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A Synergy of ICP–MS/AES and Machine Learning for Elemental Characterization of Soil

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A comprehensive analysis of soil elemental content in the Nile Delta, Egypt, was conducted using advanced analytical techniques, including Inductively Coupled Plasma Atomic Emission Spectrometry (ICP–AES) and Inductively Coupled Plasma Mass Spectrometry (ICP–MS). A total of 55 elements were analyzed across 53 soil samples. Of these, 10 major elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, and P) were quantified using ICP–AES, while the remaining elements were measured using ICP–MS. The study employed a range of statistical methods, including both descriptive and inferential analyses, to evaluate the data. Additionally, multivariate statistical analysis was applied to gain deeper insights into the shared geochemical characteristics and to identify potential common sources of pollution. Geochemical discriminative ternary diagrams, ratio biplots, and unsupervised machine learning algorithms were utilized to classify the sampling locations based common traits. Various pollution indices were calculated to evaluate the ecological situation in Nile Delta - Egypt. In addition, the background values of the geochemical elements were determined using Bayesian inference, and the influence of outliers was thoroughly analyzed. By integrating the obtained chemical elements through a combination of analytical methods and machine learning algorithms, the background values of elemental content were accurately characterized, providing a precise representation of the soil composition. The collected data can serve as a valuable baseline for monitoring the environmental situation, particularly in terms of elemental abundances, and for assessing future dynamics.

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