SEDIMENT ACCUMULATION RATES IN COASTAL AREA OF MURIA PENINSULA, CENTRAL JAVA, ELUCIDATED FROM ENVIRONMENTAL ISOTOPE ^{210}Pb

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ABSTRACT

SEDIMENT ACCUMULATION RATES IN COASTAL AREA OF MURIA PENINSULA, CENTRAL JAVA, ELUCIDATED FROM ENVIRONMENTAL ISOTOPE ^{210}***Pb***. *Sediment accumulation rates was investigated based on the profiles and inventories of* ^{210}*Pb and Constant Rate of Supply (CRS) model in sediment cores collected from the coastal area of Muria Peninsula. Sediment cores were collected using gravity corer. The derived sediment accumulation rates vary along the coastline and along the cores and appear to be higher in the eastern part than western part of the site; i.e, between 0.5 to 3.4 kg/m*^{2}*.y on the eastern part, 0.3 to 3.1 kg/m*^{2}*.y in the central and 0.5 to 2 kg/m*^{2}*.y on the western part. Highly deposited sediment may relate to the change in the up-land as well as in the coastal area itself.*

Keywords: *Sediment rate,* ^{210}*Pb, CRS model*

ABSTRAK

LAJU AKUMULASI SEDIMEN DI AREA PESISIR SEMENANJUNG MURIA, JAWA TENGAH, DENGAN ELUSIDASI LINGKUNGAN ISOTOP ^{210}***Pb.*** *Telah dilakukan investigasi laju akumulasi sedimen berdasarkan profil dan inventori dari* ^{210}*Pb dan model Constant Rate of Supply (CRS) pada sedimen core yang diperoleh dari daerah pesisir Semenanjung Muria. Sedimen diambil menggunakan alat gavity core. Laju akumulasi sedimen yang diperoleh bervariasi sepanjang pesisir dan sepanjang core dan untuk laju tersebut lebih tinggi di sebelah timur dibandingkan dengan daerah sebelah barat, yaitu antara 0,5 hingga 3,4 kg/m*^{2}*.tahun di sebelah timur, 0,3 hingga 3,1 kg/m*^{2}*.tahun in bagian tengah dan 0,5 hingga 2 kg/m*^{2}*.tahun di sebelah barat. Laju deposit sedimen yang tinggi kemungkinan disebabkan oleh perubahan di daerah daratan dan daerah pesisir tersebut.*

Kata kunci: *Laju sedimen,* ^{210}*Pb, model CRS*

1. INTRODUCTION

The isotope ^{210}Pb (T½ = 22.3 y) is a decay product of gaseous ^{222}Rn escaping from the surface of soil to the atmosphere, returns to the surface soil or water reservoirs within a couple of weeks as solid fallout[1]. Part of the ^{210}Pb activity coming from the fallout and adsorbed in the surface sediments is called unsupported and it is strictly connected with sedimentary processes on the contrary to the ^{210}Pb produced inside the sediment matrix. For old (>150 years) sediments, covered with later deposited layers, this radionuclide is basically in radioactive equilibrium with ^{226}Ra, its long-lived precursor. Therefore, the unsupported part of ^{210}Pb activity in the bottom sediment layers can be simply calculated as a difference between the specific activities of these two radionuclides. The different models connecting the ^{210}Pb specific activity profile of sediment cores with sediment deposition dates or the rate of sedimentation are described in the literature[2]. The most widely used method for the lakes, coastal zones or estuaries, where sedimentation processes are intensified by anthropogenic actions is the constant rate of supply (CRS) of unsupported ^{210}Pb[3].

Muria Peninsula is located in the northern of Central Java. The coastline is about 35 km long from 6⁰26′52′S; 110⁰42′49″E to 6⁰25′25″S;111⁰01′38″E. Muria Peninsula, in particular Ujung Lemah Abang is the candidate site of the first Indonesian Nuclear Power Plant. There are two major rivers in this area, namely; Balong and Gelis River. Several integrated research has been conducted such as database of site in related to the natural and artificial radionuclides in ecosystems component biotic and abiotic of ecosystems[4,5]. The principal object of this paper is to present the result of measurements of environmental isotope ^{210}Pb in marine sediment core taken from coastal area of Muria Peninsula, and to determine sediment accumulation rates using this data.

