Geochemical Characterization of Egyptian Red Sea Mangrove Sediments: Composition, Pollution Sources, and Environmental Implications

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Presentation outlines

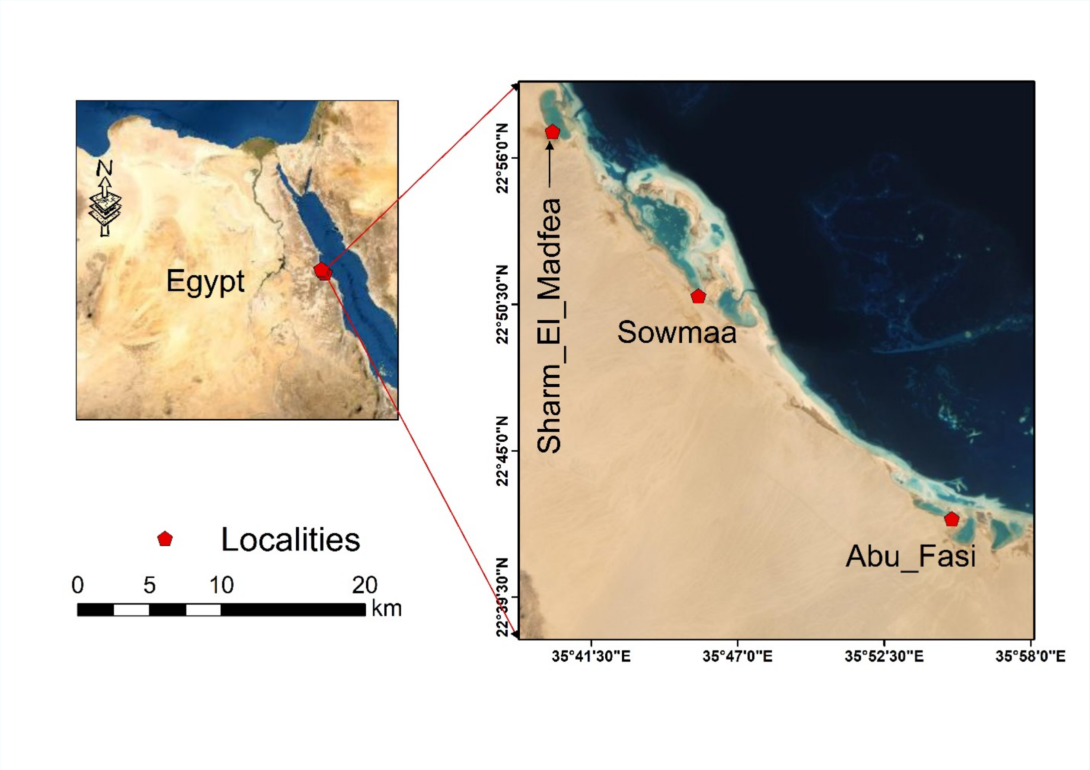
Introduction

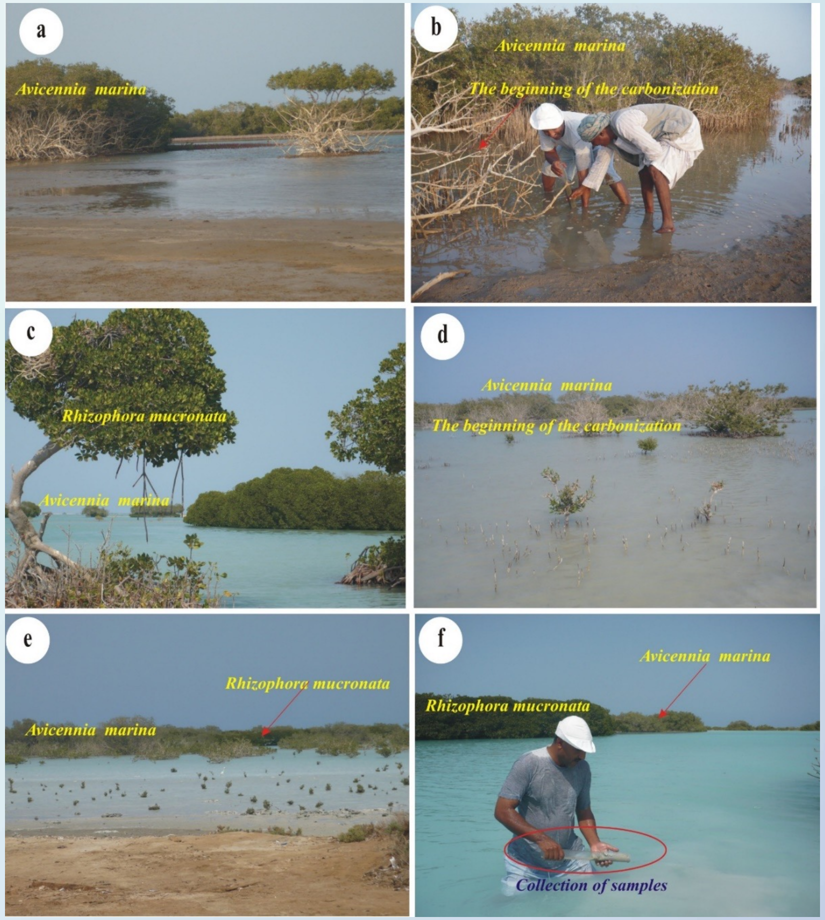
- Mangrove sediment environment refers to the soil or substrate on which mangrove trees grow. They also can serve as a sink or source of trace metals in an aquatic ecosystem.
- Three areas were surveyed (Sharm El Madfea, Sowmaa and Abu Fasi) and they are located along the coastal areas of the Egyptian Red Sea.
- The investigated areas are of great importance for Egypt as the elemental composition of the mangrove sediments in these areas will help to obtain more information about the ecological situation and a better understanding the geochemical characteristics not only of the mangroves but also of the marine life.
- The elemental content of the samples studied was determined using inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma atomic-emission spectrometry (ICP-AES).

