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PENENTUAN DOSIS INTERNA PADA MANUSIA AKIBAT KONSUMSI KANGKUNG (*Ipomoea reptans*) TERPROSES YANG TERKONTAMINASI RADIONUKLIDA CESIUM-134 DAN *STRONSIUM-85*

INTERNAL DOSE DETERMINATION ON HUMAN AS RESULT OF PROCESSED KANGKUNG (*Ipomoea reptans*) CONSUMPTION CONTAMINATED BY RADIONUCLIDE CESIUM-134 AND STRONTIUM-85

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Abstract: *Research has been done to find out internaL dose that can be received by human as result of consumption kangkung that growth in contaminated soil by caesium-134 and strotium-85. Kangkung was planted in soil contaminated with caesium-134 and strontium-85 for 70 days. After harvesting, a part of the plant separated and the other part being washed and boiled and then the radionuclide content for all of the plant were measured using spectrometer gamma. From the measurement and calculation, washing, boiling and sauteing process gives quite significant impact in reducing activity percentage of radionuclide which were about 23,5, 14,4 and 9,8 for strontium- 85 and 28,2, 58,5 and 47,4 for caesium-134. The result of equivalent dose calculation showed that each internal dosesis still bellow the limit of 5 mSv/year, and the dose was 0,053 mSv/year until 0,137 mSv/year.*

Key words: *kangkung, contamination, cesium-134, strontium-85, activity, internal dose*

Abstrak: *Penelitian dilakukan untuk mengetahui dosis interna yang dapat diterima oleh manusia akibat mengkonsumsi kangkung yang tumbuh pada tanah terkontaminasi oleh radionuklida cesium-134 dan stronsium-85.Penelitian dilakukan dengan cara menanam tanaman kangkung pada media tanah terkontaminasi Cs-134 dan Sr-85selama 70 hari. Setelah panen, sampel tanaman diproses dengan pencucian, perebusan dan penumisan kemudiadiukur kandungan radionuklidanya dengan menggunakan spektrometer gamma. Dari hasil pengukuran diperolehbahwa ketiga proses memberikan pengaruh yang cukup besar terhadap penyisihan radioaktivitas dari sampeltanaman, yaitu sebesar 23,5, 14,4 dan 9,8 untuk stronsium-85 dan 28,2, 58,5 dan 47,4 untuk cesium-134. Hasilperhitungan dosis ekivalen menunjukkan nilai dosis interna dari masing-masing radionuklida berada dibawahambang batas sebesar 5 mSv/tahun, yaitu bernilai antara 0,053 mSv/tahun sampai 0,137 mSv/tahun.*

Kata kunci: *kangkung, kontaminasi, cesium-134, stronsium-85, aktivitas, dosis interna*

INTRODUCTION

In order to meet a demand of energy that keep on increasing, alternative energy resources has became such a popular issue in many countries. Nowadays, besides coal and gas as the replacement of petroleum, nuclear energy takes big enough portion of world energy resources, generates about 16% of world's electricity from 435 commercial nuclear power reactors. Indonesia has two research-scale nuclear reactors at this time, even though the government has commited to start two nuclear power plant in 2016. The resolution has been announced at the national long-term scheme of work.

Relatively, the usage of neclear technology as power generator is safe. However, it's still has risk which is came from the process and waste. The operation of nuclear reactor produces some radionuclide-type substances. The radionuclides release to environment can be caused by a nuclear accident triggered by some factors, for example the leakage of fuel-shell, imperfect handling while replacing the fuel or cracking at reactor's cooling pipe. Some of toxic radionuclides that can be released are strontium and cesium. Both of these radionuclides are easily dissolved in water and disseminated at soil.

Soil contamination with radionuclides has a long-term radiological impact because it is readily transferred through food chains to human beings. Plant uptake is the major pathway for themigration of radiocesium and radiostronsium to human diet (T. Sauras, 1998). Radionuclide cesium-137 and strontium-90 are fission product from nuclear fuel, which emitted gamma rays that has a high toxicity and can cause damage to human health. These radionuclides also have long half-time radioactivity, because of that the contamination may stay in environment for long time (Eisenbud, 1973).

Exposure to ionizing radiation, whether natural or man-made, can cause two kinds of health effects. Effects for which the severity of the damage caused is proportional to the dose, and for which a threshold exists below which the effect does not occur, are called "deterministic" effects. Under normal conditions, the dose received from natural radioactivity and routine exposures from regulated practices is well below the threshold levels, and therefore deterministic effects are not relevant to these recommendations (Eisenbud, 1973).