2. EXPERIMENTAL

2.1. Sedimentation rate determination from Constant Rate of Supply (CRS) model[6].

At a constant rate of supply of the unsupported ^{210}Pb radionuclide model (CRS) the age of sediment − t in the layer at a distance of x from the sediment/water interface is given by the equation:

$$A_z = A_o e^{-bz} \qquad (1)$$

The rate of sedimentation, S, is equal to λ/b in cm/year, where

λ = ^{210}Pb radioactive decay constant of 0,03114

$A(z)$ = excess ^{210}Pb activity at depth z

$A(o)$ = activity at the surface (or bottom of the uniformly mixed layer)

b = the slope defined by a regression through the data

z = depth

Assuming a constant activity at the surface, the model is simplified to the following equation:

$$S = \frac{\lambda_{^{210}Pb}}{b} \qquad (2)$$

where the slope (b) of the regression line through data is plotted as the natural log of unsupported ^{210}Pb activity as a function of sample depth.

The unsupported ^{210}Pb concentration will vary with depth in accordance with the formula:

$$C = C(o)e^{-\lambda t} \tag{3}$$

where *C(o)* is the unsupported ^{210}Pb concentration of sediments at the sediment water interface and the radioactive decay constant (λ) of ^{210}Pb is:

$$\lambda_{^{210}Pb} = \frac{\log 2}{22{,}26} = 0{,}3114.y^{-1} \tag{4}$$

or

$$\lambda_{^{210}Pb} = \ln\frac{2}{22{,}26y} = 0{,}3114.y^{-1} \tag{5}$$

as previously stated.

The age of sediment layers with ^{210}Pb concentration *C* is therefore:

$$t = \frac{1}{\lambda_{^{210}Pb}}\ln\left[\frac{C_o}{C}\right] \tag{6}$$

Based on the law of radioactive decay, the CRS model, is used to determine the age of a given depth from a ^{210}Pb vertical profile within a sediment column. The CRS model is the most widely accepted model and is dominated by constant direct atmospheric fallout. The model is based on assumptions that the unsupported ^{210}Pb is supplied at a constant rate to sediments through time, the initial ^{210}Pb concentration in the sediment is variable, and the influx rate of sediment is variable. Because the CRS model assumes constant fallout of ^{210}Pb, it also considers that no post-depositional mixing occurs. Another assumption is that the transport parameters are independent of sedimentation rate. Given these inherent assumptions, the CRS model is usually appropriate in bodies of water where there has been little or no sediment disturbance. Sediment mixing typically results in a flattening of the profile of ^{210}Pb activity versus depth in the surficial sediment layers. In the CRS model, the sediment accumulation rate can vary.

The initial concentration *Co(t)* of unsupported ^{210}Pb in sediment of age *t* years must satisfy the following:

$$C0(t)\ r(t) = \text{constant} \tag{7}$$

where *r(t)*= (g/cm^{2}yr) is the dry mass sedimentation rate at time *t*.
From this equation, a relation for the age of deposit at depth *x* is developed as follow:

$$t = \frac{1}{\lambda}\ln\left[\frac{A_o}{A_x}\right] \tag{8}$$

where A_0 is the total unsupported ^{210}Pb activity in the sediment column and A_x is the total unsupported ^{210}Pb activity in the sediment column beneath depth *x*.

The sedimentation rate, r, is calculated directly from the formula:

$$r = \frac{\lambda A_x}{C} \tag{9}$$

2.2. Sampling Methodology

The location of the sampling sites is depicted in Figure 1 and the details on core collection are shown in Table 1. The core samples were collected in shallow subtidal areas using a gravity corer with 50 mm inner diameter. The inner part of the corer tube is made of plexiglas, and the outer part from stainless steel. Three cores have been selected for analysis of sediment accumulation rates in the sampling area. Cores were subsampled every 1 cm on the upper (0-12) cm, 2 cm on the middle (12-30) cm and 3 cm below 30 cm. Tightly packed samples were transported to the laboratory and stored in 4°C in refrigerator till the analyses.

