TOXICITY OF NICOTINE TO AQUATIC LIFE

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ABSTRACT

Bioassays were made on 10 species of fish, 8 species of aquatic insects, and 11 species of plankters. The insects were more tolerant than fishes and plankters. Sodium carbonate and lime increased nicotine toxicity. Nicotine detoxified in 8 days in alkaline and in 30 days in neutral waters. Nicotine, at 3.2 ppm, produced severe histopathological lesions in the livers and kidneys of fish. Mixed with lime, the prospect of nicotine as fish poison greatly increased.

INTRODUCTION

Nicotine, a plant alkaloid, has potentiality of a fish poison (Konar 1969a, 1970). Nicotine is more toxic to fish than to aquatic insects (Phillips and Swingle 1940, Brown 1951). This paper describes the toxicity of nicotine to freshwater fishes, insects and plankters; the influence of turbidity, sodium carbonate and lime on the toxicity of nicotine; the residual toxicity of nicotine in water; and the histopathological effects of nicotine on fish.

MATERIALS AND METHODS

Nicotine [1-methyl-2 (3'-pyridyl) pyrrolidine] is an insecticide derived from the plant, *Nicotiana* sp. The water-soluble formulation, nicotine sulphate (distributed by Bharat Pulverising Mills Pvt. Ltd., Bombay), containing 40% pure nicotine was used. All test animals except rohu, were collected from local ponds; rohu were purchased from local hatcheries. The plankters were acclimatized to test conditions for 2 days, and other organisms for 15-20 days. The fishes were fed rice-bran, mustard-oil cake and prawn dust, and the insects, fish fry.

Bioassays on fish and aquatic insects were conducted after the methods described earlier (Basak and Konar 1976). For bioassays on plankton, pond water (pH, 7.8; methyl orange alkalinity, 110 ppm as CoC03; total hardness, 205 ppm as CaC03; D0, 8.5 ppm) with its plankton population was treated with 1, 2, 5, 10, 20, 40 and 50 ppm of nicotine in separate aquaria. During 168-h tests, the abundance of a plankton in an aquarium was verified from its presence in each of twenty 50-ml samples of water, and total mortality from its absence from 20 samples of water (Konar 1969b).

The toxicity of mixtures of nicotine and 100 ppm of sodium carbonate or nicotine and 100 ppm of lime to fish and insects was determined. Control aquaria received 100 ppm of sodium carbonate or lime. The influence of 500, 13,750, and 20,000 ppm turbidity (suspended solids) on the toxicity of nicotine (applied with 100 ppm of sodium carbonate or of lime) was assessed using the air-breathing fishes, lata (105-115 mm), singhi (130-137 mm), and khalisa (55-71 mm). The controls were maintained. The tests were run for 48 h.

The residual toxicity of 5 ppm nicotine was determined in outdoor earthen vessels holding 20 liters of water (15-25 C). The first vessel was kept unmodified, the second mixed with 100 ppm of sodium carbonate, the third with 100 ppm of lime, and the fourth with 100 ppm sodium carbonate and 1000 ppm clay (dried and powdered). The pH of water was 7.3 in the first vessel and 8.8 in other vessels. Batches of young khalisa (30-35 mm) were placed in the water at 2-day intervals to record fish mortality. Tests were continued until all survived for 2 days.

Histopathological studies were made on singhi and rohu exposed to 3.2 ppm nicotine (Lillie 1954). The fishes were sampled before death and preserved in Bouin's solution.

RESULTS

Toxicity to fishes, aquatic insects and plankton

On exposure, fish were excited and surfaced after 10-20 minutes; some jumped up, and a few swam erratically near the surface. After 30-40 minutes of surfacing, the fins and gill-covers were paralysed and the fish dropped to the bottom. As opercular movement ceased, the fish occasionally jumped up to gulp air at the surface. Then the fish died within 5-50 h. The toxicity of nicotine varied with species (Table 1). Nandus and rohu were more susceptible and lata, more tolerant.

The insects showed varied reactions. On exposure, the anisopteran nymphs were greatly excited, and swam around, occasionally ejecting water through anus. After 10-15 minutes, they became lethargic and settled at the bottom. The bugs and beetles stretched their legs and became inactive 24 h before death. No insect surfaced at any time. The toxicity of nicotine also varied with species of aquatic insects (Table 1). The anisopteran nymphs were the most sensitive and adult *Dytiscus* the most tolerant. Insects died within 2-7 days after exposure.

The plankters showed varied response. The zooplankters (namely, *Cyclops, Nauplius, Daphnia* and *Ceriodaphnia*) were killed at 2 ppm in 168 h;

Cypris tolerated this concentration. *Diaptomus, Gastrotrica* and *Brachionus* tolerated up to 50 ppm for 168 h. All phytoplankters (*Volvox, Pandorina* and *Closterium*) survived 5 ppm for 168 h.

