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Study on Annual Internal Radiation Dose from Consumption of Sweet Potatoes Contaminated by ^{134}Cs

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Abstract

The transfer of ^{134}Cs from soil to sweet potato crops has been investigated. Sweet potato crops were cultivated in soil contaminated by ^{134}Cs with concentration of 167.62 Bq/g as well as in non-contaminated soil as control. The ^{134}Cs activity concentrations of leaves, stems, roots, tubers and the whole plant were determined every week up to 16 weeks. ^{134}Cs activity concentrations of soil in root zone and outside root zone were also determined. The maximum transfer factor for the whole sweet potato plants takes place at the second week with TF value of 1.277. The maximum TF value for each parts are roots (18.448), tubbers (13.153), stems (1.241), and leaves (0.746). Annual equivalent dose was calculated based on the activity of sweet potato plants at harvest time. This research obtained annual internal radiation dose from consumption of sweet potatoes contaminated by ^{134}Cs of 0.0185 mSv/year. This value compared with average annual dose limits recommended by BAPETEN, IAEA and ICRP respectively was 0.14%, 0.37%, and 0.19%.

Keywords *: Annual internal radiation dose, Sweet potato plants, Contamination soil, Radiocesium.*

1. Introduction

Radiocesium is one of the radionuclide fission products that released to the environment at the time of reactor accident. ^{134}Cs is an important radionuclide for the assessment because of its high fission yield, relatively long half life of 2.05 years, and relatively high transferability in the environment and in the human body[1]. A major migration path of ^{134}Cs from soil to human is through the food chain and ingested by human[2]. This is due to ^{134}Cs behaves as a tracer for potassium, one of macronutrients in plant. Therefore, soil contaminated by ^{134}Cs causes a long-term radiological effect.

Radionuclide transfer from soil to plant is influenced by several factors, such as type of plant, type of radionuclide, soil characteristics, and environmental factors[3]. The radionuclide uptake factor is expressed by a transfer factor (TF) which can be described as a simple comparison between the radionuclide concentrations in the plant and in the soil[4]. The values of TF rely heavily on climate and geographical conditions. At this time, TF data issued by the International Atomic Energy Agency (IAEA) was mainly based on the research conducted in the area for a sub-tropical climate and very limited data for a tropical climate.

Sweet potato (*Ipomoea batatas*) is a type of crops from Central America and spreads around the world, including Indonesia in the 16th century. In Indonesia, sweet potato is a secondary food and for some areas such as Papua is a primary food[5]. Food crop statistic data from years 2005 to 2008 provided an average value of sweet potato production in Indonesia of 1.8 million tons per year. A national survey in 2007 presented data on the average consumption of sweet potato of 0.046 kg per capita per week, the second largest crop after cassava[6]. In addition, sweet potato is also used as cattle feed.

The equivalent dose was introduced to take into account the dependence of the harmful biological effects on the type of radiation being absorbed. The equivalent dose is therefore a measure of the risk associated with an exposure of radiation[7]. An internal radiation dose coefficient of 1.3 x 10^{-8} Sv/Bq for radiocesium is used to obtained the internal radiation dose contribution from the consumption of sweet potatoes contaminated by ^{134}Cs[8].

This research carried out some experiments for the uptake of ^{134}Cs from soil to sweet potato crops in a tropical climate. Transfer factor was calculated as a function of growth time up to 16 weeks, thus this TF data gives a contribution to the very limited TF data for a tropical climate issued by IAEA. From the data of ^{134}Cs concentration in sweet potato plants, we have obtained annual internal radiation dose from consumption of sweet potatoes contaminated by ^{134}Cs.

2. Materials and Methods

2.1 Media preparation

Six different vessels were prepared. Each vessel has volume of 1x1x0.5 m^3. Two vessels were used as control and the other four vessels were used as treatment. Each control vessel was filled with 120 kg Andosol soil which has been mixed with organic fertilizer for the growth of sweet potato plants. Contaminated soil was prepared by adding $^{134}CsNO_3$ liquid to the mixture of Andosol soil and organic fertilizer to have a homogeneous activity concentration of 167.62 Bq/g. Each treatment vessel was filled with 120 kg contaminated soil. The radionuclide activity in the contaminated soil must be high enough so that its radiations can be detected by gamma spectrometer, but it gives a radiation dose below the limits that allowed for researchers and the environment.

2.2 Cultivation

Vine cuttings of Sari varieties sweet potato plants were obtained from the Indonesian Agency for Agricultural Research and Development. The description for Sari varieties sweet potato plants are listed in Table 1. Then, 16 homogeneous vine cuttings were selected to be cultivated in each vessel with a distance of 20 cm among the others. Therefore, there were 32 vine cuttings for control cultivated in two vessels and 64 vine cuttings for treatment cultivated in four vessels.

