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Estimation of effective radiation dose for households living in rare earth mines in Nam Xe, Lai Chau province

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Abstract - According to the United Nations Scientific Council on the Effects of Atomic Radiation (UNSCEAR), the global average dose level for the community is 2.4mSv/year. People living in the areas with high levels of radiation will cause adverse effects on their health. There are two main components that cause the dose of radiation, mainly due to the inhalation of radon and the extra dose of gamma radiation. The paper presents the results of assessment of natural effective radiation doses on the basis of the projected outpatient dosimetry in 70 households living in Mau and Mo village of Nam Xe, Phong Tho distrist, Lai Chau province.

Keywords: *Rare earth mine, radon concentration, gamma dose rate, outdoors and indoors effective dose.*

I. INTRODUCTION

High dose irradiation causes adverse effects on human health. The hazard level of natural radioactivity is assessed by the annual total effective dose. The total dose of natural radiation in each area is determined by the following principal components:

- Internal radiation exposure through the gastrointestinal tract due to eating, drinking with radioactive substances, and through inhalation by breathing radon in the air.

- External radiation exposure mainly from X rays, gamma radiation, neutrons, cosmic rays and other artificial sources.

According to the UNSCEAR 2000 Report the global average exposure is 2.4 mSv.year^{-1}, in which the gamma irradiation is 20%; The radon in the air is 59%, the composition of cosmic radiation is 15%; the remaining is 6% [10].

The natural irradiation dose in different places is mainly due to the variation of the external radiation exposure components from gamma irradiation and the internal radiation exposure due to the radon concentration of the geological formations on the living environment in the area. The cosmic radiation dose and the dose of dietary projection are not variable.

The rare earth deposit site in Nam Xe commune, Phong Tho district, Lai Chau province is composed of geological formations of Phong Tho - Tam Duong complex, Yen Yen, Pusamcap and Early Triassic Intrusive Formations - Ba Vi system, there appear to be many rare earth ores containing radioactive substances such as uranium and thorium. The soil is strongly weathered to create arable land. Thus, the gamma radiation field, radon gas measured higher than neighboring areas.

The Nam Xe rare earth area consists of North Nam Xe and South Nam Xe rare earth mines, in two maps with numbers F-48-27-D and Phong Tho map number F-48-39-B ratio 1:50.000. This is a high mountain, rugged, ore layers distributed in the eruption layer of the Vien Nam formation, from the left bank of Nam Xe

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stream with the height of 450 m, in the opposite direction of the mountain to the south with the height of more than 1.200 m. The sloping slope of 30 ÷ 40^{o} is fragmented by many streams, the main vegetation of the local residents is the grass, reeds and large trees are only sparse in some areas on the sides of streams [1].

Population living in villages is mainly ethnic minorities, including Thai, Nhang inhamlets including Man, Mo and Nam Xe. The main living conditions are farming and animal husbandry. This is a condition in which radioactive substances are easily dispersed, washed drift from the richest areas into the surrounding areas into the living water.

The results of the geological study of Nam Xe mine have two types of ore deposits is original ore and weathered ore. The ore composition is mainly composed of lanthanum, cerium, praseodymium and neodymium. In addition to the ore, there are also radioactive elements, such as uranium, thorium.

Rare-earth ore content: mainly in the lightweight group (cerium-lanthanium group), TR_2O_3 spectral analysis results show that the content of oxide elements is as follows: lanthanum 32%, cerium 43%, yttrium: 1.8%, gadolinium: 1.5%, neodymium: 21.7%. Average content TR_2O_3 = 9.76 ÷ 11.98%; U_3O_8 = 0.1 ÷ 0.03%; ThO_2 = 0.003 ÷ 0.055%; barite of about 30%, in addition to dispersed elements (tantalum and niobium) [4,5,6].

Nam Xe hydrocarbon mine has completed the exploration and preparation for exploitation and processing in the coming time. Radiation works will increase the radiation dose and spread radioactive contaminants in the area.

