Distribution of ^{137}Cs In the Surface Soil of Serpong Nuclear Site

E. Lubis*
Center for Radioactive Waste Technology, National Nuclear Energy Agency
Puspiptek-Tangerang 15310, Indonesia

ARTICLE INFO

Article history:
Received 18 May 2010
Received in Revised form 13 July 2011
Accepted 20 July 2011

Keywords:
Atmospheric release
^{137}Cs concentration
Serpong nuclear site
Surface soil

ABSTRACT

The distribution of ^{137}Cs in the surface soil layer of Serpong Nuclear Site (SNS) was investigated by field sampling. The Objectives of the investigation is finding the profile of ^{137}Cs distribution in the surface soil and the T_f value that can be used for estimation of radiation dose from livestock product-man pathways. The results indicates that the ^{137}Cs activity in surface soil of SNS is 0.80 ± 0,29 Bq/kg, much lower than in the Antarctic. The contribution value of ^{137}Cs from the operation of G.A.Siwabessy Reactor until now is undetectable. The T_f of ^{137}Cs from surface soil to *Panisetum Purpureum*, *Setaria Spha Celata* and *Imperata Cylindrica grasses* were 0.71 ± 0.14, 0.84 ± 0.27 and 0.81 ± 0.11 respectively. The results show that value of the transfer factor of ^{137}Cs varies between cultivated and uncultivated soil and also with the soils with thick humus.

INTRODUCTION

Cesium-137 is one of the most important contaminations from fallout nuclear debris because of its long physical half-live and affinity for biological systems. Body burdens of this radionuclide in man result principally from the food-chain sequence: air and precipitation to plants, plant to milk and meat, with dairy and beef cattle as the principal vectors between plants and man diets.

The ^{137}Cs is a man-made artificial radionuclide with a half-life of about 30.2 years. Most of its activity concentration in surface soil was originated from the upper and under grounds thermonuclear weapons test (TWT) in the 1950's and 1960's [1]. These activities totally were stopped in the 1980's. When the ^{137}Cs was ejected into the stratosphere, which is circulated globally and then later deposited on the land surface and attached itself to the soil. The total of TWT in the atmosphere until 1980 reached 155 Megaton (Mt), each of 1 Mt produces ^{131}I (4200 PBq), ^{90}Sr (3,9 PBq) and ^{137}Cs (5,9 PBq). The total of ^{137}Cs was released to the atmosphere from TWT up to 910 PBq, (1 PBq=10^{15}Bq) [1]. According to the half-live of ^{137}Cs without regarding its residence time in the atmosphere, the residue of ^{137}Cs in the atmosphere now is estimated around 300 PBq. The residence time of ^{137}Cs in the atmosphere is a few years, so its activity concentrations in the atmosphere become more decreasing [1].

In the operation of a nuclear reactor and reprocessing plant a small activity of artificial radionuclides are also released to the environment, the activity concentrations is ignored if compared to the total released from TWT. The Chernobyl accident in 1986 adds the activity concentration of ^{137}Cs in the atmosphere up to 28 PBq [1].

Serpong Nuclear Site (SNS) is located in the Banten Province, 30 km from Jakarta City. There is no reprocessing plant in the SNS. The potential source of ^{137}Cs released to the atmosphere in the SNS come from the operation of 30 MWt G.A. Siwabessy Research Reactor, that has been operated since 1987. Based on the Safety Analysis Report (SAR), the release of ^{137}Cs to the atmosphere from this reactor is around 1.07×10^5 Bq/y [2]. The radionuclide released from this reactor stack to the atmosphere will be dispersed by the wind and then finally deposited around the SNS through the dry and wet deposition processes. Based on the site-specific meteorological data, the maximal value of the dispersion factor (D_f) for 60 m stack height occuring in 800 m radius is 10^{-7} sec.m^{-3} [3]. The operational period of G.A. Siwabessy Reactor will be more than 40 years. The deposition of ^{137}Cs in the environment is assumed will be increasing the potential radiation dose receiving by population who live around SNS. The distribution of ^{137}Cs in the surface soil of SNS and also their transfer factor (T_f) to the grasses were described in this paper.

