Statistical Analyses of heavy metal contamination of Ronneburg, a former uranium mine

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Contamination of the environment is one of the most important fields of studies in modern analytical science. Mining activities are known as a source of contamination on the surrounding environment. The type and the degree of contamination are related to the geology and geography, as well as to the mining technique. Hence, during and after the period of mining activities, environmental studies, and remediation plans are necessary. This study is a part of a large project that focuses on the remediation strategy for Ronneburg, a former uranium mine in eastern Germany. The focus of the study is on a former leaching heap (Gessenhalde) of Ronneburg. Acid mine drainage was used to leach the material of the heap in order to extract uranium. After the mine abandon, the heap was removed and replaced using fill material in order to prevent contamination from spreading. However, the contamination was later measured within the filled material The specific conditions of this area, such as low pH value and high concentration of heavy metals, gives the study area the potential conditions for a contaminated environment, which explains why the spread of contamination is still on-going. Hence, a test site (Gessenwiese) was established at the base of Gessenhalde in order to be used as a test area for geological and microbiological studies, and to study remediation strategy. Multivariate statistical analyses including cluster analysis (R- and Q-mode), cross-correlation, multivariate outlier detection, and fuzzy clustering, have been used to investigate the source of contamination. The results were used to identify the probable contamination sources and to improve and optimize the remediation strategy.

The statistical methods were used for 174 groundwater samples, 33 soil water samples, 90 soil samples, and 10 slate samples. With regard to the results obtained through various statistical analyses, we can conclude that:

The heavy metals infiltrated the former leaching heap and the surrounding environment and spread the contamination to the groundwater, surface water, soil, and plants. Various geochemical processes such as precipitation and co-precipitation play a role on persistence of the contamination. An increase of the contamination was observed trending the south to the north of the test site, and no seasonal effect was observed by statistical analyses. Several factors played a role in spreading the contamination to the surrounding environment. The composition of the glacial sediments of the test site as well as the pH, play a role on distribution and concentration of the heavy metals. The specific conditions of the groundwater such as shallow depth and return flow that occurs during the period of heavy precipitation events play a role on contamination spread to the surface soil. Regarding these processes and the results using fuzzy cluster analysis, the composition of the slates is not the sole factor leading to heavy metal contamination in the soil water and soil samples.

To summarize, with regard to the stability of the contamination distribution/pattern, our results confirms that the intervals of sampling can be reduced to two times per year. It is suggested to design a systematic sampling net/profile that covers all types of glacial sediments surrounding the location of the samples that has overlap with other geological/geochemical information (e.g., borehole profiling, variety of sample types, monitoring groundwater fluctuation, etc.). In this case, more (geo)statistical methods can be performed and, hence, more details can be investigated with less physical work. It will help the project to decrease expenses and optimize the project economically.