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Estimation of the radionuclide distribution in sediment in coast area

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Abstract: The study of the radionuclide distribution in sediment is a very important aspect in environmental impact of the low level radioactive liquid waste (LLW) from coastal nuclear facilities or nuclear power plant. Even now we do not know much about it. In this paper, a simple and useful method is put forward and it is used to estimate the nuclide distribution in sediment. The result showed that the LLW from nuclear facility or nuclear power plant will do a little harm to the sediment nearby. But the harm is not very serious. Much works have to be done before full understanding of the situation.

Keywords: radionuclide; coast area; deposit characteristic; sediment

Introduction

The radionuclides in low-level radioactive liquid waste (LLW) from coastal nuclear facilities or nuclear power plants will be diluted, diffused and transported in the coast area. And they will also deposit in the sediment. How to estimate the effect of deposit radionuclides is a very important task for the environmental impact assessment of nuclear facilities.

There are a few research works deal with radionuclide deposit in sediment. Nelson (Nelson, 1976) did the measurement of distribution of sediments and associated radionuclides in the Columbia River below Hanford. Denham and Soldat (Denham, 1975) did comprehensive analysis about radionuclides deposit in the riverbed. In the Regulatory Guide 1.109 (USA NRC, 1981) by U.S.A. NRC, an estimate method, which can be used to estimate the radionuclide deposit in sand, is put forward. But according to the research done by Zhang Y.X. *et al*. (Zhang, 1999), the final equation of the Guide 1.109 was not right, they did some theoretical study and gave a very formal method to estimate the radionuclides deposit in sediment on the basis of actual hydrological condition. But many tests must be done in the laboratory and much survey has to be done in the field before their method can be used actually.

In this paper, a very simple and conservative method was put forward to estimate the radionuclides deposit in sediment. Since the achievement of distribution coefficient in suspend material and sediment is very important in estimation, the method, which was used to get this coefficient, will be discussed first.

1 Determination of distribution coefficients in suspend material and sediment

Generally, there are two methods to get the distribution coefficient in the laboratory, one is batch test, and the other is column test (Chen, 1998). Both batch test and dynamic test are conducted in this paper, but the dynamic test, which we used at this time, is not the column one. We design a facility to simulate the actual marine hydrology condition.

About the samples, they were directly from a certain place of Huanghai Sea. The liquid used in laboratory was the actual seawater in that area which was after micropore filtration, and the materials on the filtration paper were taken as suspend materials. The sediment samplers used in test were also directly from surface ones in bottom of that area.

The distribution coefficient is defined as the ratio of the radionuclides counting in unit mass solid media and the one in unit volume liquid media.

1.1 Result from batch test

The batch test, which we did in laboratory, is according to the typical method (Chen, 1998). The distribution coefficients of ^{137}Cs in suspend material and sediment is determined from this test. The liquid is the actual seawater, the suspend material and sediment are from the actual field. Table 1 and Table 2 show some of the results of the test.

Table 1 Distribution coefficient of ^{137}Cs from batch test (ml/g)

Media	pH = 6	pH = 7	pH = 8	pH = 9	
Suspend material	1536	1425	1331	1139	
Sediment No.1	502	522	477	462	Clay
Sediment No.2	55	56	68	50	Silt

Table 2 Distribution coefficient of ^{137}Cs in suspend material from batch test

Concentration of suspend material, g/L	0.2	0.4	0.8	1.2	20.0	33.0	50.0	100.0
Distribution coefficient, ml/g	1414	1419	1471	1540	1520	1464	1346	1332

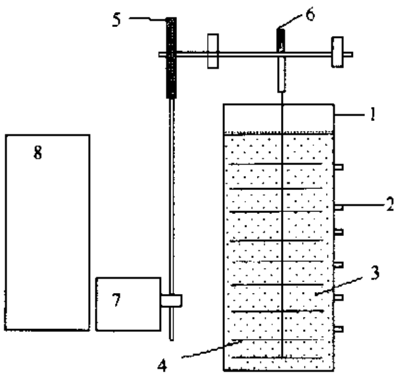

Fig.1 Schematic diagram of turbulent experiment facility

1. experimental barrel; 2. mouth of sampling; 3. experimental serosity; 4. vibrator fence; 5. eccentric wheel; 6. belt pulley; 7. direct current dynamo; 8. controllable silicon rectifier

