general, this toxic effect changes with respect to species and size of fish and the duration of exposure. The results of the present study show that toxicity of deltamethrin for fingerling European catfish under such conditions is also time-dependent. However, some other researchers have shown that exposure time is not significant in LC_{50} determinations for fish (Lakota et al. 1985).

In the present study, behavioral responses of the test fish were observed at 1-12 h during the first day of exposure and then every 12 h during the last three days of exposure. Normal behavior was observed for fish of the control group and 0.25 μg L^{1} concentration. Fingerling fish exposed to 0.50 μg L^{-1} also showed normal behavior during exposure for the first 48 h, but afterwards some abnormalities, such as less general activity and loss of equilibrium, when compared with the control group fish. First changes in behavior were observed 20 min after exposure to the five highest deltamethrin concentrations (0.75, 1, 2, 3 and 4 μg L^{-1}). The abnormal behavioral responses observed at all concentrations higher than 0.50 μg L^{-1} were loss of equilibrium, hanging vertically in the water, rapid gill movement, erratic swimming, swimming at the water surface, air gulping from the water surface, or staying motionless on the aquarium bottom. In addition to these, it was observed that there was lightening in colour of fingerling European catfish.

Similar behavioral responses determined in this study have been observed with the guppy (Viran et al. 2003), freshwater catfish, *Heteropneustes fossilis* (Saha and Kaviraj 2003) and young mirror carp, *Cyprinus carpio* (Calta and Ural 2004) exposed to various concentrations of the synthetic pyrethroids cypermethrin and deltamethrin.

Although under field conditions synthetic pyrethroids are considered to pose less risk due to its high adsorption to soil, these data should be considered when assessing potential ecosystem risks. In addition, Kumaragura and Beamish (1981) reported that acute toxicity of synthetic pyrethroids to fish was negatively correlated to temperature. Therefore, the presence of pyrethroids in the aquatic environment when water temperature decreased may increase the toxic impact on fish (Moore and Waring 2001).

In conclusion, deltamethrin contamination is dangerous to aquatic ecosystems, and this fact should be taken into consideration when this insecticide is used in agriculture or in the control of mosquito populations. Biological methods could be used for controlling mosquito and flies instead of deltamethrin in order to protect the natural environment.

Table 1. Cumulative mortality of fingerling European catfish (n = 100 in five replicates).

Concentrations ($\mu g\ L^{-1}$)	Number of dead fish 1 h	24 h	48 h	72 h	96 h
Control	-	-	-	-	-
0.25	-	-	-	-	-
0.50	-	-	-	9	20
0.75	-	-	14	35	67
1	-	17	39	70	93
2	25	59	83	95	ND
3	70	91	ND		
4	94	ND			
Chi-Square value	0.32	1.20	1.38	4.29	6.03
p	<0.05	<0.05	<0.05	<0.05	<0.05

ND: No data because of 100% mortality, (-): Not dead, h: hour.

Table 2. Lethal concentrations (LC_{10-90}) of deltamethrin depending on time (1-96 h) for fingerling European catfish.

Point	Lethal concentration values with 95% confidence limits ($\mu g\ L^{-1}$)* 1 h	24 h	48 h	72 h	96 h
LC_{10}	1.662[a] (1.450-1.828)	0.747[b] (0.598-0.872)	0.641[c] (0.540-0.724)	0.491[d] (0.232-0.639)	0.392[e] (-)
LC_{20}	1.911[a] (1.719-2.063)	0.937[b] (0.789-1.061)	0.798[c] (0.704-0.878)	0.597[d] (0.349-0.746)	0.493[e] (-)
LC_{30}	2.114[a] (1.940-2.255)	1.104[b] (0.960-1.226)	0.935[c] (0.847-1.016)	0.687[d] (0.462-0.849)	0.566[e] (-)
LC_{40}	2.304[a] (2.146-2.439)	1.269[b] (1.130-1.393)	1.071[c] (0.984-1.160)	0.774[d] (0.572-0.971)	0.628[e] (-)
LC_{50}	2.497[a] (2.350-2.634)	1.446[b] (1.311-1.577)	1.215[c] (1.126-1.325)	0.866[d] (0.679-1.134)	0.686[e] (-)
LC_{60}	2.706[a] (2.563-2.856)	1.648[b] (1.509-1.799)	1.379[c] (1.268-1.525)	0.969[d] (0.782-1.366)	0.745[e] (-)
LC_{70}	2.949[a] (2.795-3.133)	1.895[b] (1.738-2.089)	1.579[c] (1.437-1.786)	1.093[d] (0.883-1.713)	0.807[e] (-)
LC_{80}	3.261[a] (3.075-3.513)	2.232[b] (2.030-2.514)	1.849[c] (1.653-2.160)	1.257[d] (0.997-2.280)	0.880[e] (-)
LC_{90}	3.750[a] (3.485-4.147)	2.800[b] (2.489-3.289)	2.303[c] (1.999-2.826)	1.528[d] (1.159-3.458)	0.981[e] (-)

*Lethal concentration values in rows with different letters significantly differ ($p<0.05$ for each case), (-): No data because of $p>0.05$

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