Bull. Environm. Contam. Toxicol. 23,487-490 (1979)

Cadmium Toxicity to Freshwater Algae

P. T. S. Wong, G. Burnison, and Y. K. Chau
Canada Centre for Inland Waters, Burlington, Ontaria, Canada L7R 4A6

Cadmium is always found in association with zinc. However, Zn is an essential trace element in living cells whereas Cd has no known useful biological function. In fact, Cd is ranked among the most hazardous trace elements in the environment. Cadmium can exist in water as complexes with organic matter, chelated, absorbed onto organic particulate materials or detritus, absorbed onto inorganic matter or in the form of the free ion. These forms may behave differently in terms of toxicity and availability to algae.

Little information is available regarding the effect of Cd on aquatic biota, particularly at the primary producer level as shown in recent reviews published on cadmium toxicity. (ANONYMOUS 1977, RAY & COFFIN 1977).

In this report, we present data to demonstrate that the degree of Cd toxicity to freshwater algae depends on the indicators used for measuring the effects and the algae species selected for the bioassay.

MATERIALS AND METHODS

Four algal species, Ankistrodesmus falcatus var. acicularis, Chlorella vulgaris (obtained from the Ontario Ministry of Natural Resources, P. O. Box 213, Rexdale, Ontario) Scenedesmus quadricauda (culture collection #11, Dr. P. Healey, Fresh Water Institute, Winnipeg, Manitoba) and Chlorella pyrenoidosa (obtained from Dr. C. Nalewajko, Scarborough College, Toronto, Ontario) were studied. The inoculum used in each toxicity bioassay was prepared by growing each algae in 50 mL CHU-10 medium (CHU 1942) on a rotary shaker (130 rpm) at 20°C under 24 h illumination (5000 lux) until the cells reached exponential growth (around 5 days).

The effect of Cd, as Cd nitrate, Cd chloride, Cd carbonate and Cd acetate, on cell growth was determined by adding a 1.0 mL inoculum of axenic A.falcatus to 9.0 mL of either CHU-10 medium or filter-sterilized (0.45 μ Sartorius membrane filter) Hamilton Bay water, both contained additions of 0.1 mL of a Cd salt at 6 concentrations ranging from 30 ppb to 10 ppm Cd. Duplicate controls without Cd additions were included. The cells were grown under

0007-4861/79/0023-0487 $01.00

the conditions described above. At various time intervals, a 0.5 mL subsample was taken and cell numbers determined using the Coulter Counter, Model B with a 100 μm aperature.

The effect of Cd, as $CdCl_2$, on ^{14}C-carbonate uptake by all four algal species was examined. A 0.6 mL algal inoculum and 0.5 mL of one of eight Cd concentrations were added to 13.5 mL CHU-10 medium in 25-mL flasks, in duplicate. Dark duplicates at four concentrations were treated similarly. After a 24 h incubation at the described conditions, a 0.4 mL aliquot of 0.32 μCi/mL ^{14}C-sodium carbonate (58.8 mCi/mmole) was added to each flask. After incubating 4 h, the cells were fixed with 0.1 mL of neutralized formalin. Each sample was filtered through 0.45 μm membrane filters (Sartorius) and rinsed with about 5 mL medium under vacuum (~17 cm Hg). All filters were dissolved in Bray's fluor (BRAY 1960) and the radioactivity determined by liquid scintillation counting.

