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# Geochemistry of Rare Earth Elements in Pahang River Sediment, Malaysia

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**ABSTRACT**
Rare earth elements (REE) are a set of 17 chemically similar metallic elements including 15 lanthanides, scandium and yttrium. The current status of REE as a global strategic commodity has encouraged the identification of REE ore deposits. This research is carried out to identify the mining feasibility of fluvial sediment REE and to understand the sediment's physical and chemical characteristics and effects on the geochemical behaviour of REE in the longest river of Peninsular Malaysia namely Pahang River. Surface sediment samples were collected along Pahang River (n=44) in approximately 10 km distance intervals. The sediment samples were analyzed using XRF to determine the major oxide content. Meanwhile, REE content in the sediment samples was extracted using the Total Digestion method and analysed using ICP-MS. The results show the average value of ΣREE at surface sediments of the Pahang River is 42.58 ppm and can be considered too low to be economically mined. Each area shows higher fractionation of light REE than heavy REE with negative europium anomalies, suggesting sediments in this area were derived from felsic rocks. The concentration of REE in Pahang River surface sediments was controlled by the porosity and organic matter as showed by the correlation of ΣREE with porosity ($R^2$=0.65) and organic matter content ($R^2$=0.71). In conclusion, this research's findings are generally useful for further REE mineral exploration and fluvial sediment environmental monitoring.

***Keywords:*** XRD analysis; Rare Earth Elements; Pahang River, Organic Matter

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## Introduction

Located on the east coast of Peninsular Malaysia, the Pahang River (459 km) is the longest and river in Peninsular Malaysia with a main bedrock of granite and limestone; and sedimentary rock e.g. shale, sandstone, respectively [1], it contributes annual fluvial sediment fluxes of 20.4 Mt discharge into the southern South China Sea [2]. Fluvial sediments as the particles or grains eroded from rocks and soils and then deposited on the river bed, carry traces of the parent earth materials [[3], [4], [5]], including rare earth elements (REEs) which are a group of chemically similar, naturally occurring elements but present in trace amounts [6].

The current high-tech trend in the development and miniaturization of electronic products, clean energy generators, military systems, communication systems, and satellites which rely on the magnetic, luminescent, and electrochemical properties of REEs has immensely induced the increasing demand for REEs and economically making them a strategic commodity [[7], [8]]. Studying the elemental distribution via geochemistry in Pahang Rivers can help us not only to understand the systems and history of Earth, and inspect environmental conditions but more importantly to explore mineral deposits which are high anomalies of certain commercial elements or minerals over appreciable areas which are profitable to be mined [[9], [10], [11], [12], [13]].

Recent research has reported the potential of granite as an REE source [14], therefore, we expect Pahang River with a major granitic background might have the potential to develop fluvial REE mining. In this research, REEs were traced along the river sediments, as one of the geochemical mapping methods in regional and detailed scales is to trace the pathway of elemental movement and locate the source of elements or minerals. There are limited detailed studies available on the geochemistry and mineralogy of the tropical rivers from the East Coast of Peninsular Malaysia as previous studies were focused on the near- and estuary area [[6], [15]], therefore, geochemical studies focusing on REE from upper to lower courses of tropical river sediment is thus needed to decipher the broad view of the sediment provenance. This study was performed to characterize the chemical composition of Pahang River sediments in terms of major oxides and elements, minerals, and rare earth elements (REE) and evaluate the geochemical behaviour of REE in tropical Pahang Rivers.

## Experimental part

*Sample Collection*

The surface sediments were collected at 0 to 20cm from the river bed along the Pahang River by using an Ekman grab sampler, sealed in labelled transparent polyethylene (PE) bag and stored at 4℃ for further processing. The coordinates of the sampling locations were acquired by global positioning system (GPS) Garmin GPSMAP 62s and mapped by geographic information system ArcGIS 10.2, as shown in Figure 1 and Table 1.

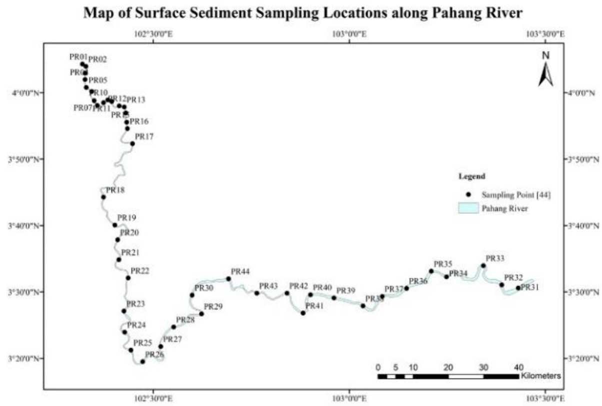


**Figure 1** - Map of surface sediment sampling location along the longest river in Peninsular Malaysia namely the Pahang River