Objectives

- Characterize the mangrove sediments in terms of the elemental composition
- Perform bivariate, multivariate statistical analyses, and discriminant plots to elucidate the geochemical provenance of sediments
- Calculate the extent of pollution using several indices
- Identify the sources of pollution of the mangrove sediments,
- Establish baseline data related to the geochemical elements that could serve as a background for possible changes in the future

Investigated area and sampling





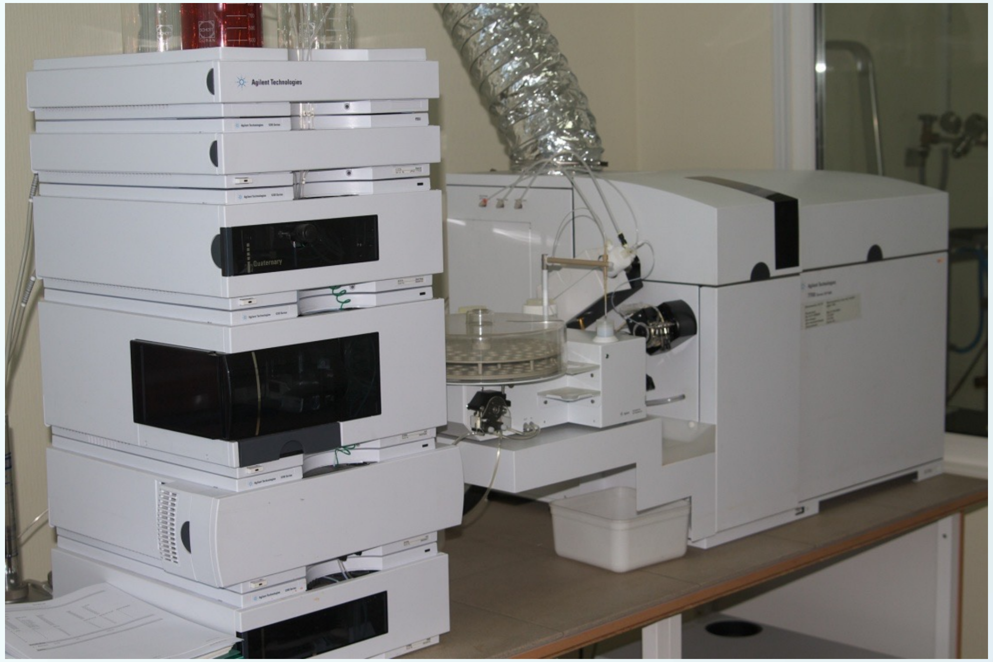
A total of 26 samples of mangrove sediments were collected from the three areas of Sharm El Madfea, Sowmaa and Abu Fasi.

Analytical techniques

- The elemental analysis by ICP-AES and ICP-MS methods was carried out in the Laboratory of Analytical Chemistry of the shared research facilities "Primorsky Centre for Local Elemental and Isotopic Analysis" of the Far East Geological Institute, Far Eastern Branch of the Russian Academy of Sciences, Vladivostok, Russia.
- An open acid digestion technique with mixture of HNO_3-HF-$HClO_4$ was used to perform the samples preparation.
- Major elemental composition was determined using the iCAP 7600 Duo (Thermo Scientific, USA) inductively coupled plasma atomic emission spectrometer in radial plasma observation mode.
- Samples were analyzed for a wide range of trace elements using the Agilent 7700x and 8800 (Agilent Technologies, USA) quadrupole inductively coupled plasma mass spectrometers.
- The quality of the measurements was weighted using certified reference materials (CRM)
- The relative standard deviation RSD% ranged from 0.16 % for SiO_2 to 17.8 % for Te, respectively.

Analytical techniques

ICP-MS Agilent 7700x (Agilent Technologies Int., USA)



- Highly accurate determination of trace elements with atomic mass from 7 to 238 a.m.u. in various objects is performed.
- ICP-MS Agilent 7700 can operate as a standalone station and as a detector for HPLC, determining not only the concentration, but the speciation of elements, e.g. As (III) or As (V).

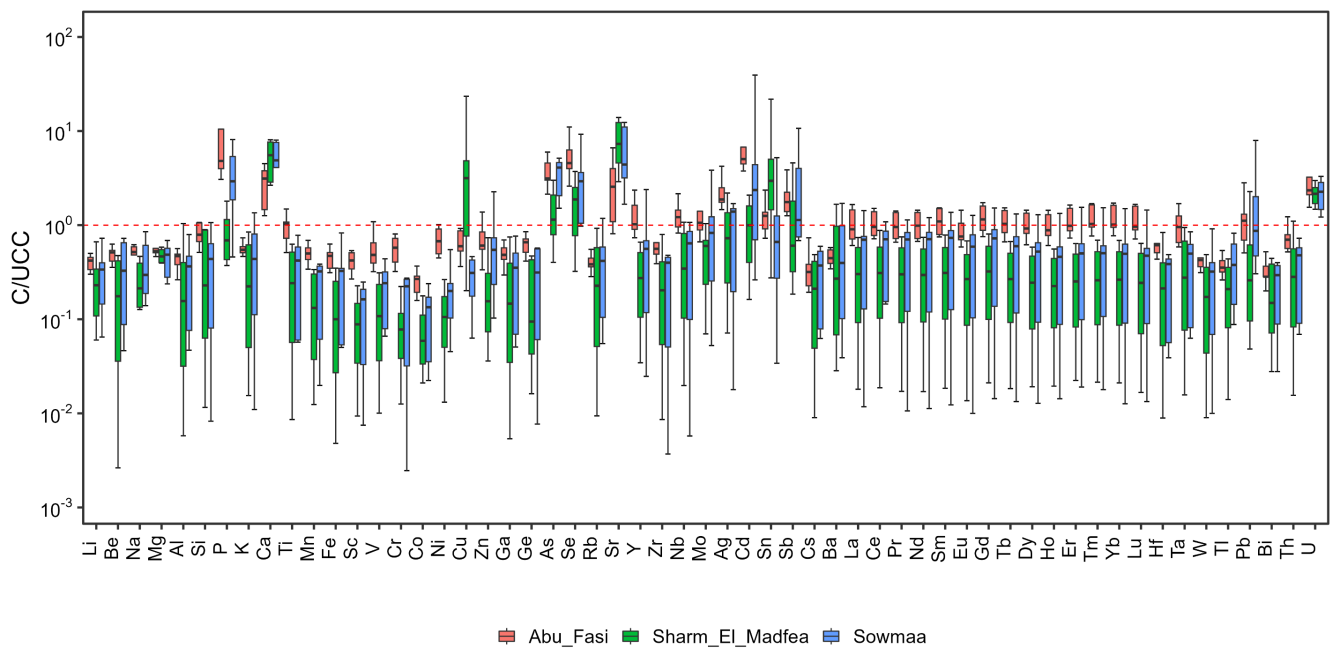
ICP-AES spectrometer ICAP 7600 Duo (Thermo Scientific, USA).