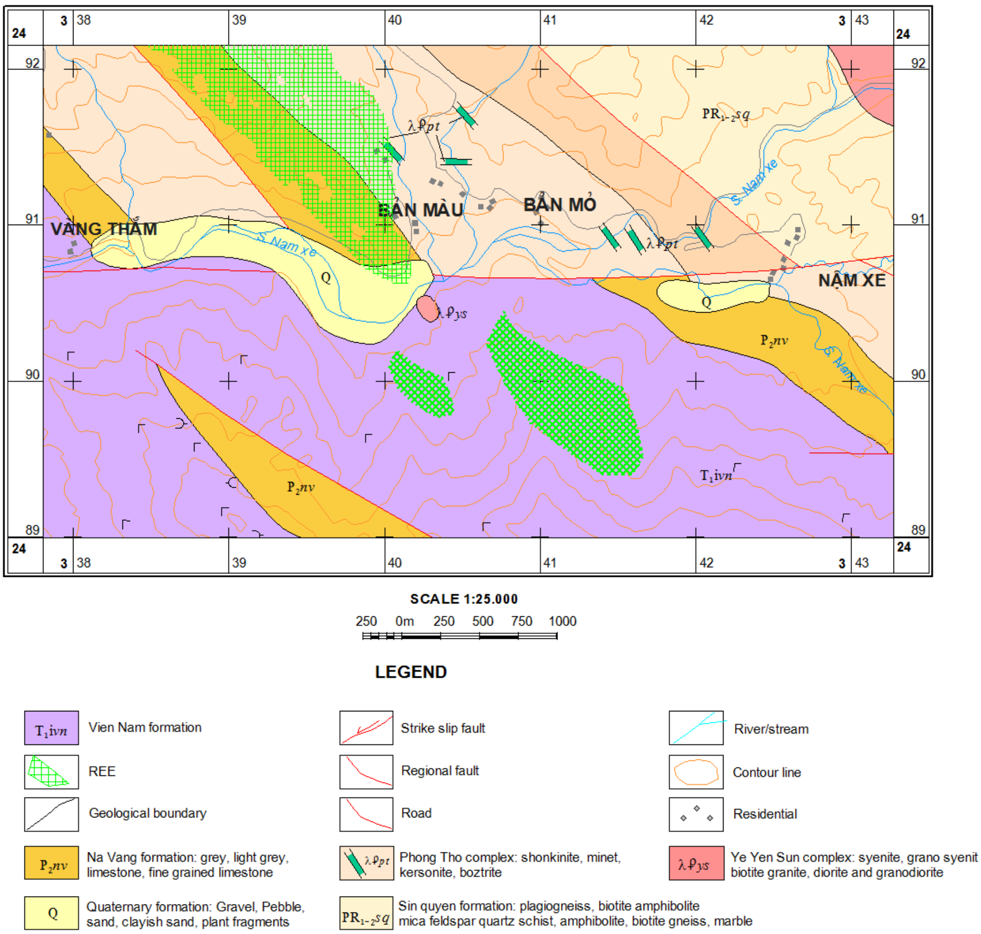

Fig. 1. Location of the survey

II.METHODS OF RESEARCH AND RADIATION DIFFERENTIAL COMPONENTS

A. Research methods

To evaluate the value of natural radiation dose for households living in villages Mau and Mo, Nam Xe rare earth mine, the following methods have been used [7,8]:

- Measurement of environmental gamma dose rate using a Russian-made Inspector with an accuracy of 0.01 $\mu Sv.h^{-1}$.

- Measurement of environmental radon concentration using a USAmade RAD - 7 machine, with a sensitivity of 5 $Bq.m^{-3}$.

In the study area, the authors measured the dosage of gamma radiationand radon concentration in the house and outside the households living in the village. The sample size is 70 households.

B. Effective dose of external exposure

The effective dose from gamma radiation consists of the external exposure due to gamma irradiation in the house and the dose externally due to the external gamma radiation projected onto the human body during corresponding periods of time when people are out home.

Outdoor radiation depends on the content and nature of the radioactive substances present in the geologic formations near the topsoil. Indoor irradiation is primarily affected by building materials, customary practices, which may be greater than the dose outside the home if the rock material is used with radioactive material.

Assessment of the effective dose depends on the conversion coefficient of absorption in the air into the effective dose and the room occupancy coefficient. UNSCEAR recommends using a 0.7 Sv/1.0 Gy conversion factor, occupancy coefficient with indoor and outdoor time periods of 0.8 and 0.2.

The recommended dosage form for indoor and outdoor use is UNSCEAR as follows[10]:

$$E_{TN}(\gamma) = D_T(nGy.h^{-1}) \times 8760 \times 0.8 \times 0.7Sv.Gy^{-1} \quad (1)$$

$$E_{NN}(\gamma) = D_N(nGy.h^{-1}) \times 8760 \times 0.2 \times 0.7Sv.Gy^{-1} \quad (2)$$

$$\text{Or: } E_{TN}(\gamma) = H(\mu Sv.h^{-1}) \times 8.76 \times 0.8, \quad mSv.year^{-1} \quad (3)$$

$$E_{NN}(\gamma) = H(\mu Sv.h^{-1}) \times 8.76 \times 0.2, \quad mSv.year^{-1} \quad (4)$$

where: E_{TN} and E_{NN} are the indoors and outdoors effective doses due to gamma radiation; D_T and D_N are the dose rates absorbed by gamma radiation in the home and outside. H is the dose rate equivalent by gamma radiation.

