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The public committed effective dose caused by consumption of foods & foodstuffs in Ninh Thuan

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Abstract: Based on the data set about radionuclides concentration in foods and foodstuffs obtained from the implementation of the National Projects on "Investigation on radionuclides and toxic elements concentration in the main kinds of foods & foodstuffs of Vietnam" and "Assessment of Marine Environmental Radioactivity Status for two selected sites of Nuclear Power Plant in the near future at Ninh Thuan Province", a calculation software of the International Commission for Radiological Protection (ICRP), the public committed effective doses (for adult only) caused by consumption of main foods & foodstuffs in the studied experimental region were estimated. In general, the committed effective doses for adult public caused by the daily intake of radionuclides of U, ^{232}Th, ^{210}Pb, ^{210}Po, ^{226}Ra, ^{40}K, ^{90}Sr, ^{137}Cs and ^{239,240}Pu are: 7.9×10^{-5}, 4.1×10^{-6}, 1.1×10^{-2}, 1.7×10^{-1}, 1.4×10^{-3}, 1.2×10^{-1}, 2.32×10^{-4}, 1.9×10^{-4}, 2.7×10^{-9} (mSv/year), respectively, and the contribution of U, Th series, ^{40}K and artificial radionuclides are 61.3%, 38.6% and 0.1%, respectively.

Keywords*: Public committed effective doses, Foods & foodstuffs.*

I. INTRODUCTION

In the internal dose, it's most concerned about the intake of the radionuclides by inhalation, then the ingestion and finally the skin [1]. In this work, however, we only mention the internal dose with the metabolic model for the digestive system related to the food consumed by humans for eating purpose and the application of the ICRP Dose Coefficient software for calculation based on data on the daily intake of the U, Th, ^{40}K, ^{210}Pb, ^{210}Po, ^{226}Ra, ^{90}Sr, ^{137}Cs and ^{239,240}Pu radioactive isotopes for people in Ninh Thuan Province [2].

II. METHOD OF CALCULATION

Application of software "ICRP Dose Coefficient" for calculating with the following fundamental parameters [5], [6].

Scope of the program: Calculating committed equivalent dose per intake unit (dose coefficients) in different tissues and committed effective dose per intake unit (dose coefficients). The results are applied to both radiation workers and people for all radionuclides intake by ingestion and inhalation described in ICRP Publication 68 (for radiation workers in the different particle size) and ICRP Publication 72 (for people under the difference age). The results are also applied in the calculation of doses for different accumulative time intervals after intake into the body of the radionuclides.

The radionuclides: The software shows the results of all radionuclides in ICRP Publication 68 and ICRP Publication 72. The nuclear data are applied according to ICRP/Publication 38. The results show

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parameters of dose calculation of radiation workers and the public according to ICRP Publication 60 and IAEA Safety Series No. 115.

Age group: Adults: from 17 years.

Selection of the dose coefficient value f1 for public dose by ingestion: The dose coefficients for most of the radionuclides intake by ingestion are only a coefficient value f1 for all chemical types of food and foodstuff. These values are applied according to Appendix A.1 of ICRP Publication 72 or reference the Table II-VI of the IAEA Safety Series No. 115.

Time period: The software provides calculations for more than 10 or 5 time period. In addition, the software also gives the constants apply to all ages with the time periods as follows: 1, 7, and 30 days; 1, 5, 10, 20, 30 and 45 years. End of the time period changes for each age group that is accumulated up to 70 years. The software was applied to these values described in ICRP Publications 68 and 72.

The target tissues: The software shows the dose coefficients for 33 tissues/target organs including the tissues in the respiratory system. In addition, the software also gives dose coefficients for the component tissues, colon, lung and other tissues/organs. The software has options to calculate for all tissues or only a tissues that have weighting factors according to Table 7 of ICRP Publication 68. The colon weighting factors were applied according to Table 1 of ICRP Publication 69. The volume or each age of the digestion system is applied according to Table 1 of ICRP Publication 56.

The biological models: The biological models according to ICRP Publication 30 have been developed with consideration the committed effective dose in the process of entering the body and are applied in accordance with the ICRP Publication 68 and 72.

Equivalent dose for the tissues/organs: The equivalent dose for the tissues/organs (remainder) is usually calculated as an average dose by the weight of the tissues/organs listed in Table 9 of the ICRP Publication 68. For exceptions, the equivalent doses are applied in accordance in Table 2 of ICRP Publication 60.