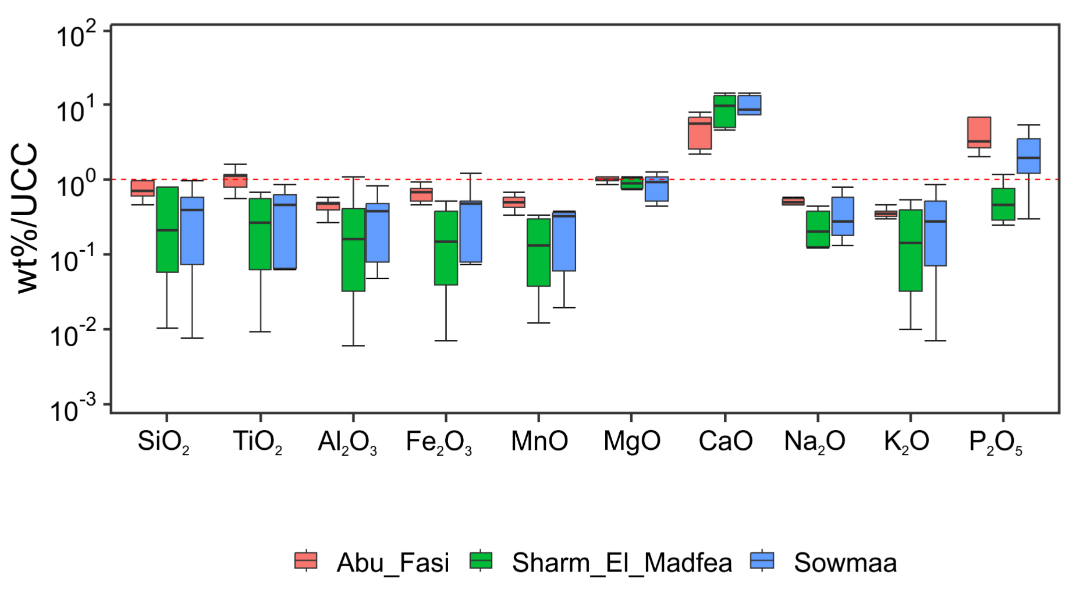
- Designed to determine the elemental composition of various objects. An optimized spectrometer scheme provides the simultaneous measurement of the analytical lines in the range of 166 to 847 nm with high resolution.
- Determination of up to 59 chemical elements in one sample simultaneously. Concentrations range of 6 orders of magnitude with a sensitivity of 1 ppb.

Geochemical abundances

The mass fractions of a total of **58 major and trace elements** were determined in the mangrove samples.

The normalized values show that the elements above the background can be indicated in descending order as follows: P > Cd > Sr > Ca > U > Se > As > Sn > Cu > Sb > Pb > Mo > Ag.





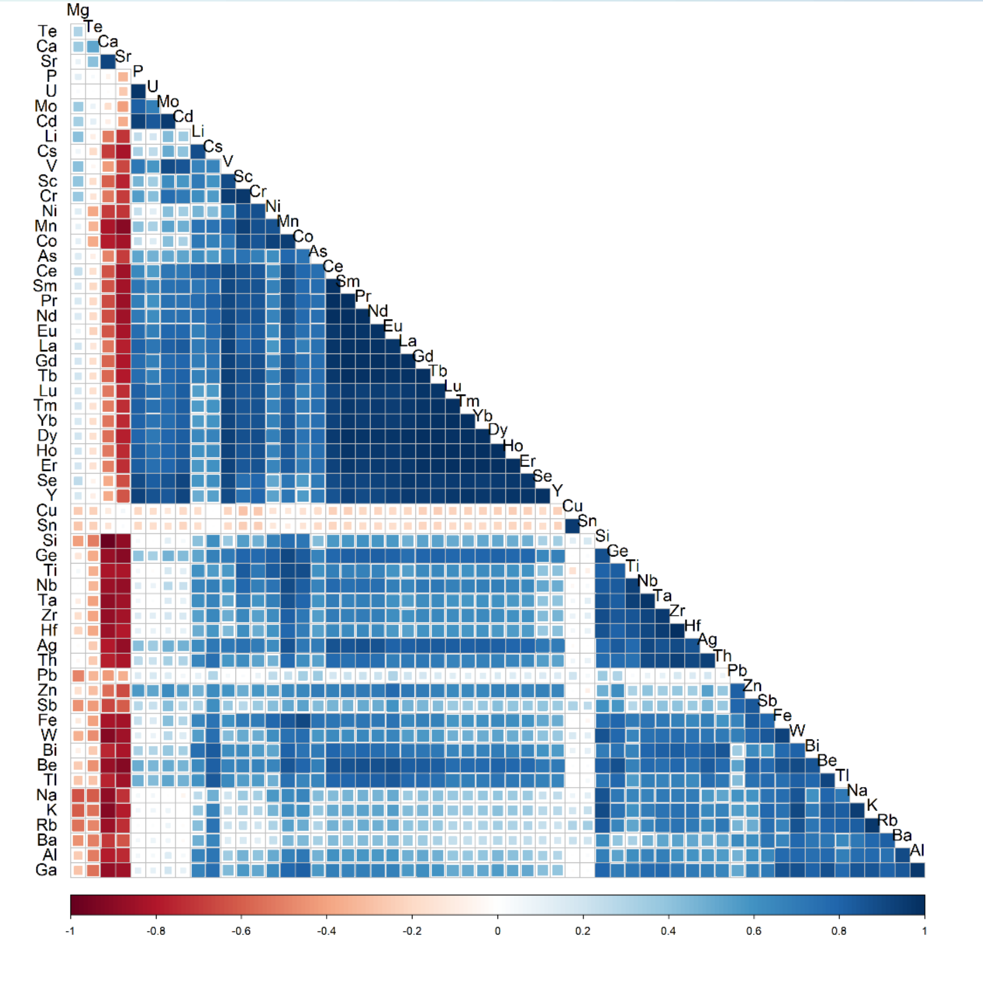
Likewise, the normalized oxides can be indicated in descending order as follows: P_2O5> CaO> MgO> TiO_2> SiO_2> Fe_2O_3> Al_2O_3> Na_2O> K_2O> MnO.