The importance of plants in the transfer of radioactive contamination along the food chain has led to the development of numerous studies, whose main objective has been to evaluate the absorption of radioniclides by plants through their roots.

Radiocesium and radiostrontium that has been released to the environment can be deposed to soil and plant then being bioaccumulate in plant. Contaminated plant that is consumed by a human can cause internal problems in the human body. Radionuclide soil-to-plant transfer is a crucial process in the dose assessment of human exposure via food chain. One of plant that largely consumed by human is Kangkung (*Ipomoea reptans*) or swamp cabbage which has become a major protein and mineral source, especially for a tropical developing country like Indonesia. Kangkung can absorp many kind of subtances, also radioniclides, to its growth (http://www.iptek.net.id, 2008). Usually, kangkung is consumed by humans after being washed, boiled and also sauted.

The objective of this study was to determine the equivalent dose on human as result of consuming processed kangkung that contaminated by Cs-134 and Sr-85. To simplify research and to reduce the level of radioactive waste formed, this research used cesium-134 which has similar chemical characteristic as its isotope with half life 2.05 years and strontium-85 with a half life 64.8 days as the replacement of cesium-137 and strontium-90.

METHODOLOGY

The research was carried out at Green House, Pusat Teknologi Nuklir Bahan dan Radiometri, BATAN Jl. Taman Sari No. 71 Bandung. This research refer on the study of Fujimoto in 1993 titled "General Protocol for Transport Measurement Transfer of Radionuclides from Air, Soil, and Freshwater to the foodchain of Man in Tropical and Subtropical Environt" (Fujimoto, 1993), with some modification related to facilities condition.

Initial growth-media is made in purpose to uniform plants age and planting condition. Container that used is made of plastic with 10 cm height. Composition that enhanced in the container are 21 kg soil + 7,5 kg shell of rice + 7,5 kg compost. This research uses soil taken from PTNBR Batan yard, physically the soil characteristic is silt loam (Alfiyan, 2001). Soil chemical characterictic of PTNBR BATAN soil shown in the **Table 1**.

Table 1

Soil Chemical Characteristic PTNBR BATAN*

No	Parameter	Characteristic	unit
		Macro elemets	
1	pH	6.4	-
2	C	2.82	%
3	N	0.23	%
4	C/N	12	%
5	P	2.5	ppm
6	K	672.2	ppm
		Exchangeable macro elements	
10	Ca	17,7	ma/100g
11	Mg	2,89	ma/100g
12	K	1,94	ma/100g
13	Na	0,27	ma/100g
14	KTK	34,5	ma/100g
		Micro Elements	
15	Fe	2,5	ppm
16	Mn	11,1	ppm
17	Cu	0,5	ppm
18	Zn	3,9	ppm

*Analysed by Laboratorium Penguji Balai Penelitian Tanaman Sayuran, Lembang, 2008

Each treatment media contains about 127,5 kg of soil contaminated by Cs-134 and Sr-85. Addition of Sr-85 is conducted by enhance 300 ml Sr-85 sollution with activity 114,6 Mbqs into 643,684 kg soil, until its concentration becomes 180,564 Bqs/g. Whereas contamination Cs-134 are conducted by enhance 20 ml of its sollution with activity 21,756 Mbqs into the same amount of soil until activity finally become 68,775 Bqs/g. To get homogeneous concentration in soil, mixing is needed more than once by using hoe and small spade.

Plants from initial media-growth are cultivated in treatment and control continuation media-growth at the next step. The distance between planting point is as far as 20 cm at with existed 25 plants in every container.

Plants sampling are conducted in range of time every 5 day for plants at treatment media and every 10 day for plants at control media. Once crop requires 3 individual units that taken in random and have relatively similar in physical growth.

Kangkung samples are cleaned until there is no more soil remains at plants part. Hereinafter plants are cut to dissociate plants into three bodyworks, those are root, trunk and leaf. The three mentioned group of plants organ then sliced slightly to speed up draining process. Draining process are conducted constructively oven in temperature 1000 C during hour 3-4. Furthermore, the dried sample was counted in MCA (Multi Channel Analyzer) of Gamma Spektrometer. The sample have to be wrapped before placed in MCA, it is necessary to avoid the HPGe detector being contaminated by sample. Spesification of Gamma Spektrometer shown in **Table 2**.