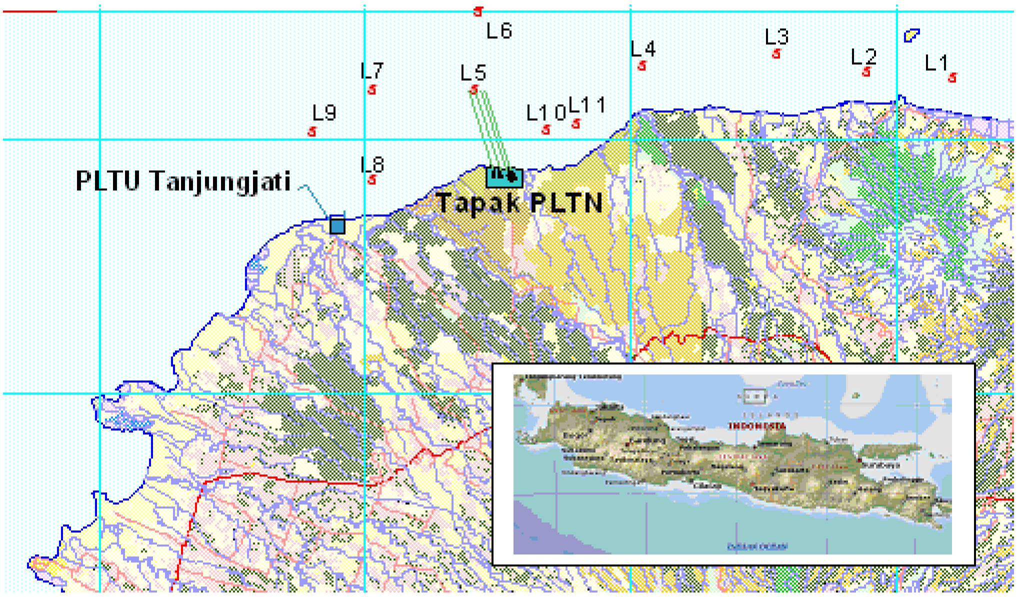


Figure 1. Sampling Location in Muria Peninsula

2.3. Analytical Procedures

Before the radioactivity measurements, samples were oven-dried for 3 days at 60°C, crushed to pass through 0.5 mm sieve for homogenizing. The wet and dry samples are weighted for water content. ^{210}Pb was measured via its granddaughter ^{210}Po assuming there is radioactive equilibrium between these radionuclides. The analysis was performed in the Marine and Environment Laboratory, Center for the Application of Isotopes and Radiation, National Nuclear Energy Agency, BATAN. ^{209}Po as an internal standard was added to 3 g of dried sediment and then each sample was digested in conc. HCl, HNO_3 and H_2O_2[7,8]. After acid digestion, ^{210}Po was spontaneously deposited for four hours on a copper disc which was then placed in a-counter for about 3 hours. Alpha activity was measured using multichannel analyzer Genie 2000 with Passiveted Implanted Planar Silicon (PIPS) detector Canberra A450-20AM.

Table 1. Information on Sediment Collected from Coastal Area of Muria Peninsula

Sampling point	Position		Length of samples (cm)	Water depth (m)	Remarks
	Latitude (N)	Logitude (E)			
1.	-06^0 23′ 18,4″	110^0 52′ 48,2″	43	8,5	Core L4 (Core 1)
2.	-06^0 24′ 01,0″	110^0 47′ 06,0″	35,5	11,5	Core L5 (Core 2)
3.	-06^0 25′ 49,1″	110^0 44′ 01,7″	46	12	Core L9 (Core 3)

2.4. Quality Assurance

The accuracy of the ^{210}Pb procedure was checked in independent experiments by determining the measured radionuclides in two standard reference materials: SRM IAEA-300 (Baltic Sea sediment) and IAEA-368 (Pacific Ocean sediment). The obtained activity concentrations were close to the reported values with deviations not exceeding 10%[8].