Table 3 Distribution coefficients from turbinate test, ml/g

Rotary speed, r/s	Concentration of the suspend material in seawater, g/L		
	0.2	0.6	1.2
1	–	1268	–
3	1839	1945	1922
5	–	1965	–

1.2 Result from dynamic test

The distribution coefficient of ^{137}Cs is also determined by using turbinate facility (Fig.1), which is designed on the basis of facility by Yang and Qian (Yang, 1986). The results of the test are shown in Table 3. It shows that the value of the distribution coefficient in suspend material does not change largely under high turbinate condition. But under low turbinate condition, the value of distribution coefficient is much smaller, the reason may be that it did not reach the absorption equilibrium. Since there are some problems in doing this test, the result of this test is just taken as an example and will not be used in following estimation.

1.3 The recommended distribution coefficient

For ^{137}Cs, distribution coefficient in suspend material is 1500 g/ml, while in sediment (silt) is 477 g/ml, this is also for ^{134}Cs. These values will be used in following estimation.

2 The method to estimate the radionuclide deposit in sediment

It is assumed that concentration contour in the seawater is gotten either from the result of physical simulation or that of mathematics modeling, it is also assumed that these results does not consider the decay of radionuclide and radionuclide absorption by suspend material and sediment.

In this paper, the decay of radionuclide and the absorption by sediment are also omitted. The radionuclide concentration in seawater is C_w (Bq/m^3); the concentration in suspend material is C_s (Bq/kg); the suspend material concentration in seawater is F (kg/m^3), so, the total radionuclide concentration in water body C_{total} (Bq/m^3) can be expressed as follows,

$$C_{total} = (1 + K_d \times F) \times C_w, \tag{1}$$

where, K_d is distribution coefficient of radionuclides in suspend material, m^3/kg, that is,

$$K_d = C_s / C_w. \tag{2}$$

From Equation (1) and (2), if the total radionuclide concentration is known, the concentration in water can be gotten.

The following equation was used to get the radionuclide distribution in sediment,

$$D = \rho_d \times d \times C_d, \tag{3}$$

where, D is the radionuclide deposit in the surface sediment, Bq/m^2; ρ_d is density of the surface sediment, here 1550 kg/m^3 is used according to actual hydrological condition; d is depth of the effective deposit, here 0.025m is used; C_d is radionuclide concentration in the surface sediment, Bq/kg.

About the determination of C_d, (1) if in somewhere on the bottom of the sea where deposit is stronger than erosion, then the radionuclides concentration of suspend material C_s is taken as C_d; (2) if in somewhere on the bottom of the sea where deposit is less than erosion, that is, no sediment deposit on the bottom of sea, the C_d can be achieved as follows,

$$C_d = K'_d \times C_w, \tag{4}$$

where, K'_d is the distribution coefficient of nuclides in sediment (m^3/kg).

From above, we can calculate the nuclide deposit in the surface sediment under difference deposit environment and difference concentration in seawater.

It shows that when there is deposit in somewhere, we consider that the sediment in the sea is from suspending material. Since the distribution coefficient of suspend material is much larger than that of sediment, the quantity of absorb radionuclides by suspend material is larger than that of sediment under the absorption balance condition. So, this is a very conservative method.