C. Effective dose of radon gas

Radon-induced radiative effects include indoor radon exposure and irradiation exposure to radon in the human body during times when people are indoors and outdoors.

$$E_{NN(Rn)} = C_{Rnnn} \times 0.6 \times 1760\ h \times 9.10^{-9} Sv/(Bq.h.m^3) = 0.0095 \times C_{Rnnn} \quad (5)$$

$$E_{TN(Rn)} = C_{Rntn} \times 0.4 \times 7000\ h \times 9.10^{-9} Sv/(Bq.h.m^3) = 0.025 \times C_{Rntn} \quad (6)$$

where: C_{Rnnn}, C_{Rntn} is the radon concentration outside the home and in the home; With a home stay of 7000 hours a year, the time spent at outdoor is 1760 hours a year.

III. RESULTS AND DISCUSSION

The results of the study of the environmental gamma dose in the area receiving the average gamma dose rate outside the home were 0.51 $\mu Sv.h^{-1}$ equivalent to 0.89 $mSv.year^{-1}$. Indoors is 0.54 $\mu Sv.h^{-1}$ equivalent to a dose of 3.78 $mSv.year^{-1}$.

The average radon concentration outside the home is 170 $Bq.m^{-3}$, equivalent to a dose of

1.62 mSv.year^{-1}. The average indoor radon concentration is 179 Bq.m^{-3}, equivalent to a dose of 4.48 mSv.year^{1}. The total dose of natural radiation from the gamma ray and radon sources that each household in the area may suffer is shown in Table I.

The survey results show the maximum effective dose value in the Mau hamlets is 25.17 mSv.year^{-1}, the minimum value is 5.02 mSv.year^{-1}, the average is 12.33 mSv.year^{-1}; In the Mo hamlets, the maximum value is 17.67 mSv.year^{-1}, the minimum value is 5.37 mSv.year^{-1}, the average is 7.64 mSv.year^{-1}.

The results of the survey also show that the effective dose value of the households living in the Mau hamlets is higher than that of the households living in the Mo hamlets, this is because of the households in the area of the Mau living near rare earth ore bodies with high levels of radioactive substances.

Table I. Results of natural radiation dose in households surveyed

TT	**Head of household name**	**Indoors, outdoors**	**Radon Concentration (Bq.m^{-3})**	**Gamma dose rate (μSv.h^{-1})**	**Effective dose (mSv.year^{-1})**
1	Ly Van Phu (Mau)	Indoors	562*	**0.60**	**25.17**
		outdoors	623	0.57	
2	Lo Van Thuong (Mau)	Indoors	332*	**0.62**	**17.41**
		outdoors	400	0.55	
3	Lo Van Thanh (Mau)	Indoors	80	**0.64**	9.67
		outdoors	225	0.60	
4	San Van Tien (Mau)	Indoors	189*	**0.67**	**12.63**
		outdoors	212	0.68	
5	San Van Hy (Mau)	Indoors	221*	**0.62**	**12.75**
		outdoors	202	0.55	
6	Vui Van Sui (Mau)	Indoors	212*	0.40	9.61
		outdoors	90	0.37	
7	Ho Van Mi (Mau)	Indoors	403*	**0.64**	**18.52**
		outdoors	308	0.59	
8	Ho Van Sui (Mau)	Indoors	233*	**0.62**	**13.29**
		outdoors	220	0.59	
9	Vui Van Vang (Mau)	Indoors	200*	**0.60**	**13.00**
		outdoors	302	0.53	
10	Mung Van Sang (Mau)	Indoors	412*	**0.63**	**19.54**
		outdoors	416	0.50	
11	Nong Thi Hong (Mau)	Indoors	487*	**0.60**	**21.51**
		outdoors	435	0.57	
12	Liu Thi Hung (Mau)	Indoors	532*	**0.76**	**24.68**
		outdoors	501	0.74	
13	Nung Van Chieng (Mau)	Indoors	502*	**0.66**	**24.53**
		outdoors	654	0.65	
14	Đo Van Huy (Mau)	Indoors	295*	**0.69**	**16.68**
		outdoors	351	0.65	

