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Toxic Effects of Industrial Effluents on Hatchability and Viability of *Cyprinus carpio* Eggs

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Both field and laboratory studies have revealed that the early developmental stages of fishes are most susceptible to pollutants. Acidification of water and low concentrations of metals and pesticides reduce egg hatchability /viability and larval survival, which are of great concern for recruitment of fishes (von Westernhagen 1988). There have been studies of embryo viability and hatching success of freshwater fishes at low concentrations of single toxicants in clean water (Lockwood 1976; McCormick et al.1984; Mayes et al. 1986; Dave et al. 1987). However,there is paucity of information on the embryo viability and hatching success of fishes in effluents containing mixtures of organic and inorganic toxicants. Recently, the toxic effects of industrial waste and domestic sewage on embryo viability of rainbow trout, Salmo gairdneri (Fraser and Clark 1984); of pulp and paper mill effluent on egg hatchability of pike, Esox lucius (Tana and Nikunen 1986) and bleached kraft mill effluent on early life stages of brown trout, Salmo trutta (Vuorinen and Vuorinen 1987), have been studied. Hence, the aim of the present study was to examine the effect of different industrial effluents on the hatchability and viability of Cyprinus carpio eggs and to determine their safe levels for discharge.

MATERIALS AND METHODS

Bioassays were conducted in the laboratory for 96 hr to study the toxicity of industrial effluents to the eggs of Cyprinus carpio. Effluents of tannery, vegetable oil, fertilizer and paper industries were collected from M/s Punjab Tannery, Jalandar; M/s Markfed Vegetable and Allide industries, Khanna; M/s National Fertilizer Limited, Nangal and M/s ABC Paper Mill, Hoshiarpur, respectively. The physico-chemical

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Table 1. Chemical analysis of industrial effluents.

Parameters	Industrial Effluents			
	Tannery	Vegetable oil	Fertilizer	Paper mill
Color	Dark brown	Yellowish	Colorless	Brownish
pH	5.2	9.5	8.2	8.7
DO(mgL^{-1})	3.5	2.3	6.5	6.0
BOD(mgL^{-1})	1400	2900	20	852
COD(mgL^{-1})	3200	392	35	2070
Suspended solids(mgL^{-1})	2329	390	54	994
Dissolved solids(mgL^{-1})	5534	870	360	2195
Chloride (mgL^{-1})	2640	205	3	171
chromium (mgL^{-1})	10.5	-	0.02	-
Oil(g/gal)	-	10.52	-	-
Grease(%)	-	0.05	-	-
Ammonia (mgL^{-1})	-	-	7.0	-

analysis of the effluents are given in Table 1.

Freshly fertilized eggs of C. carpio were collected from breeding tanks of Fish Seed Farm of Punjab Agricultural University, Ludhiana. About 50 eggs (attatched to small pieces of vegetation) at early cleavage stage were placed in cylindrical jars (10x15cm) containing one liter of test solution. Dechlorinated tap water (5-6 mgL^{-1}DO; 7.6-7.8 pH; 300-310 mgL^{-1} alkalinity) at $24\pm1^{o}C$ temperature was used to dilute the effluents. The various concentrations of the effluents were prepared using dilution techniques. The effluent concentrations used in the various tests were based on preliminary range-finding tests.

Eggs were examined daily until hatching was complete. Dead eggs/larvae were recorded and removed when observed. The day, at which >50% of eggs hatched at a given concentration was recorded as the mean day to hatch. At the completion of hatching, the normal, abnormal and dead larvae were counted. After hatching, larvae were reared under similar conditions for two days to estimate the viable hatch. Ninety-six hr LC_{50} values with 95% confidence intervals were calculated by Probit analysis (Finney 1971). The Safe Application Rate (SAR) was calculated by the formula of Basak and Konar (1977).

RESULTS AND DISCUSSION

One-hundred percent hatch occurred at 0.0001(P/V) tannery and vegetable oil factory; 0.01(P/V) fertilizer and 0.1(P/V) paper mill effluent (Table 2). Abnormal larvae recorded at higher concentrations of effluents showed deformities of the head, tail and vertebral column. The comparison of the LC_{50} values (Table 3) revealed the high toxicity of tannery effluent followed by vegetable oil, fertilizer and paper mill effluent.