TABLE 1. 168-*h toxicity of nicotine to fishes and aquatic insects. The concentrations are given in terms of active ingredient.*

Organisms	Size range (mm)	Concentrations (ppm)		
		LCO	LC50	LC100
FISHES:				
Nandus (*Nandus nandus*)	61-127	1.0	2.21	3.2
Rohu (*Labeo rohita*)	60-69	1.0	2.39	3.2
Singhi (*Heteropneustes fossilis*)	98-110	2.0	2.63	3.2
Pankal (*Mastocembelus pancalus*)	119-125	1.0	2.70	4.0
Nuria (*Esomus danrica*)	38-49	2.0	2.82	4.0
Punti (*Puntius sophore*)	43-75	1.0	2.37	5.0
Khalisa (*Trichogaster fasciatus*)	39-62	2.0	3.56	6.4
Tengra (*Mystus vittatus*)	90-96	3.2	4.76	6.4
Cuchia (*Amphipnous cuchia*)	170-220	3.2	5.74	10.0
Lata (*Channa punctatus*)	75-110	6.4	8.45	13.0
AQUATIC INSECTS:				
Anisopteran nymph	19-29	4.0	7.13	13.0
Diving beetle (*Dytiscus* sp.)				
larva	36-42	6.4	9.10	13.0
adult	26-30	400.0	598.41	700.0
Water scorpion (*Nepa* sp.)	17-24	6.4	8.77	16.0
Water bug (*Spherodema annulatum*)	20-25	20.0	31.92	50.0
Water stick (*Ranatra filiformis*)	24-32	40.0	63.39	100.0
Black beetle (*Hydrophilus* sp.)	26-31	50.0	72.95	100.0
Giant water bug (*Belostoma* sp.)	70-86	80.0	115.35	200.0
Olive brown beetle (*Cybister* sp.)	38-40	80.0	289.88	640.0

Influence of sodium carbonate, lime and turbidity on nicotine toxicity

The influence of 100 ppm of sodium carbonate or of lime on the toxicity of nicotine to various species of fishes and insects was assessed (Table 2). Sodium carbonate or lime increased the toxicity of nicotine. The concentration of nicotine and the time required for total mortality decreased considerably.

Lata, singhi and khalisa were killed in 13 h, respectively, by 2, 2.5 and 5 ppm of nicotine (mixed with sodium carbonate or lime) in waters having 500, 13,750 and 20,000 ppm of turbidity.

Residual toxicity in water

In clear water (pH 7.3), 5 ppm of nicotine detoxified in 30 days. In water having 100 ppm of sodium carbonate or lime, 5 ppm of nicotine dissipated in 8 days; the turbidity at 1000 ppm had no influence on the detoxification.

Histopathological effects

In singhi, the hepatic cells of livers degenerated and numerous dark-stained patches appeared. In rohu, the hepatic cells swelled greatly and vacuolated. In the kidneys of both the fishes, the renal epithelial cells ruptured, the tubules collapsed and a few glomeruli degenerated. Apparently, acute levels of nicotine quickly penetrated fish body to induce severe histological lesions.

TABLE 2. *Effective concentrations of nicotine for 100% kill of fish and aquatic insects when applied with 100 ppm of sodium carbonate or of lime.*

Organisms	Size range (mm)	Nicotine concentration (ppm)	Time for 100% kill (h)
FISHES:			
Pankal	74-85	0.50	13
Nandus	72-100	1.60	13
Nuria	45-46	2.0	3
Lata	70-105	2.0	6
Rohu	55-65	2.5	11
Singhi	130-140	2.5	7
Cuchia	500-570	3.2	13
Punti	45-50	4.0	13
Tengra	90-95	4.5	10
Khalisa	69-70	5.0	13
AQUATIC INSECTS:			
Anisopteran nymph	16-21	10.0	13
Water bug	20-26	40.0	20
Water stick	26-30	80.0	20
Black beetle	27-31	80.0	13
Diving beetle (adult)	25-32	300.0	13
Olive brown beetle	38-40	500.0	43

DISCUSSION

Obviously, the air-breathing organisms were generally more tolerant than non-air-breathers. The predatory fishes and many aquatic insects were air-breathers. As the crustacean plankters (copepods and cladocerans) were water- breathers, they were susceptible to nicotine.

Sodium or calcium salts activate the toxicity of nicotine. When applied to water, nicotine sulphate decomposes and the active principle, nicotine, is set free. When a weak alkali or a basic salt is added, a large amount of nicotine is rapidly released in water and hence the toxicity is increased. This observation is corroborated by Thatcher and Streeter (1923), Levine and Richardson (1934) and Wunder (1950).

The most remarkable reaction of exposed fish is quick surfacing. During surfacing, they can be easily caught and removed to fresh water where they recover speedily (Konar 1970). If not removed, the fishes drop to the bottom due to paralysis. The quick surfacing and recovery of fish by nicotine may be of value in fishery management. Thus nicotine may be useful for live-capture of fish from revervoirs. Suitable activators, such as lime, may be used to increase the toxicity of nicotine; this will reduce the application cost, increase the action on fish and reduce residual hazards. Furthermore, nicotine applied with lime may be useful for eradicating fishes from even turbid waters. Nicotine, however, will not be suitable for the control of predatory aquatic insects from nursery ponds.

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