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Transfer Factors Analysis of ^{210}Pb and ^{40}K Natural Radionuclides from Paddy Fields to Rice Plants in Malang Raya, East Java

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Abstract— Naturally Occuring Radioactive Materials (NORM) on earth consist of natural materials containing radioactive material. Nature-produced radionuclides are called primordial radionuclides, which are found in soil, plants, water and air. This research was conducted on rice plants in five locations in Malang, namely Singosari, Malang Kota, Karangploso, Kepanjen and Pujon. This research aims to measure ^{210}Pb and ^{40}K natural radionuclides in paddy fields and rice plants, to analyze the value of ^{210}Pb and ^{40}K natural radionuclide transfer factors from paddy fields to rice plants. The research used samples of rice plants and rice fields from five different sampling locations in the Malang area. The sample was prepared and measured using a gamma spectrometer at PTKMR BATAN, Jakarta. The results show that the value of ^{40}K radionuclide concentration was higher than the concentration value of ^{210}Pb due to the effect of fertilizer utilization on rice fields compared to contamination of Pb or heavy metals. The transfer value of ^{210}Pb factor was obtained only in root sample from Karangploso location which is 21,00 while the transfer value of the ^{40}K factor was obtained in all parts of the sample, in which the lowest value of 0,20 was obtained in seed samples from Malang city location and the highest value of 20,60 was found in the Pujon stem sample.

Keywords— *Rice plants, ^{210}Pb and ^{40}K elemental radionuclides, paddy fields, Gamma Spectrometer.*

I. INTRODUCTION

Indonesia is a country that has very good potential in the agricultural sector. Indonesia at the international level is one of the second largest rice producers and consumers after China. Rice production and the condition of rice consumption in Indonesia every year is increasing along with the development of technological advances in the agricultural sector and the use of various types of fertilizers. The use of inorganic fertilizers is one of the contamination sources of soil, water and air around rice plants in the form of natural radiation which can be harmful to human health. Radiation effects could have a negative impact on human health, therefore it needs an increase in awareness among researchers and the general public [1].

Nitrogen fertilizers or chemical fertilizers are used gradually over a long period of time, in excessive amounts, resulting in scattered chemicals in fertilizers and a negative impact on the environment. The negative impacts include, the contamination of soil and water, reducing the level of soil fertility and the dependence of farmers economically and socially as well as having an impact on public health. The content of natural radioactive substances in the elements ^{210}Pb and ^{40}K as the basic ingredients of chemical fertilizers can be used as an indicator amount of chemical fertilizers and the duration of accumulation fertilizer pollution in the environment. Because generally the half-life of radioactive substances is very long, including Potassium 40 (1,3 x 10^9 years), there is no limit in environmental soil pollution due to the use of chemical fertilizers related to the history of the time of use [2].

Based on the research conducted (Tjondronegoro, 1990), it was obtained (a) there was a difference between exposure to natural radiation on earth crust rocks due to human activities that spread natural radiation to a wide environment; (b) there is a relationship between radiation exposure and the concentration of radioactive substances in the area of agricultural land; (c) there is a relationship between the spread of radioactive substances in agricultural areas and the behavior of farmers, namely the time span used for the spread of fertilizers, the amount of fertilizer used and the cropping pattern of the use of fertilizers [3].

Radiation is a beam of energy in the form of particles or electromagnetic waves [4]. Based on the ability to ionize, radiation consists of two types, namely ionizing radiation and non ionizing radiation. Ionizing radiation is radiation which can cause ionization, when interacting with matter, or in other words, it can generate electrically charged particles (positive ion and negative ion). Examples of ionizing radiation include cosmic rays, x rays, alpha particle (α), beta particle (β), gamma particle (γ) and neutron. Non-ionizing radiation is radiation that does not cause ionization. Examples of non ionizing radiation include radio waves, microwaves and infrared light [5].

