Note

Sorption of Low-level Radwaste by *Spirulina*[†]

Chia-Lian TSENG, Pao-Shan WENG* and Kuan-Han SUN*

Nuclear Science and Technology Development Center,

*Institute of Nuclear Science,

National Tsing Hua University

Hsinchu 30043, Taiwan, R.O.C.

Received November 5, 1985

The feasibility of using spirulina as adsorbent for the treatment of low-level liquid radwaste is studied. The experimental results indicate that the sorption capacity of spirulina is good for the di- and trivalent metallic ions at pH 3-7, but rather poor for the mono-valent metallic ions and non-metallic ions. Some factors affecting metal ion uptake by spirulina such as the content of detergent, sodium ion in liquid radwaste and the stability of spirulina under γ irradiation were also investigated.

Key Words: sorption, low-level radwaste, *spirulina*

1. Introduction

Spirulina is a species of algae with protein content as high as 70%. It was discovered by French scientists in Africa in 1962. Large scale studies of this species have been carried out since then by researchers of many countries including Republic of China¹⁾. *Spirulina* grows very rapidly with cultural time 4 to 7 days only. The grown *spirulina* can be separated easily from the cultural medium. All the salient points mentioned above are very attractive for the applications of *spirulina* as a metal adsorbent in radwaste treatment.

2. Experimental

2.1 Reagent preparation

2.1.1 Adsorbent

The *spirulina* sample was given by the Union Chemical Laboratory of the Industrial Technology Research Institute as the spray dry product.

2.1.2 Radioactive tracers

Barium-133, ¹³⁷Cs, ²¹⁰Pb, and ²⁴¹Am were pur-

chased from the NEN, England. Others were prepared by irradiating high purity metals or compounds in the 1 MW Tsing Hua Open-pool Reactor (THOR) with a thermal neutron flux of $2 \times 10^{12} \text{ n cm}^{-2} \text{ s}^{-1}$. All the reagents were of analytical grade (E. Merck Co.). The detergent used was obtained from the market.

2.2 Experimental procedures

In a 50 ml flask was filled with 30 ml of the solution containing the radio-tracers with carrier generally at 12-46 μg each except for the adsorption capacity measurement where the carrier added is higher to 1000 μg for Hg(II) and 300 μg for the other metal ions (see below). The pH value was adjusted before 100 mg *spirulina* was added. After thorough shaking, the *spirulina* sank to the bottom. Five milliliters of the supernatant solution was taken and its radioactivity was then measured using a well-type NaI(Tl) scintillation counter.

3. Results and Discussion

3.1 Effect of pH on the uptake of ions

The pH dependency on the adsorption efficiency of *spirulina* for various ions in liquid radwaste was shown in Fig. 1. It is noted that

[†] *Spirulina* を用いた低レベル放射性廃棄物の吸着。
曾家亮, 翁實山, 孫觀漢: 國立清華大學保健物理組, 中華民國台灣新竹市300。

the adsorption efficiency of *spirulina* for Hg(II) at pH 1.7–7.0 and for the di- and trivalent metallic ions at pH 3–7 appears to be useful for radwaste treatment. However, the sorption is rather poor for mono-valent metallic ions and non-metallic ions. The sorption rate is generally very rapid for the di- and trivalent metallic ions mentioned above. Increasing the shaking time from 30 seconds to 5 minutes resulted in the increase of adsorption efficiency 4% only. This is advantageous for radwaste treatment.

Fig. 1 Adsorption efficiency of *spirulina* vs. pH values.

3.2 Adsorption capacity measurement

For given concentrations of carriers of metallic ions Co(II), Zn(II), Hg(II), and Ce(III), the adsorption efficiency of *spirulina* vs. its quantity used is shown in Fig. 2. The adsorption efficiency for various ions increases linearly with increasing quantity of *spirulina*. It is also noted that the adsorption efficiency varies with different ions. It is found that the adsorption capacity of 100 mg *spirulina* is 136 μ g for Co(II), 180 μ g for Zn(II), 225 μ g for Ce(III), and 780 μ g for Hg(II).

Fig. 2 Adsorption capacity of *spirulina* for various metallic ions.

