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# Evaluation of Radioactivity in Surabaya Coastal Estuary Ecosystem with Spectrometry α, β, γ

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**Abstract:** Radioactivity levels have been measured in sediment samples, *Echornia crassipes* and *Anadara granosa* at the Surabaya river estuary. Measurement data were obtained by spectrophotometric method, which is a way of measuring and identifying radionuclides through observations of the spectrum emitted with detector material. The results of measurements and calculations that have been done show that the mean concentration of activity α, β, γ (gross) in water in the Morokrembangan estuary and Kenjeran river estuary is still below the threshold value of group C waters quality. Radionuclide identification results indicate the presence of natural radionuclides K $^{40}$, Tl $^{208}$ and Pb $^{212}$, whereas artificial radionuclides Pu $^{239}$ and Cs $^{137}$ were not detected in all samples.

**Key words:** Radioactivity, water quality, spectrophotometry α, β, γ.

## Introduction

Surabaya coastal estuary waters are a unique ecosystem. This is because the coast of Surabaya is a place of accumulation of various contaminants originating from direct release, fall from the atmosphere and disposition from the mainland.

Coastal Surabaya is an area that has various functions. Coastal land area becomes a place of institutional activities, industrial areas and residential areas. The sea, coastal area is a place that empties into the Kenjeran River and the Morokrembangan River, and is a place of domestic waste disposal (Subakir, 1999). The geographical position, geological and geomorphological conditions of the city of Surabaya and the rivers that pass through it affect the quality of its waters. Therefore, the condition of the quality of its waters needs to be assessed, especially from the radiological aspect.

To discuss water quality from the radioecological aspect, it is necessary to study radioactivity related to gross radiation exposure, identification, accumulation, distribution factors and bioaccumulation factors as well as the mechanism of radionuclide displacement in the components of the aquatic ecosystem. This research is considered to be important because research work on the reported radioactivity of environmental radioactivity is still lacking (Taftazani et al., 1998).

## Material and Method

The materials used for this study include water, sediment, animal biota (*Andara granos*) and plant biota (*Eichornia crassipes*). The spectrometer α, β, γ consists of a Schlumberger ECT-34 solid ZnS detector, a Geiger Muller Counter Ortec 401A counter, a spectrometer with a Ge (Li) detector, MCA Ortec 7010, Houston Omnigraphic Plotter Instrument (2000 recorder), HV

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Power Supply Canberra 3105 model, stabilizer Philips 4000 VA, and Canberra Model 2021 Spectroscopy Amplifier. The standard radioisotope sources used as calibrators are Am $^{241}$ ($\alpha$), Sr $^{90}$ ($\beta$) and Eu $^{152}$ ($\gamma$).

Samples were taken from two areas, namely the Morokrebangan River and the Kenjeran River estuary. Both these locations are estuarine waters in the Surabaya Coast. Plant water, *Eichhornia crassipes*, is selected as a biota representing the habitat. Shellfish (*Andara granosa)* were chosen because their mobility is very low and they live in sedimentary waters. Both types of biota have a high resistance in accumulating pollutants without turning off their lives, so it is a good bioindicator to show water quality (Taftazani, et al., 1999). Water samples are taken from the waters around plants, while sediments are taken from rocks found on the coast.

Preparation of samples consists of preparation of water samples, sediments and aquatic biota (water hyacinth and shellfish). Preparation of water samples is done by acidification using $HNO_3$, it is concentrated through heating until a dry sample is ready to be chopped. Sediment preparation begins with cleaning material from various impurities and dried at room temperature. After that it is crushed until smooth and homogenised and then sieved at 100 mesh. The sample is ready to be analysed in accordance with the required amount. The biota sample begins with taking soft tissue, then dried in a freeze dryer. As with other preparations, the next process of biota is crushed until smooth and ready to be chopped. All the dry samples from the above preparations were ready to be analysed for exposure to radiation $\alpha$ and $\beta$ (gross) with $\alpha$ and $\beta$ a low background enumerator (LBC) and ready to be identified radionuclide content with a spectrometer.