Primordial radionuclides have exist since the formation of the universe, and consisted of uranium- series radionuclides with uranium parents (U-238) and the end of stable lead nuclide (Pb-206), radionuclide Thorium series with the parent Thorium (Th-232) and the end of the lead stable nuclide (Pb-208) [8]. NORMs (*Natural Occuring Radioactive Materials*) is a radioactive material found in nature that is part of human life. Almost all ingredients in nature, both in the body, in food, or in the environment contain radioactive ingredients. Every process and activity that produces NORM is closely related to the type of radionuclide and the pathway of radioactive material entering the human body, as well as the radiological effects it causes[9].

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This study aims to analyze ^{210}Pb and ^{40}K transfer factor radioactivity in paddy fields and rice plants in the Malang region, specifically the content of ^{210}Pb and ^{40}K radionuclides present in paddy fields and rice plants using a Gamma Spectrometered. Provides information and can recommend to the government through BAPETEN about the concentration of ^{210}Pb and ^{40}K in the fields and rice plants. The result of tents research will provide information and recommendation to here.

II. Research Method

This research was carried out on October 2018 until April 2019, took place at the Biophysics Laboratory of the Departement of Physics, Faculty of Mathematics and Natural Sciences, Soil Mechanics Laboratory and Geology, Faculty of Engineering, Material Laboratory, Department of Physics, Faculty of Mathematics and Natural Sciences, FTP Power and Agricultural Machinery Laboratory, Brawijaya University and PTKMR Laboratory at Indonesian Nuclear Energy Agency (BATAN), South Jakarta.

The tools used in this study are in accordance with the reference standard IAEA (International Atomic Energy Association). The tools used include gamma spectrometer, Marrineli standard 1 liter, vial standard 200 ml, Tray/baki SS, oven, furnace, araldite glue, silicon spatula, digital scales, sieve 60 mess, pestle and flour scoop, sand shovel, blender, marker, match, sample burner, label paper, big blue box, scissor, plastic bag, sack, standard measuring cup 1 liter, plastic clip, laboratory eyeglasses and masker gloves fire resistance. The materials used in this study are soil and rice plants which consists of roots, stems, leaves, seeds and rice husks each of 5 kg from 5 locations. This research was divided into several stages, namely preparation of materials and tools, sampling of rice plants, and measurement. Samples were taken randomly at five location that located in Malang Raya (Malang City, Singosari, Karangploso, Kepanjen dan Pujon Kidul). At each sampling, geographical information will be recorded by GPS. Each rice plant in each sampling location was taken 5 kg from each sample including roots, stems, leaves, seeds, husks and rice fields. The plants were then washed three times with fresh flowing water, so that any contamination that might stick on the outside (skin) of the plant was gone. Then the plants was separated (cut) roots, stems, leaves and seeds and chopped rather roughly with a size of ~ 1 cm before drying under normal sunlight for two days. Then the chopper was dried in an oven for 48 hours at 95°C, so that most of the moisture is removed. The next process is fogging with an oven temperature >100°C so that at least 300 grams of dry ash sample are obtained. Soil samples were homogenized and dried in an oven at 95°C, then crushed mashed and filtered using a "60 mesh" sieve. Each dry sample was stored in a 1000 mL Marinelli beaker and 175 ml standard vial before analysis. The samples were stored for 30 days to obtain radioactive equilibrium or radioactive decay of elements ^{210}Pb and ^{40}K before measurement stage using gamma spectrometer.

In the measurement process with gamma spectrometer, calibration was carried out first γ-spectrometer. The radiation source decay was the was counted using existing standard sources using a gamma spectrometer. Standard sources were enumerated for 3 hours to determine the amount of radiation decay from standard sources and the amount of activity from the standard sources that used. The standard source elements enumerated in this study were ^{210}Pb and ^{40}K. Spectrometer-γ calibration was done in two ways the first one is energy calibration and efficiency calibration. But in this research energy calibration was carried out. Energy calibration was done by counting standard points ^{210}Pb and from the lowest to highest energy range (keV). Enumeration was carried out at a distance of 20 cm from the detector for 3600 seconds. The acquisition (enumeration) used the GENIE 2000 program, so that a calibration curve was obtained which shows the relationship of the number of the channel with gamma energy. Then the sample / background / background enumeration process was carried out by counting standard 1000 ml beaker marinelli and standard 175 ml vial blank using a gamma spectrometer with HPG detector for 17 hours. The next final process was enumerating samples where the sample that has been left for 30 days in standard 1000 ml beaker marinelli and standard 175 ml vial was airtight, then chopped using a Gamma Spectrometer, by placing the sample on the HPGe detector for 17 hours. From this step, the activity of the radionuclides were obtained which is then converted into the concentration of the radionuclides.

