Environmental Pollution (Series A) **36** (1984) 75–82

Toxicity of Lower than Permissible Levels of Chromium (VI) to the Freshwater Teleost *Nuria denricus*

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ABSTRACT

The impact of chromium (VI) on the freshwater teleost Nuria denricus *in concentrations ranging from 0 to 100 mg litre^{-1} was studied by computer-aided long-term static bioassays. The metal induced marked changes in the fishes' swimming and feeding patterns. It caused erosion of fin rays, ulceration, and finally death. The median lethal dose (LD_{50}) and safe concentration (SC) values obtained from the present experiments reveal that the prevailing allowable levels of chromium in drinking water, irrigation waters and effluent discharges are too high and may lead to environmental damage.*

INTRODUCTION

There are many ways in which chromium is released into the environment. It is spewed into the atmosphere with the burning of fossil fuels (Torrey, 1978) and is one of the constituents of a large number of industrial effluents, particularly of the tanning industry (Dad *et al.*, 1980; Rajamani & Madhav Krishna, 1982), electroplating units (Deutch, 1961; Sharma, 1982), chromate industry (Rajendrababu & Nandkumar, 1982), iron and steel industry (Hattingh, 1977), and cooling towers (Elwood *et al.*, 1980). Greater than natural concentrations of chromium in air, soil, surface waters and biological materials have been reported in urban areas, especially those which are highly industrialised (United States

Environ. Pollut. Ser. A. 0143-1471/84/$03·00

Office of Water Resources Research, 1972; Forstner & Wittman, 1979; Soni & Abbassi, 1980).

Although chromium is an essential micronutrient for plants and animals at trace levels (Gross & Heller, 1946; Underwood, 1971; Schwarz, 1974), it is toxic at higher concentrations. Due to unrestricted discharge of chromium in the air, water, soil and food, a stage may soon come when chromium pollution may be as widespread and dangerous as that of mercury, lead and DDT. The present study was undertaken to evaluate the safe concentration of chromium to a common freshwater fish (channelfish, *Nuria denricus*) and to compare the prevailing standards for drinking water, irrigation water and effluents recommended by national and international agencies.

MATERIALS AND METHODS

Dilution water

Filtered well-water was used in the bioassays. The quality of the test water was determined periodically according to standard methods. Only slight variation in water quality was observed during the course of the experiment (Table 1). The well-water presumably did not contain chromium

TABLE 1
Characteristics of the Water Used in the Bioassays

Parameter	*Range*
Electrical conductivity (μmhos cm^{-1})	27·9–31·7
pH	6·1–6·3
Alkalinity (mg litre^{-1})	4·0–6·0
Total hardness (mg litre^{-1})	4·0–5·0
Calcium hardness (mg litre^{-1})	1·0–3·0
Sulphate (mg litre^{-1})	Absent (< 1·0)
Chlorides (mg litre^{-1})	10·0
Nitrate (mg litre^{-1})	Absent (< 0·05)
Nitrite (mg litre^{-1})	Absent (< 0·05)
Iron (mg litre^{-1})	0·3
Bicarbonate (mg litre^{-1})	6·0
Total dissolved solids (mg litre^{-1})	87·85
Appearance	Clear

as the solvent extraction–spectrophotometric and atomic absorption spectrometric methods (De *et al.*, 1971) (sensitivity 0·001 mg litre^{-1}) failed to detect it.

Toxicant solution

A stock solution of chromium (VI) was prepared by dissolving reagent grade potassium dichromate in distilled water.

Bioassays

Healthy, adult *Nuria denricus* (average length 5 cm, average weight 500 mg) were collected from a freshwater pond and were acclimated for 2 weeks. No mortality was observed during acclimation. Subsequently, batches of 30 organisms were randomly picked and released into glass aquaria containing 15 litres of water. Fourteen aquaria, each with a control, were treated with metal concentrations varying from 0 to 100 mg litre^{-1} by adding measured volumes of stock solution plus dilution water to achieve the desired overall concentrations in the aquaria. The rest of the bioassay was carried out as per standard methods (Rand *et al.*, 1975). Each test aquarium was observed continuously for the first day (when mortality in higher concentrations was high) and subsequently four times a day. The organisms were provided with an adequate supply of food and air throughout the period of acclimation and toxin exposure. The median lethal dose (LD_{50}) values were calculated by a computer-aided analysis of mortality data using the trimmed Spearman–Karber method (Hamilton *et al.*, 1977). The program, written in FORTRAN IV, was run on a computer at Montana State University.

RESULTS

The LD_{50} values and their lower and upper limits at 95% confidence levels for *N. denricus* are presented in Table 2. Safe concentration (SC) values, calculated on the basis of incipient LD_{50} of chromium to *N. denricus* found by us and the application factor (AF) of chromium for fish (Kenaga, 1979), reported elsewhere, are presented in Table 3. The

TABLE 2
Median Lethal Dose (LD_{50}) of Hexavalent Chromium for *N. denricus*

Number of hours	*LD_{50} (mg litre^{-1})*	*95% Confidence levels*	
		Lower	*Upper*
24	55·54	47·95	64·33
96	28·93	22·18	37·75
288	2·91	—	—
384	2·67	1·95	3·65
480	1·72	1·10	2·67

recommended minimum levels of chromium in irrigation waters, inland surface waters and drinking water given by various agencies are also presented in Table 3 for comparison with the safe concentration obtained from the present study.