**Table 1** - Coordinates of surface sediment sampling locations along the Pahang River

| Sampling Locations | Latitude | Longitude |
|---|---|---|
| PR 01 | 04° 04' 19.20" N | 102° 19' 08.40" E |
| PR 02 | 04° 03' 57.59" N | 102° 19' 40.80" E |
| PR 03 | 04° 02' 56.40" N | 102° 19' 33.59" E |
| PR 04 | 04° 01' 58.80" N | 102° 19' 33.59" E |
| PR 05 | 04° 00' 46.79" N | 102° 19' 44.39" E |
| PR 06 | 04° 00' 10.80" N | 102° 20' 34.80" E |
| PR 07 | 03° 58' 47.99" N | 102° 20' 56.40" E |
| PR 08 | 03° 58' 04.79" N | 102° 21' 25.19" E |
| PR 09 | 03° 58' 30.00" N | 102° 22' 22.80" E |
| PR 10 | 03° 58' 55.20" N | 102° 23' 02.40" E |
| PR 11 | 03° 58' 40.80" N | 102° 23' 38.40" E |
| PR 12 | 03° 58' 01.20" N | 102° 24' 46.79" E |
| PR 13 | 03° 57' 50.39" N | 102° 25' 33.60" E |
| PR 14 | 03° 56' 56.39" N | 102° 25' 48.00" E |
| PR 15 | 03° 55' 33.60" N | 102° 25' 55.20" E |
| PR 16 | 03° 54' 36.00" N | 102° 26' 02.39" E |
| PR 17 | 03° 52' 19.19" N | 102° 26' 49.20" E |
| PR 18 | 03° 44' 16.80" N | 102° 22' 22.80" E |
| PR 19 | 03° 40' 04.80" N | 102° 24' 07.20" E |
| PR 20 | 03° 37' 51.59" N | 102° 24' 32.40" E |
| PR 21 | 03° 34' 51.60" N | 102° 24' 43.20" E |
| PR 22 | 03° 32' 06.00" N | 102° 26' 09.60" E |
| PR 23 | 03° 27' 07.19" N | 102° 25' 29.99" E |
| PR 24 | 03° 23' 56.40" N | 102° 25' 37.20" E |
| PR 25 | 03° 21' 14.40" N | 102° 26' 34.79" E |
| PR 26 | 03° 19' 30.00" N | 102° 28' 22.79" E |
| PR 27 | 03° 21' 46.80" N | 102° 31' 08.40" E |
| PR 28 | 03° 24' 43.19" N | 102° 33' 07.20" E |
| PR29 | 03° 26' 41.99" N | 102° 37' 22.80" E |
| PR 30 | 03° 29' 31.20" N | 102° 35' 56.40" E |
| PR 31 | 03° 30' 35.99" N | 103° 25' 51.59" E |
| PR 32 | 03° 31' 04.79" N | 103° 23' 20.39" E |
| PR 33 | 03° 33' 57.59" N | 103° 20' 31.19" E |
| PR 34 | 03° 32' 16.79" N | 103° 14' 52.80" E |
| PR 35 | 03° 33' 07.20" N | 103° 12' 32.40" E |
| PR 36 | 03° 30' 32.39" N | 103° 08' 45.60" E |
| PR 37 | 03° 29' 20.39" N | 103° 05' 02.40" E |
| PR 38 | 03° 27' 53.99" N | 103° 02' 05.99" E |
| PR 39 | 03° 29' 05.99" N | 102° 57' 39.59" E |
| PR 40 | 03° 29' 34.79" N | 102° 54' 03.59" E |
| PR 41 | 03° 26' 49.20" N | 102° 52' 55.20" E |
| PR 42 | 03° 29' 49.19" N | 102° 50' 27.59" E |
| PR 43 | 03° 29' 49.19" N | 102° 45' 50.39" E |
| PR 44 | 03° 31' 58.79" N | 102° 41' 31.19" E |

*Analysis of Major Oxides and REE in the sediment samples*

The sediment sample collected was weighted before and after being heated at 105°C with air ventilation of 50% in the oven until a constant weight was no longer reduced after repetitive heating. The sediment particles with mesh size below 250-µm were selected to be homogenized and pulverized to less than 45µm in a laboratory ball mill machine before sample digestion.

The samples were then analysed for major oxides analysis using Energy Dispersion XRF (EDXRF) which is outfitted with a rhodium (Rh) x-ray tube that operates at a voltage of 40 kV, and a current of 30µA for integration times ranging from 60-600 sec.

For REE analysis, about 0.2 g of the pulverized sediment sample was introduced into a 50-ml polytetrafluoroethylene (PTFE) beaker. 68% nitric acid (HNO3), 48% hydrofluoric acid (HF) and 50% hydrogen peroxide (H2O2) with a volumetric ratio of 4:3:2 with a total of 27 ml were poured carefully into the PTFE beaker and swirled to homogenize [[16], [17]]. All REE excluding Pm, were analyzed by Perkin-Elmer Elan DRC-e ICPMS at the laboratory of Universiti Kebangsaan Malaysia.