* Corresponding author.
E-mail address: erlub@batan.go.id

The gained data will be adding the data-base that can be used for estimating the radiation dose potential receiving by the population who live in the surrounding of SNS.

EXPERIMENTAL METHODS

Location and sampling

Sampling locations were selected in the direction of north, south, east and west in the radius of 800 m from stack release of G.A. Siwabessy reactor. A sampling location as a control station is chosen in the direction of the west in off-site area with distance of 5 km from the reactor. For having the sample in the same condition, the sampling station were selected base on the criteria, i.e., without presence of any big trees, surface elevation not more than 5^o and neither agriculture activities. The coordinate of the sampling location was determined by Geo Position Satellite (GPS), as shown in Table 1.

Table 1. Sampling location in on-site and off-site area of SNS.

Location	Ordinate	
	Latitude	Longitude
Station-1 (south)	6^o21'18.4"	106^o40'56.0"
Station-2 (east)	6^o20'55.2"	106^o39'54.9"
Station-3 (north)	6^o21'1.8"	106^o39'27.1"
Station-4 (west)	6^o21'1.1"	106^o40'8.2"
Station-5 (off-site area)	6^o23'9.0"	106^o40'16.6"

The grasses in the top of surface soil such as the sorts of *Panisetum Purpureum*, *Setaria Spha Celata* and *Imperata Cylindrica* were sampled and put into the plastic bag of 5 kg volume. The surface soil in each station were sampled in the area of 50 cm × 50 cm. The surface soil was sampled in each interval of 5 cm until 25 cm of depth using plastic spoon and then collected into the plastic bag of 10 kg volume. The gravel, litter, roots and others are taken out from the samples.

Preparation sample

The 5 kg of surface soil samples were put in the plastic tray than dried in the open air during 3 days. The dried soils were ground and filtered with 25 mesh filter. The 1 kg of dried soil than was drying again in the oven at 110^oC for 24 hours and then put into 1 liter marginally beaker. The gamma spectrum were measured using MCA with Ge(Li) detector with 24 hours counting time and the activity of ^{137}Cs were analyzed with GAMATREK software [5].

Transfer factor

The transfer factor (T_f) of ^{137}Cs in the grass that growing in the surface soil was calculated by assuming that a steady state condition was reached. The T_f value is the activity concentrations ratio between ^{137}Cs in the grass with the same activity of that radionuclide in the soil.

RESULTS AND DISCUSSION

The activity concentration of ^{137}Cs in the surface soil layer at SNS area are shown in Table 2.

Table 2. The activity concentrations of ^{137}Cs (Bq/kg) in surface soil of SNS.

Depth (cm)	Station				
	1	2	3	4	5
0 - 5	1.02	0.65	0.37	0.94	0.78
5 - 10	1.20	0.81	0.82	1.16	0.91
10 - 15	0.38	1.41	0.76	0.82	1.13
15 - 20	0.34	0.71	1.18	0.71	0.46
20 - 25	0.58	0.58	0.71	0.86	0.78
Sum	3.52	4.16	3.84	4.49	4.06
Range	0.34 – 1.20	0.58 – 1.41	0.37 – 1.18	0.71 – 1.16	0.46 – 1.13
Average	0.70	0.83	0.77	0.90	0.81
Deviation	0.39	0.33	0.29	0.17	0.24

The ^{137}Cs concentrations in surface soil layer of SNS (on-site), station 1 - 4 are 0.70 ± 0.39 Bq/kg, 0.83 ± 0.33 Bq/kg, 0.77 ± 0.29 Bq/kg, and 0.90 ± 0.17 Bq/kg. If concentrations of one station is compared statistically with another ones, the results are insignificantly different at 90 % confident level. The average ^{137}Cs concentrations on-site area is 0.81 ± 0.24 Bq/kg. The ^{137}Cs concentrations in off-site area (station 5) is 0.80 ± 0.24 Bq/kg. If the average ^{137}Cs concentrations on-site area is compared statistically with the concentration in off-site area, the results are insignificantly different at 90 % confident level. These data show that the ^{137}Cs concentration in surface soil of SNS is dominantly comes from the fallout. The contributions of ^{137}Cs from the operation of G.A. Siwabessy Reactor up to now is insignificant.

