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# Assessment of radon and heavy metals in drinking water from some areas of Ra-ngae District, Narathiwat Province, Thailand

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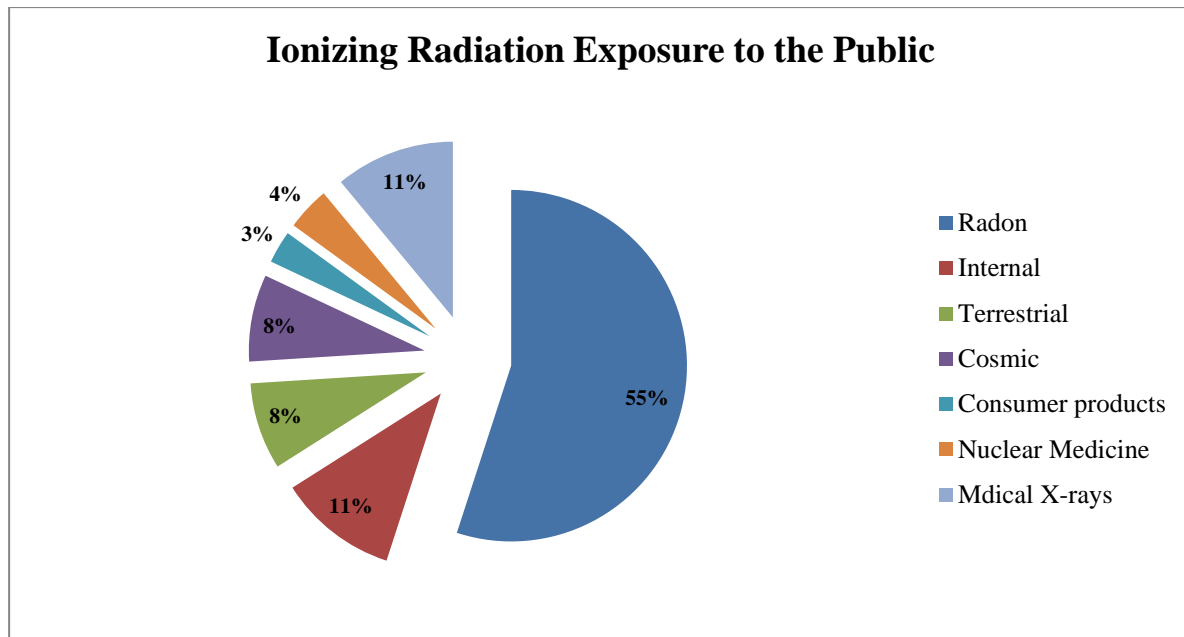
**Abstract.** The presence of radon and heavy metals in water is considered as a potential threat to public health. This study aimed to estimate the health risk related to radon concentration and heavy metals in drinking water samples, which taken from in Kalisa sub-district of Ra-ngae district, Narathiwat province. Radon concentration was measured by a solid state nuclear track detector (SSNTD, CR-39). The measured values ranged from 0.17 to 7.63 Bq l<sup>-1</sup>, which is much below the safe limits proposed by the US Environmental Protection Agency (US EPA) and UN Scientific Committee on the Effects of Atomic Radiation. The mean annual effective dose calculated for these samples was also found to be within the limits provided by WHO and EU council. Three mineral water sources were also analyzed for concentration of certain heavy elements like As, Fe, and, Pb by using inductively coupled plasma-optical emission spectrometer, (ICP-OES). Out of these, concentrations of As were found to exceed the permissible limits suggested by WHO. However, safety limit of national standard for arsenic in drinking water remains at 0.05 mg l<sup>-1</sup>.

## 1. Introduction

Radon (<sup>222</sup>Rn) is the heaviest of noble gas formed by radium (<sup>226</sup>Ra) which is a decay product of Uranium (<sup>238</sup>U). It has a half – life of 3.8 days and it emanates from rocks and soil. Being a radon gas, that diffuses through soil and rock during the radioactive decay process, it remains concentrated in surrounded places like underground, though cracks in foundation, cave or houses. When the water is consumed for drinking, cleaning, showering and other daily life routines, radon can easily escape from water into air and accumulated up to a very dangerous of indoor radon concentration. Since most of radon escape, living only minimal in the water itself, the health risk from ingestion of radon is considered minor. However, It should be noted that, if the radon levels are adequately high, in a long-term exposure may cause health damage from inhalation. Therefore, more than half of dose their natural background radiation exposure to humans come from radon (figure 1). The source of ionizing radiation exposure of the population of the United States shown that in figure 1, the main source of radiation exposure, with 55 % comes from radon sources [1, 2,]. Actual values vary depending on where people live and how they spend their time. It is well known that constant exposure to high radon concentrations may cause lung cancer [3, 4]. Because radon can diffuse into tissues of the stomach wall and damage sensitive cells, it might