## Results and Discussion

*Physical Characteristic and Organic Matter in Pahang River Sediments*

Pahang River sediments, as shown in Figure 2, were mainly dominated by relatively clear grains (PR01-PR05, PR08-PR11, PR13-15, PR21, PR28, PR30-PR32, PR35, PR37-39) and other greyish powdery coating grains instead of light brown of Kelantan River surface sediments due to different mineralogical composition and weathering conditions. Dry-bulk density of surface sediments along Pahang River, as shown in Figure 3 had a x̅±s of 1.44±0.45g/cm$^3$, was least dense at PR42 (0.73g/cm$^3$) and was densest at PR10(2.07g/cm$^3$). Organic matter content (OM) of Pahang surface sediments also had a fluctuated pattern with x̅±s of 3.23±3.19%, highest OM at PR40(10.05%), and lowest OM at PR28 (0.20%) as shown in Figure 3. Pahang River surface sediments OM shows a strong positive correlation with porosity ($R^2$=0.87) suggesting their OM were highly influenced by the porosity as shown in Table 2.

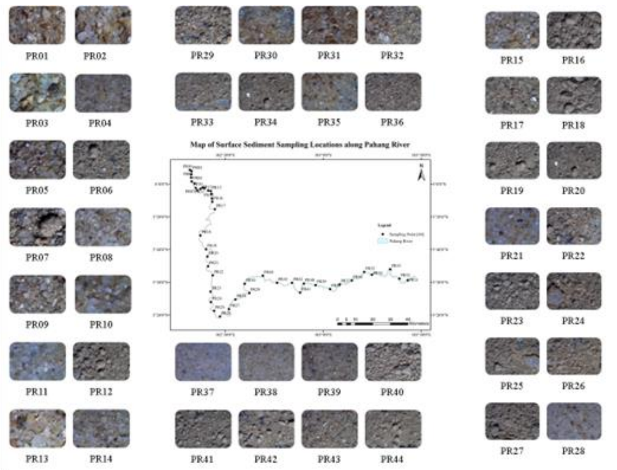


**Figure 2** - Pahang River surface sediments under stereoscopic at 5x magnification

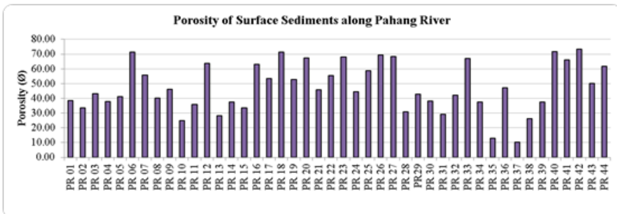


**Figure 3** - Porosity of surface sediments along Pahang River

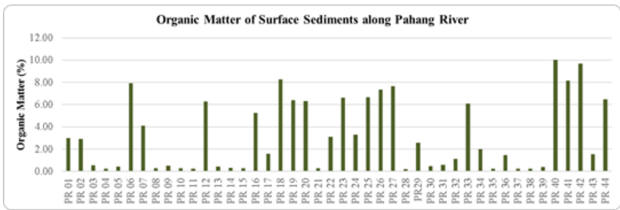


**Figure 4** - Organic matter content of surface sediments along the Pahang River

**Table 2** - Correlation between physical characteristics of Pahang River surface sediments

| Correlation Coefficient, rPR | Organic Matter (%) | Dry-bulk density (g/cm$^3$) | Porosity (ϕ) |
|---|---|---|---|
| Organic Matter (%) | 1 | | |
| Dry-bulk density (g/cm$^3$) | -0.875 | 1 | |
| Porosity (ϕ) | 0.875 | -1 | 1 |

*Major Oxide in Pahang River Sediment*

The result of major oxides in sediments from the Pahang River is shown in Table 3. Maturity of Pahang river surface sediments was ranked as the following: PR08> PR24> PR30> PR10> PR21>PR02> PR28> PR13> PR11> PR32> PR15> PR03> PR14> PR29> PR04> PR09> PR01> PR34> PR31> PR05> PR12> PR36> PR35> PR17> PR25> PR37> PR07> PR38> PR16> PR41> PR18> PR33> PR39> PR20> PR19>

PR40> PR42> PR22> PR44> PR27> PR06> PR23> PR43> PR26. By applying the geochemical classification proposed by Herron (1988) [18], among 44 sampling locations along Pahang River, there are 22 subarkose, 7 wacke, 6 arkose, 3 litharenite, 3 quartz arenite and 3 shale as shown in Figure 5.

