Assessment of rare earth and actinides (U and Th) elements in soil samples from Kapar industrial area, Selangor

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Abstract. The study of rare earth and actinide elements have received attention nowadays due to rapid development in the extraction of the rare earth industry in Malaysia. Soil samples (18 areas) collected from the Kapar industrial area were analysed by using the neutron activation analysis (NAA) technique for the determination of rare earth elements and actinides (U, Th) concentration. The concentration of rare earth element such as La, Ce, Nd, Sm, Eu, Tb, Dy, Yb and Lu were ranged from 14.7–61.4, 30.6–132.8, 11.7–44.0, 2.12–9.60, 0.37–1.43, 0.03–1.57, 2.20–7.45, 0.28–0.81, and 1.99–4.15 mg/kg, respectively. The concentrations of uranium and thorium were a range of < 0.1–6.74 and 12.6–30.1 mg/kg, respectively. The results of geo-accumulation indicate the all-rare earth elements can be categorised as uncontaminated in all areas with an Igeo value below 0. The concentration of U can be categorised as uncontaminated to moderately contaminated (Igeo class 1) with Igeo values of 0 to 1 in the area of D, F, H, I, L, and N, whilst other areas can be categorised as uncontaminated with Igeo value < 0 (Igeo class 0). The thorium concentration in B, L, and N areas can be categorised as moderately contaminated with Igeo value 1 to 2 (Igeo class 2), whilst most of the area can be categorised as uncontaminated to moderately contaminated (Igeo values 0 to 1). The sources of Th contamination most likely originated from the anthropogenic and geogenic processes.

1. Introduction

In Malaysia, the pollution issues of rare earth elements (REEs) and actinide elements (U and Th) have become the attention of authorities from the government agencies, non-governmental organisations (NGOs), researchers, and members of the public. Rapid development in the rare earth industry in Malaysia related to REEs activities such as mining, mineral and rare earth processing, recycling and recovery of by-products, waste treatment of rare earth, and final disposal is also an issue. The U and Th elements become attention due to health hazards related to the radiation level. However, the effect of REEs concentration is still uncertain because the unknown threshold standard level of REEs will have an adverse effect on human health and other organisms.

Soil contamination may be increased due to continuous input from various human activities, such as industrial, agriculture, mining, logging activities and residential, highway, and road development.
Besides that, soil contamination can also originate from geogenic processes such as landslides, terrestrial runoff, and land erosion. Kapar area is one of the industrial areas in Selangor state of Malaysia. Many activities in the Kapar area include electrical, cable industry, aluminium smelter, glove, steel manufacturing, coating, plastic, and wood industries. Besides that, Kapar area was located the coal power plant, which could be contributed to the pollution. The objectives of the study in Kapar industrial area are to identify the level and distribution of rare earth and actinides (U and Th) elements.

Study of rare earth, U, Th, heavy metal and trace element of Gebeng industrial area, Manjung and central of Perak, Sabah, and Sarawak area in soil has been done for the purpose to identify the distribution, concentration level, and status of soil contamination[1–3]. Generally, the contamination level (Igeo) of RREs in the soil of the Gebeng industrial area can be classified as uncontaminated to moderately contaminated with Igeo values was ranged from < 0 to 1.6, whilst uranium (U) can be categorised as uncontaminated (Igeo value < 0) and thorium (Th) was categorised as uncontaminated to moderately contaminated (Igeo value < 0 – 0.9). The REEs contamination in soil of Manjung and central of Perak (0-10 cm depth) can be classified as uncontaminated to severely contaminated with Igeo value was ranged from less than 0 to 4.38. The uranium can be categorised as uncontaminated to moderately contaminated (Igeo value < 0 – 2.60), whilst the thorium can be categorised as uncontaminated to slightly contaminated (Igeo value < 0 – 1.98)[2]. The sources of soil contamination in the Manjung and central of Perak was originated from widely used fertiliser in agriculture activities which contains Dy, Lu, Tb, and U [2].