cause stomach cancer in scarce cases. However, once radon enters the bloodstream through the stomach or small intestine, it is typically eradicated from the body through the lungs and will not target other organs. The majority of ingested radon is thought to be exhaled when the blood flow carries it to the lungs. Based on a National Academy of Science Report, EPA estimates that radon in drinking water causes about 168 cancer deaths per year: 11% from stomach cancer caused by consuming water and 89% from lung cancer caused by breathing radon released to indoor air from water [5]. Many studies have been done worldwide to determine its concentration in different environmental media in order to minimize its adverse effects on human health [6-11].



**Figure 1.** Ionizing Radiation Exposure to the public [1].

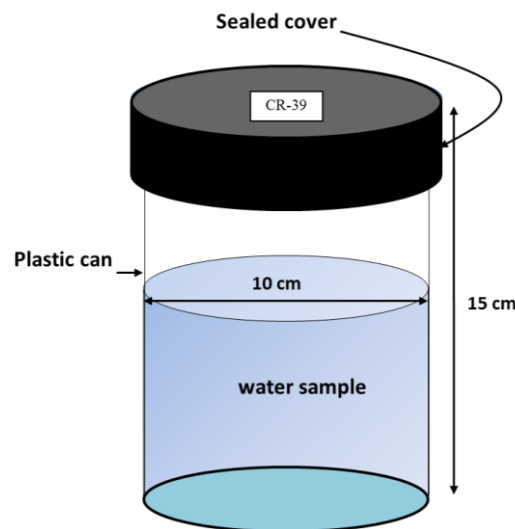
One of the important issues is heavy metals contamination in water that are thought to be one of the serious environmental problems all over the world, because of their carcinogenic effect on human and harmful impacts on the environment. Contamination of heavy metals in water is concerned, including toxic metals (such as mercury (Hg), chromium (Cr), lead (Pb), cadmium (Cd) and arsenic (As), iron (Fe), nickel (Ni), copper (Cu), zinc (Zn) etc. Due to some these metals is even human carcinogens health hazards caused by water that are reported by many authors from different parts of the world over a decade [12-15].

Therefore, this study aimed to assess the health risk related to radon concentration and heavy metals in drinking water in different sources from some area of Kalisa sub-district, Ra-ngae District, Narathiwat.

## 2. Theoretical Background

### 2.1 SSNTDs Technique

Radon concentration in drinking water was performed by using a solid-stated nuclear track detector (SSNTDs) with CR-39 (Columbia Resin 39). The detectors are samples of solid material where exposition to ionizing radiation generates tracks due to local damage of the detector. Radon detection by SSNTDs is based on the production of alpha particle tracks in polymeric material, such as cellulose nitrate films LR-115 and allyl diglycol carbonate plastic films CR-39 [16], which was used as detectors during the radon measurement in this study. Tracks are caused by the breaking of a long polymer chain. Along these tracks, the detector is more responsive to chemical attack. Therefore, these regions have a much faster velocity of etching with regard to undamaged material. Etching of several hours allows for enlarging of the damage to micrometer dimension, which can be observed with a microscope. In this study, the CR-39 plastic detector is usually placed inside a cylindrical tube of 10 cm inner diameter, and 15 cm in length shown in figure 2.



**Figure 2.** A schematic diagram of the SSNTDs technique, with CR-39 detector for determining radon in water samples.

### 2.2 Calculation of Radon concentration

The radon concentration in the water sample was obtained by the comparison of track density emitted on the CR-39 detector was placed in a sealed-cup in each water sample, and that of the standard water sample, which are shown in figure 3, by using the relation [17],