**Table 3** - Major Oxides of Pahang River surface sediments

| Location | Major Oxide Percentage (%wt) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $Al_2O_3$ | CaO | $Fe_2O_3$ | $K_2O$ | MgO | MnO | $Na_2O$ | $SiO_2$ | $TiO_2$ |
| PR 01 | 3.79 | 0.332 | 1.68 | 3.98 | 0.388 | 0.202 | 0.381 | 88.4 | 0.136 |
| PR 02 | 3.4 | 0.113 | 0.594 | 2.83 | 0.242 | 0.179 | 0.265 | 91.4 | 0.127 |
| PR 03 | 3.54 | 0.16 | 0.665 | 3.4 | 0.269 | 0.162 | | 91.6 | 0.165 |
| PR 04 | 3.94 | 0.101 | 0.684 | 3.98 | 0.259 | 0.168 | 0.102 | 90.7 | |
| PR 05 | 4.37 | 0.102 | 0.769 | 4.69 | 0.265 | 0.109 | | 89.5 | 0.1 |
| PR 06 | 18.1 | 0.419 | 4.73 | 6.49 | 0.888 | 0.186 | | 68 | 0.739 |
| PR 07 | 9.73 | 0.25 | 2.11 | 5.74 | 0.377 | 0.121 | | 81.2 | 0.302 |
| PR 08 | 2.95 | 0.171 | 0.69 | 2.38 | 0.2 | 0.101 | | 93.5 | |
| PR 09 | 3.99 | 0.28 | 0.721 | 4.05 | 0.27 | 0.18 | | 90.4 | 0.105 |
| PR 10 | 3.21 | 0.186 | 0.811 | 2.82 | 0.28 | 0.264 | | 92.2 | 0.146 |
| PR 11 | 2.83 | | 0.538 | 2.97 | 0.19 | 0.216 | | 93.2 | |
| PR 12 | 12.8 | 0.431 | 4.09 | 4.31 | 0.704 | 0.236 | | 76.5 | 0.476 |
| PR 13 | 3.14 | 0.125 | 0.812 | 2.89 | 0.236 | 0.105 | 0.214 | 92.3 | 0.102 |
| PR 14 | 3.42 | 0.116 | 1.13 | 3.75 | 0.359 | 0.139 | | 90.8 | 0.237 |
| PR 15 | 3.19 | 0.162 | 0.594 | 3.35 | 0.176 | 0.212 | | 92.3 | |
| PR 16 | 14.1 | 0.469 | 3.88 | 5.69 | 0.846 | 0.183 | 0.314 | 73.6 | 0.518 |
| PR 17 | 6.47 | 0.131 | 1.41 | 5.58 | 0.447 | 0.117 | 0.336 | 85.1 | 0.225 |
| PR 18 | 18.2 | 0.373 | 4.98 | 5.83 | 0.921 | 0.191 | 0.12 | 68.2 | 0.751 |
| PR 19 | 15.7 | 0.295 | 3.83 | 6.34 | 0.705 | 0.128 | | 72 | 0.649 |
| PR 20 | 15.3 | 0.436 | 3.89 | 6.33 | 0.765 | 0.17 | 0.137 | 72.1 | 0.612 |
| PR 21 | 3.3 | 0.175 | 1.17 | 2.83 | 0.271 | 0.125 | | 92.1 | |
| PR 22 | 10.9 | 0.5 | 3 | 7.06 | 0.759 | 0.155 | | 76.6 | 0.469 |
| PR 23 | 17.2 | 0.519 | 5.97 | 6.54 | 0.725 | 0.159 | | 67.4 | 0.708 |
| PR 24 | 9.58 | 0.199 | 6.66 | 2.32 | 1.99 | 0.123 | | 78.3 | 0.678 |
| PR 25 | 14.4 | 0.277 | 3.56 | 5.18 | 0.643 | 0.148 | | 74.9 | 0.538 |
| PR 26 | 10.7 | 0.919 | 9.6 | 10.2 | 0.554 | 0.388 | 2.32 | 63.3 | 1.24 |
| PR 27 | 16.7 | 0.527 | 4.64 | 6.47 | 0.807 | 0.238 | 0.48 | 68.8 | 0.725 |
| PR 28 | 3.15 | 0.125 | 0.683 | 2.89 | 0.23 | 0.22 | | 92.6 | 0.08 |
| PR29 | 4.53 | 0.471 | 1.54 | 3.63 | 0.348 | 0.153 | 0.376 | 87.8 | 0.265 |
| PR 30 | 3.1 | 0.14 | 0.64 | 2.78 | 0.2 | 0.14 | | 92.9 | 0.11 |
| PR 31 | 5.79 | 0.117 | 1.18 | 4.31 | | 0.195 | | 88.2 | 0.141 |
| PR 32 | 4.19 | 0.15 | 0.79 | 3.14 | 0.26 | 0.16 | | 91.2 | 0.11 |
| PR 33 | 13.2 | 0.474 | 4.12 | 6.25 | 0.85 | 0.206 | 0.65 | 72.9 | 0.583 |
| PR 34 | 8.45 | 0.126 | 1.54 | 4.05 | 0.399 | 0.104 | | 84.8 | 0.334 |
| PR 35 | 1.91 | 0.387 | 1.77 | 5.83 | | 0.187 | | 89.1 | 0.09 |
| PR 36 | 7.91 | 0.162 | 1.74 | 5.37 | 0.413 | 0.12 | | 83.9 | 0.243 |
| PR 37 | 2.02 | 0.413 | 1.71 | 6.19 | 0.25 | 0.88 | | 88.4 | 0.102 |
| PR 38 | 2.11 | 0.427 | 1.61 | 6.31 | | 0.214 | | 88.4 | 0.125 |
| PR 39 | 2.27 | 0.41 | 2.05 | 7.46 | | 0.271 | | 86.5 | 0.105 |
| PR 40 | 19.9 | 0.325 | 5.22 | 5.92 | 0.794 | 0.208 | | 66.5 | 0.803 |
| PR 41 | 18.9 | 0.241 | 4.75 | 5.78 | 0.783 | 0.119 | 0.117 | 68.2 | 0.751 |
| PR 42 | 20 | 0.354 | 5.4 | 6 | 0.815 | 0.249 | | 66 | 0.838 |
| PR 43 | 5.4 | 0.532 | 3.41 | 10.5 | | 0.224 | | 78.5 | 0.565 |
| PR 44 | 15.8 | 0.253 | 4.01 | 6.69 | 0.692 | 0.143 | | 71.4 | 0.63 |