Table 1. Description for Sari varieties of sweet potato plants

1	Year released	2001
2	Parent number	MIS 104-1
3	Derivation	Crossing between Gajah Rante and Lapis
4	Harvest time	3.5 – 4.0 months
5	Plant type	Semi compact
6	Dry material content	28 %
7	Fiber content	1.63 %
8	Other properties	Quite pests resistant

Source: Indonesian Agency for Agricultural Research and Development

2.3 Sampling observations

Observations were carried out every 7 days for soil and plants grown in contaminated media and every 14 days in control media, by sampling 3 plants, soil in root zone, and soil outside root zone. The plant samples were washed with water and then separated into 4 parts; those were leaves, stems, roots, and tubers. In order to determine the activity concentration of contaminated soil, it was taken three soil samples in root zone at a depth of about 3 cm from root and three soil samples outside root zone at a depth of about 20 cm from root. The plants and soil samples were dried at a temperature of 100°C for 3 hours using an oven, and then counted using High Purity Germanium (HPGe) gamma spectrometer for 600 seconds.

2.4 Data analysis

Data of plant dry weight cultivated in contaminated and control media is evaluated according to the growth time to know the influence of ^{134}Cs to the sweet potato plants. Data ^{134}Cs concentration in plants and soil was analyzed based on soil-plant compartment[4)].

The transfer factor was calculated as a simple comparison between the ^{134}Cs concentrations in plants (C_2) and soil (C_1):

$$TF = \frac{C_2}{C_1} \quad (1)$$

Annual internal radiation dose (H) is obtained from ^{134}Cs concentration in tubers when harvested (C_{tubers}) and the average consumption of sweet potatoes contaminated by ^{134}Cs per capita per year (K)[8)]

$$H = C_{tubers} \times K \times 1.3 \times 10^{-8} \quad (2)$$

3. Results and Discussion

Figure 1 provides the average dried weight of 3 samples of plants as a function of growth time for control and contaminated plants. The first four weeks is the vegetation period, the contaminated and control plants were not different significantly. Entering the tuber formation period, contaminated plants have a greater rate of growth. However, in the tuber filling period both contaminated and control plants were likely to drop their leaves so that their biomass decreased significantly. It was noticed from these results that there is no negative influence from the presence of ^{134}Cs in soil to the growth of sweet potato plants.

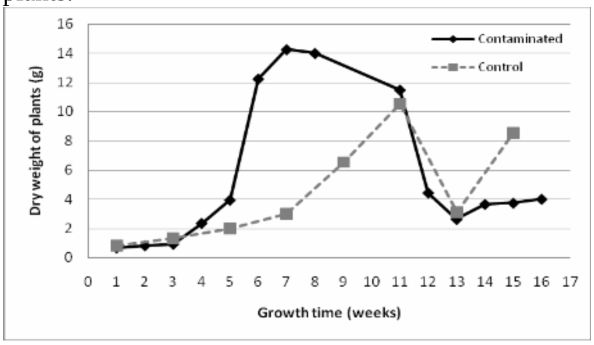

Figure 1. Growth curves of contaminated and control plants

The ^{134}Cs activity concentrations of soil in root zone and outside root zone are shown in Figures 2 and 3. The absorption process of water and minerals from the soil by plant roots occurs in the epidermis. From the curves of the ^{134}Cs activity concentration of soil in root zone and outside root zone, it can be seen that the distribution of ^{134}Cs in soil concentrated in the root zone. Entering the third week, the ^{134}Cs concentration increased caused by the formation of young roots in the vegetation phase. Then ^{134}Cs concentration decreased due to absorption of ^{134}Cs by plants, and then on the tenth week, ^{134}Cs concentration increased again in the tuber formation phase. The similar patterns in the curve of Figure 2 during root growth and tuber growth may be related to the formation of tissues in the two processes.

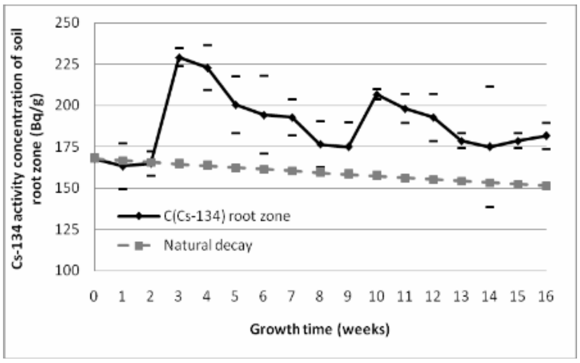

Figure 2. ^{134}Cs activity concentrations of soil in root zone as a function of growth time

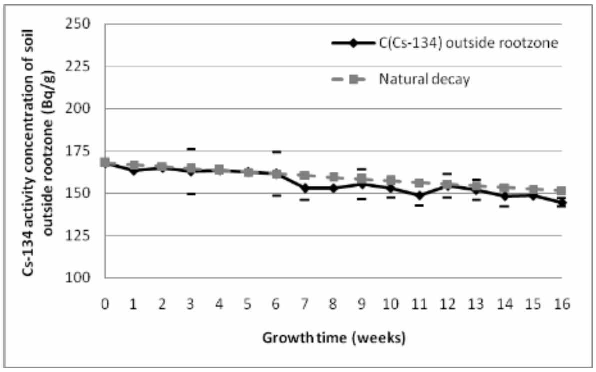

Figure 3. ^{134}Cs activity concentrations of soil outside root zone as a function of growth time

^{134}Cs activities in a whole plant and also in four separated parts: leaves, stems, roots, and tubers are shown in Figure 4 as a function of growth time. The results indicated that sweet potato crops have an ability to take up ^{134}Cs from contaminated soil. The data of ^{134}Cs activity of a plant is the average from three plants for each observation.