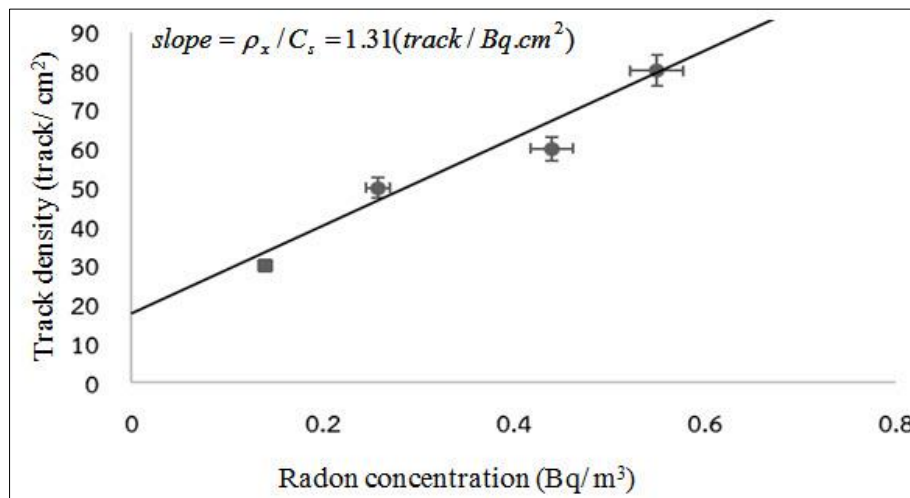
$$C_x = \rho_x (C_s / \rho_s) , \quad (1)$$

where,  $C_x$ : alpha particle concentration in the unknown sample.

$C_s$ : alpha particle concentration in the standard sample.

$\rho_x$ : track density of the unknown sample (track  $\text{cm}^{-2}$ ).

$\rho_s$ : track density of the standard sample (track  $\text{cm}^{-2}$ ).



**Figure 3.** The relation of radon gas concentration and track density in water standard sample.

### 2.3 Calculation of the annual effective dose in water sample

The annual effective dose of individual consumer due to intake of radon from drinking water can be evaluated using following the relation [18].

$$AED_w = C_w C_{Rw} D_{cw} , \quad (2)$$

where,  $AED_w$ : the annual effective dose ( $Sv\ y^{-1}$ ) due to ingestion of radionuclide from the consumption of water.

$C_w$  : the concentration of radon in the ingestion drinking water ( $Bq\ l^{-1}$ ).

$C_{Rw}$  : the annual intake of drinking water ( $370\ l\ y^{-1}$ ).

$D_{cw}$  : the ingestion dose conversion factor for radon ( $5 \times 10^9\ Sv\ Bq^{-1}$ ).

### 2.4 Calculation of radon exhalation rate ( $E_{ex}$ )

The radon exhalation rate of any sample is defined as the radon flux released from the surface area, when in the unit  $Bq\ m^{-2}\ h^{-1}$  can be obtained from the expression [19].

$$E_{ex} = \frac{CV\lambda}{A(T + \lambda^{-1}(e^{-\lambda T} - 1))} , \quad (3)$$

Where,  $C$ : the integrated radon exposure ( $Bq\ m^3$ )

$V$ : the volume of air in cup ( $m^3$ ) =  $0.00038\ m^3$

$\lambda$ : the decay constant of radon ( $h^{-1}$ ) =  $0.00755\ h^{-1}$

$A$ : the surface area of sample ( $m^2$ ) =  $0.003847\ m^2$

$T$ : the exposure time (h) = 30 day = 720 h

## 3. Methods

### 3.1 Sample collection

30 shallow well water samples and 3 mineral water sources were collected distribute in the study area. The well water sample collection was done in communities with comparatively high populations. The collection of well water samples was taken one sample per site in 250 ml plastic bottles by using water sampling tool that shown in figure 4.



**Figure 4.** Water sample collection in the study area: (a) and (b) shallow well water samples were collected from different homes, (c) and (d) mineral water sample were collected from different sources.

### 3.2 The experiment setup

Radon gas concentration in water samples was attained using the SSNTDs technique as shown in figure 2. After the exposure time (30 day), the track detectors (CR-39) were removed, etched in 6.25 N with NaOH solution at a temperature of 60° C for 6 h, The tracks were counted using an optical microscope at 100X and then using the calibration equation to convert the track density to radon concentration.

The heavy metals in 3 samples of mineral water sources were determined and analysis in this resolution by inductively coupled plasma optical emission spectrometry (ICP-OES) at Instrument Center, Faculty of Science and Technology, PSU, Pattani Campus.