Groupe – wise comparison and intercorrelation

In order to conduct further analysis, the dataset was statistically treated with respect to the outliers. The outliers were identified and handled as they have the potential to distort the distribution of data and affect its normality.

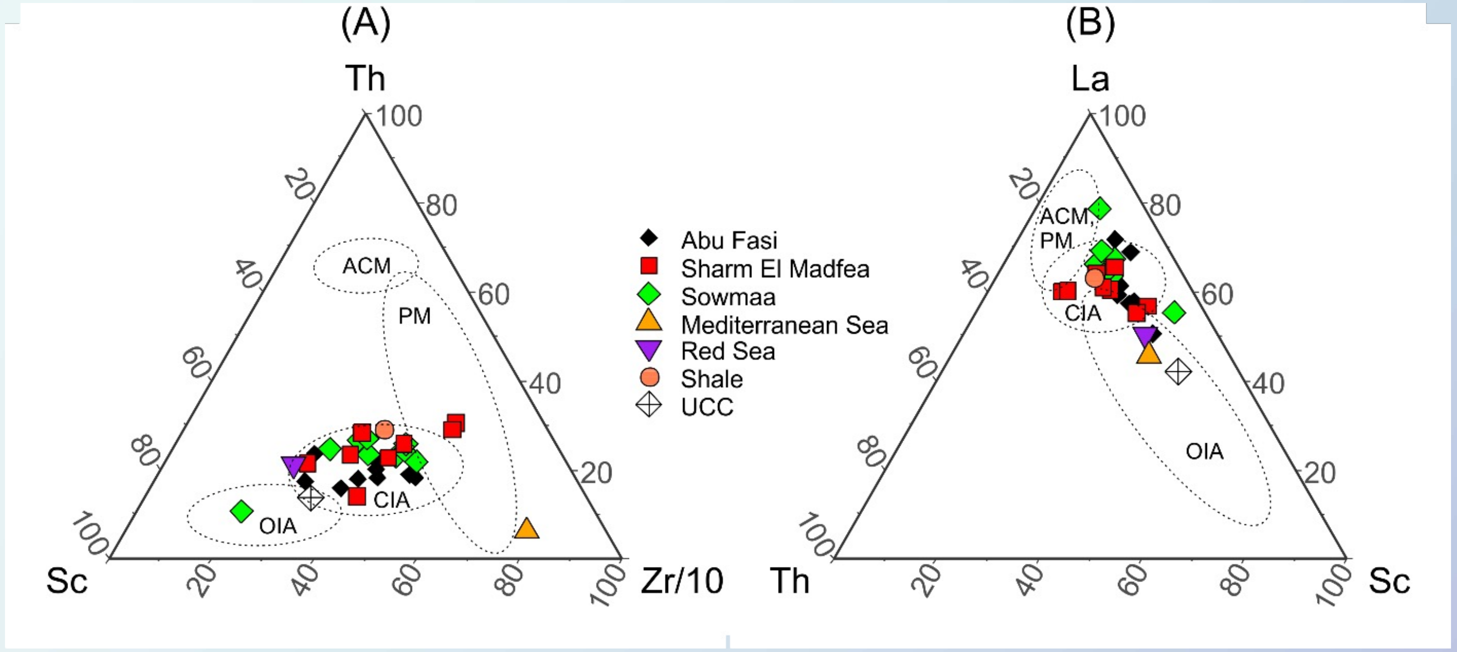
Using the Pearson method, a correlation matrix was generated to identify the key trends and relationships among the elements obtained

Tukey multiple comparisons of means revealed that the probability among them is quite high than ($\alpha = 0.05$) as follows: Sharm El Madfea vs Abu Fasi ($p = 0.85$), Sowmaa vs Abu Fasi ($p = 0.98$), and Sowmaa vs Sharm El Madfea ($p = 0.93$)



Geochemical provenance

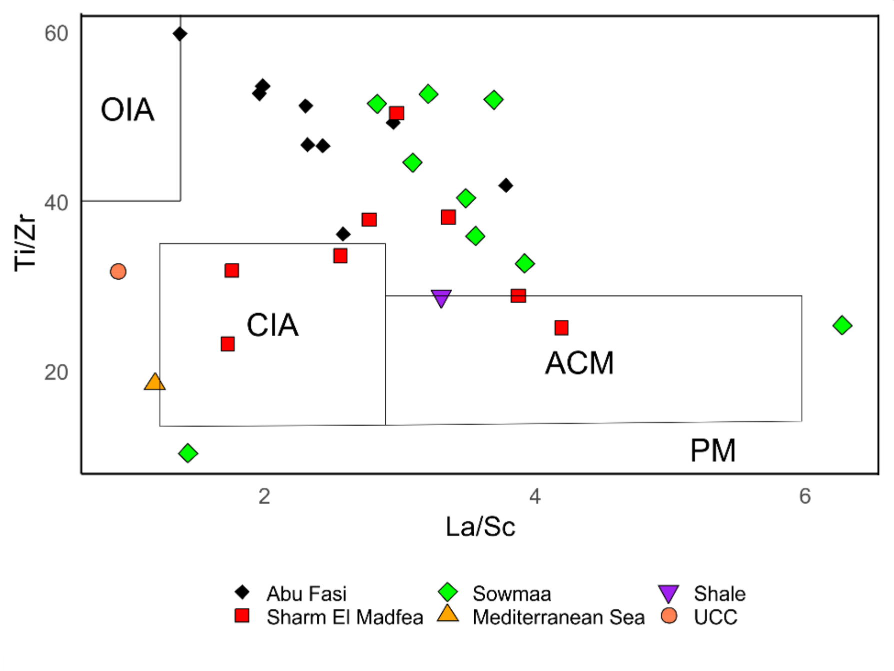
- Discriminant plots and layouts were used to elucidate the geochemical provenance of the element-bearing sediments.
- The layouts used are the ternary diagrams and the ratio indicator plots in order to differentiate the sediments in terms of provenance on the basis of the elemental composition.