*Distribution of REEs in Pahang River Sediments*

Pahang River surface sediments had an average total REE of 42.581 ppm, LREE of 34.531 ppm HREE of 8.050 ppm as shown in Figure 6, and also in Table 4. PR06 with LREE 95.789 ppm and HREE 22.888 ppm contributing to a total REE 118.677 ppm was the highest among other Pahang River surface sediments, also having cerium being the main contributor as shown in Figure 7. The enrichment factor of each REE is also far below the economic value as illustrated in Figure 8. The spatial distribution of total REE was mapped in Figure 9.

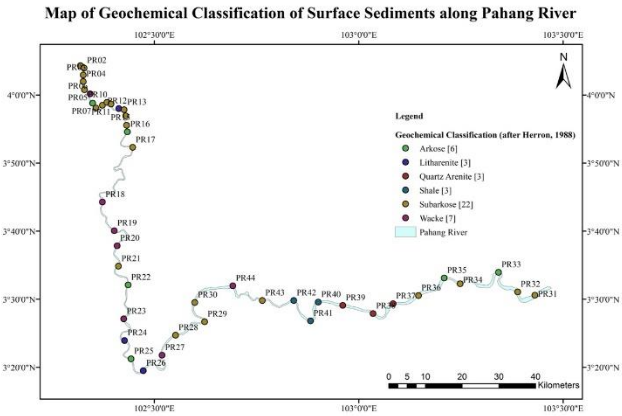


**Figure 5** - Map of geochemical classification of Pahang River surface sediments

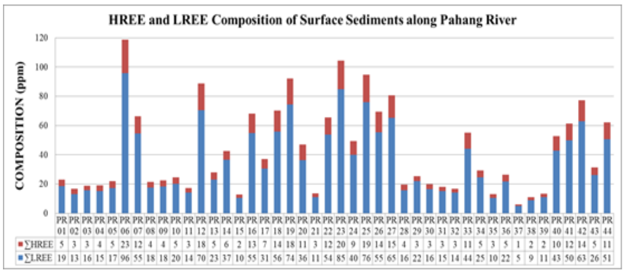


**Figure 6** - Total heavy rare earth elements (HREE) and light rare earth elements (LREE) composition (without decimal places) in Pahang River sediments.