The ^{137}Cs concentrations in surface soil of the Antarctic and Japan nuclear sites were shown in Table 3 and 4 [6].

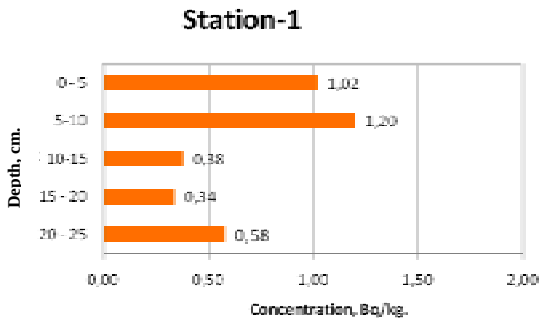
Table 3. The concentrations of ^{137}Cs in surface soil in the Antarctic [5].

Sample Number	^{137}Cs ,(Bq/kg)
1	0.22 ± 0.06
2	1.40 ± 0.10
3	1.20 ± 0.10
4	undetectable
5	undetectable
6	1.40 ± 0.06
7	0.07 ± 0.04
8	0.26 ± 0.06
9	undetectable
10	6.30 ± 0.50
11	1.40 ± 0.40
Range	0.07 – 6.30
Average	1.40
Deviation	0.40

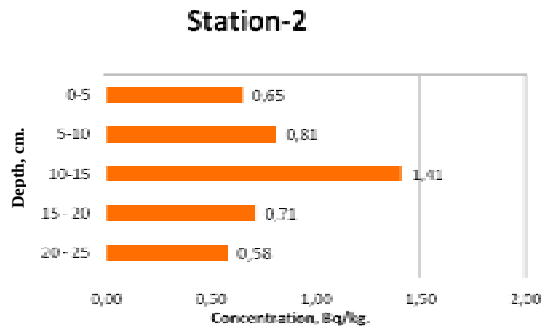
Table 4. The concentrations of ^{137}Cs in surface soil in Japan nuclear sites [6].

Sampling Location	^{137}Cs, (Bq/ kg.)
Fokuoka	7.90 ± 0.30
Kyoto	10.0 ± 0.30
Osaka	6.0 ± 0.27
Okayama	0.23 ± 0.07
Tokushima	4.10 ± 0.23
Kagawa	20.0 ± 0.50
Fokouka	4.60 ± 0.23
Nagazaki	62.0 ± 0.80
Miyazaki	5.60 ± 0.27
Okinawa	6.90 ± 0.29
Komamoto	88.0 ± 1.0
Yamagata	18.0 ± 0.50
Saitama	8.60 ± 0.32
Niigata	16.0 ± 0.40
Ehime	23.0 ± 0.50
Gunma	3.30 ± 0.20
Aomori	1.80 ± 0.15
Gifu	12.0 ± 0.40
Range	0.23 – 88.0
Average	16.55
Deviation	0.37

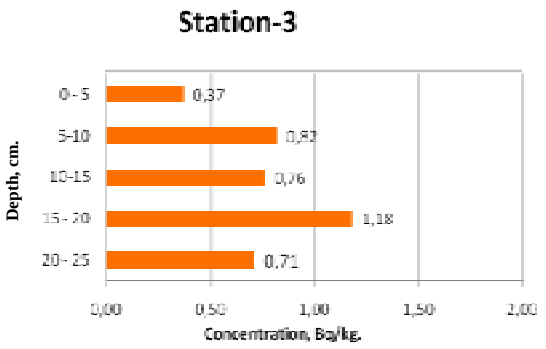
The ^{137}Cs concentrations in the Antarctic is assumed to come from fallout, the concentrations range is 0.07 – 6.7 Bq/kg with average of 1.40 ± 0.40 Bq/kg. In Japan, it concentrations range is 0.23 – 88.0 Bq/kg with average of 16.55 ± 0.37 Bq/kg. Japan is one of the nuclear industry country in with more than 74.9 % of electricity come from the nuclear power plant (NPP) [8]. The ^{137}Cs concentration in surface soil in Japan has significant value coming from the NPP operations. If the ^{137}Cs concentration in surface soil of SNS is compared statistically with the concentrations in the Antarctic and Japan, the results are significantly different. This data indicates that the concentration of ^{137}Cs in SNS is dominantly coming from the fallout.



