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Public dose assessment from external and internal radiation exposure in an elevated-level natural radiation area of Dong Pao (Lai Chau province) in Vietnam

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Outlines

1. Pupose of the study
2. Methods
3. Results and discussion
4. Conclusion

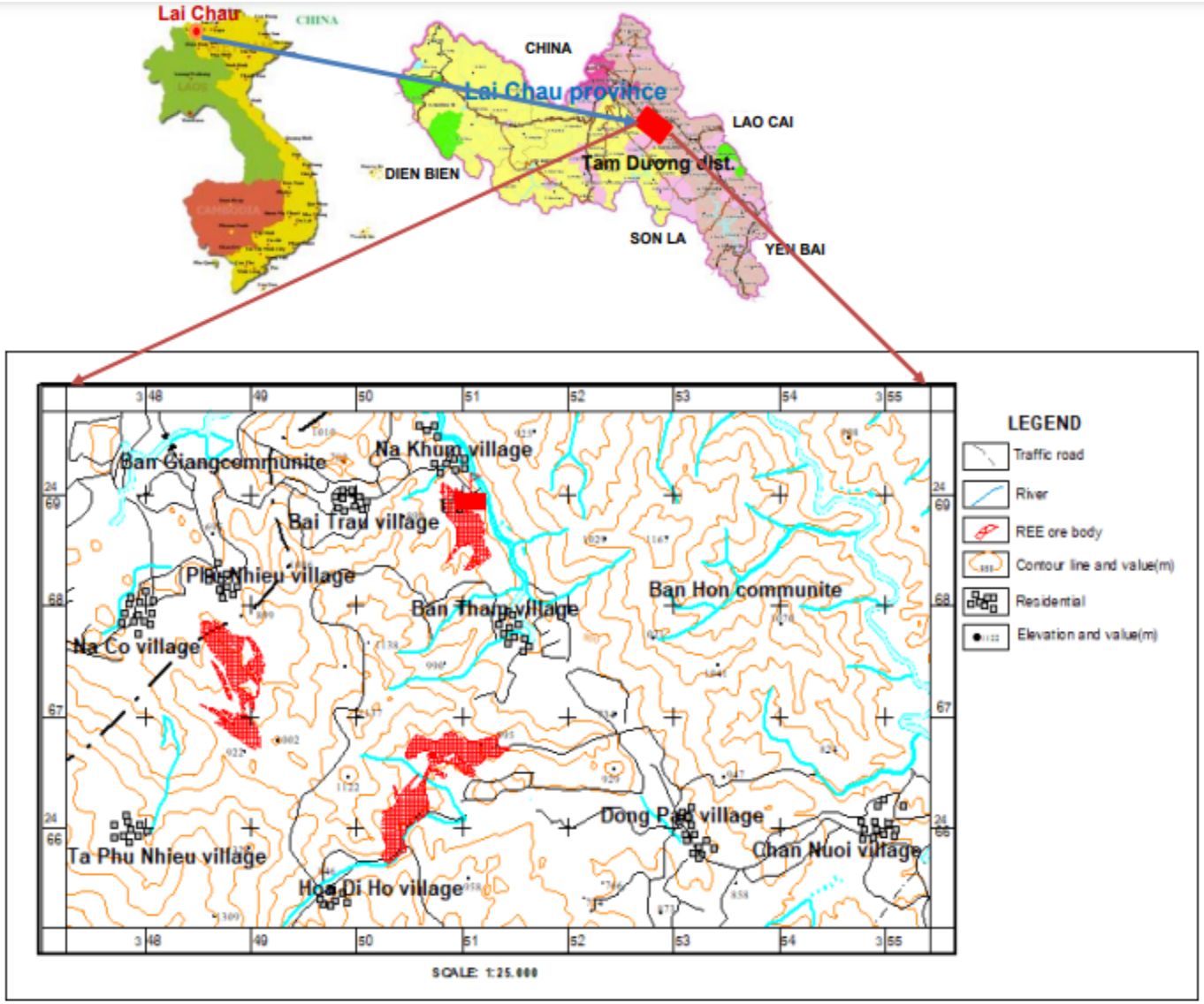
1. Pupose of the study

to evaluate the impact of radiation exposure caused from natural radioactive materials in Rare Earth Element deposit (REE) in Dong Pao village, Lai Chau province, Northern part of Vietnam to the public in the region.