III. RESULTS AND DISCUSSION

A. Daily intake level of radioactive isotopes into the human body through the digestion of adults in Ninh Thuan Province

Table I and Fig 1 show the daily intake levels of U, Th, ^{40}K, ^{210}Pb, ^{210}Po, ^{226}Ra, ^{90}Sr, ^{137}Cs and ^{239,240}Pu in the human body through the digestion of adults in Ninh Thuan Province.

The contributions are arranged in descending order: ^{40}K (97.21%), ^{210}Po (1.49%), ^{210}Pb (0.41%), U (0.44%), Th (0.19%), ^{226}Ra (0.15%); and artificial nuclides order ^{137}Cs (0.07%), ^{90}Sr (0.04%), ^{239,240}Pu (0.0001%).

Table I. Daily intake of radioactive isotopes with adults of Ninh Thuan Province (Bq/person/day) [2], [3], [4]

Food groups	***Daily intake* (g/person/ day)**	***Daily intake of U, Th, ^{40}K, ^{210}Pb, ^{210}Po, ^{226}Ra, ^{90}Sr, ^{137}Cs and ^{239,240}Pu by the main diet (Bq/person/day)***								
		U	***Th***	***^{40}K***	***^{210}Pb***	***^{210}Po***	***^{226}Ra***	***^{90}Sr***	***^{137}Cs***	***^{239,240}Pu***
Rice	362.4	0.0714	0.0163	7.14	0.0533	0.1734	0.0091	0.0544	0	0
Other cereals	21.5	0.0028	0	0.91	0.0084	0.0232	0.0004	0.0022	0	0
Tubers	8.4	0	0.0003	0.60	0.0006	0.0019	0	0	0	0

Vegetable leaves	142.7	0.0210	0.0397	14.81	0.0347	0.1094	0.0310	0.0057	0	0.00006
Vegetable tubers	37.8	0.0027	0.0016	2.15	0.0106	0.0240	0.0008	0.0019	0.0026	0
Fruits	89.2	0.0113	0.0141	6.97	0.0135	0.0468	0.0100	0	0	0
Meats	71.8	0.0117	0.0044	4.73	0.0409	0.1271	0.0132	0.0022	0.0022	0
Eggs/milk	25.1	0.1001	0.0100	9.17	0	0	0	0.0032	0.0303	0
Fishes	48.4	0.0078	0.0094	4.33	0.0429	0.2317	0.0041	0.0058	0.0042	0
Other aqua-products	6.3	0.0010	0.0019	0.34	0.0084	0.0461	0.0010	0.0003	0	0
Total of intake	**813.6**	**0.2298**	**0.0977**	**51.15**	**0.2133**	**0.7836**	**0.0696**	**0.0213**	**0.0393**	**0.00006**

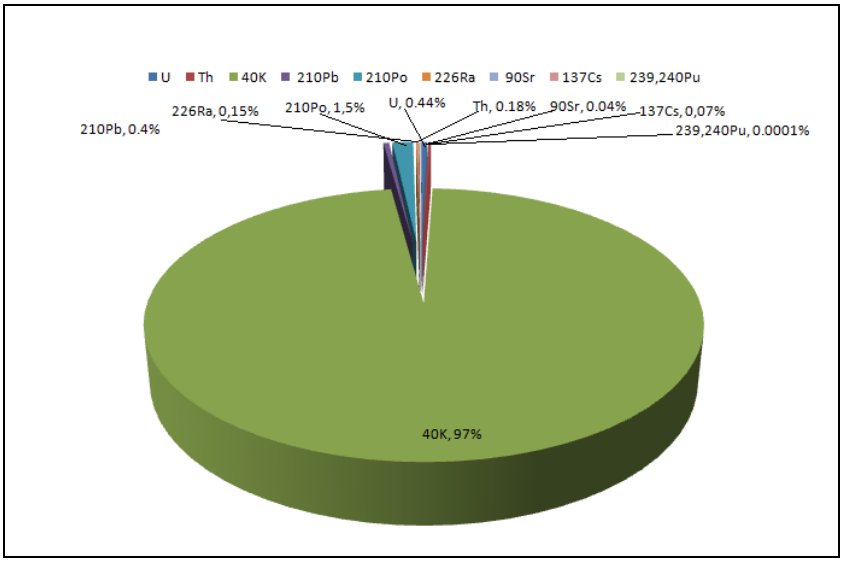

Fig. 1. Daily intake level of radionuclides into the human body through the digestion of adults in Ninh Thuan Province.