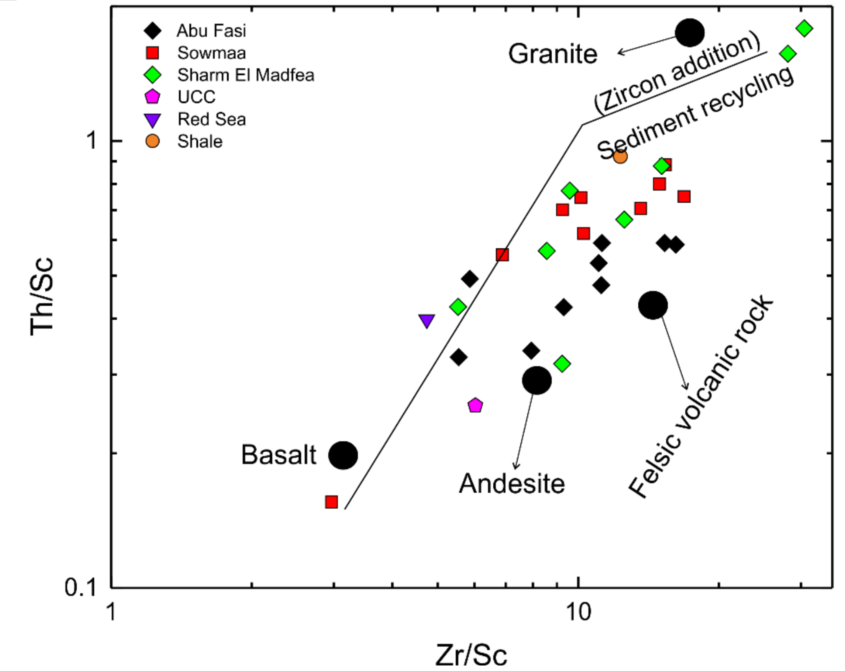


Ternary diagram illustrating the relation of Sc–Th–Zr/10 (A) and Sc–La–Th (B) after (Bhatia and Crook, 1986). Dotted lines represent the dominant fields for the various tectonic settings: OIA - Oceanic Island Arc; CIA - Continental Island Arc; ACM - Active Continental Margins; PM - Passive Margins

Geochemical provenance

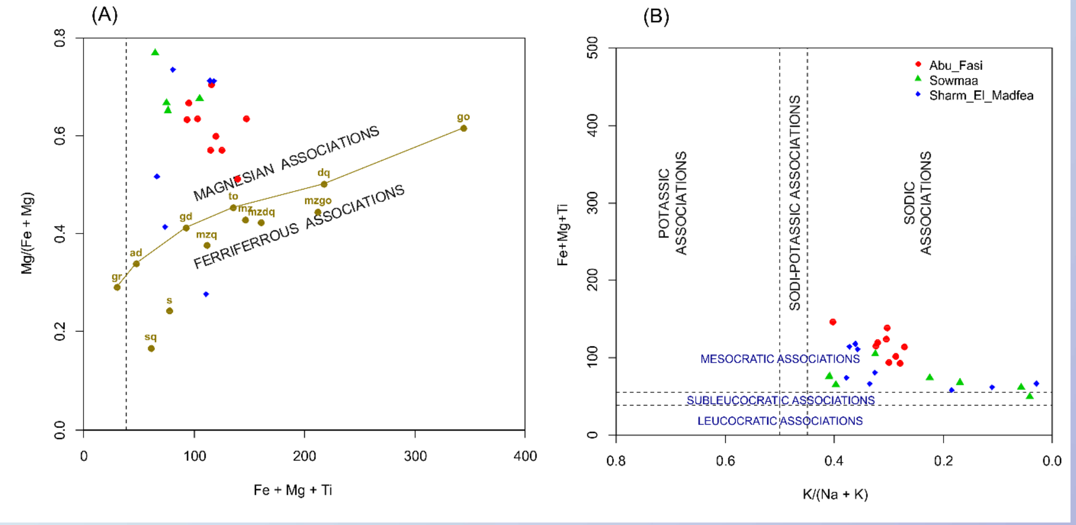
The results show that the mean value of the Ti/Zr ratio is 48.6 and La/Sc is 2.4 for the Abu Fasi area, again indicating that the sediments are close to Oceanic Island Arc OIA.