The result of counting process with Gamma Spektrometer was shown as amount lue of energy level in count-per-second (cps) units. The highest possibility appearance of energy level from each radionuclides was different, approximately 604 KeV for Cs-134 and about 540 KeV for Sr-85. The device efficiency was needed to reform the count-per-second unit to Bq unit. Radionuclides activities at plants was calculated by devide the count value with efficiency of the Gamma Spektrometer.

Table 2
Gamma spektometer spesification at PLKL laboratory. PTNBR-BATAN

No	Device Nama	Type/Model
1	HPGe detector	Tennelec CPVDS 30-30125
2	Pre amplifier	Tennelec Seri No. 2265
3	Bias Suply Voltage	Tennelec TC 950
4	Luquid N Tank	Tennelec
5	Amplifier	Tennelec TC 244
6	MCA Card	Nucleus Model 8000
7	CPU	IBM Model 30286
8	Monitor	IBM Model 30286
9	Printer	Epson LQ 1050

Radionuclides concentration in plant body was obtained by comparing the activities values with the plant sample mass, whereas the radionuclides concentration in soil was calculated by devide the activities with soil sample mass.

$$Activity = sample\ count\ value\ (cps) x \frac{Activity\ std\ (Bq)}{Count\ Value\ std\ (cps)} \ldots\ldots\ldots . (1)$$

$$\eta_{devices} = \frac{Count\ value\ std\ (cps)}{Activity\ std\ (Bq)} \ldots\ldots\ldots (2)$$

The activity counting with Gamma Spektrometer was not always at the same time of sampling taken place, therefor time correction is needed to obtain the actual activity at ampling time (T_0). The time correction formulas is:

$$A = A_0 e^{-\lambda t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots . (3)$$

where:
A = Activity at t time
A_0 = Initial activity
λ = Radionuclides decay constant

Half life ($T_{1/2}$) of a radionuclide is time interval that needed by substance necleus (atomic core) to disintegrate become half of the original amount. Mathematically, where λ is sintegrate constancy, the half time can be formulated as:

$$T_{1/2} = \frac{0.693}{\lambda} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

International Atomic Energy Agency (IAEA) made a formulation of total dose that would be received by human if consuming diet contained by radionuclides, the equation is:

$$For\ Cesium \quad H = C_{2(t)}\ x\ K\ 1.3\ x\ 10^{-8}$$
$$For\ Strontium \quad H = C_{2(t)}\ x\ K\ x\ 2.4\ x\ 10^{-8} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where :
H = Equivalent dose acceptance (Sv)
$C_{2(t)}$ = Radionuclide concentration at food sample at t time (Bq/gram wet mass)
1,3 x 10^{-8}= Cesium effective dose coefficient (Sv/Bq)
2,4 x 10^{-8}= Strontium effective dose coefficient (Sv/Bq)
K = Annual consumption

Every single data that obtained from each sample compiled in a form and grouped so the concentration average can be calculated. The group was differentiated by part of the plant body, those are root, trunk and leaf. Based on the concentration average values, a graphic curve of radionuclide concentration towards time was made, so then the alteration patern of the radionuclide concentration in plant can be studied farther.

RESULT AND DISCUSSION

Early time of the research, soil sample was counted with the MCA to obtain initial activity and concentration of Cs-134 and Sr-85 by using formulas that shown in equation (1),(2),(3) and (4). Sample was taken from five different point, four point at the corner of container and one more in the middle of container. The average concentration of Sr085 and Cs-134 in sequence were 170,303 and 68,776. The complete soil initial concentration shown in **Table 3**.

Table 3
Initial radionuclides concetration in soil

Sample		C Sr (Bq/gr)	C Cs (Bq/gr)
Container 1	Point 1	166.128	67.101
	Point 2	197.849	71.714
	Point 3	170.453	64.884
	Point 4	165.365	65.061
	Middle Point	206.525	77.664
Container 2	Point 1	147.751	65.486
	Point 2	130.713	62.247
	Point 3	155.591	70.628
	Point 4	171.442	73.228
	Middle Point	191.214	69.741
Average		170.303	68.776

As the ability of plant that can uptake radionuclide elements from soil and water, it makes big opportunity to radiocesium and radiostrontium being accumulated in plant body. Total uptake of radionuclides in plant depends on many factor, few of all are plant transfer factor, radionuclide availability, radionuclide characteristic and many more. Radionuclide activity measurement in plant, kangkung in this research, has the same method with radioactivity measurement in soil. Over all, Sr-85 and Cs-134 activity accumulated in kangkung plant in sequence shown in **Figure 2** and **Figure 3**.