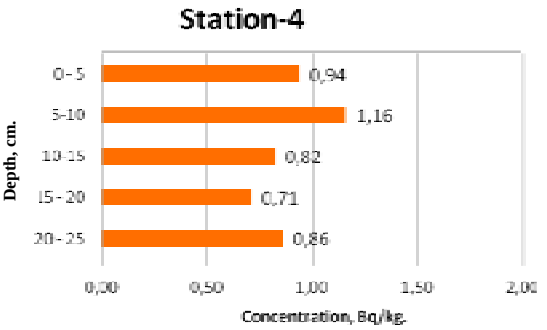
(a)



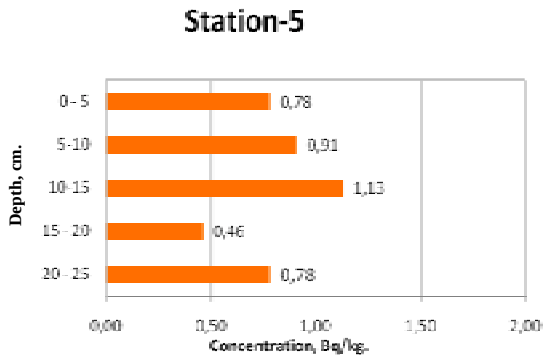
(b)



(c)



(d)



(e)

Fig. 1. Distribution ^{137}Cs concentration in surface soil of SNS.

The ^{137}Cs distribution in the surface soil layer as the depth function in station-1 to station-5 were shown in Fig. 1a-e. The surface soil type in SNS, based on the survey results of Institute Technology of Bandung [7], is latteric clay with permeability (K) equal to 10^{-7} m. second^{-1}. The soil were sandy, some gravels and reddish color, and the pH range is 5 to 6,6. This soil type is easy saturated by the water. If there is a raining the water will runoff and very small of water will migrate to the deeper soil. Some of the minerals that contains in the surface soil may be soluble in the rain water and will migrate / runoff to the lower location by the gravitation. The ^{137}Cs were bounded by fine clay, organic compound that exist in the surface soil, by minerals of illit and mica by chemical – physical process.

The surface soil in each stations until 25 cm of soil depth contains a lot of humus and roots of the grass, small latteric clay, sand and gravel. Figure 1a-e show that the ^{137}Cs were exceedingly migrating on the layer of 20 – 25 cm. The ^{137}Cs concentration distribution in each station were significantly different, it may happen because of the variation of soil composition and the plants that covers the surface soil. The ^{137}Cs concentration in the first layer is slightly smaller than the second layer, it may happen because of the variability of surface soil elevation / topography. If there is a raining, a small of ^{137}Cs may be soluble in the rain water and will be transported by runoff.

The ^{137}Cs concentrations in *Panisetum Purpureum*, *Setaria Spha Celata* and *Imperata Cylindrica* growing in the surface soil and the value of transfer factor (T_f) are shown in Table 5 and Table 6.

Table 5. The activity concentrations of ^{137}Cs (Bq/kg) in the grass at SNS.

Location	*Panisetum Purpureum*	*Setaria Spha Celata*	*Imperata Cylindrica*
1	0.63	0.72	0.67
2	0.53	0.82	0.57
3	0.54	0.66	0.63
4	0.57	0.82	0.79
5	0.57	0.52	0.58
Range	0.53 – 0.63	0.52 – 0.82	0.57 – 0.79
Average	0.57	0.71	0.65
Deviation	0.04	0.11	0.08

Table 6. The transfer factor (T_f) of ^{137}Cs in the grasses.