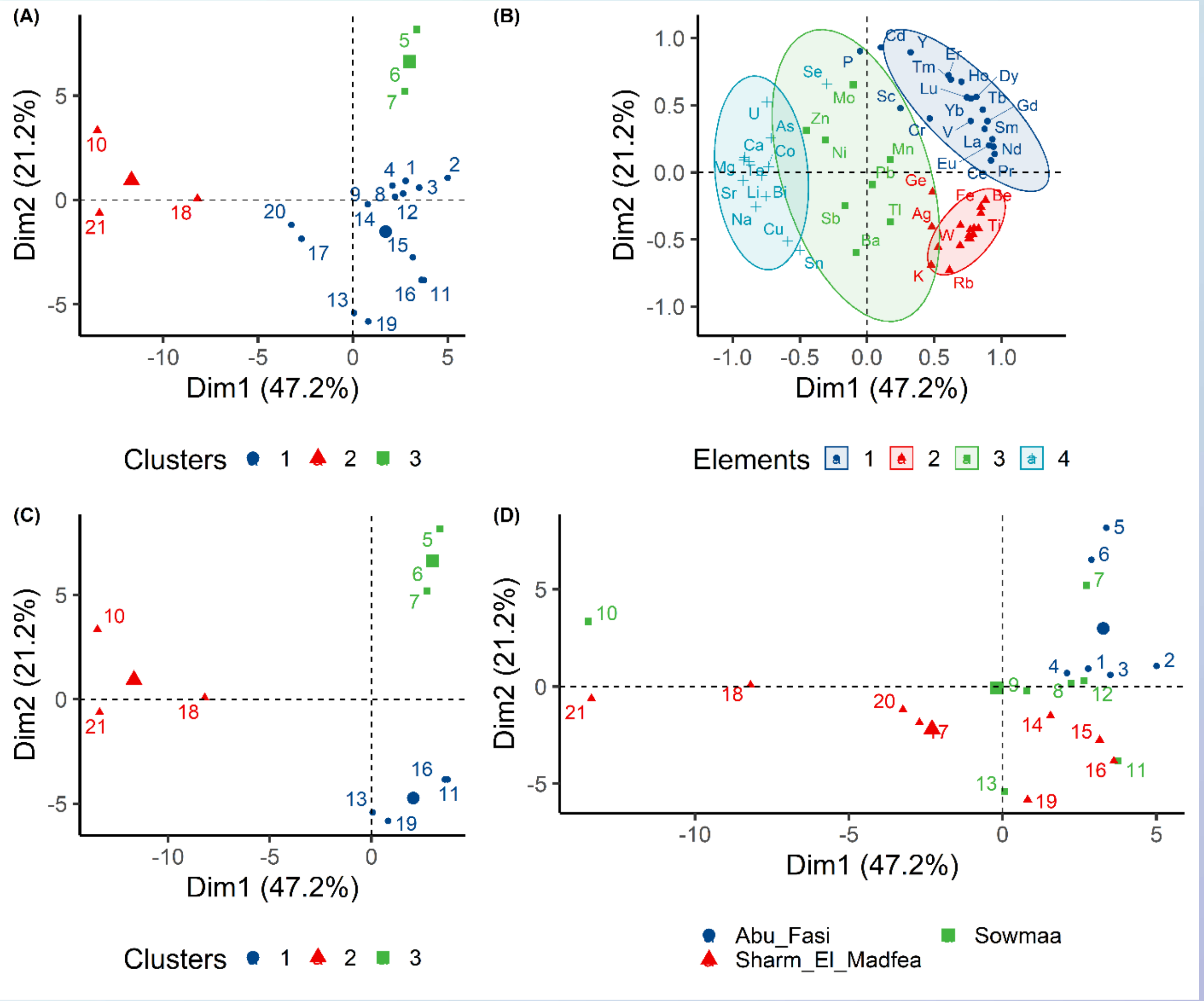
Notably, higher Th/Sc ratios were observed in Sharm El Madfea, indicating a greater input of Th into the sediments.

It was noticed a significant association of Mg over Fe and mostly because of the elevated amounts of Mg (A), while in (B) a remarkable contribution of Na was found and consequently the samples are close to the sodic association. These results can be explained by the weathering from the Red Sea, since Na is a marine element and mostly originates from the sea.



Multivariate statistical analysis

- The outliers were statistically treated and removed. Later, the data was transformed using centered log-ratio before PCA.
- The first two PCAs were plotted as they accounted for approximately 70% of the dataset.
- As shown in Fig. A, the R-mode PCA revealed three clusters. However, a comparison with Fig. D, there is some overlap. This can be attributed to the similarity of the geochemical characteristics of the samples studied.
- The Q-mode PCA calculated four groups of the elements. The elements were clustered with respect to their common geochemical features fig. B.
- Fig. c shows the samples with high contribution to the first two PCAs

