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THE INFLUENCE OF POTASSIUM ON THE REMOVAL OF ^{137}Cs BY LIVE *CHLORELLA* FROM LOW LEVEL RADIOACTIVE WASTES

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PLATO P. and DENOVAN J. T. *The influence of potassium on the removal of* ^{137}Cs *by live* Chlorella *from low level radioactive wastes*. RADIATION BOTANY **14**, 37–41, 1974.—The objective of this study was to determine the concentration of stable potassium that must be present in a radioactive waste solution to maximize the uptake of radiocesium by algae without a substantial reduction in algal growth. Laboratory cultures of *Chlorella pyrenoidosa* were grown under continuous culture conditions, and the accumulation of ^{137}Cs by the algae was measured. Potassium ion concentrations below 15 mg/l reduced the growth of *C. pyrenoidosa* but increased the accumulation multiples for ^{137}Cs. The removal efficiencies, which represent the combined effects of algal growth and accumulation multiples, obtained for ^{137}Cs ranged between 88 and 83 per cent for potassium concentrations between 2 and 15 mg/l but were reduced to less than 20 per cent when the potassium ion concentration was greater than 15 mg/l or less than 2 mg/l.

INTRODUCTION

WHEN low level radioactive wastes from nuclear facilities are discharged directly into the water environment, aquatic organisms may take up certain radionuclides and concentrate them to levels many times greater than those in the surrounding water.[10] If aquatic organisms were grown under controlled conditions and allowed to concentrate the radionuclides present in a radioactive waste solution, the radioactivity of the solution could be reduced considerably. Biological methods, such as trickling filters and activated sludge units, have been used for many years in sewage treatment plants to treat conventional organic wastes.

Studies by FOSTER[4] on the Columbia River suggest that several aquatic organisms might be used in a process designated to concentrate radionuclides. Foster's work and that of others[5,6] indicate that algae might be the most efficient organism for such a process. These studies have shown that various species of algae concentrate certain radionuclides several thousand times the concentration found in the water around the algae, which suggests that their use in a radioactive treatment process might be possible.

In order to obtain the maximum uptake of radionuclides by algae, the ionic composition of the substrate must be controlled. AUSTIN, KLETT and KAUFMAN[1] have reported that the steady-state concentration of strontium activity in the cells of *Chlorella pyrenoidosa* depends on the concentration of calcium and magnesium, elements that are chemically similar to strontium. Similarly, it has been shown that potassium and rubidium ions interfere with the uptake of ^{137}Cs by *Chlorella*.[3,12] The order of preference of alkali-metals ion uptake by *Chlorella* is potassium, rubidium, cesium and sodium.[8] Therefore, the degree of removal of radioactive cesium from liquid wastes will be influenced by the concentration of potassium in water.

Potassium is a metabolic requirement for algae, and under low potassium concentrations growth and photosynthesis are low and respiration is high.[7] Algae may take up large quantities of cesium, but they are unable to substitute it for potassium in metabolism.[3,13] There will be little algal growth if only cesium is present with no potassium.

The purpose of this study was to determine the potassium concentration at which the uptake of cesium is maximized while algal growth is not influenced substantially.

The species of algae selected for this study was *Chlorella pyrenoidosa*. *C. pyrenoidosa* can be grown on several different substrates including a completely inorganic nutrient solution.[1] According to MYERS, PHILLIPS and GRAHAM,[9] of a number of different unicellular algae examined *C. pyrenoidosa* gave the highest density and daily yield. Also, pure culture conditions are not required for *C. pyrenoidosa* as it is not inhibited by bacterial contaminants. *C. pyrenoidosa* has been cultivated on a large scale.

PROCEDURE

The experiments required for this study were performed with acrylic algal culture chambers as shown in Fig. 1. In each experiment the algal culture chambers were filled to a height of 33·5 cm with 1·5 l. of algae and nutrient suspension.

The nutrient solution was pumped into the algal culture chamber, and a waste solution was simultaneously removed. The waste solution contained algae that had accumulated radioactive and nutrient ions together with radionuclides and nutrients not taken up by the algae.