When there is erosion in somewhere of the sea, there is no

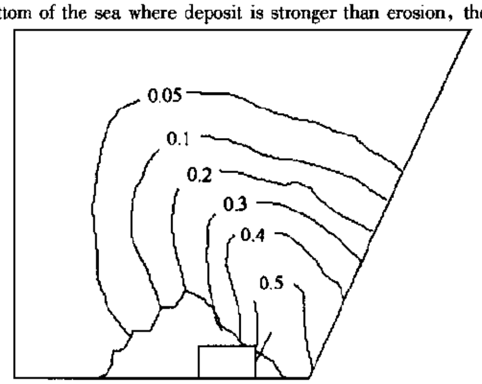

Fig.2 Concentration distribution from a certain nuclear facility

deposit actually. We assumed that there is an absorption balance between the surface sediment and seawater, so the nuclides deposit under this assumption is also very conservative.

3 An example

Fig. 2 shows the concentration distribution from a nuclear facility outlet, which is achieved by physical simulation. The figure in the picture shows the relative concentration.

The average suspend concentration in seawater is 0.24 g/L, the radionuclides concentration in seawater and suspend material can be calculated and shown in Table 4. The initial concentration in outlet is 2.82E0 Bq/m^3 for ^{137}Cs and 2.18E0 Bq/m^3 for ^{134}Cs.

Then according to the deposit or erosion situation on the bottom of the sea, which is whether from investigation or from physical simulation, the nuclides deposit distribution in the sediment can be calculated and the estimated result for this example is shown in Table 5.

Since the area near the outlet of the nuclear facility in general condition is usually an erosion one. So the largest figure at Table 5 is not existed.

We compared the results from this paper and the radionuclide background values in China Sea. We found that ^{134}Cs did not find in the seawater and deposit of Donghai Sea and Bohai Sea (the reason is that the half life of ^{134}Cs is only about 2 years), while ^{137}Cs were 6.7×10^{-3} Bq/L and 3.85×10^{0} Bq/kg in the seawater and deposit of Donghai Sea, and were 7.3×10^{-3} Bq/L and 5.41×10^{0} Bq/kg in the seawater and deposit of Bohai Sea (Cai, 1992). Also we found that ^{137}Cs was 3.78×10^{-3} Bq/L in the sea water of Huanghai Sea (CCGR, 1993). So, the results of this paper were a little smaller than the radionuclide background values.

Table 4 Radionuclide concentrations in water and suspend material

D_i	^{134}Cs		^{137}Cs	
	C_s, Bq/kg	C_w, Bq/m^3	C_s, Bq/kg	C_w, Bq/m^3
1.0	2.40E0	1.60E0	3.11E0	2.07E0
0.5	1.20E0	8.01E-1	1.56E0	1.04E0
0.4	9.62E-1	6.41E-1	1.24E0	8.29E-1
0.3	7.21E-1	4.81E-1	9.33E-1	6.22E-1
0.2	4.81E-1	3.21E-1	6.22E-1	4.15E-1
0.1	2.40E-1	1.60E-1	3.11E-1	2.07E-1
0.05	1.20E-1	8.01E-1	1.56E-1	1.04E-1

Note: D_i is the relative concentration contour in seawater near the outlet, and D_i equal to 1 means the radionuclide concentration in outlet

Table 5 Radionuclide distributions in sediment, Bq/m^2

D_i	^{134}Cs		^{137}Cs	
	Deposit area	Erode area	Deposit area	Erode area
1.0	–	2.96E1		3.83E1
0.5	4.65E1	1.48E1	6.04E1	1.92E1
0.4	3.73E1	1.19E1	4.83E1	1.54E1
0.3	2.79E1	8.89E0	3.62E1	1.15E1
0.2	1.86E1	5.93E0	2.41E1	7.67E0
0.1	9.30E0	2.96E0	1.21E1	3.83E0
0.05	4.65E0	1.48E-1	6.04E0	1.92E0

4 Conclusion and discussion

A simple and conservative method is put forward in this paper. According to its physics meaning, this method is very feasible. Since it is not a very accurate method, we now do some theory research and experiments to achieve an accurate method.

Also from above, we can see that the LLW from nuclear facility or nuclear power plant will do a little harm to the sediment nearby. But the harm is not very serious.

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