Meanwhile, to analsze the content of $Pu^{238}$ radionuclides still need to proceed with the chemical separation process. Before enumerating the sample, the spectrometer is calibrated first. Calibration is carried out using a standard radioisotope source that has known the initial activity and date of manufacture as well as the characteristics of its energies. The data enumeration is then analysed (regression equation, energy calibration, efficiency calibration and others).

## Results and Discussion

The results of the sample preparation are presented in Table 1. Treatment in environmental preparation will not change the radiation level because radioactive symptoms are only determined by the nucleus of the atom concerned and cannot be influenced by external factors such as temperature, pressure, shape of compounds and others.

The quantity of environmental samples taken into account in the analysis is the mass after preparation, while the concentration factor is used to convert the enumeration results and calculate the concentration of sample activities. Qualitatively measure environmental radioactivity from the type of transmitter $\alpha$ or $\beta$, the

**Table 1: Sample preparation results**

| *No.* | *Code* | *Samples quantity* | | *Concentration factor* | *Quantity of the sample for analysis* | | | |
|---|---|---|---|---|---|---|---|---|
| | | *Before preparation (±0.05)* | *After preparation (±0.0005) gr* | | *Gross α (±0.0005) gr* | *Gross β ( ±0,0005) gr* | *γ ( ±0.0 005) gr* | *$Pu^{238}$ (±0.0005) gr* |
| 1 | A-1 | 20 litres | 4.599 | 0.2300 gr/l | 1.502 | 1.000 | 40.005 | 15 ml* |
| 2 | A-2 | 20 litres | 4.720 | 0.2360 gr/l | 1.503 | 1.001 | 40.010 | 15 ml* |
| 3 | B-1 | 5 kg wet | $3.850 \times 10^3$ | 0.7700 | 1.503 | 1.001 | 105.213 | 2.002 |
| 4 | B-2 | 5 kg wet | $4.330 \times 10^3$ | 0.8660 | 1.502 | 0.998 | 105.051 | 2.001 |
| 5 | C-1 | 2 kg wet | 51.050 | 0.0255 | 1.499 | 0.999 | 29.782 | 1.999 |
| 6 | C-2 | 2 kg wet | 52.125 | 0.0261 | 1.500 | 0.002 | 30.201 | 1.998 |
| 7 | D-1 | 3 kg wet | 96.010 | 0.0300 | 1.501 | 1.001 | 51.089 | 1.999 |
| 8 | D-2 | 3 kg wet | 97.021 | 0.0323 | 1.502 | 1.000 | 53.820 | 2.001 |

Information:
1. Code: A-1 = Morokrembangan River estuary water
A-2 = Kenjeran River estuary water
B-1 = Morokrembangan River estuary sediment
B-2 = Kenjeran River estuary sediment
C-1 = Water hyacinth for estuary of the Morokrembangan
River C-2 = Water hyacinth for Morokrembangan
D-1 = Morokrembangan River estuary shells
D-2 = Kenjeran River estuary shells
2. Sign * shows the quantity of samples measured by volume.

sample needs to be separated from the other transmitter radionuclides so that only the desired radionuclide is measured. In the gross measurement of environmental radioactivity, the sample does not require a separation process so that what is measured is all the activity of the existing radionuclide mixture.

The spectrometer stability test results for enumeration α showed that from ten times the measurements under the same conditions (operating voltage HV = 1380 V), the $\chi^2$ count was obtained = 5.0472. This value is located between two $\chi^2$ table boundary values of (2.70 - 19.00) at a 95% confidence level and 9 degrees of freedom. Thus the Sclumberger ECT-34 detector ZnS detector on and Geiger Muller Counter Ortec 401A, is considered to be the optimum condition and quite stable. The spectrometer stability test results for enumeration β under the same conditions (operating voltage HV = 1380 V) a $\chi^2$ count = 8.7705 was obtained. This value lies between the two table boundary values $\chi^2$ of (0.484 - 11,000) at a 95% tolerance and 4 degrees of freedom. Thus the counter is considered to be at the optimum and fairly stable condition.