2. Methodology

2.1. Sampling of soil samples from Kapar industrial area.

Soil samples (15 cm depth) were collected from 18 areas of the Kapar Industrial area using an auger and transferred into a polyethylene bag (1 kg). Soil samples were then transported to the laboratory. At the laboratory, the soil samples were then dried at 60°C in an oven and ground using agate mortar. The powdered soil samples were kept in polyethylene bottles for analysis. The sampling areas of soil and the description of activities at the sampling site of Kapar areas were depicted in Figure 1 and Table 1, respectively.
Table 1. The description of activities in the sampling site.

| Location | Longitude  | Latitude  | Activities description |
|----------|------------|-----------|------------------------|
| Area A   | 101.444050 | 3.086883  | Residential area        |
| Area B   | 101.414833 | 3.135467  | Meru South Industrial Park – Electrical, cable industry, aluminium smelter, glove and steel industry |
| Area C   | 101.413933 | 3.086017  | Sg. Kapar Industrial Park – automotive, plastic, glove, wood, steel, costing industries. |
| Area H   | 101.408100 | 3.110433  | Close to Kapar coal power plant, and agriculture area |
| Area D   | 101.325917 | 3.117333  | Residential area, and agricultural area |
| Area E   | 101.396900 | 3.058667  | Agricultural area, and residential area |
| Area F   | 101.351550 | 3.098500  | Residential area        |
| Area G   | 101.368967 | 3.111217  | Residential area, and shop lot |
| Area I   | 101.401333 | 3.136033  | Residential area        |
| Area J   | 101.365667 | 3.122550  | Kapar Industry Park – manufacturing, coating, plastic, and wood industry. |
| Area L   | 101.356283 | 3.145483  | Residential area, and small agriculture area |
| Area M   | 101.332883 | 3.153767  | Residential area, and small agriculture area |
| Area N   | 101.318383 | 3.173833  | Tambak Jaya - Food industry, manufacturing, wood, furniture, plastic and coating industry |
| Area O   | 101.317650 | 3.200883  | Agriculture area, and residential area |
| Area P   | 101.309333 | 3.206017  | Agriculture area, and residential area |
| Area Q   | 101.315367 | 3.241900  | Residential area        |
| Area R   | 101.306417 | 3.201217  | Agriculture area, and residential area |

2.2 Analysis of soil samples by using Neutron Activation Analysis (NAA) technique

Approximately 0.20 g of powdered soil samples were weighed using an analytical balance and transferred into small polyethylene vials (Ø = 1 cm × H = 3 cm) and sealed prior to the irradiation process. The duplicate soil samples, blank, mix standard and standard reference materials (SRMs) (IAEA-SL-1, SRM 2709a-San Joaquin Soil) were irradiated in the PUSPATI TRIGA Mark II Reactor at the Malaysian Nuclear Agency for 6 hours at 750 kW, with a thermal flux of 4.0 × 10^{12} n.cm^{-2}s^{-1} (RR-Rotary rack)[4–7]. The cooling times of soil samples, blank, mix standard, and SRM were varied from 2 to 4 days for the first counting and 3 to 4 weeks for the second counting. The counting process for the analysis of long half-life radionuclides of rare earth elements (La, Ce, Nd, Sm, Eu, Tb, Dy, Lu, and Yb) and actinides elements (U and Th) in soil samples, blank and SRM were performed for one hour each by using high-resolution hyper-pure germanium (HpGe) gamma detector. A comparative method was applied to measure the elemental concentrations in the sample. The comparative method was based on the comparison between the net count of the samples and the weight of the standard to the net count of the standard and weight of the sample according to the Eq. (1) [4,8,9]and the data were reported in dry weight (d.w.).

\[
C_{\text{smp}} = C_{\text{std}} \times (W_{\text{std}} \times N_{\text{smp}})/(W_{\text{smp}} \times N_{\text{std}})
\]

where: \(N_{\text{smp}}\) and \(N_{\text{std}}\) are the net counts of the peak area of the sample and standard, respectively; \(C_{\text{smp}}\) and \(C_{\text{std}}\) are the concentration of the sample and standard, respectively; \(W_{\text{smp}}\) and \(W_{\text{std}}\) are the weight of the sample and standard, respectively.

2.3 Contour map

All contour maps of REEs, U and Th concentrations were done using Surfer software (version 11). Kriging interpolations were conducted to visually examine the contour map of the REEs, U and Th concentration distribution in the soil of the Kapar industrial area.
3. Results and discussion

3.1 The concentration of rare earth elements (REEs), U and Th in soil sample

Soil samples were collected in eighteen selected areas in Kapar industrial for the analysis of elemental pollution using the Neutron activation analysis (NAA) technique. The concentrations of rare earth, uranium, and thorium were tabulated in Table 3.1. The concentration of rare earth element such as La, Ce, Nd, Sm, Eu, Tb, Dy, Yb, and Lu were ranged from 14.7 – 61.4, 30.6 – 132.8, 11.7 – 44.0, 2.12 – 9.60, 0.37 – 1.43, 0.03 – 1.57, 2.20 – 7.45, 0.28 – 0.81, and 1.99 – 4.15 mg/kg, respectively whilst the concentrations of uranium and thorium (actinides) elements were range of < 0.1 – 6.74 and 12.6 – 30.1 mg/kg, respectively. Average concentrations of all elements of rare earth showed lower than igneous granitic rock - IGR crust values. However, the average concentration of U (4.13 mg/kg) and Th (20.3 mg/k) showed slightly higher than the igneous granitic rock - IGR crust values as tabulated in Table 2.

