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Intern. J. Environmental Studies, 1983, Vol. 22, pp. 43–47
0020-7233/83/2201-0043 $18.50/0
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Printed in the United Kingdom

STRESS-INDUCED ENHANCEMENT OF REPRODUCTION IN EARTHWORM *OCTOCHAETUS PATTONI* EXPOSED TO CHROMIUM (VI) AND MERCURY (II)— IMPLICATIONS IN ENVIRONMENTAL MANAGEMENT

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(Received June 6, 1983)

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In continuation of earlier studies[1] on the impact of heavy metal pollutants on earthworms, the mortality and reproduction in *Octochaetus pattoni* exposed to chromium (VI) and mercury (II) at levels varying from 0 to 25 ppm were studied. While both metals induced significant mortality at all levels of exposure, they also caused an enhancement in reproduction, as revealed by the higher production of juveniles and bits in metal-exposed animals compared to controls. The significance of the results in environmental management is discussed.

Earthworms have since long been recognised to play an influencial role in maintaining the balance of the soil-water environments by increasing the biowaste-assimilation capacity and fertility of the soil. They aid in the maintenance of aeration, water permeability and nutrient turn-over of the soil, and in bringing the pH of the stressed soils back to normal.[2–4] In recent years considerable interest has also increased in utilising earthworms in the treatment of biowastes.[5–9] The earthworms have been reported to grow rapidly in biowastes, converting them into castings of high manural value. The earthworms have also shown promise as a source of protein-rich food.[10–12]

Lately, there has been an emphasis on the evaluation of the environmental impact of the disposal of heavy-metal containing industrial and domestic waste-waters on land. As earthworms are important receiving organisms of such wastes, and their is a sparseness of studies on the pollution biology of earthworms,[1,13–17] specially on the toxicity of common heavy metals towards earthworms and the impact of the metals on the reproduction of the earthworms, we have initiated a programme of study, the first part of which had been reported earlier.[1] The present paper is a continuation of the earlier report and extends the studies to the impact of chromium (VI) and mercury (II) on earthworms *Octochaetus pattoni*.

EXPERIMENTAL

The collection, acclimatation and treatment of the animals was done as detailed earlier[1] unless otherwise stated. The experiments were performed during August–September, utilising duplicate sets of randomly picked 30 animals each at a given concentration. The controls had an identical number of animals kept under conditions, exactly the same as those maintained for exposed animals. Through indepen-

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dent experiments, the average density of *O. pattoni* populations in their natural soil environments in Kerala was found to be 120/m^3. The same population density was kept in the toxicity experiments to simulate a real-life environmental for the animals. Cement tanks were used in the present experiments for holding the worms instead of black paper covered beakers used previously. The animals were acclimatised in a large cement tank in soil mixed with animal dung. Exactly similar soil treated with animal dung was used in the experimental tanks. The chromium (VI) and mercury (II) solutions, using potassium dichromate and mercuric chloride respectively, were prepared and standardised as per standard methods.[18]

RESULTS

The results are summarised in Tables I–IV. A typical set of mortality data, pertaining to mercury, is presented in Table I. Similar trends relating mortality to metal concentration and duration of exposure were observed in cases of chromium. It is

TABLE I

Representative data on mortality in earthworm *Octochaetus pattoni* exposed to various concentrations of mercury (II)

No. of days	Mortality in mercury (II), ppm				
	0.0 (%)	0.5 (%)	1.0 (%)	2.0 (%)	5.0 (%)
0	0	0	0	0	0
5	0	5	15	33.3	40
10	0	10	20	40	100
15	0	10	25	60	100
30	0	20	35	60	100
40	0	35	50	66.6	100
50	0	35	55	73.3	100
60	0	35	60	80	100

TABLE II

The median lethal dose (LD_{50}) values for the exposure of earthworms *Octochaetus pattoni* to chromium (VI) and mercury (II)

No. of days	Median lethal doze (LD_{50}), ppm	
	Chromium (VI)	Mercury (ii)
5	—[a]	—[b]
10	—[a]	2.39
15	—[a]	1.66
30	—[a]	1.51
40	20.0	1.04
50	17.38	0.91
60	15.14	0.79

[a]Mortality was less than 50 percent in the highest concentration of chromium (VI), (20 ppm).

[b]Mortality was less than 50 percent in the highest concentration of mercury (II), (5 ppm).