## 4. Results and Discussion

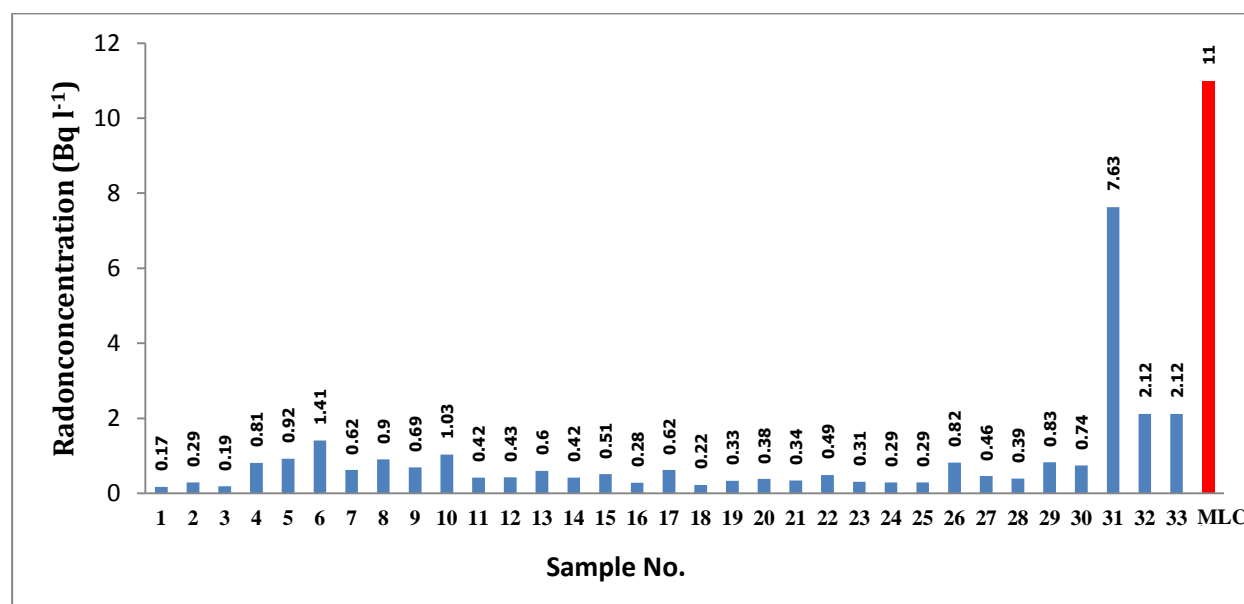
The results were investigated for radon concentration of drinking water samples, which collected different areas of the Ra-ngae District, Narathiwat province, Thailand. The radon measured values ranged from 0.17 to 7.63 Bq l<sup>-1</sup> shown in figure 5. The sample No.1- No.30 are well water and the sample No.31- No.33 are mineral water, which collected from the different sources in the area. The highest of radon concentration was obtained in mineral water sample No.31 with 7.63 ± 0.62 Bq l<sup>-1</sup>, and the average values of radon concentration are 0.85 ± 1.31 Bq l<sup>-1</sup>. These results are lower than the USEPA recommended Maximum Contaminant level (MCL) of 11 Bq l<sup>-1</sup> [20]. The results also

compared with the values recommended by EU council and WHO, it was found that the values of this study area are within the permissible limit [21, 22], that results were obtained in figure 5.

Table 1, represent the values of annual effective doses;  $AED_w$  of ingestion for water consumption (mineral water and well water). The committed effective dose intake water for adults due to ingestion of this water was estimated to evaluate potential health hazards doses of public exposure from radon. The annual effective dose  $AED_w$  in all studied samples were found to be lower than the recommended value of  $1 \text{ mSv y}^{-1}$  given by EPA (2000) [23]. Therefore, the radon exhalation rate;  $E_{ex}$  ranged from  $0.22 - 9.68 \text{ } \mu\text{Bq m}^{-2} \text{ h}^{-1}$ , while the average value is  $0.22 \pm 1.08 \text{ } \mu\text{Bq m}^{-2} \text{ h}^{-1}$ . Which, means the result is still within the allowed limit of EPA (2000).

The levels of some metals (As, Fe and Pb) were determined in mineral water, collected from 3 sources in during the summer season of the Kalisa sub-district, Ra-ngae District Narathiwat province, Thailand. The maximum concentration of heavy metals was found  $0.023 \text{ mg l}^{-1}$  for As in mineral water used for drinking in the study area. The average value of heavy metals in the mineral water was followed in order:  $\text{As} > \text{Pb} > \text{Fe}$ , that shown in figure 6.