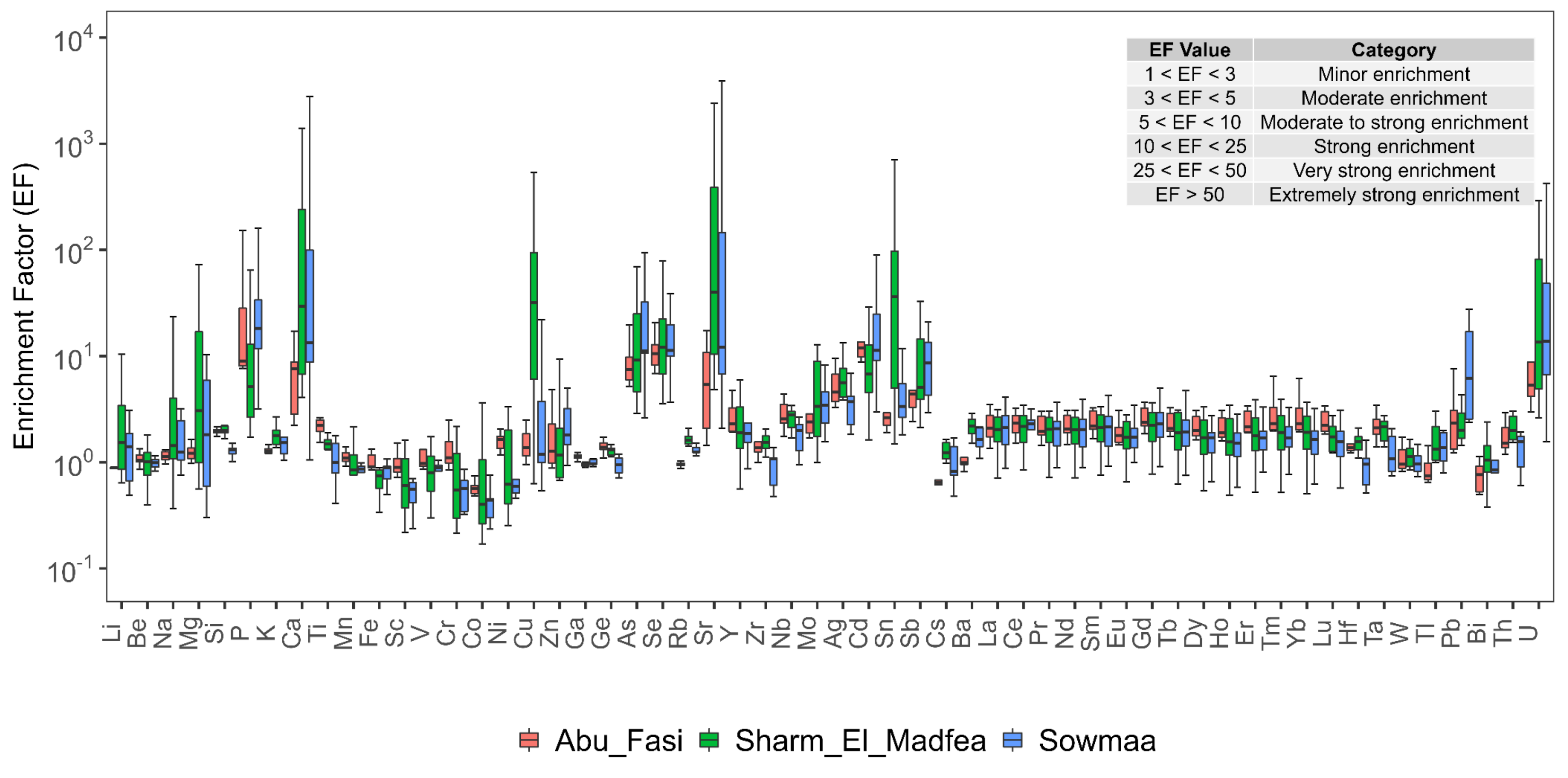


Pollution characterization and source identification

- The geochemical elemental **<u>background (regionally or worldwide)</u>** should be used to determine the extent of metal contamination and to distinguish between anthropogenic and geogenic impacts.
- The pollution characterization can be quantified and qualified using individual and complex pollution indices. For instance, the indices that were conducted are:
  - Single pollution index SPI
  - Enrichment factor EF
  - Nemerow pollution index PINem
  - Modified pollution index MPI
  - Pollution load index PLI, and
  - **Total pollution index TPI.**

Enrichment Factor EF

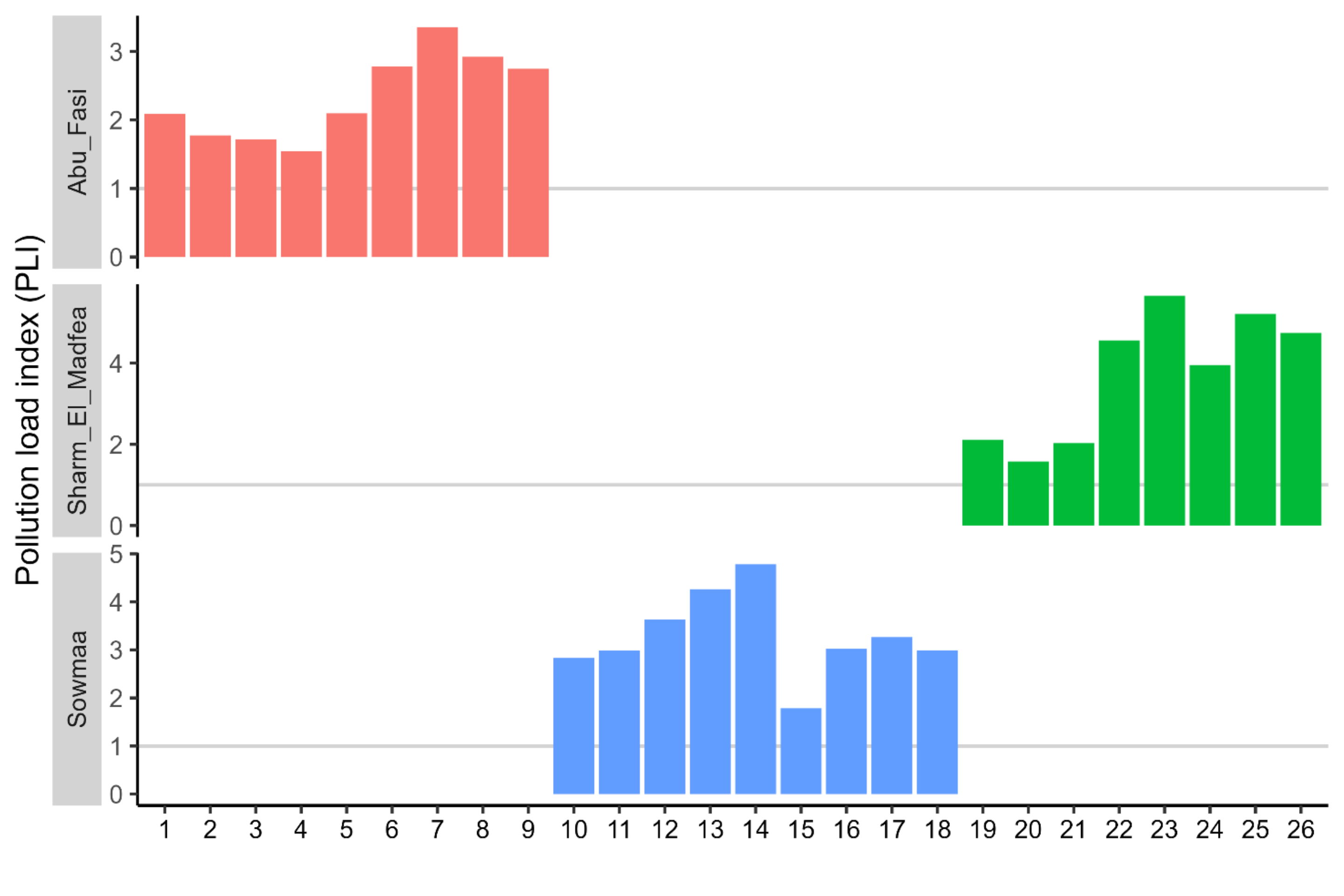
The elements namely Mg, As, Se, P, Cu, Cd, Sn, U, Ca, and Sr are sorted as strong to extremely strong enriched elements. Whereas EF for other elements ranges from 1-3 (minor enriched elements)



- PI – Nemerow indicated that almost all the samples are seriously polluted as the values are much higher than 3 according to the interpretation categories of PI – Nemerow given, except the site #20. Similarly, modified pollution index MPI was calculated, and the results showed that almost all samples are highly polluted (MPI greater than 10), except for samples No. 1, 2, 3, 4 and 5 from Abu Fasi, 11 and 15 from Sowmaa and finally 19, 20 and 21 from Sharm El Madfea.

