Quantification of map similarity to demonstrate the efficiency of magnetic pre-screening for heavy metal pollution assessment in top soil

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Abstract: From large amounts of published results, a significant correlation between magnetic susceptibility (MS) and heavy metal (HM) concentration is well established. However, bivariate correlation analysis does not imply causality, because if there are extreme values, which often appear in magnetic data, they can lead to seemingly excellent correlation. It seems clear that site selection for chemical sampling based on magnetic pre-screening can deliver a superior result for outlining HM pollution, but this conclusion has only been drawn from qualitative evaluation so far. In this study, we use map similarity comparison techniques to demonstrate the usefulness of a combined magnetic-chemical approach quantitatively.

All available data were from the "Schwarze Pumpe", a large coal burning power plant located in eastern Germany. The soil in its surrounding of "Schwarze Pumpe" is suitable for a demonstration study, because (1) it was heavy fly-ash polluted; (2) the magnetic natural background was very low; (3) magnetic investigation could be done in undisturbed forest soil. Magnetic susceptibility (MS) of top soil was measured by a Bartington MS2D surface sensor at 180 locations and by a SM400 downhole device in ~0.5m deep vertical section at 90 locations. Cores from the 90 downhole sites were studied for heavy metal concentration analysis. Then using above results by 85 sites we created a spatial distribution map to define the true pollution condition in "Schwarze Pumpe" which we named "True Pollution". Different sets comprising 30 sites were chosen by arbitrarily selection from the above 85 sample sites (we refer to four such maps: "S1-4"). Additionally, we determined a "Targeted" map from 30 sites selected on the basis of the pre-screening MS results.

Here, two techniques of map comparison analysis were used. Firstly, we applied kappa statistic and fuzzy set theory to compute similarity between two maps by Map Comparison Kit software; secondly, we employed Delaunay Triangulation principle and Dihedral angle theory to validate the result. Furthermore, combining both methods we used a series of indices (Kappa, Kfuzzy, Klocation, mean value of Dihedral angle) to

determine the quality of the final results. Meanwhile, the advantages and disadvantages of using these two different approaches were also compared and discussed. The results indicate that the similarity between the "Targeted" and "True Pollution" is higher than that between "S1-4" and the "True pollution". It manifests that magnetic pre-screening can provide a reliable basis for targeted selection of chemical sampling sites, which certificates the superior efficiency of a combined magnetic-chemical site assessment in comparison to a traditional chemical-only approach.

Keywords: (Magnetic Susceptibility, Map Comparison, Heavy Metal, Magnetic Environment)