Location	Transfer Factor, (T_f)		
	Panisetum Purpureum	*Setaria Spha Celata*	*Imperata Cylindrica*
1	0.90	1.03	0.96
2	0.64	0.99	0.69
3	0.70	0.86	0.82
4	0.63	0.91	0.88
5	0.70	0.64	0.72
Range	0.63 – 0.90	0.64 – 1.03	0.69 – 0.96
Average	0.71	0.84	0.81
Deviation	0.14	0.27	0.11

The concentrations of ^{137}Cs in *Panisetum Purpureum* is 0.57 ± 0.04 Bq/kg, in *Setaria Spha Celata* is 0.71 ± 0.11 Bq/kg and in *Imperata Cylindrica* is 0.65 ± 0.08 Bq/kg respectivelly. Based on the statistical test, the ^{137}Cs concentrations in the grass were insignificantly different in 90 % confident level. The T_f of ^{137}Cs in *Panisetum Purpureum*, *Setaria Spha Celata* and *Imperata Cylindrica* were 0.71 ± 0.14, 0.84 ± 0.27 and 0.81 ± 0.11 respectively. Soil-to-plant transfer factor for soil layer 0 – 5 cm in the Czech Republic was reported. The results show that the transfer factor the soil-to-plant for uncultivated soil is 0.33 ± 0.01 and for cultivated soil is 0.24 ± 0.05. The results also show that for soil layer 0 – 20 cm, the transfer factor for uncultivated soil is 0.69 ± 0.01 and for cultivated soil is 0.24 ± 0.05 [9]. These differences in ^{137}Cs contaminations are caused by the fact the transfer of ion cesium fixing clay mineral in the soil to the crops growing there is low and in the high nutrient content and the high pH-value of agriculturally used soils also inhibit transfer. In contrast the transfer to plant in the soils with thick humus layers in SNS is relatively high. The results show that value of the transfer factor varies between cultivated and uncultivated soil, between the depth of the soil and also with soils with thick humus.

CONCLUSION

The ^{137}Cs concentration in surface soil on-site and off-site of SNS were insignificantly different. The ^{137}Cs concentration in SNS is much lower than the ^{137}Cs concentration in the Antarctic. This results indicates that the contribution of the ^{137}Cs from G.A. Siwabessy reactor operation is insignificant. The operation of G.A. Siwabessy reactor is running well following the operational standard and safety regulation. The ^{137}Cs concentration distribution as function of the depth soil were varied because of the composition of soil and the topography of surface soil. The T_f of ^{137}Cs in *Panisetum Purpureum, Setaria Spha Celata* and *Imperata Cylindrica* are 0.71 ± 0.14, 0.84 ± 0.27 and 0.81 ± 0.11 respectively.

REFFERENCES

1. B. G. Bennet, *Exposure from Worldwide Release Radionuclide*, Proceedings of A Symposium on Environmental Impact of Radioactive Release, Vienna (1995).
2. Anonymous, *Environmental Impact Analysis Report, Multipurpose Reactor MPR-30*, BATAN (1986) 6.
3. E. Lubis and Syahrir, *Dispersion Factor of Radionuclide that Released to the Atmosphere at Serpong Nuclear Site*. Proceedings Seminar of Nuclear Fuel Cycle and Radioactive Waste Proccessing Technology, Serpong (1987). (in Indonesian).
4. Anonymous, *Analytical Radioactivity Procedure for Environmental Samples*, BATAN, Jakarta (1986). (in Indonesian).
5. T. Hashimoto, T. Morioto, Y. Ikeuchi, K. Yoshimizu, T. Torii and K. Kimura, *Survey of Artificial Radionuclide in the Antarctic*, Proceeding NIPR symposium on Antarctic Geo sciences No.2, Tokyo, Japan (1988).
6. Anonymous, *Radioactivity Survey Data in Japan, ISSN 0441-2516, NIRS-RSD*, National Institute of Radiological Science Chiba, Japan (1996).
7. Anonymous, *Shallow Ground Water Survey and Construction of Monitoring Wells in the Surrounding Area of Reaktor Serba Guna*, Faculty of mineral, Institute Technology of Bandung, Puspiptek Serpong (1987).
8. Capacity Factor for Japan's NPPs. http://www.scribd.com./doc/53441314/ Retrieved in January (2011).
9. http://www.iaea.org/iris/collection/NCLcollection store/-public/33/058/3305889.pdf.