Fig. 1. Gamma spectrometer

Natural Radionuclide Concentration

The equation used to calculate the concentration of radionuclides contained in the sample is as follows [10]:

$$C_{avg} = \frac{(N_{SP} - N_{BG})}{\varepsilon_\gamma . p_\gamma . W_{Sp}} \pm \text{Ut} \qquad \text{(i)}$$

With :

C_{avg} : radioactive average substance concentration in the sample (Bq / kg)

N_{SP} : sample count rate (cps)

N_{BG} : background count (cps)

ε_γ : enumeration efficiency (%)

P_γ : yield of gamma energy (%)

W_{Sp} : sample weight (kg)

The uncertainty of the measurement concentration (U_T) can be calculated by the equation :

$$U_T = C_{avg}\ x \sqrt{\left[\frac{u_{sp}{}^2 + u_{BG}{}^2}{N_{Sp}{}^2 - N_{BG}{}^2}\right] + \left(\frac{u_\varepsilon}{\varepsilon_y}\right)^2 + \left(\frac{u_P}{p_y}\right)^2 + \left(\frac{u_w}{W_{Sp}}\right)^2} \qquad \text{(ii)}$$

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With :
U_T : measurement uncertainty (Bq/kg)
u_{Sp} : sample enumeration uncertainty (%)
u_{BG} : uncertainty of background (%)
u_ε : uncertainty of efficiency in gamma energy (%)
u_p : uncertainty of yield (%)
u_w : uncertainty of sample weight (%)

Natural Radionuclide Transfer Factor

Calculation of radionuclide transfer factor (TF) from soil to plant is defined using the following equation [11] :

$$TF = \frac{Radionuclide\ activity\ in\ plant\ material\ (Bq.kg^{-1}.dry\ weight)}{Radionuclide\ activity\ inthe\ soil\ (Bq.kg^{-1}.dry\ weight)}$$

III. RESULT AND DISCUSSION

The results of the study obtained results of radionuclide concentrations from samples for five rice fields locations in Malang Raya that is Singosari, Malang Kota, Karangploso, Pujon. Overall the types of radionuclides detected were natural radionuclides including, among others ^{210}Pb and ^{40}K. These nuclides have half-lives from seconds to days. Enumeration time for each sample of either a vial or marinelli was carried out for 61200 seconds (17 hours) according to the standard operating procedur. The distribution of ^{210}Pb and ^{40}K in five locations in Malang Raya, is presented in Figure 2 to figure 7.

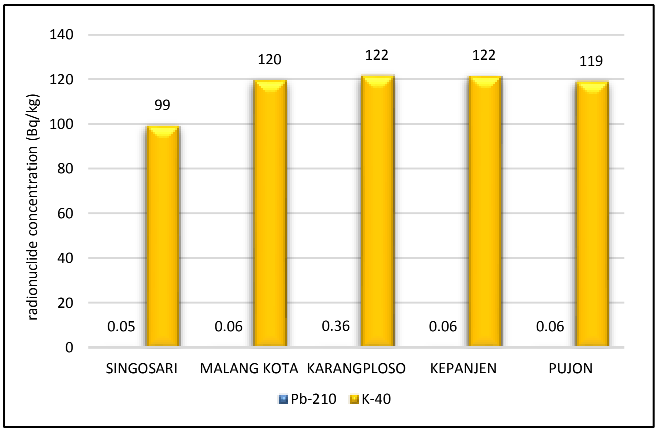

Fig. 2. Concentration of ^{210}Pb and ^{40}K in soil sample

From Figure 2 can be seen that the highest concentration of natural radionuclides is found in the ^{40}K element which is measured in the soil samples at Karangploso and Kepanjen locations which are 122 Bq/kg. ^{210}Pb Radionuclide is a daughter nuclei of ^{226}Ra so that the concentration of natural radionuclides obtained is lower than ^{40}K.