Spectrometer γ calibration is done with two kinds of calibration namely energy calibration and efficiency calibration. Calibration is done by counting the $Eu^{152}$ standard radioisotope sources (half-life 13.1 years). Measurement of n - peak γ energy Eu $^{152}$ from the lowest energy to the highest energy can be done simultaneously with the help of the Multi Channel Analysis (MCA) tool. The results of the spectrometer γ energy calibration obtained a linear regression equation $y$ = 0.5605, $x$ = 0.4982 with a regression coefficient of 0.9999. While the calibration efficiency of the spectrometer γ results in a linear regression equation $y$ = –1.0698, $x$ + 2.6335 where $y$ = ln ε($E$) and $x$ = ln $Ex$ = ln $E$ and with a regression coefficient of 0.9999. This linearity can only be applied to energies greater than 300 keV. For energies less than 300 keV, this linear relationship does not apply. Therefore, quantitative analysis of radionuclides with energies less than 300 keV is not performed.

The results of the enumeration and the calculation of the gross α activity concentration are presented in Table 2. From the table it appears that the value of measured radiation exposure in water at the two research locations of the Morokrembangan estuary and Kenjeran estuary is still below the threshold value of group C quality standards according to PP RI No. 20/1990 concerning controlling water pollution by 0.1 Bq/l. This shows that the condition of the environmental quality of the coastal waters of Surabaya is still in the good category in terms of gross (α) radioecological aspects .The concentration of gross (α) activity in sediment samples from the two study sites was higher than in water samples and biota. This shows the affinity of radionuclides for association with sediments and sediment particles is higher than with water or biota.

The results of the enumeration and the calculation of the concentration of gross β activity are presented in Table 2. The data show that the value of measured radiation exposure in water at the two study areas is still below the threshold quality standard of group C waters according to Government Regulation 20/1990, namely 0.1 Bq /l. Similar to gross α, the concentration of gross β activity in sediment samples from the two study areas was higher than in water samples and biota. This shows that the condition of the environmental quality of the coastal waters of Surabaya is still in the good category in terms of gross β radioecological aspects.

The types of radionuclide are identified by γ spectrofotometer. Calculations are only carried out for energies greater than 300 keV (radionuclides $Tl^{208}$ and $K^{40}$ ). The identification results showed the presence of radionuclides $Pb^{212}$ (238.63 keV), $Tl^{208}$ (510.70 keV), and $K^{40}$ (1460.70 keV). Whereas radionuclide $Pu^{238}$ (α) and $Cs^{137}$ (661.66 keV) were not detected in all samples. Thus the Surabaya coastal waters ecosystem has not been contaminated with artificial radionuclides as a result of activation or fission. This might be due to the condition and location of Surabaya's coastal waters which are relatively shallow and surrounded by the surrounding islands. The condition and location resulted

**Table 2: Results of enumeration and calculation of gross α activity concentration**

| *No.* | *Sample* | *Gross α and β activity concentration (Bq/gr)* | | | |
|---|---|---|---|---|---|
| | | *Morokrembangan River Estuary* | | *Kenjeran River Estuary* | |
| | | *Gross α* | *Gross β* | *Gross α* | *Gross β* |
| 1 | Water | 0.0257 ± 0.0053 | 0.1700 ± 0.0419 | 0.0338 ± 0.0062 | 0.4048 ± 0.0640 |
| 2 | Sediment | 0.0982 ± 0.0107 | 0.3900 ± 0.0627 | 0.1299 ± 0.0121 | 0.5146 ± 0.0728 |
| 3 | Eichhornia | 0.02176 ± 0.0158 | 1,1600 ± 0,1097 | 0.2209 ± 0.0158 | 0.8186 ± 0.0910 |
| 4 | Anadara granosa | 0.1684 ± 0.0140 | 0.6866 ± 0.0837 | 0.1859 ± 0.0146 | 0.4052 ± 0.0460 |