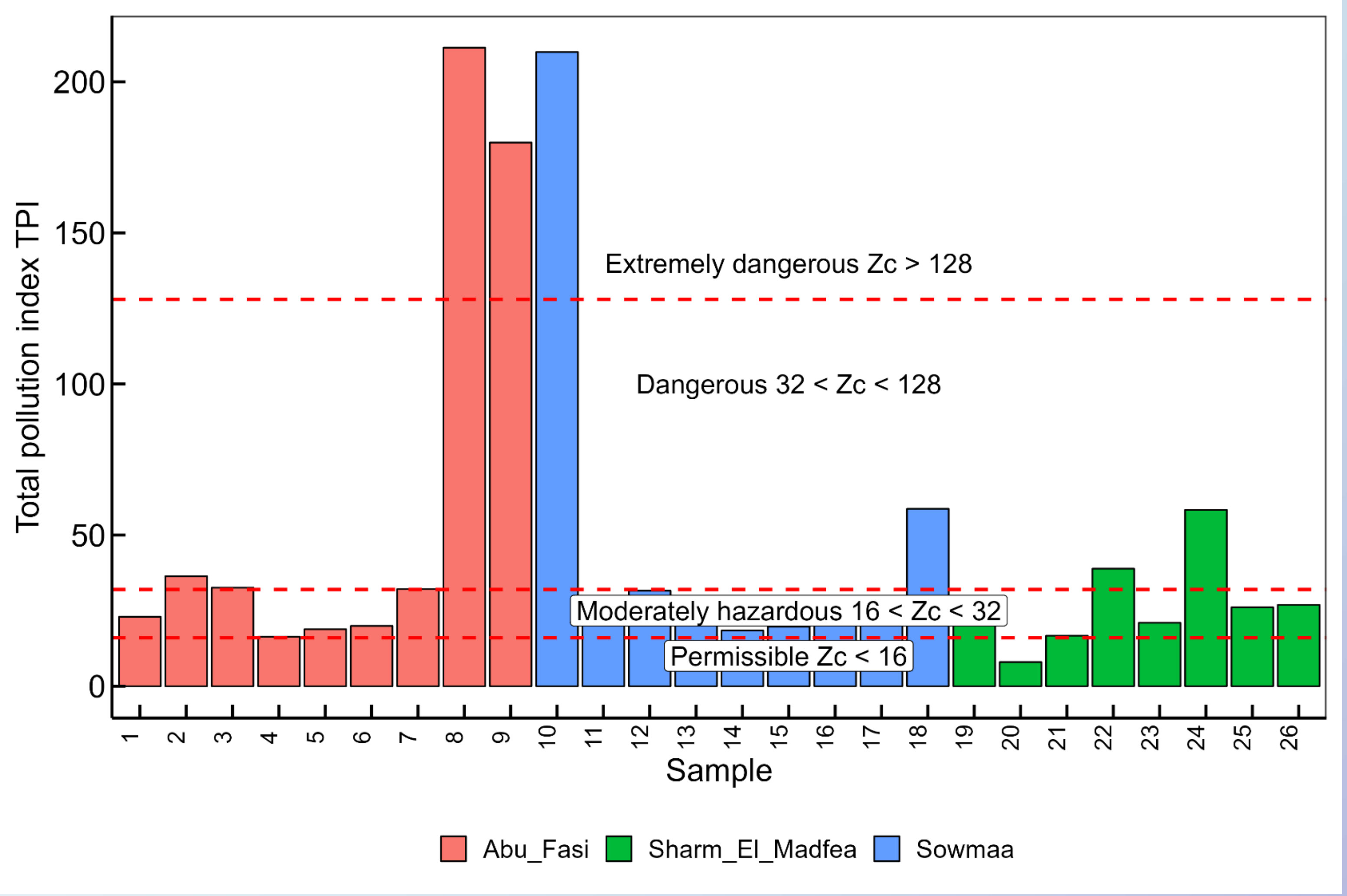
Pollution load index PLI

The figures clearly show that the pollution load index is higher than one. Therefore, there is significant pollution and steps should be taken to address this problem and protect the mangrove habitat from pollution.



Total pollution index TPI

According to the criteria of the TPI classification, Abu Fasi and Sowmaa have been identified as extremely dangerous sites (8, 9 and 10 respectively).



Concluding remarks

- Mangrove sediments along the Egyptian coast of the Red Sea were successfully characterized with regard to their elemental composition and the associated pollution,
- Significant mass fractions were found in the Abu Fasi area compared to the other two areas,
- Ratio indicators and discriminant layouts indicate that most of the samples are close to continental island arcs (CIA). In addition, Sharm El Madfea has lower sedimentation and high Th/Sc ratios, suggesting a significant Th input into the sediments,
- The PCA identified groups of common geochemical features that indicate common sources of contamination. These are primarily crustal association, marine weathering and anthropogenic inputs.
- EF analysis indicated Mg, As, Se, P, Cu, Cd, Sn, U, Ca, and Sr as strongly to extremely enriched elements, suggesting a mixed source of contamination (geogenic and anthropogenic).
- Pollution indices show that site #8,9 and 10 in Abu Fasi and Sowmaa were classified as extremely hazardous due to the influence of phosphate mining and transportation.

Thank you!

Contacts.

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