All elements of rare earth showed obviously higher in N area compared to other areas. The activities of the N area are related to the food industry, manufacturing, wood, furniture, plastic, and coating industries. The concentration of uranium (6.74 mg/kg) showed higher in the I area which is located at Kapar Industry Park and most activities related to manufacturing, coating, plastic, and wood industries. The B area is located at Meru South Industrial Park showed a higher thorium concentration (30.1 mg/kg) and was mainly related to industries of electrical, cable, aluminium smelter, glove, and steel.

### Table 2. The concentration (mg/kg) of rare earth element in soil of Kapar Industrial area.

| Location | La  | Ce  | Nd  | Sm  | Eu  | Tb  | Dy  | Lu  | Yb  | U   | Th  |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Area A   | 26.2| 56.2| 22.9| 3.82| 0.68| 0.94| 3.66| 0.57| 3.12| 3.27| 23.9|
| Area B   | 24.9| 39.9| 20.3| 2.12| 0.37| 0.53| 2.20| 0.59| 3.07| 3.92| 30.1|
| Area C   | 14.7| 30.6| 11.7| 2.38| 0.40| 0.55| 3.83| 0.41| 2.30| 3.21| 13.8|
| Area D   | 38.6| 89.4| 31.3| 6.02| 0.79| 0.97| 6.83| 0.46| 2.73| 4.58| 20.4|
| Area E   | 20.6| 74.2| 21.1| 3.48| 0.60| 0.75| 4.42| 0.44| 2.42| 3.83| 16.9|
| Area F   | 34.7| 78.5| 37.5| 5.55| 0.73| 0.92| 5.43| 0.43| 2.85| 4.90| 22.4|
| Area G   | 61.3| 42.7| 17.4| 2.55| 0.56| 0.63| 3.52| 0.42| 2.15| 2.77| 21.3|
| Area H   | 31.8| 80.3| 30.8| 4.93| 0.67| 0.76| 3.62| 0.28| 2.05| 5.18| 20.5|
| Area I   | 24.2| 54.4| 20.4| 5.52| 0.67| 0.73| 4.37| 0.39| 3.21| 6.74| 19.6|
| Area J   | 16.7| 37.7| 14.4| 3.13| 0.44| 0.61| 3.25| 0.38| 2.30| <0.1 | 19.9|
| Area K   | 17.2| 40.6| 12.6| 3.48| 0.53| 0.76| 3.13| 0.36| 2.33| <0.1 | 19.0|
| Area L   | 17.5| 37.8| 15.4| 4.25| 0.71| 1.01| 4.50| 0.61| 3.63| 5.08| 26.5|
| Area M   | 25.5| 60.6| 28.9| 4.82| 0.65| 0.72| 3.40| 0.29| 1.99| 3.25| 12.6|
| Area N   | 61.4| 133 | 44.0| 9.60| 1.43| 1.57| 7.45| 0.81| 4.15| 6.35| 28.2|
| Area O   | 32.8| 70.5| 24.1| 5.07| 0.78| 0.72| 4.13| 0.49| 2.41| 2.89| 18.0|
| Area P   | 46.8| 68.3| 35.8| 5.67| 0.74| 0.03| 2.68| 0.33| 3.25| 3.91| 16.7|
| Area Q   | 37.1| 58.4| 25.4| 4.57| 0.61| 0.03| 2.88| 0.30| 2.81| 3.18| 14.4|
| Area R   | 27.3| 63.1| 15.8| 3.62| 0.58| 0.80| 4.71| 0.31| 2.46| 3.00| 20.3|
| Average  | 31.1| 62.0| 23.9| 4.48| 0.66| 0.69| 4.11| 0.44| 2.74| 4.13| 20.3|
| IGR crust* | 45.0| 81.0| 33.0| 8.80| 1.40| 1.40| 6.30| 1.10| 3.50| 3.00| 8.50|

*Igneous granitic rock - IGR crust value published by Turekian and Wedepohl, 1961.
3.2 Geo-accumulation (I_{geo}) index