In Figure 4, the ^{134}Cs activity of a whole plant increased with duration of exposure time from the first week until the 8th week. Entering the 9th week, this activity decreased significantly and then it had small fluctuation and finally that uptake rate was relatively constant.

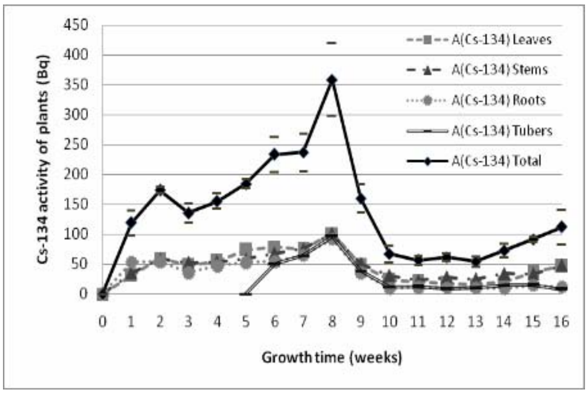

Figure 4. ^{134}Cs activity of leaves, stems, roots, tubers and the whole plant

^{134}Cs concentration of plants is calculated by dividing the ^{134}Cs activity of the plants with their dry weight so that ^{134}Cs concentration of plants varies with growth time. Transfer factor from soil to sweet potato plants was determined using equation (1) and the results for leaves, stems, roots, tubers, and plants as a whole are shown in Figure 5.

The maximum transfer factor for plants as a whole occurred at the second week with TF value of 1.277. The maximum TF values for each parts are roots (18.448), tubbers (13.153), stems (1.241), and leaves (0.746). Two largest values were at the roots and tubers. These spikes are due to the low dry weight of roots and tubers with high activity in them in the beginning of the tissue growth. It is important to note because the tuber is the main part of sweet potato crops which consumed by human.

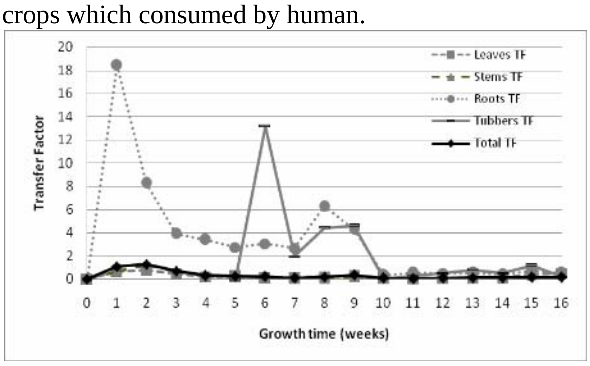

Figure 5. Transfer factor of ^{134}Cs from of soil to sweet potato plants as a whole and in the plant parts

Annual internal radiation dose was calculated based on equation (2) where the ^{134}Cs activity of tubers at harvest time is 0.594 Bq/g. If it is asummed that the tubers are steamed thus it means radionuclide lost due to the cook processing is very small. Social and economic result of a national survey in 2007 provided average data on consumption of sweet potato of 0.046 kg per capita per week or is equal to 2.392 kg per capita per year. From this data and using equation (2), the annual internal radiation dose was 0.0185 mSv/year. Table 2 lists the result value compared with average annual dose limit recommended by BAPETEN, IAEA and ICRP.

Table 2. Rocommended Annual dose limit and contribution values of annual internal radiation dose from consumption of sweet potatoes contaminated by ^{134}Cs

Annual Dose Limit		Annual Internal Radiation Dose	Contribution value
Data Source	(mSv/tahun)	(mSv/tahun)	%
Badan Pengawas tenaga Nuklir (BAPETEN),1999	13	0.0185	0.14
*International Atomic Energi Ag*ency (IAEA), 1994	5	0.0185	0.37
International Commision on Radiological Protection (ICRP),1993	10	0.0185	0.19

It seems that the annual internal radiation dose from consumption of contaminated tubers is far below the limit dose. However, total equivalent dose on each person is influenced by the exposed from all pathways available in the environment and the consumption pattern of each person. The transfer factor and annual internal radiation dose values can be used as a risk assessment evaluation of the radiological impact in case there is a radionuclide released to the environment.

4. Conclusion

Sweet potato crops have significant ability to take up ^{134}Cs from contaminated soil. The maximum transfer factor for the whole sweet potato plants takes place at the second week with TF value of 1.277. The maximum TF value for each parts are roots (18.448), tubbers (13.153), stems (1.241), and leaves (0.746). It is important to note because the tuber is the main part of sweet potato crops which consumed by human. The annual internal radiation dose from consumption of sweet potatoes contaminated by ^{134}Cs has been obtained and this value has been compared with average annual dose limit recommended by BAPETEN, IAEA and ICRP.

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