TABLE III

Reproduction (formation of juveniles, bits and cocoons) and mortality in earthworms *Octochaetus pattoni* exposed to varying concentrations of chromium (VI)

	Chromium (VI) concentration, ppm			
	0.0 (%)	2.0 (%)	10.0 (%)	20.0 (%)
Juveniles (total found per 60 animals)	12	9	12	12
Bits (total found per 60 animals)	6	12	21	18
Cocoons (total found per 60 animals)	15	9	12	6
Mortality began (in days)	Nil	9	5	3
100% mortality (in days)	Nil	—	—	—
% mortality in 60 days	0	25	25	70

TABLE IV

Reproduction (formation of juveniles, bits, and cocoons) and mortality in earthworms *Octochaetus pattoni* exposed to varying concentrations of mercury (II)

	Mercury (II) concentration, ppm				
	0.0 (%)	0.5 (%)	1.0 (%)	2.0 (%)	5.0 (%)
Juveniles (total found per 60 animals)	12	15	18	18	21
Bits (total found per 60 animals)	6	18	12	9	3
Cocoons (total found per 60 animals)	15	9	9	3	0
Mortality began (in days)	Nil	5	3	3	3
100% mortality (in days)	Nil	—	—	—	7
% mortality in 60 days	0	35	60	80	100

shown that no mortality was observed in controls during the course of the experiments (60 days), and consistent trends were obtained showing a morality (percent death) to increase with the metal concentration and duration of exposure. These observations differed from the ones reported in the previous study, but were similar to the ones observed in cases of other invertebrates.[19,20]

The Median Lethal Dose (LD_{50}) values (Table II), calculated as per standard procedures,[18] show that mercury (II) is approximately 20 times more toxic than chromium (VI) for *O. pattoni*. The standards for allowable levels of these metals in drinking water, set by United States Environmental protection Agency[21] (*USEPA*), as well as by the authority of the Minister of National Health and Welfare Canada[22] (*AMNHWC*), which are 0.05 ppm for chromium (VI) and 0.001 ppm for mercury, indicate the mercury: chromium toxicity ratio as 25:1. This is close to the ratio shown

TABLE V
Concentrations of mercury and chromium in various industrial effluents

Industrial sources	Mercury, ppm	Chromium, ppm	Reference no.
Electroplating industry	—	15–70	24
Chrome tanning industry	—	40	
Cooling tower blow down	—	10–60	
Chloralkali industry	0.5 –4.0	—	25
Smelters	0.08–2.0[a]	—	

[a]Dissolved mercury.

by the present study. However, the standards, set by the Indian Standards Institution (*ISI*) for the discharge in inland surface waters,[23] which are 0.1 ppm for chromium (VI) and 0.01 ppm for mercury, indicate the mercury: chromium toxicity ratio of 10:1. This is at variance with the *USEPA*, *AMNHWC* and our conclusions.

In earthworms exposed to chromium (VI) mortality began within three days of exposure (Table III), and by ninth day mortality had occurred even in earthworms exposed to 2 ppm of chromium. Similarly in case of earthworms exposed to mercury (II), mortality began within three to five days of exposure. In case of both metals there was significant mortality in 60 days exposure in all concentrations, while no mortality was observed in controls.

In the previous paper[1] we reported that chromium (VI) enhanced the reproduction in earthworms (*P. posthuma*) in spite of being highly toxic. The results of present investigations on *O. pattoni* support and substantiate those findings. Thus, in spite of the toxicity of the metal, the earthworms exposed to chronium (Table III) yielded an average of 11 juveniles per set (60 animals) against 12 juveniles per set yielded by controls, while the bits formation was 17/set in chromium exposed worms compared to 6/set in controls. Mercury showed even a more striking effect on reproduction—with 18 juveniles/set and 10.5 bits/set in mercury-exposed animals against 12 juveniles/set and 6 bits/set, respectively, in controls. The cocoon formation was, however, lower in metal-exposed animals, compared to controls in both cases. It appears that the stress on the earthworms induced by the metals causes them to become hyper-productive. The exact mechanism may be understood only through extensive biochemical investigations, some of which are presently in progress.

The mortality data clearly brings out the toxicity of chromium and mercury towards *O. pattoni*, even when the metals are present in dissolved form in concentrations of 2.0 ppm and 0.5 ppm respectively. The levels of these metals present in various industrial effluents are far higher than these concentrations (Table V).[24,25] It may be seen that the utilisation of such effluents for irrigation, even after diluting them several times, would be harmful to earthworms, and it is likely to be harmful to the soil environment and consequently to agricultural production, in general, due to the crucial role played by earthworms in maintaining soil quality. As toxicity generally increases with decrease in the body weight of animals,[26] the effluents containing these metals are also likely to be harmful to other smaller soil organisms.

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