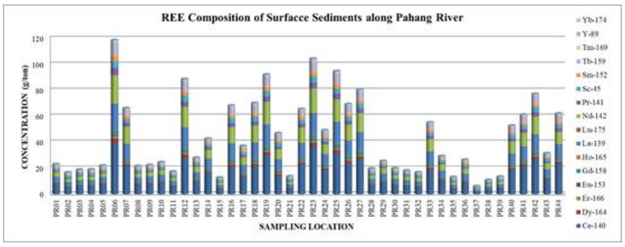


**Figure 7** - REE elemental composition in Pahang River surface sediments.

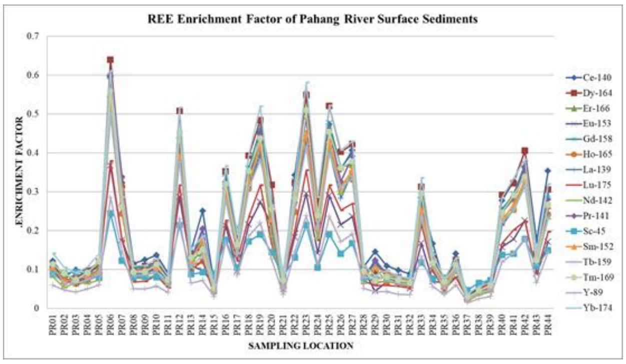


**Figure 8** - REE enrichment factor in Pahang River sediments

**Table 4** - Total REEs of surface sediments along Pahang River

| Location | ∑LREE | ∑HREE | Total REE |
|---|---|---|---|
| PR01 | 18.527 | 4.537 | 23.064 |
| PR02 | 13.179 | 3.483 | 16.662 |
| PR03 | 15.603 | 3.218 | 18.822 |
| PR04 | 15.186 | 3.774 | 18.959 |
| PR05 | 17.262 | 4.664 | 21.926 |
| PR06 | 95.789 | 22.888 | 118.677 |
| PR07 | 54.641 | 11.623 | 66.264 |
| PR08 | 17.507 | 4.019 | 21.526 |
| PR09 | 18.267 | 4.078 | 22.345 |
| PR10 | 20.073 | 4.540 | 24.613 |
| PR11 | 14.224 | 3.138 | 17.362 |
| PR12 | 70.406 | 18.264 | 88.670 |
| PR13 | 22.864 | 5.155 | 28.019 |
| PR14 | 36.535 | 6.113 | 42.648 |
| PR15 | 10.441 | 2.283 | 12.724 |
| PR16 | 54.835 | 13.399 | 68.235 |
| PR17 | 30.536 | 6.607 | 37.143 |
| PR18 | 55.736 | 14.441 | 70.177 |
| PR19 | 74.311 | 17.805 | 92.117 |
| PR20 | 36.394 | 10.611 | 47.005 |
| PR21 | 10.932 | 2.748 | 13.680 |
| PR22 | 53.841 | 11.751 | 65.591 |
| PR23 | 84.791 | 19.595 | 104.386 |
| PR24 | 39.846 | 9.363 | 49.210 |
| PR25 | 75.970 | 18.828 | 94.799 |
| PR26 | 55.253 | 14.164 | 69.417 |
| PR27 | 65.230 | 15.349 | 80.579 |
| PR28 | 15.749 | 3.930 | 19.680 |
| PR29 | 21.958 | 3.461 | 25.419 |
| PR30 | 16.463 | 3.450 | 19.914 |
| PR31 | 15.127 | 2.968 | 18.095 |
| PR32 | 14.000 | 2.794 | 16.794 |
| PR33 | 44.104 | 11.074 | 55.179 |
| PR34 | 24.546 | 4.700 | 29.246 |
| PR35 | 10.375 | 2.684 | 13.059 |
| PR36 | 21.726 | 4.715 | 26.441 |
| PR37 | 4.922 | 1.153 | 6.075 |
| PR38 | 8.928 | 1.938 | 10.866 |
| PR39 | 11.005 | 2.394 | 13.399 |
| PR40 | 42.858 | 9.908 | 52.767 |
| PR41 | 49.740 | 11.509 | 61.249 |
| PR42 | 62.832 | 14.393 | 77.226 |
| PR43 | 26.182 | 5.285 | 31.467 |
| PR44 | 50.676 | 11.393 | 62.069 |