The growth chambers were operated under the following environmental conditions:

Temperature: 25±2°C

Concentration of CO_2: 3 per cent (by volume)

Illumination period: 16 hr on, 8 hr off

pH of the culture medium: 6·0±0·2

Light intensity: 10,800 lux* measured at the center of the growth chambers.

Experiments were designed to find the potassium concentration that will result in the maximum accumulation of ^{137}Cs by the algae. Each acrylic growth chamber contained a nutrient solution with a predetermined concentration of potassium phosphate monobasic (KH_2PO_4). In order to replace any phosphate ions (PO_4^-) lost due to a reduction in potassium ions (K^+) and to maintain the desired ionic strength, portions of the KH_2PO_4 were replaced with sodium phosphate monobasic ($NaH_2PO_4.H_2O$) as shown in Table 1. Sodium was used as a substitute for potassium since algae will discriminate against sodium in favor of cesium.[7] The concentrations of potassium ion added in the form of KH_2PO_4 ranged from 350 to 0 mg/l.

The algae were grown under the environmental conditions listed previously, and the growth of the algae in each growth chamber was measured with a spectrophotometer. As each of the algal suspensions approached the end of the exponential phase of growth, nutrients containing $2·5\times10^{-5}$ μCi/ml of carrier free ^{137}Cs were pumped into the culture chambers, and

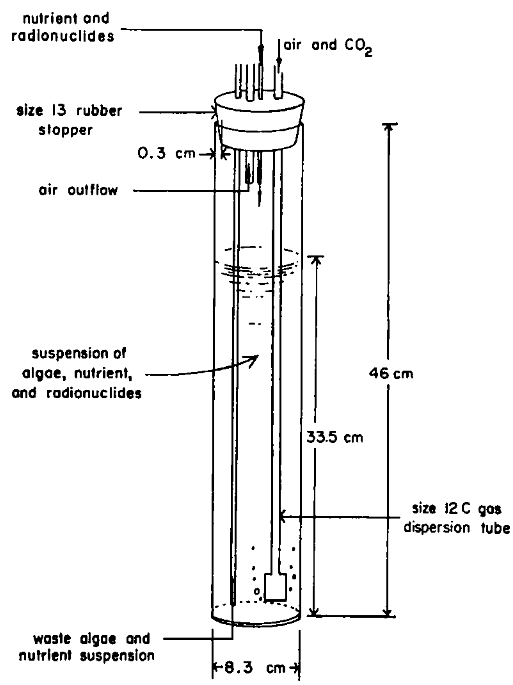

FIG. 1. Acrylic algal growth chamber showing system for delivering nutrients and air plus CO_2.

*Light was provided by eight 40 W Sylvania Gro-Lux fluorescent lamps and four 75 W incandescent bulbs.

Table 1. *Potassium and sodium concentrations in nutrient solutions to determine the influence of potassium ion concentration on accumulation of* ^{137}Cs *by* C. pyrenoidosa

Potassium ion concentration (mg/l)	Concentration of KH_2PO_4 (g/l)	Concentration of NaH_2PO_4 (g/l)	Concentration of K^+ (moles/l)	Concentration of Na^+ (moles/l)
350	1·22	0	$8·96 \times 10^{-3}$	0
150	0·52	0·71	$3·84 \times 10^{-3}$	$5·12 \times 10^{-3}$
50	0·17	1·06	$1·28 \times 10^{-3}$	$7·68 \times 10^{-3}$
25	0·085	1·148	$6·4 \times 10^{-4}$	$8·32 \times 10^{-3}$
15	0·051	1·184	$3·84 \times 10^{-4}$	$8·58 \times 10^{-3}$
5	0·017	1·219	$1·28 \times 10^{-4}$	$8·83 \times 10^{-3}$
2	0·007	1·23	$5·0 \times 10^{-5}$	$8·91 \times 10^{-3}$
0	0	1·24	0	$8·96 \times 10^{-3}$

waste algal suspensions were pumped out at a constant rate which produced continuous log-phase cultures. Measurements were then made of the ^{137}Cs concentrations in the algal phase and in the liquid phase in each of the growth chambers. From these data and the activity present in the influent nutrient solution it was possible to correlate the accumulation multiples* of *C. pyrenoidosa* for ^{137}Cs as a function of potassium ion concentration.