The Center of Tam Duong district, Lai Chau province in the northewest of Viet Nam

2. Methods

2.1. Study region

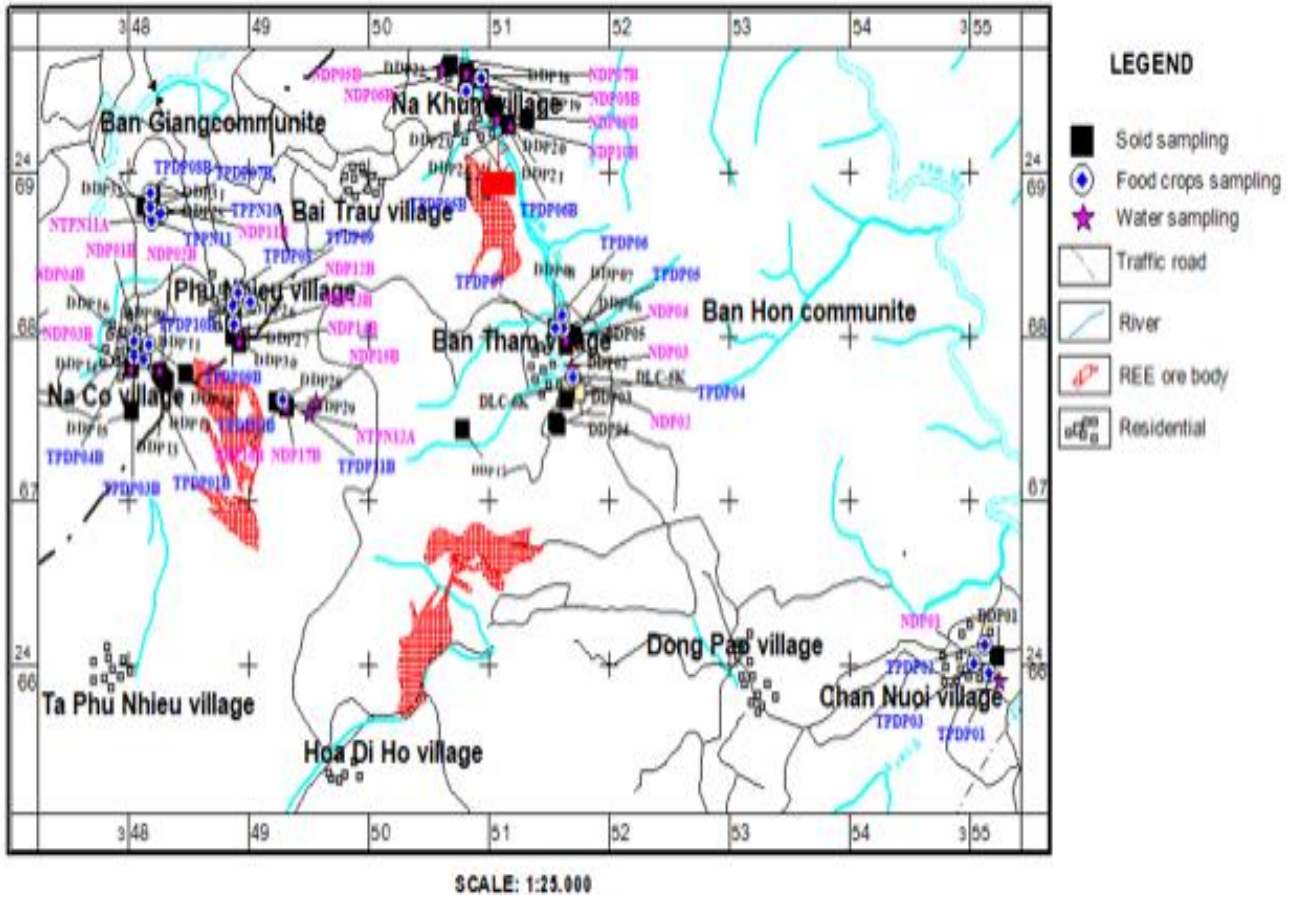


- Tam Duong district, Lai Chau province
- ✓ Location: 22°10’ - 22°30’N, 103°18’-103°46’ E; area: 68.5x10^3 ha
- ✓ Elevation: 600-800 m *amsl*
- ✓ Population: around 56 thousand heads

- REE deposit in Dong Pao
- ✓ Area: 120 ha
- ✓ Reserve of total TR_2O_3: 1.1x10^6 tone;
- ✓ Mineral: bastnaesite $(Ce,La)CO_3F$
- ✓ Uranium+Thorium impurity content: ~0.1 ppm in the deposit.

2.2. Dosimetry study

2.2.1. Sampling sites and samples collected



A map showing sampling sites of the study

- ✓ 34 surface (0-20 cm) soil samples
- ✓ 23 drinking water from local residents
- ✓ 17 rice and corn from the residents
- ✓ 5 vegetables

were sampled and transported to Ha Noi for treatment before radioactivity concentration of nuclides in the samples was determined

2.2.2. Sample treatment

- ✓ *Soil was air dried*, then sieved through 1 mm mesh,
- ✓ Dry the soil at 105 ^{o}C to constant weight,
- ✓ Load the samples into 3π containers and sealed the samples with silicone resin for 21 days for equilibrium to attain.

- ✓ Rice and corn was washed then boiled to the ready-to-eat foods as the local famers used to do;
- ✓ The boiled samples were dried at 105 ^{o}C to dryness then ground to powder, loaded it into 3π containers (Marinelli Beakers) and sealed with silicone resin for 21 days before radioactivity concentration of radioactive nuclides was quantified;
- ✓ Vegetable was boiled, dried at 80 ^{o}C to dryness, ground to powder, loaded it into 3π containers, sealed the containers with silicone resin for 21 days before radioactivity measurement.
- ✓ Water samples were filtered through nilon filters to remove sand/suspended matters, then loaded it into 3π containers, sealed with silicone resin for 21 days before radioactivity measurement.