in obstruction of congenital radioactive contamination brought by the movement of water from the Pacific Ocean to the Indian Ocean through Indonesian waters with a capacity of 106 $km^3$ . According to Syarbaini et al. (1988), actually waters around the Java Sea already contain artificial radionuclides, such as $Cs^{137}$, $Pu^{238}$, $Pu^{239,240}$, $Am^{241}$ and so on. However, the concentration of radionuclide activity is still lower compared to other countries such as Japan, America and Europe and the threshold set by BATAN/IAEA. Based on these studies indicate that the concentration of artificial radionuclides in the Java Sea ecosystem is in accordance with the concentration of radionuclides originating from the fall-out. So, based on this fact it can be concluded that the radionuclides found in the environment of the Java Sea and its surroundings came from the drop of nuclear weapons testing in the atmosphere.

The concentration of radionuclide activity in sediments is related to the tendency of radionuclides to associate with sediments and sediment particles, which are expressed as distribution factors. Whereas the tendency of a radionuclide to associate with biota in waters is expressed by bioaccumulation or bioconcentration factors as stated in Table 5. Distribution factors and bioaccumulation factors are calculated based on gross exposure at each location and have no physical significance. This is because the gross measurements do not provide information about the type of radionuclide contributing to radiation exposure, so the calculated distribution factors and bioaccumulation factors are unknown from what elements.

From Table 3 it appears that the concentration of activity in the sediment samples at the two study sites shows a higher level of exposure than in water. This is due to the affinity of radionuclides for association with sediments and sediment particles in waters higher than water.

Radionuclide accumulation in the body of biota is caused by the process of dispersion and dissolution of radionuclides in water. The process causes the movement and accumulation of radionuclides in the body of biota in the aquatic environment. If the concentration of radionuclide activity in the body of a biota is greater than its environment it is called bioaccumulation, and if it is smaller than its environment it is called bioconcentration.

## Conclusion

The concentration of α and β (gross) activities in water at the mouths of the Morokrembangan and Kenjeran estuaries is still below the threshold quality standard of group C waters, while the activities in sediments and biota cannot be evaluated because there is no quality standard in comparison. The radionuclide identified are $Pb^{212}$, $Tl^{208}$ and $K^{40}$. Whereas $Pu^{236}$ (α) and $Cs^{137}$ were not detected in all samples. This shows that all radionuclides detected in the sample are natural radionuclides and Surabaya coastal waters ecosystems have not been contaminated with artificial radionuclides as a result of activation or fission.

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**Table 3: Radionuclide distribution factors in sediments and bioaccumulation factors in biota**

| *No.* | *Measureable amount* | *Estuary* | *Distribution factor ($F_D$) in sediments (l/gr)* | *Bioaccumulation factor ($F_B$)* | |
|---|---|---|---|---|---|
| | | | | *Eichhornia crassipes (l/gr)* | *Anadara granosa (l/gr)* |
| 1 | Gross α | Morokrembangan | 12.7894 ± 2.9801 | 0.9386 ± 0.2052 | 0.8547 ± 0.1900 |
| | | Kenjeran | 14.1034 ± 2.9026 | 0.7227 ± 0.1423 | 0.7528 ± 0.1502 |
| 2 | Gross β | Morokrembangan | 7.6803 ± 2.2543 | 0.7570 ± 0.1992 | 0.5269 ± 0.1443 |
| | | Kenjeran | 4.6660 ± 0.9897 | 0.2241 ± 0.0434 | 0.1372 ± 0.0309 |
| 3 | Radionuclides $Tl^{208}$ | Morokrembangan | th | th | th |
| | | Kenjeran | th | th | th |
| 4 | Radionuclides $K^{40}$ | Morokrembangan | 21.8200 ± 8.4838 | 2.6034 ± 0.8075 | 1.9841 ± 0.7689 |
| | | Kenjeran | 24.4569 ± 9.9746 | 2.5636 ± 1.0453 | 2.5772 ± 1.0415 |

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