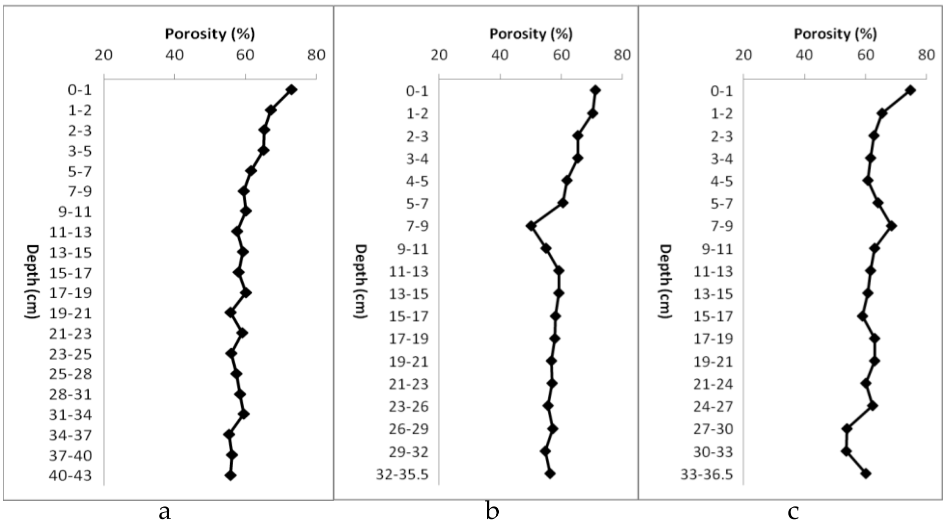
3. RESULT AND DISCUSSION

Porosity of the sediment layers of core 1, core 2 and core 3 are shown in Figure 2. The porosities of core 1 and core 2 are changed due to the consolidation from above 70% just below the top of the core to about 60% at the base of the core, while in core 3 from about 60% on the top to 45% at the bottom. All cores show higher porosity on the surface and decreased with depth, indicating increased compaction of the sediment.

The value of supported ^{210}Pb for all the cores was determined as 19 Bq/kg. The supported ^{210}Pb was obtained in core 1 at depth 34 cm, in core 2 at depth 29 cm, and in core 3 at depth 25 cm. Unsupported ^{210}Pb are depicted in Figure 3. The unsupported ^{210}Pb concentration measurements on core 1 (Figure 3a) scattered on the top until 19 cm and decreased from 21 to 34 cm. Using CRS model, the sediment layer in core 1 can be dated and accordingly the lowest layer (34 cm) has been deposited in the year 1905. The obtained sediment accumulation rates based on the profile of unsupported ^{210}Pb are between 0.5 kg/m^2.y and 3.4 kg/m^2.y (Figure 4a). Moreover, sediment accumulation rate were almost constant from 1905 to 1970 and increased with some fluctuation up to now. The fluctuation may be in relation with the position of core 1 near the mouth of the river.

Similar with core 1, core 2 (Figure 3b) shows the unsupported ^{210}Pb fluctuated from surface to the depth 17 cm and decreased to the bottom (29 cm). With the CRS Model one obtains sediment accumulation rates between 0.3 and 3.1 kg/m^2.y. The bottom layer was related to the date of 1895. Based on the dating sediment, sediment accumulation rates in the area of core 2 were nearly constant from 1895 to 1970 and increased from 1970 to now with the sediment accumulation rate from 1 to 3.1 kg/m^2.y (Figure 4b).

The unsupported ^{210}Pb in core 3 which is collected from western part on Muria Peninsula appear slightly different from previous both cores. Sample was collected from deeper water column compared to the previous and the contribution from the river may also less than other locations. The profile shows a decrease from just below the surface to the depth of 25 cm and mixing on the top (0-3 cm). Using CRS model, the lowest part (25 cm) was dated from 1905 (Figure 3c). Sediment accumulation rates increased steadily from 1905 to the recent year (Figure 4c) with the magnitude from 0.5 to about 2 kg/m^2.y.