- ✓ For radon monitoring: 60 double chamber RADUET of solid state nuclear track detectors (STND, CR-39 film) were installed in the dwellings of local farmers for a month.

- Sample treatment for the determination of ^{210}Po activity concentration in food

✓ Rice, corn and vegetable after boiling was dried at 80 ^{o}C till constant weight

✓ Grind the dried samples to powder

✓ 94 mBq ^{209}Po (Amersham, England) as internal standard was added to the samples to be digested with HCl + HNO_3 (3:1, v:v) at 80 ^{o}C till clear solution was obtained

✓ U, Th impurities were isolated by ion exchange method;

✓ Evaporate the solution obtained to dryness and replaced by HCl 0.1 M

✓ ^{210}Po was self-electro deposited on silver disks at 80 ^{o}C for 2 h.

- Treatment of CR-39 films to measure Rn-222 and Rn-220

✓ CR-39 films were removed from the chambers and subjected to etching at 80 ^{o}C in 6 M NaOH solution for 4 h to produce tracks;

2.2.2.Radioactivity measurement:

- ✓ Radioactivity concentration of nuclides: K-40, Ra-226, Th-232, Ac-228, Bi-214, Pb-214 in samples was determined using a gamma spectrometer (Canberra supplier);
- ✓ A alpha spectrometer (Canberra supplier) was used to quantify the activity concentration of ^{210}Po in the food samples;

✓ Radon measurement:

- The number of tracks produced in the CR-39 films by Rn-222 and Rn-220 decay was counted up under OLYMPUS CX21 microscope;
- To convert the track numbers into Bq/m^3, the RADUET detectors were calibrated at the Institute of Radiochemistry and Radioecology of the University of Pannonia, Hungary using a Rn-222 and Rn-220 calibration chamber;
- The sensitivity and background of the detectors were determined as 2.4 tracks cm^{-2} kBq^{-1} h^{-1} m^{-3} and 0.3 tracks mm^{-2}, respectively.