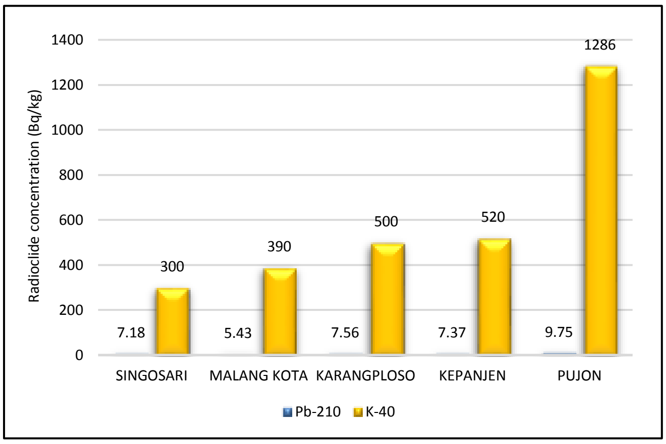

Fig. 3. Concentration of ^{210}Pb and ^{40}K in roots rice sample

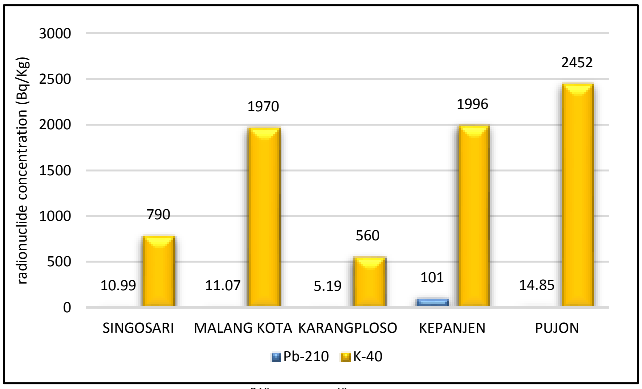

Fig. 4. Concentration of ^{210}Pb and ^{40}K in stem rice sample

The most visible calculation results found in ^{40}K nuclides from ^{210}Pb in soil, root, stem, leaf, seed and husk samples for five Malang Raya locations obtained the highest value for radionuclide concentration in the soil. For nuclides ^{40}K activity in the lower layer such as soil is greater than in the upper layer (roots, stems, leaves, seeds, husks). Nuclide ^{40}K in the soil is relatively more stable (strongly bound by the environmental matrix around sampling). The activity of a nuclide on the ground is strongly influenced by rock elements, soil types and minerals, and the process of forming the soil itself. Whereas for ^{210}Pb nuclides it is detected to be very small because for ^{210}Pb nuclides it is very difficult to find in soil or rice plants. Because the ^{210}Pb nuclide is usually obtained from heavy metals that are scattered in nature and polluted from industrial areas.

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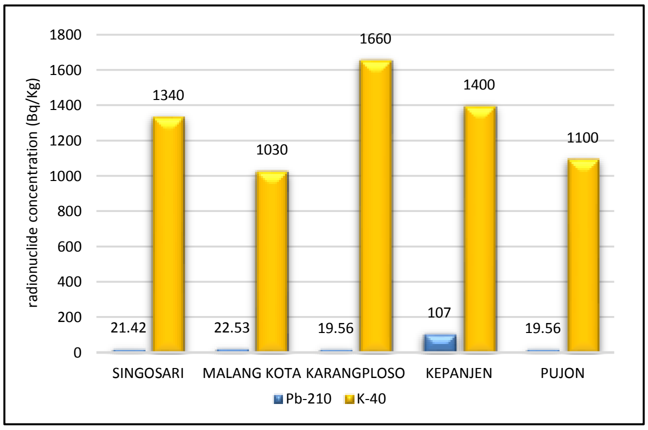