TT	Head of household name	Indoors, outdoors	Radon Concentration ($Bq.m^{-3}$)	Gamma dose rate ($\mu Sv.h^{-1}$)	Effective dose ($mSv.year^{-1}$)
15	Ta Van Thanh (Mau)	Indoors	280*	**0.63**	**14.78**
		outdoors	260	0.51	
16	Primary school (Mo)	Indoors	122*	0.43	7.39
		outdoors	62	0.42	
17	Primary school (Mo)	Indoors	220*	**0.65**	**12.20**
		outdoors	113	0.61	
18	Ly Van Lo (Mo)	Indoors	161*	0.39	8.52
		outdoors	110	0.41	
19	Ly Van Liem (Mo)	Indoors	81	0.38	6.26
		outdoors	92	0.40	
20	Vang Van Duong (Mo)	Indoors	95	0.37	6.78
		outdoors	121	0.38	
21	Vang Van Cui (Mo)	Indoors	162*	**0.76**	**11.52**
		outdoors	93	0.72	
22	Vang Van Van (Mo)	Indoors	94	**0.62**	9.36
		outdoors	181	0.54	
23	Vang Van Ken (Mo)	Indoors	421*	**0.60**	**17.67**
		outdoors	201	0.59	
24	Ly Van Nam (Mo)	Indoors	131*	0.50	8.75
		outdoors	110	0.53	
25	Vui Van Hop (Mo)	Indoors	92	0.48	7.39
		outdoors	112	0.38	
26	Vang Van Co (Mo)	Indoors	91	**0.63**	8.01
		outdoors	25	0.62	
27	Vang Van Sinh (Mo)	Indoors	102*	0.41	7.24
		outdoors	114	0.42	
28	Ly Van Đoan (Mo)	Indoors	46	**0.60**	7.64
		outdoors	132	0.59	
29	Vang Van Cam (Mo)	Indoors	138*	**0.76**	**10.98**
		outdoors	92	0.76	
30	Vang Van Chieng (Mo)	Indoors	113	**0.62**	8.75
		outdoors	61	0.57	
31	Luong Van Pao (Mo)	Indoors	103*	0.45	6.86
		outdoors	42	0.42	
32	Anh Kham (Mo)	outdoors	84	0.45	6.59
		Indoors	71	0.46	
33	Tao Van Cum (Mo)	outdoors	81	0.35	5.85
		Indoors	75	0.37	
34	Lo Van In (Mo)	outdoors	62	0.40	6.57
		Indoors	102*	0.39	

TT	Head of household name	Indoors, outdoors	Radon Concentration ($Bq.m^{-3}$)	Gamma dose rate ($\mu Sv.h^{-1}$)	Effective dose ($mSv.year^{-1}$)
35	Lo Van Chum (Mo)	outdoors	92	0.57	8.56
		Indoors	91	**0.63**	
36	Tao Van Kham (Mo)	outdoors	95	0.59	8.02
		Indoors	61	**0.65**	
37	Vang Van Sinh (Mau)	outdoors	124	0.37	9.71
		Indoors	164*	0.54	
38	Ly Van Van (Mau)	outdoors	130	0.55	**10.18**
		Indoors	151*	**0.60**	
39	Lo Van Seo (Mau)	outdoors	68	0.60	8.47
		Indoors	83	**0.67**	
40	Lo Van Sui (Mau)	outdoors	90	0.58	**10.39**
		Indoors	150*	**0.68**	
41	Lo Van Pao (Mau)	outdoors	58	0.35	5.87
		Indoors	76	0.40	
42	Lo Van Sinh (Mau)	outdoors	90	0.37	5.86
		Indoors	51	0.44	
43	Tao Van Sanh (Mo)	outdoors	75	0.39	6.54
		Indoors	88	0.42	
44	Tao Van Pao (Mo)	outdoors	87	0.49	9.10
		Indoors	151*	0.52	
45	Tao Van Pin (Mo)	outdoors	96	0.53	6.78
		Indoors	35	0.58	
46	Vang A Sinh (Mau)	outdoors	99	0.50	7.42
		Indoors	84	0.50	
47	Vang A Binh (Mau)	outdoors	79	0.67	7.90
		Indoors	26	**0.76**	
48	Vang A Pao (Mau)	outdoors	26	0.64	8.64
		Indoors	78	**0.76**	
49	Ly Van Cum (Mo)	outdoors	22	0.50	6.49
		Indoors	62	0.55	
50	Ly Van Vang (Mo)	outdoors	20	0.55	5.68
		Indoors	24	0.56	
51	Ly A Su (Mau)	outdoors	40	0.51	6.66
		Indoors	67	0.53	
52	Ly A Sinh (Mau)	outdoors	88	0.42	6.35
		Indoors	65	0.45	
53	Lo Van Bay (Mo)	outdoors	90	0.41	6.43
		Indoors	57	0.49	
54	Lo Van Nam (Mo)	outdoors	78	0.27	5.55
		Indoors	67	0.38	

