UNIVERSITI TEKNOLOGI MARA

DISTRIBUTION AND SOURCE IDENTIFICATION OF HEAVY METALS, TRACE AND RARE EARTH ELEMENTS IN SURFACE SEDIMENT OF LINGGI RIVER

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PhD

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification

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ABSTRACT

Linggi River is one of the important rivers in Negeri Sembilan which has received natural and anthropogenic pollutions from the Linggi basin's activities. The purpose of this study was to identify the pollution sources in the river and estuary of Linggi surface sediment. The heavy metals, trace and rare earth elements (REEs) were determined by the neutron activation analysis (NAA) and inductively coupled plasma–mass spectrometry (ICP-MS) while the stable isotope ratio of carbon-13 ($\delta^{13}C$) and nitrogen-15 ($\delta^{15}N$) was measured by an isotopic ratio–mass spectrometry (IR-MS). The mean concentrations of As, Cd, Pb, Sb, Zn, Br, Cr, Cs, Hf, Rb, Ta, Th, U, La, Ce, Pr, Nd, Sm, Tm and Yb were relatively higher compared to the reference crust values of the respective elements. The $\delta^{13}C$ in Linggi river surface sediment was originated from the terrestrial organic matter of C3 plants and marine plants while the $\delta^{13}C$ in estuary sediment was originated from the marine plants. Meanwhile, the $\delta^{15}N$ in Linggi surface sediment was originated from the terrestrial organic matter of C3 plants and fertilizers. Geo-accumulation (I_{geo}) result of heavy metals and trace elements was categorised as uncontaminated to very strong contaminated (class 0 to class 6) while the REEs was categorised as uncontaminated and moderately to strongly contaminated (class 0 to class 3). The modified degree of contamination (*mCd*) result indicates most of the locations of Linggi surface sediments were categorised as a moderate degree of contamination. The comparison of Linggi surface sediment quality to sediment quality guidelines (SQG) indicates that arsenic (As) concentration values in most of the locations were >68% which was above the probable effect concentration (PEC) values (33.0mg/kg). This infers that Linggi surface sediments are polluted with As and could give adverse effects on the benthic organism. The Pearson correlation indicates As showed a good correlation with Sb, Fe and C. The Ni showed a strong relationship with the element of Sb, Zn, Br, Co, Cr, Fe, Sc and S while Cs indicates a positive relationship with elements of Rb, Ta, U and Yb. The Pr indicates a strong relationship with Sm, Gd, Tb, Ho, Er, Tm, Yb and Lu. The PCA and CA results were in good agreement with each other where the Factor 1 of principal component (PC) showed the factor loading of La, Th, Sm, Ce, Nd, Tb, Yb, Hf, Lu and Gd was similar to cluster 3 of CA. Factor 2 of PCA was dominated by As, Cd, Cu, Pb, Sb, Zn, Fe, Sc, Eu, Ni and C which was similar to cluster 6 of CA. Factor 3 of PCA showed a factor loading of Br, Cr, Co and S. Factor 4 of PCA showed a factor loading of Ho, Tm, Er, Pr and Gd which was similar to cluster 1 of CA. Factor 5 of PCA was dominated by Rb, Ba, Cs, Ta and U which was similar to cluster 2 of CA. Factor 6 of PCA showed a factor loading of H which was similar to cluster 4 of CA. The discriminant analysis indicates the sources of REEs such as Gd, Pr, Ho, Sm, Tm, Lu, La, Tb, Th and Yb were originated from the forest area. The trace elements such as Cs, Rb, Ta, Pb, U, Er and H were originated from the urban area. The elements of As, Cd, Cr, Co, Cu, Fe, Sb, S, Sc Ni and Zn were originated from the agricultural area. Element of Br had a higher concentration in the estuary area and was originated from the seawater. The unique characteristic of heavy metals, trace elements and REEs can be used as an indicator to identify the sources of pollution in Linggi's surface sediment.

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