RESULTS AND DISCUSSION

The effect of $Cd(NO_3)_2$ on the population growth of A.falcatus is shown in Figure 1. In CHU-10 medium, cadmium toxicity was not observed below 1 ppm Cd compared to ≤0.5 ppm Cd in bay water. In both media virtually no growth was observed above 5 ppm Cd. The greater toxicity in bay water could be due to the presence of other toxic chemicals present. However, bay water did support faster growth before the cells turned scenescent on the sixth day. Scenescence was not observed in CHU-10 medium until the eighth day. The calculated generation times (time for a cell to divide once) at the second day in CHU-10 medium was about 30 h at concentrations below 1 ppm Cd and 480 h above 5 ppm Cd. In bay water at the third day, the generation time was about 16 h below 1 ppm Cd and about 132 h above 5 ppm Cd. The other three cadmium salts showed similar results as $Cd(NO_3)_2$ in bay water. However, in CHU-10 medium Cd carbonate and Cd acetate at concentrations ≤ 1 ppm Cd were stimulatory on the second day, but by the eighth day all four salts were similar. The reported literature values for Cd toxicity on algae vary widely, ranging from 10 ppb Cd (CONWAY 1978) to 10 ppm Cd (SPARLING 1968). Such variations could be caused by the choice of conditions, algal species and methods for bioassays used by various investigators (WONG et al. 1979). This is indeed the case, as is demonstrated in the results in Figure 2. In this experiment, ^{14}C-carbonate uptake instead of population growth was used as the method for measuring Cd toxicity. In the uptake experiment with A.falcatus, a toxic effect started around 0.5 ppm Cd as compared with 5 ppm Cd for the growth study using $CdCl_2$ and the same alga. Since the growth experiments involved longer incubation time (days) as compared with the ^{14}C-uptake experiments (hours), the algae would be expected to excrete products capable of complexing with metals and rendering the metals less toxic (OVERNELL 1976). Furthermore, different algal species responsed differently to Cd. For S. quadricauda, the presence of Cd as low as 20 ppb inhibited

80% of its ^{14}C-uptake. Chlorella species were less sensitive to Cd than Scenedesmus, however C. pyrenoidosa was much more sensitive to Cd than C. vulgaris. The reason for these different responses is not know. Similar observations of different algal sensitivities to Cd have been reported by SPARLING (1968) and HUTCHINSON & CZYRSKA (1975). The sensitivity of Scenedesmus to Cd toxicity has also been shown (KLASS et. al. 1974). In view of the acute toxicity of Cd to algae and the importance of the algae in the aquatic ecosystem, further investigations on the effects of environmental factors such as temperature, pH, complexing capacity and water hardness on Cd toxicity to algae are being carried out.

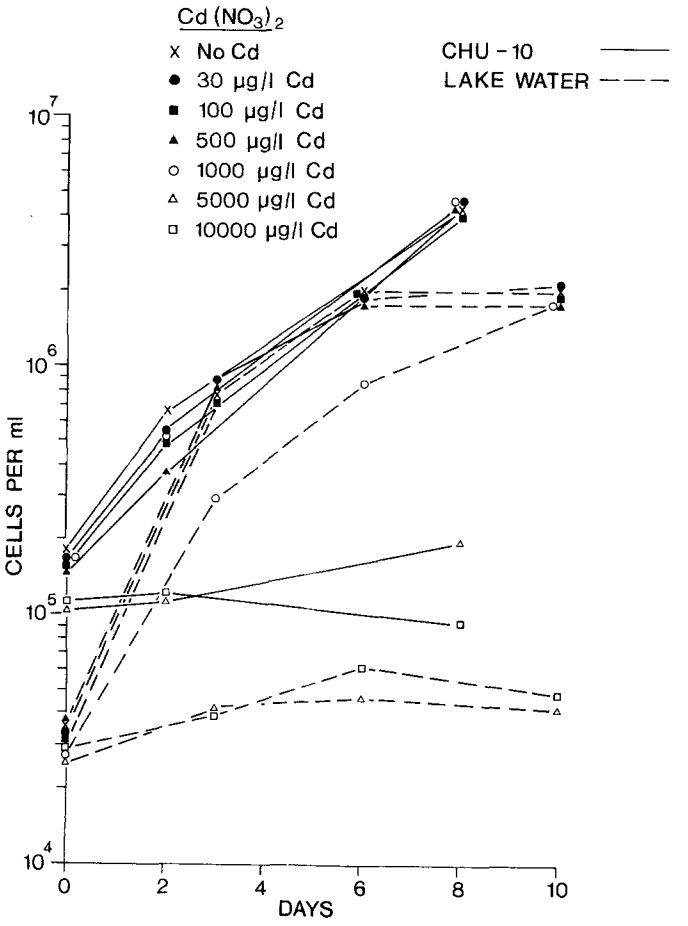

FIGURE 1. The effects of $Cd(NO_3)_2$ on the population growth of A. falcatus in CHU-10 medium and Hamilton Bay (lake water).