2.2.3. Quality control for the measurement

- ✓ QC Program applied in gamma radiation measurement for Soil, Biological samples was applied by measuring Soil (Japanese Soil: IAEA-TERC-2023-01), water, Vegetable (Japanese bamboo: Proficiency Test IAEA-TEL-2021-03), Samples supplied by IAEA,
- ✓ The deviation of the measured from the certified values for each radionuclides in the samples was less than ±5%.

A gamma-spectrometer used for the analysis of γ-emitters

An alpha-spectrometer used for the analysis of ^{210}Po

2.3. Effective dose assessment

2.3.1. Absorbed dose rate caused by gamma emitters at the ground surface 1 m

$D(nGy/h) = 0.46xA_{Ra} + 0.62xA_{Th} + 0.042xA_{K'}$ A: activity concentration in Bq/kg soil dw

2.3.2. External annual effective dose caused by gamma emitters from soil

✓ Indoor Annual Effective Dose: **IAED = D(Gy/h) x DCF x OF xT**

DCF: Dose conversion factor = 0.7 Sv/Gy

OF: indoor occupancy = 20% of the time a year (8760 h)

T: time of the year = 8760 h

✓ Outdoor Annual Effective dose: **OAED = D x DCF x OF x T**

OF= 80% of 8760 h, T = 8760h

✓ Total External Annual Effective Gamma Dose: **TAEGD = IAED + OAED**

2.3.2. Internal effective dose due to food ingestion

$$E_{in} = \sum_i (Q_i \text{ x } C_{i,r}) \text{ x } f_r \text{ x } g_r$$

Q_i: consumption rate of food *i or water* (kg/y or L/y)

$C_{i,r}$: activity concentration of radionuclide *r* in food *i* (Bq/kg *ww*)

f_r:the fractional absorption of radionuclide *r* in the gastrointestinal tract, and

g_r : the activity to dose conversion factor for the ingested radionuclide *r* (Sv Bq^{-1}).

(*The f_r and g_r values were taken from IAEA ,2014;*
Q_i were from the data of a National Nutrition Institute's survey, NNI, 2010)

2.3.3. Effective dose caused by ^{222}Rn and ^{220}Rn

$$E_{Rn\text{-}222} = C_{Rn\text{-}222} \text{ x } F_{Rn\text{-}222} \text{ x } K_{Rn\text{-}222} \text{ x } T$$

$$E_{Rn\text{-}220} = C_{Rn\text{-}220} \text{ x } F_{Rn\text{-}220} \text{ x } K_{Rn\text{-}220} \text{ x } T$$

$C_{Rn\text{-}222}$ and $C_{Rn\text{-}220}$ (Bq/m^3);
$F_{Rn\text{-}222}$ = 0.46: equilibrium factor for ^{222}Rn and its progenies
$F_{Rn\text{-}220}$ = 0.09: equilibrium factor for ^{220}Rn and its progenies
$K_{Rn\text{-}222}$ and $K_{Rn\text{-}220}$: activity to dose conversion factors:
$K_{Rn\text{-}222}$= 9 nSv. m^3/Bq.h; $K_{Rn\text{-}220}$ = 40 nSv.m^3/Bq.h; T =8760 h/y

2.3.3. Total Annual Effective Dose to the population in the study region

$$TAED = TAEGD + E_{cosmic} + E_{ing} + E_{Rn\text{-}222} + E_{Rn\text{-}220} \ \ (mSv/y)$$

2.4. Epidemiological studies

Blood of 40 persons from villages located close (within 500-1000m) to the REE deposit and 7 person from a village located at around 5 km from the REE deposit site, as the reference site, was sampled.