Fig. 5. Concentration of ^{210}Pb and ^{40}K in leaf rice sample

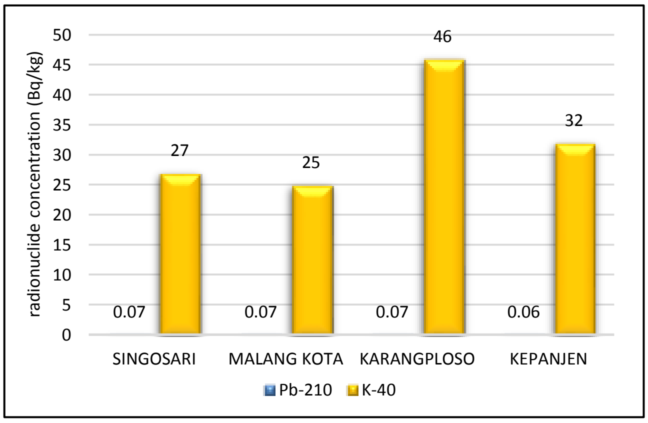

Fig. 6. Concentration of ^{210}Pb and ^{40}K in seed rice sample

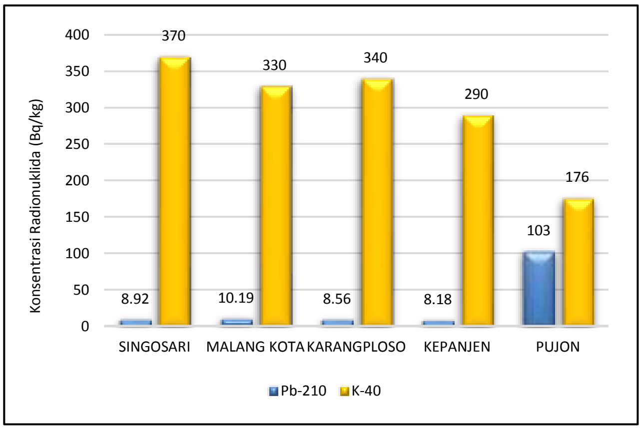

Fig. 7. Concentration of ^{210}Pb and ^{40}K in husk rice sample

The transfer factor values for ^{210}Pb or Lead radionuclides in these five locations were not detected because the soil, root, stem, leaf, seed and husk samples obtained the MDC (Minimum Detectable Concentration) value because the concentration of radionuclide ^{210}Pb in each sample was too small so it was not detected by a measurement instrument the gamma spectrometer is even said to be nonexistent. The value of the ^{40}K element transfer factor ranges from 0,20 to 20,60.

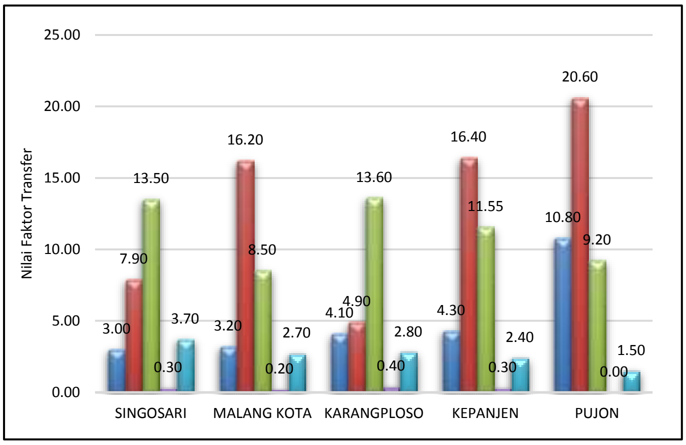

Fig. 8. Radionuclide ^{40}K Transfer Factor Value

Figure 8 indicates that the ^{40}K element of the highest transfer factor is obtained in Pujon's location trunk of 20,60. The average value of the overall trasnfer factor is indeed the highest in the straw, stems and leaves. In this study measured not straw (stem and leaf) but separate between stem and leaf therefore the average value between the stem and leaf is quite high if compared to samples of other organs such as roots, seeds and chaff. The value of the transfer factor for ^{40}K of this study for various paddy plant organs is ordered: ground to straw > land to the root > of the land to the husk > The ground to the grain. [12].