a b c

Figure 2. Porosity of Sediment; (a) Core 1, (b) Core 2, and (c) Core 3

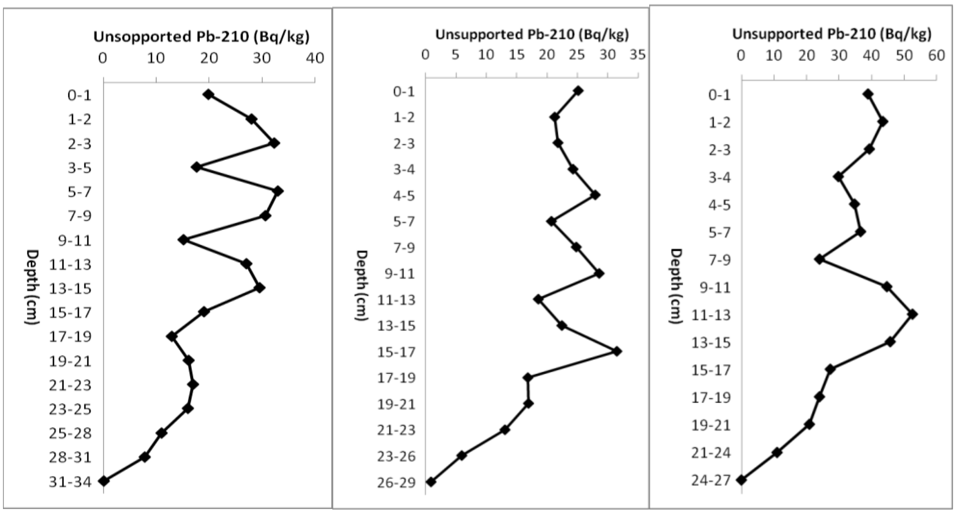


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Figure 3. ^{210}Pb Excess; (a) Core 1,(b) Core 2, and (c) Core 3

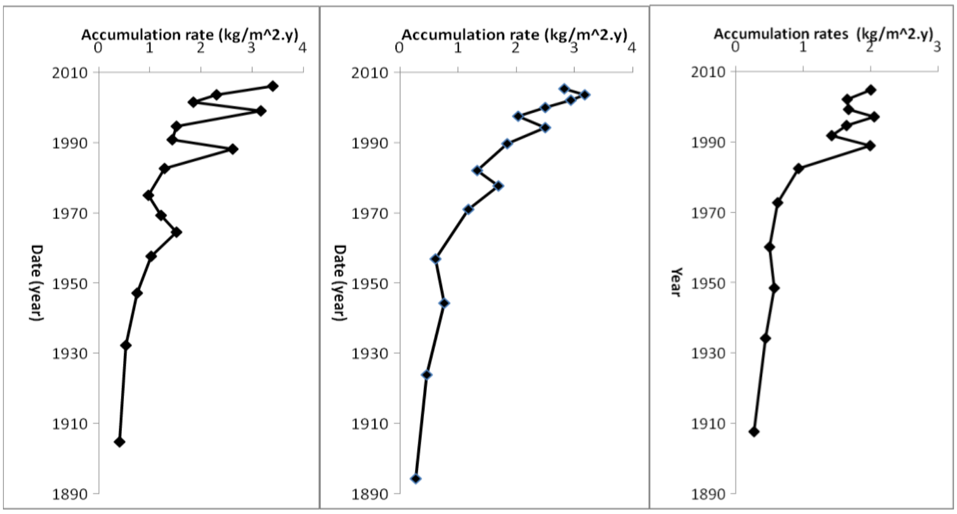

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Figure 4. Sediment Accumulation Rate; (a) Core 1,(b) Core 2, and (c) Core 3

4. CONCLUSION

Sediment cores have been collected in shallow sediment of Muria Peninsula. A detailed investigation of unsupported ^{210}Pb allowed the characterization of long-term sediment accumulation pattern on these cores. Sediment accumulation rates, derived from environmental isotope ^{210}Pb profiles are between 0.5 to 3.4 kg/m^2.y on the eastern part (core 1), 0.3 to 3.1 kg/m^2.y in the central (core 2) and 0.5 to 2 kg/m^2.y on the western part (core 3). Based on the result of analysis, it can be concluded that sedimentation is higher on the location of core 1 in the eastern part than the western part. Furthermore, it can be assumed that the sedimentation may related to the contribution from the rivers and the effect of the monsoon.

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