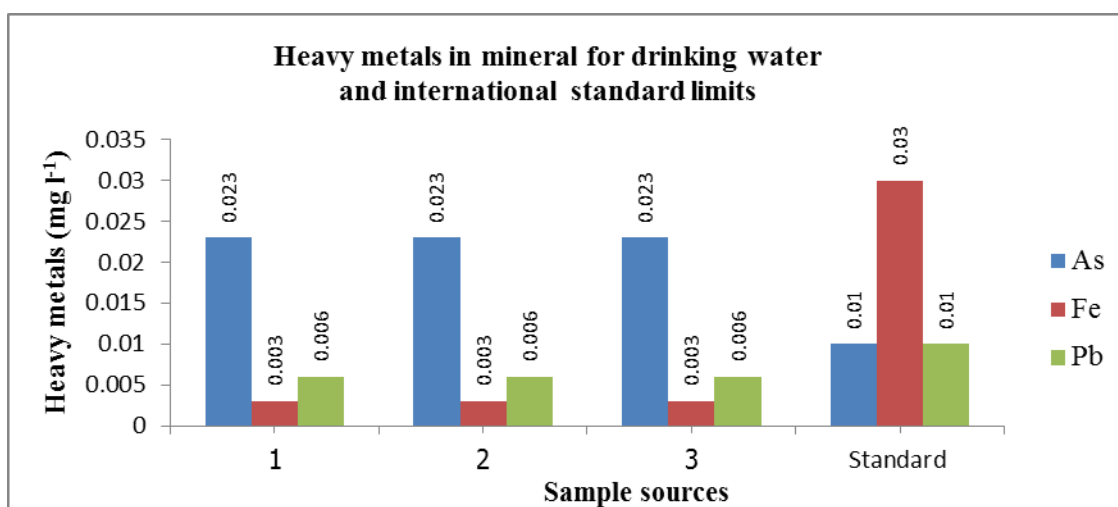
The arsenic (As) level was found to be higher than the permissible limit of recommended for drinking water of  $0.01 \text{ mg l}^{-1}$  given by WHO [24]. The concentration of arsenic with higher levels than other metals may be do to agricultural activities going on in the area. However, many countries have retained the earlier WHO guideline of  $0.05 \text{ mg l}^{-1}$  as the national standard or as an interim target. Countries where the national standard for As in drinking water remains at  $0.05 \text{ mg l}^{-1}$  include in table 2, that the currently accepted standards for As in drinking water in some selected countries [25], therefore, no health risk via consumption of water is expected of As. Furthermore, Pb and Fe did not exceed the recommended permissible limit is also to be considered safe for human consumption in drinking water.



**Figure 5.** Variation of radon concentration in drinking water collected from the Ra-ngae district, Narathiwat province, Thailand.

**Table 1** The result study of radon concentration ( $Rn_{con}$ ), annual effective dose ( $AED_w$ ), radon exhalation rate ( $E_{ex}$ ), in drinking water of the Ra-ngae district, Narathiwat province, Thailand.

Average values	Mineral water values $\pm$ SD	Well water values $\pm$ SD	Permissible limit values
$Rn_{con}$ ( $Bq\ l^{-1}$ )	$3.96 \pm 3.18$	$0.54 \pm 0.29$	11.1
$AED_w$ ( $\mu Sv\ y^{-1}$ )	$14.44 \pm 11.61$	$1.97 \pm 1.06$	100
$E_{ex}$ ( $\mu Bq\ m^{-2}\ h^{-1}$ )	$5.02 \pm 4.03$	$0.68 \pm 0.37$	38.89

**Figure 6.** Heavy metals in mineral for drinking water in units of ( $mg\ l^{-1}$ ) and international standard limits, the water collected from different sources of the Kalisa sub-district, Ra-ngae district, Narathiwat province, Thailand.**Table 2** The national acceptance standards for arsenic in drinking water [25].

Standard values	Countries
The standard is lower than $0.01\ mg\ l^{-1}$	Australia (1996) $0.007\ mg\ l^{-1}$
The standard is $0.01\ mg\ l^{-1}$	European Union (1998), Japan (1993), Jordan (1991), Laos (1999), Mongolia (1998), Namibia, Syria (1994)
The standard is lower than $0.05\ mg\ l^{-1}$ but higher than $0.01\ mg\ l^{-1}$	Canada (1999) $0.025\ mg\ l^{-1}$
The standard is $0.05\ mg\ l^{-1}$	Mexico (1994), Egypt (1995), Indonesia (1990), Oman (1987), Philippines (1987), Viet Nam (1989)

## 5. Conclusion

The present study was to investigate the public health risk from exposure to radon concentration and heavy metals in drinking water samples, which collected from the Kalisa sub-district, Ra-ngae district, Narathiwat province, Thailand. The results shown that the average value of radon concentration in drinking water as  $0.85 \pm 1.31\ Bq\ l^{-1}$  contain less than the recommended limit Maximum Contaminant level (MCL) of  $11\ Bq\ l^{-1}$  set by USEPA. Presence of metals with different sources of mineral water were found below the recommended levels of WHO, and national standards, so that the drinking water was safe for consumption and does not constitute the hazard to the citizens.



## Acknowledgements

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