B. Results of public committed effective doses caused by the consumption of foods & foodstuffs in Ninh Thuan Province of Vietnam

From the obtained data (1250 data) on concentrations of natural and artificial radioactive isotopes in foods and foodstuff (10 types) and daily intake level of U, Th, ^{40}K, ^{210}Pb, ^{210}Po, ^{226}Ra, ^{90}Sr, ^{137}Cs and ^{239,240}Pu (Table I) into the human body through the digestion of adults in Ninh Thuan Province; the public committed effective doses are calculated based on ICRP Dose Coefficient Program.

Tables II and Fig 2 show public committed effective doses of U, Th, ^{40}K, ^{210}Pb, ^{210}Po, ^{226}Ra, ^{90}Sr, ^{137}Cs and $^{239.240}$Pu radioactive isotopes into 13 tissues/organs of body by consumption of adult from the survey areas of Ninh Thuan Province.

Fig 2 also shows the highest committed effective dose of each isotope in organs/tissues. In specially:

- For U: concentration is highest in red marrow after the colon, bone surface and gonads;

- For Th: concentration is highest in the bone surface, after the red marrow and gonads;

- For ^{40}K: concentration is highest in the colon, after the gonads, stomach and lungs;

- For ^{210}Pb: concentration is highest in the red marrow, after the bone surface;

- For ^{210}Po: concentration is highest in red marrow, the liver, after the other organs/tissues;

- For ^{226}Ra: concentration is highest in the bone surface, after the red marrow;

- For ^{90}Sr: concentration is highest in red bone marrow, after the bone surface;

- For ^{137}Cs: concentration is highest in the reproductive organs, colon, stomach and after the lungs;

- For $^{239.240}$Pu: concentration is highest in the liver, bone surface, and then to the red marrow.

The results showed the behaviors of the radioactive isotope into the organs/tissues of body are closed similar for valence group of elements; such as group 1 consists of ^{40}K and ^{137}Cs, group 2 has ^{226}Ra and ^{90}Sr, group 3 has U, Th and ^{210}Pb; and ^{210}Po and ^{239,240}Pu are similar to group 2.

Table II. Public committed effective dose (mSv/year) of radioactive isotopes into tissues/organs of body by consumption of adult at Ninh Thuan Province [2]

Tissues/ Organs	**U**	**Th**	**^{40}K**	**^{210}Pb**	**^{210}Po**	**^{226}Ra**	**^{90}Sr**	**^{137}Cs**	**^{239,240}Pu**
Gonads	8.8E-06	3.9E-07	1.9E-02	2.7E-04	8.0E-03	4.1E-05	1.1E-06	3.7E-05	2.4E-10
Bladder	2.2E-06	3.2E-08	5.9E-03	6.9E-05	2.0E-03	1.0E-05	6.2E-07	1.0E-05	7.7E-12
Bone Surface	**1.3E-05**	**2.1E-06**	9.3E-04	**3.6E-03**	2.3E-03	**6.1E-04**	**3.4E-05**	2.0E-06	**9.0E-10**
Breast	2.1E-06	3.2E-08	4.6E-03	6.9E-05	2.0E-03	1.0E-05	2.7E-07	7.9E-06	7.7E-12
Oesopha-gus	2.1E-06	3.2E-08	4.7E-03	6.9E-05	2.0E-03	1.0E-05	2.7E-07	9.3E-06	7.7E-12
St wall (Stomach)	5.4E-06	7.7E-08	1.3E-02	1.6E-04	4.8E-03	2.5E-05	9.0E-07	2.2E-05	2.1E-11
Colon	1.1E-05	1.3E-07	**3.1E-02**	1.8E-04	5.2E-03	6.0E-05	1.3E-05	**2.6E-05**	6.3E-11
Liver	8.6E-06	1.7E-07	4.7E-03	1.5E-03	4.7E-02	4.6E-05	2.7E-07	9.3E-06	9.3E-10
Red Marrow	1.6E-05	1.0E-06	1.1E-02	4.7E-03	4.5E-02	5.3E-04	1.8E-04	2.2E-05	5.1E-10
Lungs	5.3E-06	7.7E-08	1.1E-02	1.6E-04	4.8E-03	2.4E-05	6.6E-07	2.2E-05	1.8E-11
Skin	4.3E-07	6.4E-09	9.0E-04	1.4E-05	4.0E-04	2.0E-06	5.5E-08	1.6E-06	1.5E-12
Thyroid	2.1E-06	3.2E-08	4.7E-03	6.9E-05	2.0E-03	1.0E-05	2.7E-07	9.3E-06	7.7E-12
Remaind-er	2.4E-06	3.3E-08	4.7E-03	1.1E-04	**4.7E-02**	1.0E-05	2.8E-07	8.6E-06	8.2E-12
Body	**7.9E-05**	**4.1E-06**	**1.2E-01**	**1.1E-02**	**1.7E-01**	**1.4E-03**	**2.3E-04**	**1.9E-04**	**2.7E-09**