TT	Head of household name	Indoors, outdoors	Radon Concentration (Bq.m^{-3})	Gamma dose rate (μSv.h^{-1})	Effective dose (mSv.year^{-1})
55	Vang Van Chinh (Mau)	outdoors	35	0.40	6.20
		Indoors	75	0.47	
56	Vang A Chinh (Mau)	outdoors	32	0.38	7.65
		Indoors	54	**0.76**	
57	Vui Mai Chac (Mo)	outdoors	69	0.56	8.65
		Indoors	73	**0.74**	
58	Vui Mai Binh (Mo)	outdoors	86	0.34	6.31
		Indoors	92	0.37	
59	Lo Van Chat (Mau)	outdoors	28	0.30	5.02
		Indoors	29	0.50	
60	Mai Van Cheo (Mo)	outdoors	74	0.53	7.57
		Indoors	75	0.58	
61	Tao Van Xanh (Mo)	outdoors	66	0.43	6.25
		Indoors	63	0.47	
62	Tao Van Nam (Mo)	outdoors	60	0.50	8.25
		Indoors	101*	**0.61**	
63	Tao Van Ngan (Mo)	outdoors	41	0.39	5.71
		Indoors	62	0.44	
64	Tao Van Tinh (Mo)	outdoors	105	0.46	6.30
		Indoors	48	0.47	
65	Lo Van Coong (Mo)	outdoors	55	0.35	5.37
		Indoors	60	0.39	
66	Lo Van Cheo (Mo)	outdoors	79	0.40	6.12
		Indoors	69	0.42	
67	Lo Van on (Mo)	outdoors	98	0.44	6.20
		Indoors	48	0.47	
68	Lo Van Cao (Mo)	outdoors	101*	0.36	6.62
		Indoors	92	0.39	
69	Hoang Van Chien (Mo)	outdoors	62	0.41	6.50
		Indoors	87	0.43	
70	Lo Van Ly (Mo)	outdoors	82	0.41	6.09
		Indoors	80	0.37	

Mau: Mau hamlets; Mo: Mo hamlets
(radon concentration in the home exceeds 100 Bq.m^{-3}[9])*

Table I shows that in 70 households, the natural radiation dose from the two main sources of radiation is gamma and radon:

- There are 32 out of 70 households have a gamma dose rate in the house is greater than or equal to 0.6 μSv.h^{-1}. Based on recommendations on the dose rate of gamma in the environment, sites with a gamma dose rate of is greater than or equal to 0.6 μSv.h^{-1} exceeded the radiation dose for permits for long-term housing [2].

- There are 30 out of 70 households have a radon concentration in the home is greater than 100 $Bq.m^{-3}$, exceeding the allowable limit for indoor radon concentration is less than or equal to100 $Bq.m^{-3}$ [9].

- There are 19 out of 70 households have total irradiation doses of two components: external irradiation by gamma irradiation and radon induced radiation is greater than or equal to 10 $mSv.year^{-1}$. According to the International Commission on Radiation Safety (ICRP) [3], this is the starting point to consider interventions to reduce the radiation dose.

The reason is that families have used building materials such as bricks, sand... of the locality to build houses and some families have built houses right on the rare earth ore body in the color village.

In the hamlets Mau and Mo, the mine has rare earth ores containing high levels of radioactive substances, causing high levels of natural radiation exposure for households living and working in the area.

IV. CONCLUSIONS

Survey results of radioactive environment inside and outside the house for the households are living, working in Mau and Mo hamlets, Nam Xe rare earth mining, Phong Tho, Lai Chau based on method of calculation the natural radiation background on the population under UNSCEAR has identified 32 out of 70 households with a radiation dose rate of is greater than or equal to 0.6 $\mu Sv.h^{-1}$, which is a recommended dose reduction measure in permanent residential settings; there are 15 out of 70 households receive an annual dose of is greater than or equal to 10 $mSv.year^{-1}$, which is a high dose, which is the start of the dose reduction measures.

In the coming time, Nam Xe mine will be exploited and processed to increase the level of natural radiation in the area. Therefore, measures must be taken to minimize the effect of radiation on the environment in the area.

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ANNEX A: Dose assesment methodologies
ANNEX B: Exposures from radiation sources