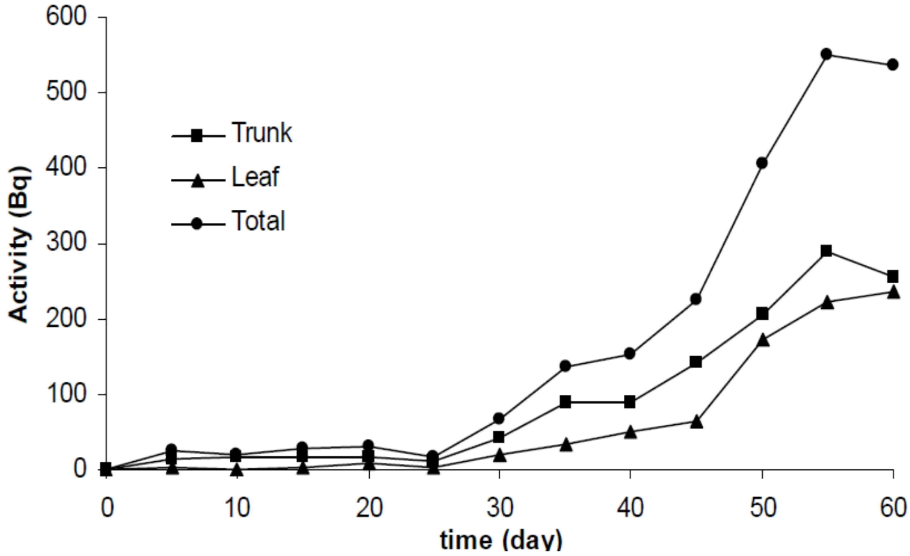

Figure 1. Activity of Sr- 85 in research plant

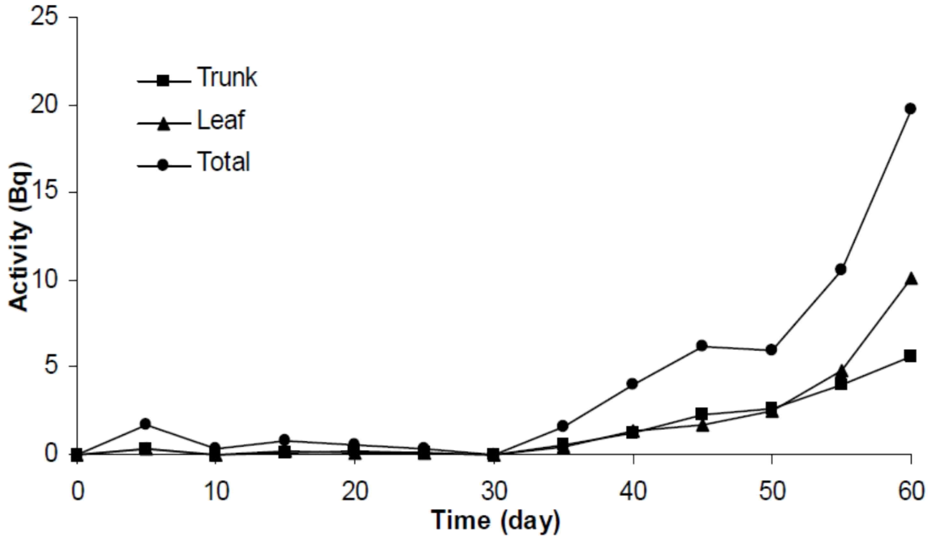

Figure 2. Activity of Cs – 134 in research plant

Figure 2 illustrated that part of kangkung plant which has the biggest accumulation level for Sr-85 was in the trunk. In the other hand, from Figure 3 seen that the highest average accumulation level for Cs-134 was in the leaf. Some process was conduct in order to reduce radioactivity accumulated in kangkung plant. The process accomodated with culinary procedure that usually done by public, those are fresh, boiled and sauted kangkung. After the process, radioactivity of the sample was counted in Gamma Spektrometer and calcaulated using equation (1), (2), (3) and (4). The result of calculation shown in **Table 4** and **Tabel 5**.