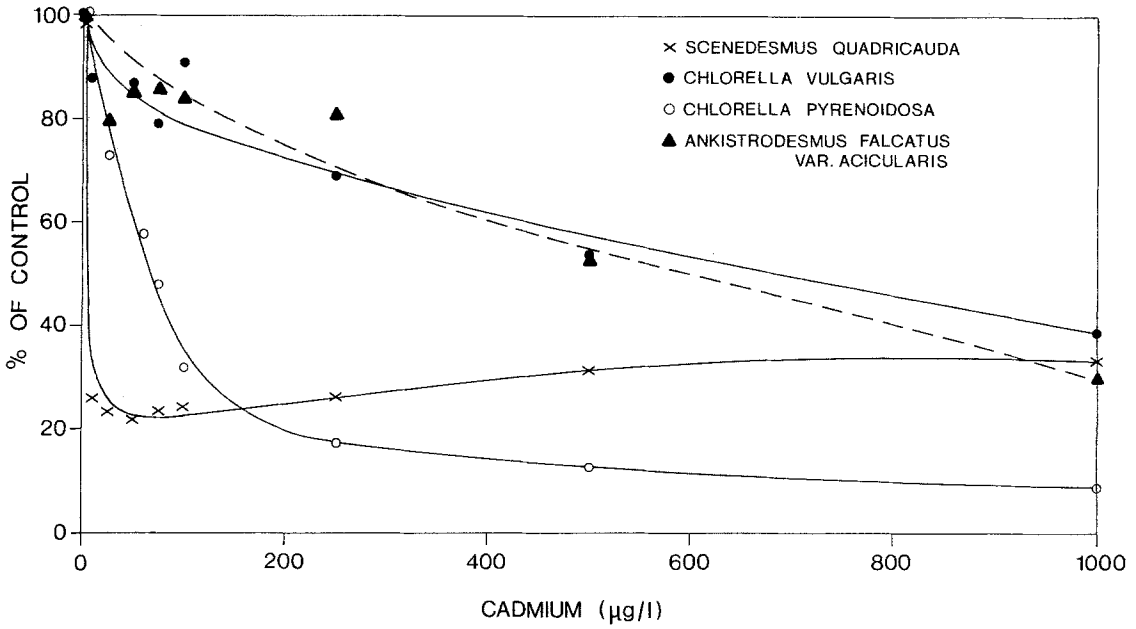

FIGURE 2. Comparative effect of $CdCl_2$ on ^{14}C carbonate uptake by four freshwater algae.

REFERENCES

ANONYMOUS. Report on cadmium in freshwater fish. Water Quality Criteria for European freshwater fish. European Inland Fisheries Advisory Commission. F.A.O. U.N. Technical Paper No. 30, 1977.

BRAY, G.A.: Anal. Biochem. 1, 279 (1960).

CHU, S.P.: J. Ecology 30, 284 (1942).

CONWAY, H.L.: J. Fish Res. Board Canada 35, 286 (1978).

HUTCHINSON, T.C., and H. CZYRSKA: Verh, Int. Ver. Limnol. 19, 2102 (1975).

KLASS, E., D.W. ROWE, and E.J. MASSARO: Bull. Environ. Contam. Toxicol. 12, 442 (1974).

OVERNELL, J.: Marine Biol. 38, 335 (1976).

RAY, S., and J. COFFIN: Ecological effects of cadmium pollution in the aquatic environment. Fisheries and Marine Service Canada, Technical Report No. 734, 1977.

SPARLING, A.B.: Interactions between blue-green algae and heavy metals. Washington Univ. Ph.D. thesis, St. Louis, Missouri (1968).

WONG, P.T.S., C.I. MAYFIELD, and Y.K. CHAU: Cadmium toxicity to phytoplankton and microorganisms. In Biogeochemistry of Cadmium, J.O. Nriagu (Ed.). Wiley-Interscience, New York, 1979. (In press).