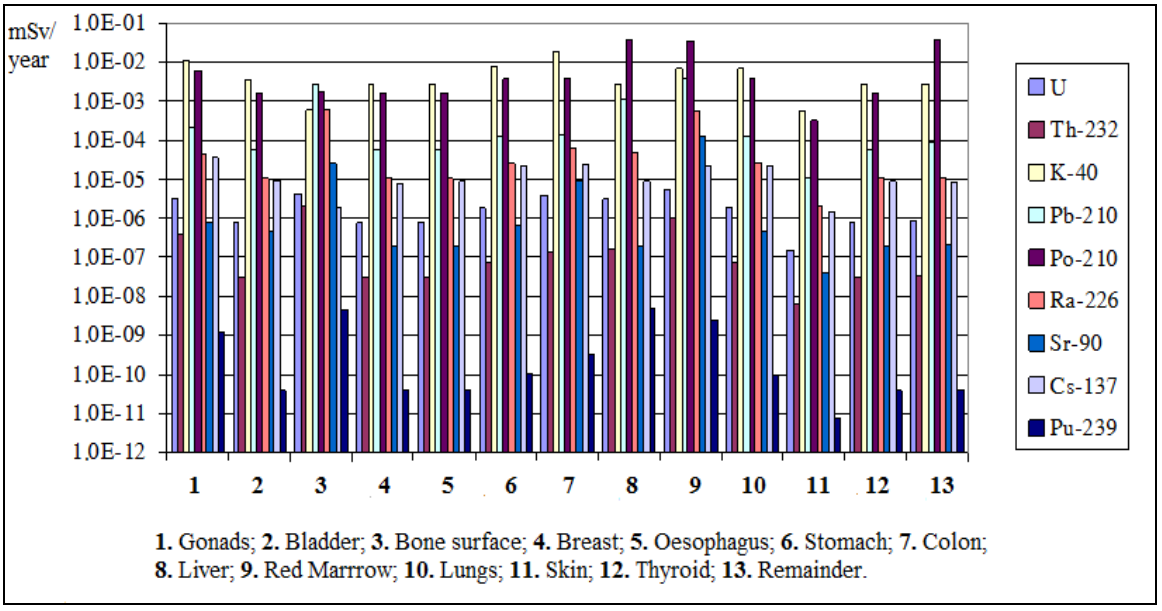

Fig. 2. Public committed effective dose of U, Th, ^{40}K, ^{210}Pb, ^{210}Po, ^{226}Ra, ^{90}Sr, ^{137}Cs and ^{239,240}Pu into tissues/organs of body

Tables III and Fig. 3 show the dose contributions of radioactive isotope groups by diet at the survey area. The largest contributions are of U, Th series, and then next to ^{40}K; while the artificial isotopes are significant contributions (61.3%, 38.6%, and 0.1%, respectively).