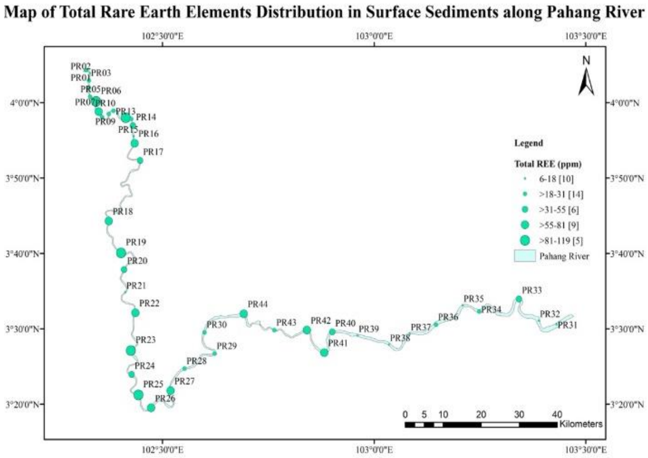


**Figure 9** - Maps of total REE in Pahang River sediments.

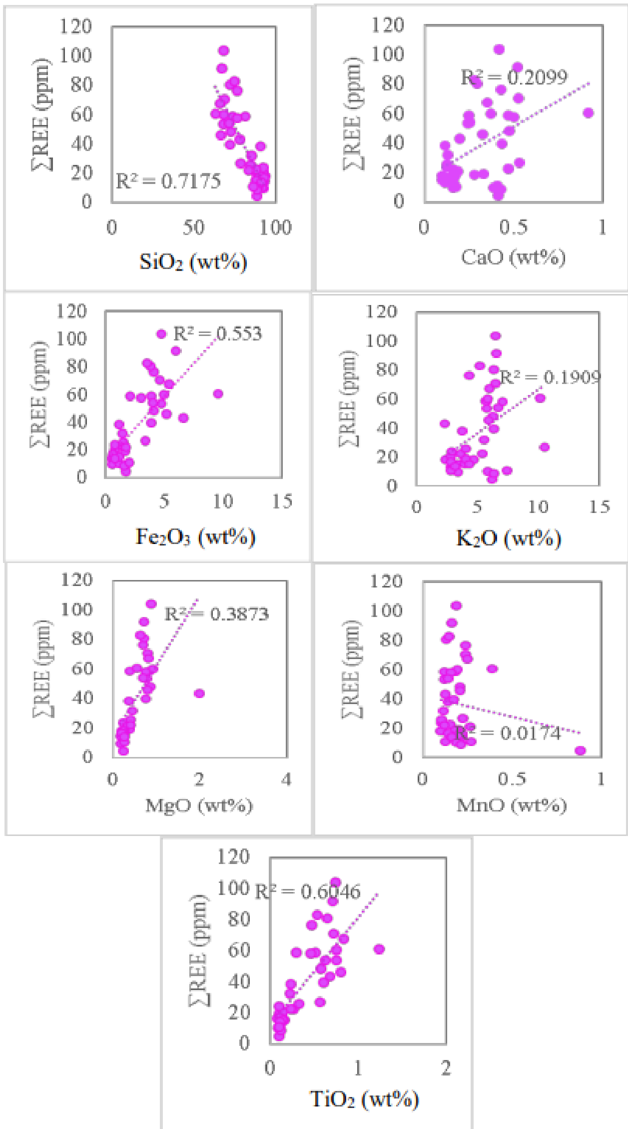


**Figure 10** - Relationship of Pahang River sediment total REE and major oxides

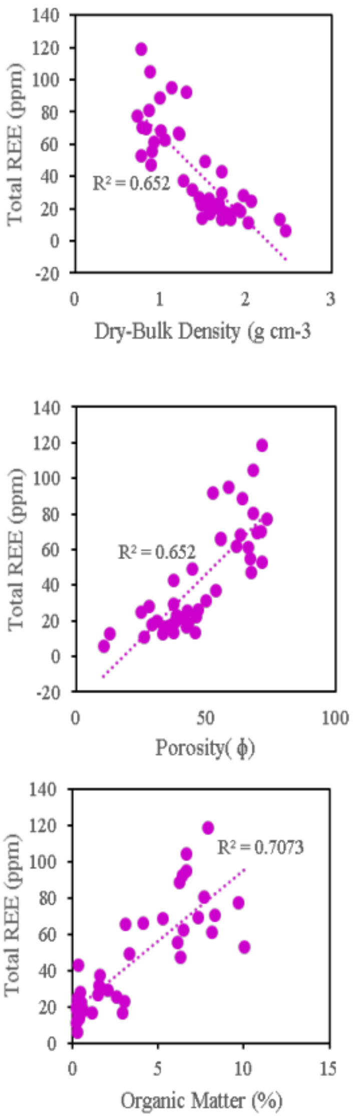


**Figure 11** - Correlation of Pahang River sediment total REE and physical characteristics.

*Geochemical behaviour of REE in Pahang River sediment*

The correlation of total REE in Pahang River sediments was made with oxides as shown in Figure 10. The strongest and weakest regression of surface sediment ΣREE was with $Al_2O_3$ ($R^2$=0.749) and $Na_2O$ (r=0.0039) respectively. Aluminium minerals in Pahang River surface sediments were thus inferred to have a profound effect on the occurrence of REE. Total REE in Pahang River surface sediment had a moderate positive correlation with $Al_2O_3$ (r=0.867), $Fe_2O_3$ (r=0.744), and $TiO_2$ (r=0.778), showing REE concentrated in aluminium, iron, and titanium minerals; a moderate negative correlation with $SiO_2$(r=-0.848) showing dilution effect of silicates in REE concentrations. REE in titanite has been proposed to interpret the growth of titanite [19]. Other than chemical influence, total REE also shows some correlations with physical characteristics: dry-bulk density and porosity ($R^2$=0.652) and organic matter ($R^2$=0.7073) as shown in Figure 11. As bulk density and porosity of sediments are mainly controlled by grain size, shape, packing, and distribution [20], it indicates grain size effect may be a factor controlling REE distribution in Pahang River sediments.