The geo-accumulation index (I_{geo}) was originally introduced by Müller (1969)[10]. The I_{geo} was used to define the degree of anthropogenic pollution by comparing the current concentration status of elemental over the pre-industrial levels of pollution in soil or sediment [4,11–15]. In Malaysia, the lack of the pre-industrial (background) data value of elements concentration acts as a reference crust value. Several authors published the reference crust value of elements such as the upper continental crust – 1 (UCC – 1)[16], mud from Queensland (MUQ)[17], igneous granitic rock (IGR)[18] and continental crust average (CCA)[19] for the comparison. In this study, rare earth element, uranium and thorium contamination in the soil of Kapar industrial area was compared to the igneous granitic rock-ICR crust values for the calculation of geo-accumulation index as described by Elias, 2021[20]. The geo-accumulation index can be calculated using Eq. (2).

\[ I_{geo} = \log_2 \left( \frac{C_n}{1.5 \times B_n} \right) \]  \hspace{1cm} (2)

where \( C_n \) is the measured concentration of interest element, \( B_n \) is the background value of interest reference element concentration from crust value (igneous granitic rock- IGR crust) [18] and 1.5 is a correction factor for the variation of the background values due to lithogenic effects in the soil. I_{geo} can be classified into seven classifications to determine the level of soil pollution. The soil pollution classification are as follows: \( I_{geo} \) value < 0 = uncontaminated (\( I_{geo} \) class 0), \( I_{geo} \) value > 0 to 1 = uncontaminated to moderately contaminated (\( I_{geo} \) class 1), \( I_{geo} \) value > 1 to 2 = moderately contaminated (\( I_{geo} \) class 2), \( I_{geo} \) value > 2 to 3 = moderately to strongly contaminated (\( I_{geo} \) class 3), \( I_{geo} \) value > 3 to 4 = strongly contaminated (\( I_{geo} \) class 4), \( I_{geo} \) value > 5 = extremely to extremely contaminated (\( I_{geo} \) class 5) and \( I_{geo} \) value > 5 = extremely contaminated (\( I_{geo} \) class 6)[11–15,21].

The status of the geo-accumulation index, the jitter and whisker plot of \( I_{geo} \) value for the RREs, U, and Th contamination in the soil of Kapar industrial area was depicted in Figure 3.1. The horizontal line showed the median value in the box plot, whilst the lower border of the horizontal line illustrates the 25 percentiles value and 75 percentiles value are the top borders of the horizontal line of the box.