TABLE 3
Comparison of Estimated Safe Concentration of Hexavalent Chromium in *N. denricus* and Water Quality Standards

Safe concentration (mg litre^{-1})	*Drinking water standards (mg litre^{-1})*			*Irrigation water standards (mg litre^{-1})*		*ISI effluent discharge standard (mg litre^{-1})*
	ISI (1981)	*ICMR (1975)*	*USEPA (1975)*	*Long-term use*	*Short-term use*	
0·003	0·05	0·05	0·05	5·0	20·0	0·1

DISCUSSION

Hexavalent chromium induced marked changes in swimming and balancing patterns. The stressed fishes exhibited erratic and rapid twisting movements, loss of balance, increased frequency of surfacing and vertical swimming compared with the smooth and predominantly horizontal swimming of fishes in the control aquaria. A marked effect on feeding was observed above 2·0 mg litre^{-1}. Fishes exposed to 0–2 mg litre^{-1} chromium consumed food completely, while in exposures of 5–100 mg litre^{-1} food

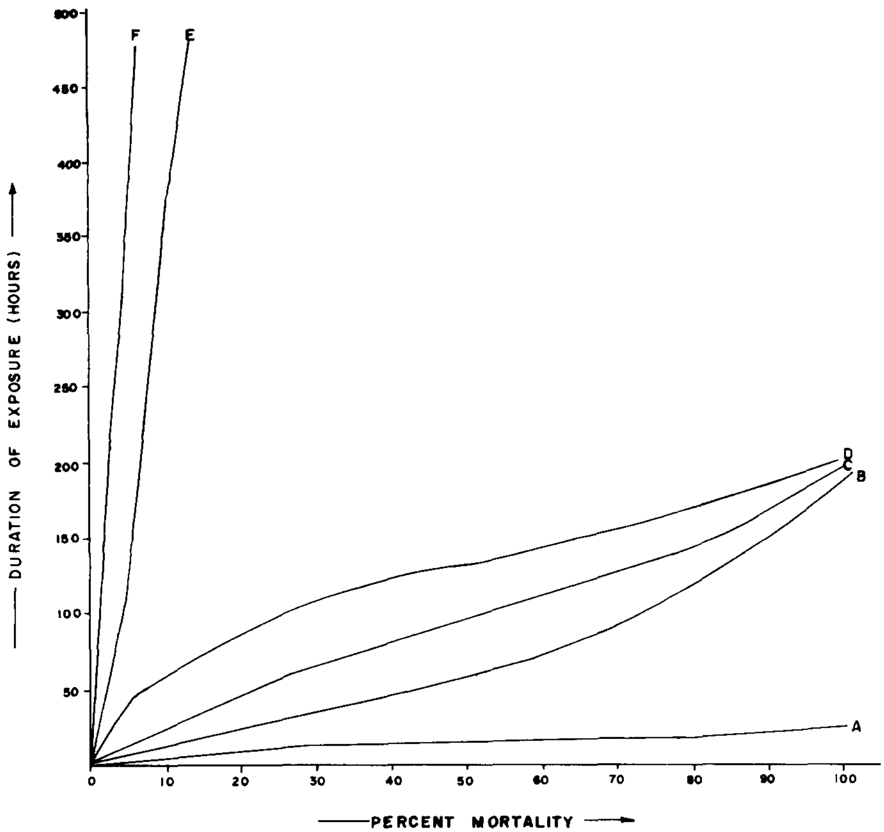

Fig. 1. Curves showing cumulative mortality of *N. denricus* with respect to time and varying concentrations of chromium: (A) $100\,mg\,litre^{-1}$; (B) $50\,mg\,litre^{-1}$; (C) $20\,mg\,litre^{-1}$; (D) $10\,mg\,litre^{-1}$; (E) $1\,mg\,litre^{-1}$; (F) $0{\cdot}1\,mg\,litre^{-1}$.

consumption was lower than normal, with a clear trend towards loss in food consumption with increase in chromium concentration. The stress gradually led to sluggishness and death. Chromium also caused erosion of fins and fin rays.

The variation in mortality with respect to time is shown in Fig. 1. In general, mortality consistently increased with chromium concentration and duration of exposure, the response being approximately linear.

A comparison of the 480-h LD_{50} value (Table 2), and the SC value (Table 3), with the allowable limit for discharge of chromium in irrigation waters for long-term and short-term use (United States Department of Interior, 1968), indicates that the prevailing standards are 3–12 times higher than the LD_{50}, and about 1660–6440 times higher than the SC, respectively, for long-term and short-term use. The freshwater teleost *N. denricus* reaches paddy fields along irrigation canals. In addition, many important catfish such as *Wallago attu*, *Channa* sp., *Clarias batrachus* and *Heteropneustus fossilis* also dwell in the muddy water of paddy fields, and during the rainy season frogs spawn in these confined waters. The present comparison of the 480-h LD_{50}, SC and prevailing irrigation water standards for chromium indicates that these levels may adversely affect the normal health and population levels of aquatic animals dwelling in the irrigation channels and paddy fields.

The difference between SC and the allowable discharge limit of chromium-containing effluent in inland surface waters (Indian Standards Institution, 1982) also indicates that this standard is about 34 times greater than the SC. Finally the disparity between the SC and the allowable drinking water standards (Indian Council of Medical Research, 1975; United States Environmental Protection Agency, 1975; Indian Standards Institution, 1981), also indicates that the standards are higher than the SC.

The present study therefore reveals that the prevailing allowable levels of chromium in drinking water, irrigation waters and effluent discharges are all too high and may lead to environmental damage.

ACKNOWLEDGEMENTS

The authors are grateful to Dr R. V. Thurston, Director, Fisheries Bioassay Laboratory, Montana State University, for kindly making available the computer facilities of MSU and to Dr S. Vasudev, Executive Director, CWRDM, for constant help and encouragement.

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