According to UNSCEAR [13] Uranium content in the food varies from 1,2 Bq/kg to 400 Bq/kg for grain. The metabolism of plants plays an important role in regulating radioactive nutrients in the food chain plant system. When radioactive non-nutrient elements are dissolved in water, the root of the plant will actively absorb which depends on the chemical activity of the soil element. After absorption by the plant, nutrients can be translocation, metabolized and stored on various parts of the plant depending on the properties of the elements and also plants. Displacement of elements from the soil to the plant is assumed constant on the low content of the ground and varies for high content in other parts [14].

Transfer of radionuclides factor from soil to Paddy plant is one of the entry of radionuclides into the body. By consuming rice that contains radionuclides, humans can receive internal doses. If the received dose exceeds the stipulated limit, it will give effect to the human health [15]. As one of the staple foodstuffs, the existence of natural radionuclides in the rice will give the danger of external radiation and interna to human health. The danger of external radiation is the gamma radiation emitted from each of the radionuclides, while the interna danger is the smell of the radon and thoron gases which are the natural radioactive gas results of Uranium and Thorium

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decay. One of the radiologic impacts of the gas is the potential for lung cancer.

The value of radionuclide transfer factor from soil to plant is influenced by several factors including the type of soil in rice fields. In this study, it can be seen that in each study location there are differences in transfer factors caused by different types of soil such as mineral and granulometric composition, organic or chemical content in soil, pH and soil fertility. If the land transfer factor that has a high fertility rate is usually greater than the transfer factor on land with poor soil conditions. Farmers' behavior, such as giving fertilization doses, processing soil and the environment around the paddy fields, is also known to affect the transfer of factors in research [16].

In addition to soil type factors and farmer behavior, there are also other factors, namely the types and varieties of rice plants planted by farmers can influence the value of radionuclide transfer factors from soil to plants. This is related to metabolism and biochemical and biophysical processes in plants. Radionuclides are often found to accumulate more in the generative part of the plant and smaller in the vegetative part of the plant. This is because the generative parts of plants need more nutrients for growth [17].

IV. CONCLUSION

Based on the research it can be concluded that:

1. The concentration value of Radionuclic elements ^{40}K is higher than the concentration value of radionuclides ^{210}Pb on all types of samples. The highest concentration value in soil samples for ^{40}K is found at the location of Karangploso and Kepanjen amounting to 122 Bq/kg, while the highest concentration value of natural radionuclides in rice plants on the element ^{40}K is found in the sample bar location Pujon Registration 2452 Bq/kg, leaf sample of the location of Karangploso 1660 Bq/kg, root samples of 1286 Bq/kg location Pujon, sample husk of 370 Bq/kg location Singosari and seed samples of 46 Bq/kg. On the location of Karangploso. While the concentration value of natural Radionulida 210Pb in all types of samples that can be measured only on the location of Karangploso for soil samples of 0,36 Bq/kg and roots 7,56 Bq/kg, location of Kepanjen on the sample trunk of 101 Bq/kg and leaves of 107 Bq/kg. And on the sample husk location of Pujon of 103 Bq/kg.
2. Rice crop can be able to absorb ^{210}Pb and ^{40}K from the soil. ^{210}Pb and ^{40}K accumulate in rice, chaff, stems, leaves, and roots. The accumulated magnitude of ^{210}Pb and ^{40}K is expressed as a transfer factor from land to rice crop. The value of the transfer factor of ^{210}Pb element is only obtained on the root sample of the location Karangploso 21,00 While the value of transfer factor ^{40}K obtained on all parts of the sample for the lowest value of 0,20 on the seed sample Malang city and the highest 20,60 there is on the Pujon location bar sample.

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