\( I_{geo} \) values and \( I_{geo} \) class of the RREs, U and Th in soil sample of Kapar industrial area were tabulated in Table 3. The \( I_{geo} \) values of all RREs shown below 0 indicate uncontaminated (\( I_{geo} \) class 0) except for the Nd element in the area of N with \( I_{geo} \) value of 0.13 (\( I_{geo} \) class 1). The concentration of RREs in the N and other areas is still considered uncontaminated (no instruction from industries activities) based on the geo-accumulation index, as shown in Figure 3.1. The \( I_{geo} \) value of the U in the area of D, F, H, I, L, and N were 0.03, 0.12, 0.20, 0.58, 0.18, and 0.50, respectively (Table 3.2). Those areas can be categorised as uncontaminated to moderately contaminated with \( I_{geo} \) class 1, while other areas were categorised as uncontaminated with \( I_{geo} \) value < 0 (\( I_{geo} \) class 0). The area of B, L, and N can be categorised as moderately contaminated with \( I_{geo} \) values = 1 to 2 (\( I_{geo} \) class 2) whilst other areas can be categorised as uncontaminated to moderately contaminated with \( I_{geo} \) value = 0 to 1 (\( I_{geo} \) class 1) for the contamination of thorium element. Precaution needs to be taken by the industries to prevent the release of elemental contamination into the soil by regularly monitoring the release of dust from the chimney and retention pond, especially in the areas that were categorised as moderately contaminated (\( I_{geo} \) class 2). The government agencies and authorities should regularly monitor the industries to follow the Environment Quality Act 1974.
| Location | La  | Ce  | Nd  | Sm  | Eu  | Tb  | Dy  | Lu  | Yb  | U   | Th  |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Area A   | -1.37 | -1.11 | -1.11 | -1.79 | -1.64 | -1.16 | -1.37 | -1.55 | -0.75 | -0.46 | 0.90 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area B   | -1.44 | -1.61 | -1.28 | -2.64 | -2.51 | -2.00 | -2.10 | -1.49 | -0.78 | -0.20 | 1.24 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (2) |
| Area C   | -2.20 | -1.99 | -2.08 | -2.48 | -2.41 | -1.93 | -1.30 | -2.00 | -1.19 | -0.49 | 0.12 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area D   | -0.81 | -0.44 | -0.66 | -1.13 | -1.41 | -1.11 | -0.47 | -1.84 | -0.94 | 0.03 | 0.68 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area E   | -1.71 | -0.71 | -1.23 | -1.92 | -1.80 | -1.49 | -1.10 | -1.91 | -1.12 | -0.23 | 0.41 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area F   | -0.96 | -0.63 | -0.40 | -1.25 | -1.52 | -1.19 | -0.80 | -1.93 | -0.88 | 0.12 | 0.82 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area G   | -0.14 | -1.51 | -1.51 | -2.37 | -1.92 | -1.73 | -1.43 | -1.97 | -1.29 | -0.70 | 0.74 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area H   | -1.09 | -0.60 | -0.68 | -1.42 | -1.66 | -1.46 | -1.39 | -2.58 | -1.36 | 0.20 | 0.69 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1)  | (1) |
| Area I   | -1.48 | -1.16 | -1.28 | -1.26 | -1.65 | -5.91 | -1.11 | -2.10 | -0.71 | 0.58 | 0.62 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1)  | (1) |
| Area J   | -2.01 | -1.69 | -1.78 | -2.08 | -2.26 | -1.79 | -1.54 | -2.12 | -1.19 | -5.49 | 0.64 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area K   | -1.97 | -1.58 | -1.98 | -1.92 | -1.98 | -1.47 | -1.60 | -2.20 | -1.17 | -5.49 | 0.58 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area L   | -1.95 | -1.68 | -1.68 | -1.64 | -1.57 | -1.05 | -1.07 | -1.44 | -0.53 | 0.18 | 1.06 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area M   | -1.40 | -1.00 | -0.77 | -1.45 | -1.70 | -1.55 | -1.48 | -2.53 | -1.40 | -0.47 | -0.02 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (2) |
| Area N   | -0.14 | 0.13  | -0.17 | -0.46 | -0.55 | -0.42 | -0.34 | -1.04 | -0.34 | 0.50 | 1.15 |
|          | (0)  | (1)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1)  | (2) |
| Area O   | -1.04 | -0.79 | -1.04 | -1.38 | -1.42 | -1.55 | -1.20 | -1.74 | -1.12 | -0.64 | 0.49 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area P   | -0.53 | -0.83 | -0.47 | -1.22 | -1.50 | -6.11 | -1.82 | -2.31 | -0.69 | -0.20 | 0.39 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area Q   | -0.86 | -1.06 | -0.96 | -1.53 | -1.77 | -6.09 | -1.71 | -2.46 | -0.90 | -0.50 | 0.18 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
| Area R   | -1.31 | -0.95 | -1.65 | -1.87 | -1.85 | -1.39 | -1.01 | -2.42 | -1.09 | -0.59 | 0.67 |
|          | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (0)  | (1) |
3.3 Contour map for distribution of REEs concentration in soil of Kapar industrial area

The contour maps of the distribution of REEs, U, and Th concentrations in the soil of the Kapar industrial area were depicted in Figure 3.2 (a) – (k). The groups of REEs (La, Ce, Nd, Sm, Eu, and Dy) and (Lu and Yb) were shown a similar trend of contour map. All rare earth elements showed higher concentrations in the N area compared to other areas. The N area which located in the activities of the manufacturing, food, wood, furniture, plastic, and coating industries. The distribution of U concentration showed equally distributed in all areas, within the range of 3.0 – 6.8 mg/kg except for the area of J and K slightly low concentration (Figure 3.2 (j)). The concentration distribution of Th showed higher in B area and close to mountain area (terrestrial area). The B Area was located electrical industry, cable manufacturing, aluminium smelting industry, glove, and steel industries. However, the indication from the contour map (Figure 3.2 (k)) also showed the possible sources of Th contamination most likely originated from the geogenic processes of the terrestrial such as land erosion, landslide, and land clearing for residential development.
(a) La  
(b) Ce  
(c) Nd  
(d) Sm  
(e) Eu  
(f) Tb
Figure 2. (a) – (k): Contour map of REEs, U and Th concentration distribution in the soil of Kapar industrial area.
4. Conclusion
The REEs such as Eu, La, Sm, Tb, Dy, Ce, Nd, Lu, and Yb showed higher in Area N compared to other areas, which is located food industry, manufacturing, wood, furniture, plastic, and coating industries. Igeo index values of REEs in the soil of Kapar industrial were less than 0, indicating the soil can be categorised as uncontaminated with REEs. The Igeo index of U can be categorised uncontaminated and as uncontaminated to moderately contaminated, whilst Th can be categorised as uncontaminated to moderately contaminated. Th concentration showed higher in Area B which is located of industrial activities such as electrical, cable industry, aluminium smelter, glove, and steel industry. Besides that, other possible sources of Th could also be originated from geogenic processes such as land erosion, landslide, and terrestrial runoff.

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