Table 4
Percentage of Sr-85 activity redustion in kangkung

Sampel	A_0 Sr (Bq)			
	Initial	Washed	Washed-Boiled	Washed - Sauted
1	92,5910	51,4736	89,2799	74,6264
2	103,5625	98,6407	85,0806	82,4142
3	82,6184	63,0603	64,1901	94,2903
Average	92,9240	71,0582	79,5169	88,7770
% Reduction		23,53	14,43	9,84

Table 5
Percentage of Cs – 134 activity reduction in kangkung

Sampel	A_0 Cs(Bq)			
	Initial	Washed	Washed-Boiled	Washed - Sauted
1	79,3401	37,2078	41,2545	38,1448
2	75,4187	74,5067	33,2717	46,1017
3	77,9870	55,4469	22,0041	38,1697
Average	77,5819	71,0582	79,5169	40,8054
% Reduction		28,18	58,53	47,4

Table 4 and **Tabel 5** showed that activity of Sr-85 and Cs-134 in proced kangkung sampel smaller than the original sample. These results may be caused of the washing, boiling and sauteing process that makes radionuclide detached from the sample to process medium. This condition was explained by the radioactivity appearance in water and oil of process medium, specially with Cs- 134. Radionuclide activity in process medium shown in **Table 6**.

Table 6
Radionuclides activities in process medium

Process Medium	A_0 Cs(Bq)			A_0 Sr (Bq)		
	Sampel 1	Sampel 2	Sampel 3	Sampel 1	Sampel 2	Sampel 3
Fresh Water	0	0	0	0	0	0
Boiled Water	0,1961	0,2599	0,2125	0	0,6336	0
Water Oil	1,0343	0,4394	1,2174	0,9097	0	0

Table 4 and **Table 5** showed that Cs-134 was easily reduce by the process, it's proven by reduction percentage of Cs-134 that has the biggest amount. It was shown that Sr-85 has smallersolubility level than Cs-134. From these tables, we may also find that the most effective process to reduce activity of Sr-85 in kangkung was by water-washing, and water-boiled process for Cs-134.

The Equivalent dose was the product of absorbed dose for radiation type and the radiation weighting factor. To obtain the annual equivalent dose, the equivalent dose multiplied with kangkung consume rate in Bandung every year. Bandung commodity consumption rate for kangkung every year was 1,242 kg (Neraca Bahan Makanan, 2003). The equivalent doses from each proced kangkung shown in **Table 7**.

Table 7
Equipment dose for contaminated kangkung

Radionuclide	Equivalent Dose (mSv/year)		
	Washed	Washed-Boiled	Washed-Saured
Sr-85	0,10097	0,13126	1,13789
Cs-134	0,08087	0,05333	0,06701

Table 7 showed that the equivalent doses was different from each radionnuclides, start from 0,10297 mSv/year to 0,13789 mSv/year for Sr-85 and from 0,05333 mSv/year to 0,08087 mSv/year for Cs-134. There are some level of equivalent dose boundary/year reference which usualy used for radiological assessment effect. The annual equivalent dose limit reference shown in **Table 8**.

Table 8
Annual equivalent dose limit reference

H/Tahun (MSv/tahun)	Sumber
13	Bapeten 1999
5	International Atomic Energi Agency (IAEA), 1994
10	International Commision on Radiological Protection (ICRP). 1993

Comparing result from **Table 7** and **Table 8** explained that the equivalent dose in every proced kangkung sample at each radionuclides was bellow the limitation of annual equivalent dose. Therefor in the case, the kangkung plant consumption was still safe.

CONCLUSION

The highest activity level of Sr-85 in kangkung plant was accumulated in trunk, on the other hand the highest average activity level of CS-134 was accumulated in leaf. Processing sample can reduce the radionuclides activity from kangkung edible parts from 9% to 47%. The best method in reducing Cs-134 from kangkung was by washed-boiled the sample with water, whereas the best way in Sr-85 reduction was by just wash it with water. The annual equivalent dose of consumption kangkung that growed in contaminated soil with 180,564 Bq/gr of Sr-85 and 68,775 Bq/gr of Cs-134 was still in safe level refering to BAPETEN, IAEA and ICRP regulation. EH 4-9

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