- ✓ Out of these numbers, 31 persons were female; 16 persons were male; 13 persons of age less than 20 year old, 18 persons of 30-50 years old, and 16 persons of older than 50 years.
- ✓ The blood samples were subject to the analysis for RBC, HbC, Platelet and WBC
- ✓ The frequency of chromosome aberrations in the lymphocytes of the inhabitants living close to the REE deposits and reference site was also analyzed.

3. Results and discussion

3.1. Annual Effective Doses

	Annual Effective Dose, mSv/y	
	Within REE deposit	Reference site
γ-IAED	0.33±0.14	0.21±0.03
γ- OAED	1.32±0.56	0.65±0.11
Total gamma dose	1.75±0.64	0.88±0.11
E_{ing}	0.22	0.22
E_{cosmic}	0.20	0.20
E_{inh}	2.82 ±0.87	1.23±0.55
Total AED	**4.57±1.08**	**2.53±0.56**

Annual Effective dose for the habitants within the REE deposits areas is in 1,.8 times higher than that for the habitnats in reference site!

3.2. Haematological parameters

3.2.1. t-test for Red Blood cell numbers of population in within REE deposits and Ref. site

By #Red Blood Cells

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	5.071304	4.954286
Variance	0.441198	0.235095
Observations	46	7
Hypothesized Mean Difference	0	
df	10	
t Stat	**0.563161**	
P(T<=t) one-tail	0.292865	
t Critical one-tail	1.812461	
P(T<=t) two-tail	0.58573	
t Critical two-tail	**2.228139**	

By Hemoglobin Number

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	137.587	140.4286
Variance	145.4923	167.2857
Observations	46	7
Hypothesized Mean Difference	0	
df	8	
t Stat	-0.54625	
P(T<=t) one-tail	0.299895	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.59979	
t Critical two-tail	2.306004	

t-test for haematological parameter between population living within REE deposits and Ref. site (cont.)

Wite Blood Cell number			
t-Test: Two-Sample Assuming Unequal Variances			
	Variable 1	Variable 2	
Mean	6.6608696	7.071429	
Variance	2.0788792	2.902381	
Observations	46	7	
Hypothesized Mean Difference	0		
df	7		
t Stat	-0.605455		
P(T<=t) one-tail	0.2819913		
t Critical one-tail	1.8945786		
P(T<=t) two-tail	0.5639825		
t Critical two-tail	2.3646243		

#Lymphocyte			
t-Test: Two-Sample Assuming Unequal Variances			
	Variable 1	Variable 2	
Mean	33.9587	36.75714	
Variance	60.9967	78.05619	
Observations	46	7	
Hypothesized Mean Difference	0		
df	7		
t Stat	-0.79225		
P(T<=t) one-tail	0.22711		
t Critical one-tail	1.894579		
P(T<=t) two-tail	0.45422		
t Critical two-tail	2.364624		

The haematological parameters of the habitants within REE deposits are not significantly diffeferent from that in referene sits as value of t-Stat < t Critical for all the parameters!

Results of the study for the chromosome aberration in the lymphocytes showed the frequency of the effect for the population living close to the REE deposits areas was the same as for the population in the reference site.

3.3. Radibiological study

An interview with the heads of the villages within the REE deposits revealed that the village population does not receive solid as well as leukemia cancer incidence!

4. Conlusion

1. The annual effective dose to the population living close to the REE deposits in Dong Pao, Tam Duong, Lai Chau is 1.8 times higher than that in reference site of 5 km far from the deposits;
2. The elevated radiation dose caused by radioactive component in REE deposits of the study region does not affect to the health of the local population. However,
3. It needs to have more numbers of population from reference site participating in the survey to ensure the statistic results.