## Conclusions

Surface sediments collected along Pahang River had a total REE of 42.581 ppm, LREE of 34.53 ppm and HREE of 8.050 ppm. The rivers' sediments showed too low REE content and thus are not economically feasible to mine. The chondrite normalized REE showed a higher fraction of LREE to HREE in this area. Our results show the geochemical behaviour of REE in fluvial sediments was controlled by porosity and organic matter content. In addition, aluminium minerals in the Pahang River have a profound effect on REE occurrence.

**Conflicts of interest.** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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# Малайзиядағы Паханг өзенінің шөгіндісіндегі сирек жер Элементтерінің геохимиясы

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**ТҮЙІНДЕМЕ**
Сирек жер элементтері (СЖЭ) – 15 лантаноидтарды, скандий және иттрийді қоса алғанда, 17 химиялық ұқсас металдық элементтердің жиынтығы. СЖЭ-ның жаһандық стратегиялық тауар ретіндегі ағымдағы мәртебесі СЖЭ кен орындарын анықтауды ынталандырады. Бұл зерттеу Малайзия түбегінің ең ұзын өзенінде, атап айтқанда Паханг өзенінде шөгінді СЖЭ өндірудің орындылығын анықтау және шөгінділердің физикалық және химиялық сипаттамаларының Малайзия түбегінің ең ұзын өзеніндегі СЖЭ геохимиялық әрекетіне әсерін түсіну үшін жүргізіледі. Жер үсті шөгінділерінің үлгілері Паханг өзенінің бойынан (n=44) шамамен 10 км қашықтықта жиналды. Шөгінді үлгілері негізгі оксид құрамын анықтау үшін РФТ көмегімен талданды. Сонымен қатар, шөгінді үлгілеріндегі ΣREE мәндері Total Digestion әдісімен алынған және ICP-MS көмегімен талданған. Нәтижелер Паханг өзенінің беткі шөгінділеріндегі ΣREE орташа мәндері миллионда 42,58 бөлігі ғана болатынын көрсетеді және оны экономикалық тұрғыдан өндіру үшін тым төмен. Әрбір аймақ теріс еуропий аномалиялары бар ауыр СЖЭ-ге қарағанда жеңіл СЖЭ фракциясының жоғарырақ екендігін көрсетеді, бұл осы аймақтағы шөгінділер қышқыл жыныстардан алынады. Паханг өзенінің беткі шөгінділеріндегі СЖЭ концентрациясы кеуектілікпен және органикалық заттармен анықталды, бұл ΣREE кеуектілігімен (R2=0,65) және органикалық заттардың мөлшерімен (R2=0,71) корреляция арқылы көрсетілген. Қорыта келгенде бұл зерттеудің нәтижелері СЖЭ минералдарын одан әрі барлау және өзен шөгінділеріне экологиялық мониторинг жасау үшін пайдалы.

***Түйін сөздер:*** рентген құрылымдық талдау; сирек жер элементтері; Паханг өзені, органикалық заттар

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# Геохимия редкоземельных элементов в отложениях реки Паханг, Малайзия

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**АННОТАЦИЯ**
Редкоземельные элементы (РЗЭ) представляют собой набор из 17 химически схожих металлических элементов, в том числе 15 лантаноидов, скандия и иттрия. Текущий статус РЗЭ как глобального стратегического товара способствовал выявлению месторождений РЗЭ. Это исследование проводится для определения возможности добычи речных отложений РЗЭ и понимания влияния физических и химических характеристик отложений на геохимическое поведение РЗЭ в самой длинной реке полуострова Малайзия, а именно в реке Паханг. Пробы поверхностных отложений были собраны вдоль реки Паханг (n=44) на расстоянии примерно 10 км. Образцы отложений были проанализированы с помощью РФА для определения содержания основного оксида. Тем временем содержание РЗЭ в пробах отложений было экстрагировано методом полного расщепления и проанализировано с помощью ICP-MS. Результаты показывают, что средние значения ΣREE в поверхностных отложениях реки Паханг составляют 42,58 частей на миллион, и их можно считать слишком низкими для экономичной добычи. На каждом участке наблюдается более высокое фракционирование легких РЗЭ, чем тяжелых РЗЭ, с отрицательными аномалиями европия, что позволяет предположить, что отложения на этом участке произошли из кислых пород. Концентрация РЗЭ в поверхностных отложениях реки Паханг контролировалась пористостью и органическим веществом, о чем свидетельствует корреляция ΣРЗЭ с пористостью (R2=0,65) и содержанием органического вещества (R2=0,71). В заключение можно сказать, что результаты этого исследования в целом полезны для дальнейшей разведки полезных ископаемых РЗЭ и экологического мониторинга речных отложений.

***Ключевые слова:*** рентгеноструктурный анализ; Редкоземельные элементы; Река Паханг, органическое вещество

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