Table III. Contribution of dose of radioactive isotopes by digestion of adult at Ninh Thuan Province [2], [3]

Food groups	**Contribution (%)**		
	U, Th series	**K-40**	**Artificial**
Rice	71.4	28.3	0.3
Other cereals	72.7	27.2	0.1
Tubers	24.7	75.3	
Vegetable leaves	44.0	55.9	0.1
Vegetable tubers	54.3	45.5	0.2
Fruits	41.4	58.6	
Meats	73.7	26.2	0.1
Eggs/milk	0.2	99.1	0.7
Fishes	84.3	15.6	0.1
Other aqua-products	93.1	6.8	0.1
Total	**61.3**	**38.6**	**0.1**

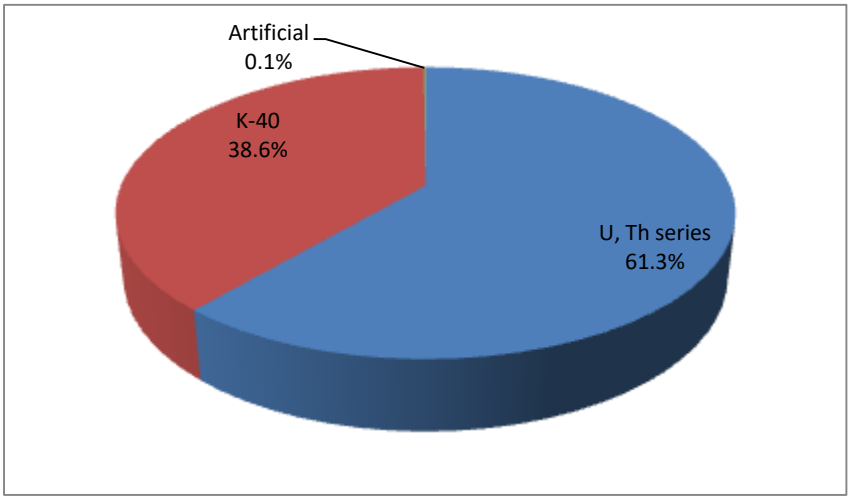

Fig. 3. Contribution of dose of radioactive isotope groups by diet in Ninh Thuan Province.

Tables IV shows public committed effective dose of adult at Ninh Thuan Province by consumption from main food groups and their contributions.

Fig 4 shows the contribution of dose by consumption of food groups of human at Ninh Thuan Province. The contribution of dose by consumption of fishes, vegetable leaves, rice, meats, fruits, eggs/milk, other aqua-products, vegetable tubers, and other cereals are 21%, 20%, 19%, 14%, 9%, 7%, 4%, 4%, and 2%, respectively.

Table IV. Public committed effective dose of adult at Ninh Thuan Province by consumption from main food groups and their contribution [2], [3]

Food groups	**Dose mSv/year**	**Contribution %**
Rice	5.7E-02	19.1
Other cereals	7.6E-03	2.5
Tubers	1.8E-03	0.6
Vegetable leaves	6.0E-02	20.0
Vegetable tubers	1.1E-02	3.6
Fruits	2.7E-02	9.0
Meats	4.1E-02	13.6
Eggs/milk	2.1E-02	7.0
Fishes	6.3E-02	20.9
Other aqua-products	1.1E-02	3.8
Total	**3.0E-01**	**100**

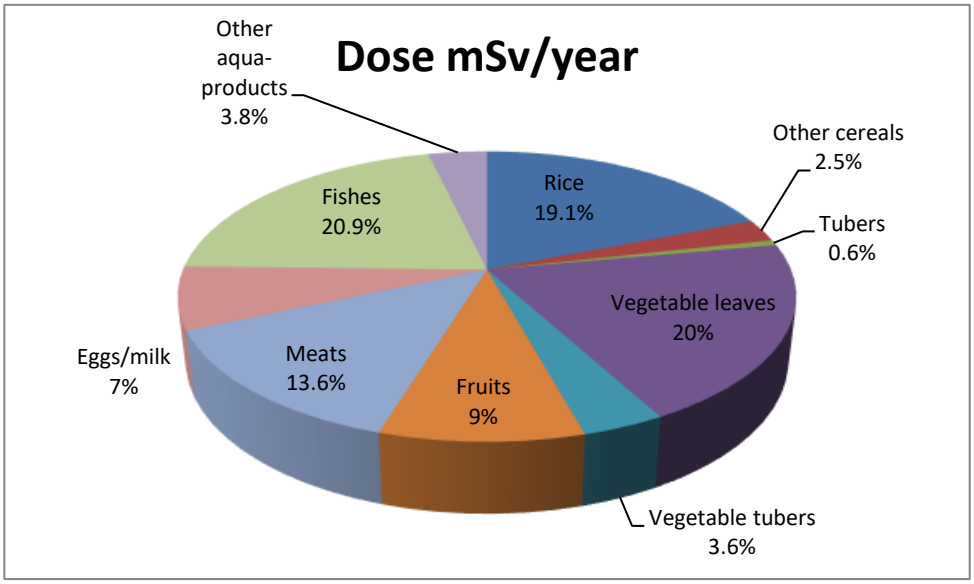

Fig. 4. Contribution of dose by consumption of food groups of human at Ninh Thuan Province.