Factory effluents in general are chemically complex; therefore, it is very difficult to understand which particular chemicalis actually responsible for the mortality of of the test animal. In the present studies, the high toxicity of tannery effluent to carp eggs may have been attributed to the heavy load of suspended solids (2329 mgL^{-1}) and dissolved solids (5534 mgL^{-1})present. The solids may have formed a coating over the chorion thereby interfering with gas exchange. Fraser and Clark (1984) noted that 14.21 mgL^{-1} of suspended solids inhibited hatching process in rainbow trout, _Salmo gairdneri_. The high concentration of chloride ions (2640 mgL^{-1}) may also have been a factor responsible for the mortality of C. carpio eggs. Doudoroff and Katz (1950) reported that chloride ions at 0.5 mgL^{-1} are harmful to fishes. Low pH at the higher concentrations of tannery effluent (> 1.0 P/V) was low enough to cause failure of egg development, since low pH causes exosmosis of eggs and, hence, the cessation of development (Kaur and Toor 1980). Chromium in tannery effluents to the level of 10.5 mgL^{-1} may also have been another factor responsible for the tannery effluent's significant toxicity to eggs. This agrees closely with the findings of Benoit (1976) that reproduction and embryo hatchability of brook trout and rainbow trout were adversely affected at concentrations of chromium above 0.35 mgL^{-1}.

The acute toxicity of vegetable oil factory effluent to fry of freshwater teleosts (_Cirrhina mrigala_, _Labeo rohita_ and _Channa punctatus_) has been attributed to the combination of factors such as alkaline pH, ammonical nitrogen, chlorides, suspended and dissolved solids, oil and grease (Kondal et al. 1984). However, in the present studies the occurrence of oil and grease in the effluent was found to be more responsible for egg and larval mortality since they formed a coating over the chorion of the eggs and the gills of larvae, thus interfering with respiration.

Toxicity of the fertilizer factory effluent to _C. carpio_ eggs may be attributed to the high concentration of ammonia (7.0 mgL^{-1}). McCormick et al.(1984) reported that ammonia above 0.91 mgL^{-1}

Table 2. Effect of industrial effluents on hatchability and viability of *Cyprinus carpio* eggs.

Effluent concentration (P/V)[a]	Percent hatch[b]	Percent mortality[c]	Percent viable hatch
Tannery effluent			
0.0001	100	0	100
0.001	90	6	94
0.01	75	8	92
0.1	45	18	82
1.0	25	40	60
1.5	0	0	0
Vegetable oil factory effluent			
0.0001	100	0	100
0.001	77	0	100
0.01	70	6	94
0.1	68	8	92
1.0	66	15	85
2.5	28	25	75
5.0	0	0	0
Fertilizer factory effluent			
0.01	100	0	100
0.05	93	0	100
0.1	87	2	98
0.5	69	0	100
1.0	42	14	86
2.0	20	30	70
3.0	0	0	0
Paper mill effluent			
0.1	100	0	100
0.5	82	0	100
1.0	76	2	98
5.0	70	6	94
10 0	65	18	82
15.0	62	32	68
20.0	0	0	0

a- Percent / Volume
b- Including abnormal larvae
c- Two days after hatch

adversely affected the hatching success and larval survival of *Lepomis cyanellus*. However, Mayes et al.(1986) noted significant decreases in the number and survival of normal larvae of freshwater fishes at

Table 3. LC_{50} (range) and Safe Application Rate values of various industrial effluents for Cyprinus carpio eggs.

Effluents	LC_{50}(P/V)	SAR(P/V)	Relative Toxicity
Tannery	0.1247 (0.041-0.385)	0.0012	81.29
Vegetable oil	1.1376 (1.089-1.189)	0.0004	8.91
Fertilizer	1.41 (1.079-1.848)	0.0213	7.19
Paper mill	10.137 (7.190-14.29)	0.1973	1.00

0.26mg NH_3-N L^{-1}. Due to the high toxicity of ammonia to fishes, a concentration as low as 1.3 mgL^{-1} has been considered as the upper limit for the survival of fish in river waters (Thakur and Deshpande 1976).Pulp and paper mill effluent has been found to be less toxic to C. carpio eggs. At higher concentrations, low hatchability was caused by the heavy load of suspended and dissolved solids. Also, growth of slime (fungus) observed in many eggs may have been responsible for egg mortality. Fraser and Clark (1984) reported that microbial growth inhibited hatching in S. gairdneri eggs following exposure to industrial domestic sewage works effluent.

From the foregoing discussion it may be inferred that not only one but a combination of factors were responsible for the toxicity of factory effluents to the early developmental stages of fish. The studies warrant further comparative tests with mixtures of effluents and their individual toxicants to determine their effect on hatching success of embryos and survival of early life stages of commercial fish species.

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