RESULTS

The experiments to determine the effect of potassium ion concentration on *C. pyrenoidosa* were conducted utilizing potassium concentrations of 350, 150, 50, 25, 15, 2 and 0 mg/l in the nutrient solution. Figure 2 shows a composite graph of the algal growth curves as affected by potassium ion concentration. Algal growth does not appear to be influenced by potassium concentrations between 350 and 15 mg/l. However, potassium concentrations less than 15 mg/l cause a reduction in the total growth of *C. pyrenoidosa*.

The accumulation multiples for ^{137}Cs, shown in Fig. 3, are low at K^+ concentrations between 25 and 350 mg/l. However, at 0, 2 and 5 mg/l the accumulation multiples increase to over 100. This indicates a definite influence of potassium on the uptake of ^{137}Cs. Thus the growth of *C. pyrenoidosa* decreases and the uptake of ^{137}Cs increases with decreasing potassium ion concentration. The removal

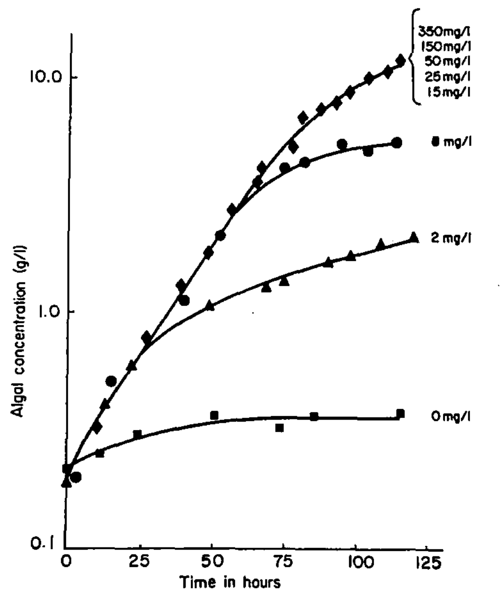

Fig. 2. Composite graph showing growth curves for *C. pyrenoidosa* grown at (K^+) concentrations of 350, 150, 50, 25, 15, 5, 2 and 0 mg/l.

*An accumulation multiple is defined as:

$$\frac{\text{radioactivity } (\mu\text{Ci/g}) \text{ in the organism (wet weight)}}{\text{radioactivity } (\mu\text{Ci/g}) \text{ in the water.}}$$

When a radionuclide has attained an equilibrium concentration within an organism, the accumulation multiple becomes the concentration factor for the radionuclide and organism.

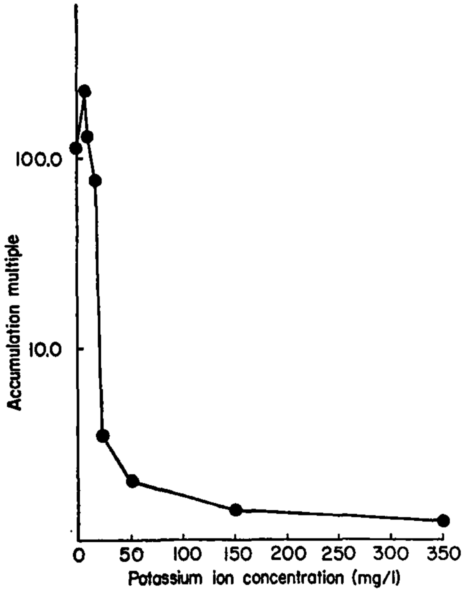

FIG. 3. ^{137}Cs accumulation multiples for *C. pyrenoidosa* as a function of nutrient potassium ion concentration.

where ^{137}Cs removal efficiency is plotted against K^+ concentrations. At 350, 150, 50 and 25 mg/l of K^+ the removal efficiencies are low due to low accumulation multiples for ^{137}Cs. At 0 mg/l of K^+ the removal efficiency is again low, not because of a low accumulation multiple, but because of the small amount of growth that takes place at this potassium ion concentration. The algae grown at 2, 5 and 15 mg/l had removal efficiencies of 88, 85 and 83 per cent, respectively. These high removal efficiencies were the result of both high accumulation multiples and high cell concentrations.