Fig 5 shows the contribution of dose by tissues/organs in human body by consumption at Ninh Thuan Province. The contribution of dose by red marrow, liver, remainder, colon, gonads, stomach, lungs, bone surface, bladder, breast, oesophagus, thyroid, skin are 22%, 20%, 18%, 11%, 8%, 5%, 5%, 3%, 2%, 2%, 2%, 1%, and 1%, respectively.

Our obtained result of the public committed effective dose in Ninh Thuan is 0.30 mSv/year similar to the result of the same type of Japanese authors assessed the public committed effective dose of Japanese people (0.32 mSv/year) according to ICRP 68 [7].

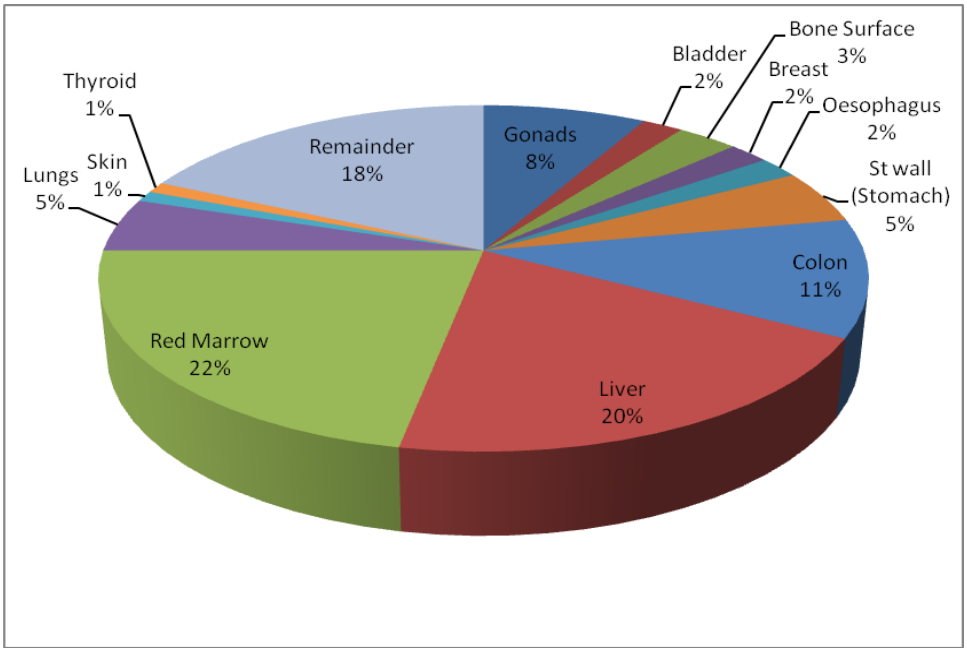

Fig. 5. Contribution of dose by tissues/organs in human body by consumption at Ninh Thuan Province.

IV. CONCLUSIONS

In general, the adult public committed effective doses caused by the daily intake of radionuclides of U, ^{232}Th, ^{210}Pb, ^{210}Po, ^{226}Ra, ^{40}K, ^{90}Sr, ^{137}Cs and ^{239,240}Pu are 7.9×10^{-5}, 4.1×10^{-6}, 1.1×10^{-2}, 1.7×10^{-1}, 1.4×10^{-3}, 1.2×10^{-1}, 2.32×10^{-4}, 1.9×10^{-4}, 2.7×10^{-9} (mSv/year), respectively, and the contribution of U, Th series is 61.3%, for ^{40}K is 38.6%, and for artificial radionuclides are 0.1%.

The total of public committed effective doses due to consumption of foods and foodstuffs for the adult in Ninh Thuan is 0.30 mSv/year, other areas (Lam Dong, Ho Chi Minh City, Tien Giang, Can Tho and Tra Vinh) are 0.21, 0.27, 0.26, 0.21 and 0.23 mSv/year, respectively [2].

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