3.3 Adsorption efficiency at pH 4

The adsorption efficiency of *spirulina* for various ions at pH 4 is shown in Table 1. For di- and trivalent metallic ions the value is

Table 1 Adsorption efficiency of 100 mg *spirulina* for various ions at pH 4 with carrier each 12–46 μ g

Ions	Adsorption efficiency (%)
Na(I)	2.3
K(I)	2.6
Rb(I)	3.7
Cs(I)	3.9
Mn(II)	76.8
Co(II)	78.3
Ni(II)	77.8
Cu(II)	75.7
Zn(II)	91.8
Sr(II)	74.4
Cd(II)	81.2
Ba(II)	82.6
Hg(II)	81.9
Pb(II)	73.3
Cr(III)	67.0
La(III)	76.4
Ce(III)	79.6
Eu(III)	73.1
Am(III)	90.2
As(III)	1.7
Se(IV)	1.3
P(V)	1.3
I(–I)	1.3

about 67.0–91.8%, and for both mono-valent metallic ions and non-metallic ions below 4%. The good sorption for di- and trivalent metallic ions may be attributed to the high content of protein in *spirulina*. The two S-containing amino acid groups, methionine and cystine in protein may bind the metal ions^{20, 21}.

In general, long-lived nuclides existing in low-level liquid radwaste are ⁵⁴Mn, ^{58, 60}Co, ⁶⁵Zn, ^{89, 90}Sr, ^{134, 137}Cs, and ¹⁴¹Ce, etc. Most of the nuclides except ^{134, 137}Cs can be adsorbed by *spirulina*. In Table 1, Cu(II), Cd(II), Hg(II), and Pb(II) which are toxic elements commonly seen in industrial waste water can also be treated with *spirulina*.

3.4 Influence of detergent

In most low-level liquid radwaste, detergent for decontamination is usually present. The existing detergent can easily react with metallic ions to form complex compounds. Thus the detergent present may tend to reduce the adsorption efficiency⁴. The decrease in adsorption

Fig. 3 Adsorption efficiency influenced by the detergent present in liquid radwaste.

efficiency as a result of existing detergent is shown in Fig. 3. It is noted that no effect is observed for the content of detergent below 0.05%. However, significant decrease in adsorption efficiency is noted as the content of detergent exceeds 0.1%. In normal cases, the content of detergent in liquid radwaste seldom reaches 0.1%.

3.5 Effect of sodium ion

Large amount of Na(I) is always present in liquid radwaste due to the regeneration of used resins in nuclear power plant. From Table 1, it is noted that the adsorption efficiency of *spirulina* for Na(I) is about 2.3%. Larger amount of Na(I) in liquid radwaste may compete with other ions and interfere with their adsorption. As shown in Fig. 4, roughly a 10% decrease in adsorption efficiency in the presence of 1% Na(I) and a 20% decrease in the presence of 5% Na(I) in liquid radwaste can be observed. However, in general, the content of Na(I) in the radwaste from a

Fig. 4 Adsorption efficiency influenced by the Na(I) present in liquid radwaste.

nuclear power plant is estimated to be below 1%.

3.6 Radiation effect

The effect of γ -radiation from ^{60}Co on the adsorption capability of *spirulina* is shown in Fig. 5. Up to an absorbed dose of 3.7×10^2 kGy radiation has no significant effect on *spirulina* as far as the adsorption efficiency for metal ions is concerned. It shows that the stability due to the γ -radiation is rather good.

Fig. 5 Effect of radiation on the adsorption efficiency.

4. Conclusion

The application of *spirulina* in low-level liquid radwaste treatment has the advantages of rapid adsorption and radiation stability, and is particularly effective for di- and trivalent metallic ions. This paper deals with the spray dry alga only. Further study can be extended to the live *spirulina*, particularly during its growing period. From this study, it is concluded that the application of *spirulina* is a potential method for low level liquid radwaste treatment.

Financial support from the Atomic Energy Council of Executive Yuan is much appreciated. The authors also thank the Union Chemical Laboratory at the Industrial Technology Research Institute for the supply of *spirulina* samples.

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