CONCLUSION

If *C. pyrenoidosa* is to be used in a process to treat low level radioactive wastes, the radionuclides to be removed must be balanced with the nutrient ions present. A proper balance will maximize the uptake of the radionuclides without a substantial reduction in algal growth.

An attempt was made to determine the proper balance of potassium in the nutrient solution and ^{137}Cs in the radioactive waste to be treated. The results of this study show that a potassium ion concentration below 15 mg/l causes the growth of *C. pyrenoidosa* to be reduced. The removal efficiencies for ^{137}Cs range between 88 and 83 per cent for potassium concentrations between 2 and 15 mg/l but are reduced to below

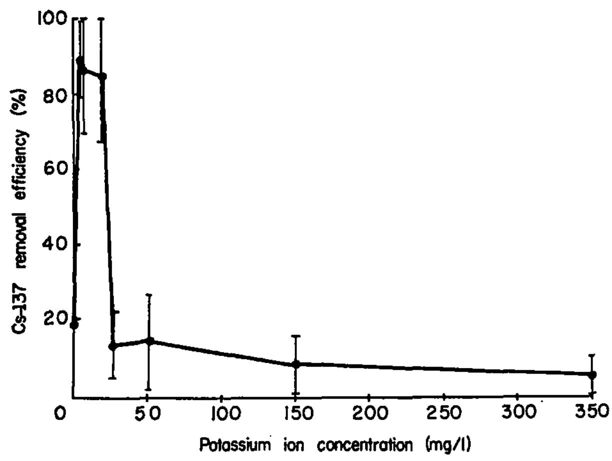

FIG. 4. ^{137}Cs removal efficiency by *C. pyrenoidosa* as a function of nutrient potassium ion concentration (error bars indicate 95 per cent confidence interval).

efficiency* for ^{137}Cs by the algae is a function of the algal cell concentration and the accumulation multiple for cesium. This is evident in Fig. 4

*Removal efficiency is defined as $C_b - C_a/C_b$ where C_b is the concentration of the radionuclide in water before algal uptake and C_a is the concentration of the radionuclide in water after algal uptake.

20 per cent when the potassium ion concentration is greater than 15 mg/l or less than 2 mg/l. At a potassium concentration of zero mg/l the accumulation multiple for ^{137}Cs is high, but the algae cannot grow to cell concentrations high enough to remove large quantities of ^{137}Cs from the waste solution. Above 15 mg/l the potassium concentration is more than adequate for maximum growth of the algae, but the potassium interferes with the accumulation of cesium.

The industrial use of algae or other biological systems for the treatment of low level radioactive wastes would appear to be most applicable where the organisms grow abundantly under existing conditions within the nuclear facility's boundaries such as in a cooling lagoon. Instead of using various physical and chemical methods(12) to eliminate algae from these areas, the algae could be allowed to grow and perhaps even fed nutrients to increase their growth.

A problem associated with the use of existing facilities is the lack of control over parameters such as light and temperature, but algae seem to grow quite well under existing conditions. The normal concentration of potassium in freshwater is approximately 2–3 mg/l.(2) The potassium concentration could be kept between 2 and 15 mg/l (found in this study to be the optimum concentration for the removal of ^{137}Cs) by the addition of appropriate amounts of a nutrient solution into the cooling lagoon. If the algae could be filtered from the effluent of the cooling lagoon,. they would provide a final method to remove radionuclides produced by the nuclear facility.

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