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HYDROLOGICAL FORENSIC INVESTIGATION COMBINING HIERARCHICAL CLUSTER ANALYSIS: A CASE STUDY OF 16TH LUM NAM JONE RESERVOIR, CHACHOENGSAO, THAILAND

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The 16th Lum Nam Jone is a 1.97 million cubic meters freshwater reservoir, located 500 meters north of 304 Industrial Park in Chachoengsao province, Thailand. For over 30 years, water from this reservoir has been vital for locals' domestic uses, agriculture, and fishery. Various complaints regarding the water's habitability since 2019 led to complete water quality analyses, which showed that the water was highly acidic with pH 2.5-3.5 and contaminated by heavy metals such as iron, manganese, copper, zinc, and lead. In other words, the water from this reservoir is not suitable for aquatic organism and water supply. The main objective of this study is to identify the source of contamination and contamination transport pathway, using a hydrogeological forensic approach, which is necessary for the relevant legal process, including the remediation plan.

Delineating the source(s) of contamination which affect the 16th Lum Nam Jone reservoir is an essential step in reducing the exposure of local communities to hazardous chemicals in the water supply. The implementation of preventative measures and remediation of ground and surface water conditions is imperative to achieve Sustainable Development Goal 6.3.

Identification of contamination sources is considered challenging in environmental studies. Many factors such as multiple contamination events, mixing of many contamination sources, adsorption on clay mineral, co-precipitation of minerals and heterogeneous lithological distribution can complicate interpretation of the findings. Hence, it is important for hydrological forensic investigation to have a thorough understanding of hydraulic connectivity between surface water and groundwater, hydrogeological characteristics, site history and potential sources of contamination.

For this case, geological and geophysical survey were opted for the preliminary site characterization. Geophysical method was helpful in screening areas of contaminated soil and groundwater. Geophysical survey, using electrical resistivity was carried out under the hypothesis that low pH contaminated water should have high electrical conductivity (low resistivity). The preliminary site investigation showed low resistivity anomalies nearby a molybdenum ore processing plant, suggesting that this factory might be a potential source of the contamination. However, this method cannot identify chemical parameters, and thus cannot be used as a stand-alone method.

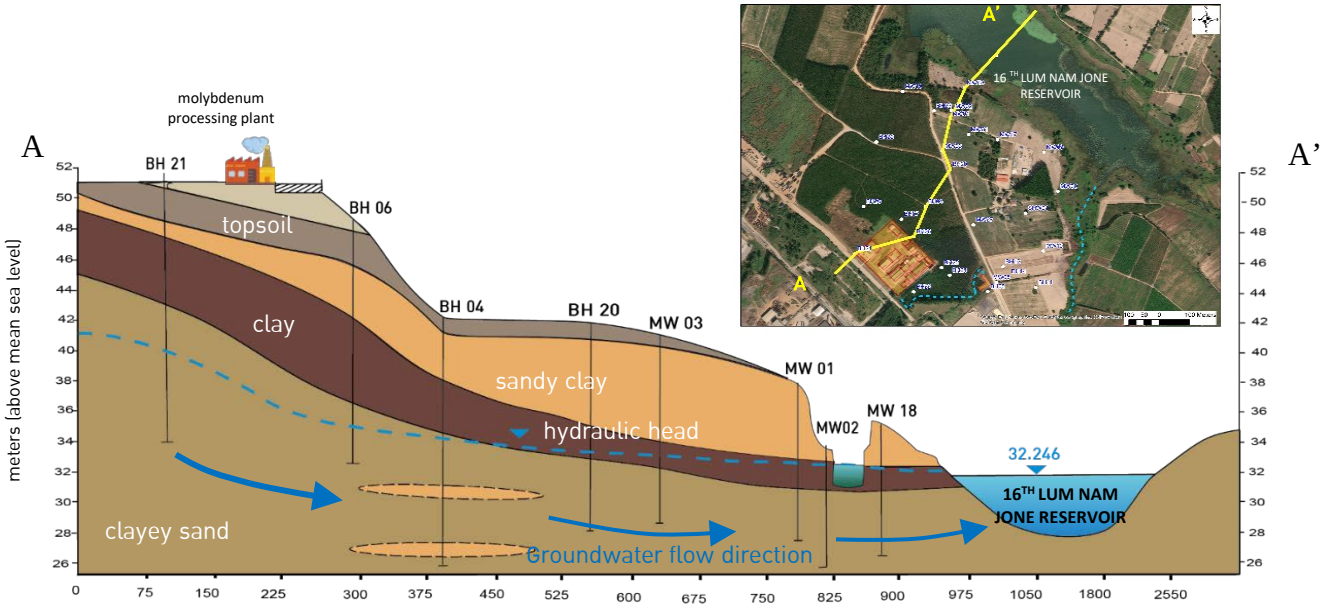

Figure 1 Hydrogeological conceptual model of the study site

The next step, hydrogeological investigation was employed to construct hydrogeological conceptual model, which showed that the groundwater in the study area flows to the 16th Lum Nam Jone reservoir (Figure 1). The hydrogeology of the area consists of unconsolidated sediment units; sandy clay, clay, and clayey sand. The water table was at 2-14 meters below the ground. Based on direct push drilling data using a Hydraulic Profiling Tool (HPT), the estimated hydraulic conductivity of the aquifer layer was 15-21 m/day. To further explore the water- chemistry relationship, cluster analysis of 33 cases data set (groundwater and surface water samples) was performed on major distinguish ion subset (Fe, Mn, Cu and Zn) using Ward's method and Euclidean distance measure. These methods are particularly suited to identify commonalities as well as differences between large data sets. The results of hierarchical clustering procedures are expressed graphically in the form of a dendrogram. In figure 2, the nodes of the dendrogram represent the grouped classes or clusters, while the length of the branches indicates the distance between the groups. Samples are arranged according to similarity. In this study, regarding to dendrogram and total dissolved solids (TDS), water samples can be classified into three main groups. The first group can be subdivided into 2 subgroups: 1.1 uncontaminated or less contaminated water samples (TDS 114 - 696 mg/L) and 1.2 slightly contaminated water samples (TDS 214 – 2,631 mg/L). The second group can be classified as contaminated water samples with high TDS (3,929 – 13,615 mg/L). The third group consists of contaminated water samples with very high TDS (11,841 – 23,217 mg/L). Moreover, the pattern or chemical signature discriminations obtained using both hydrochemistry plotting and hierarchical cluster analysis approach are in good agreement.

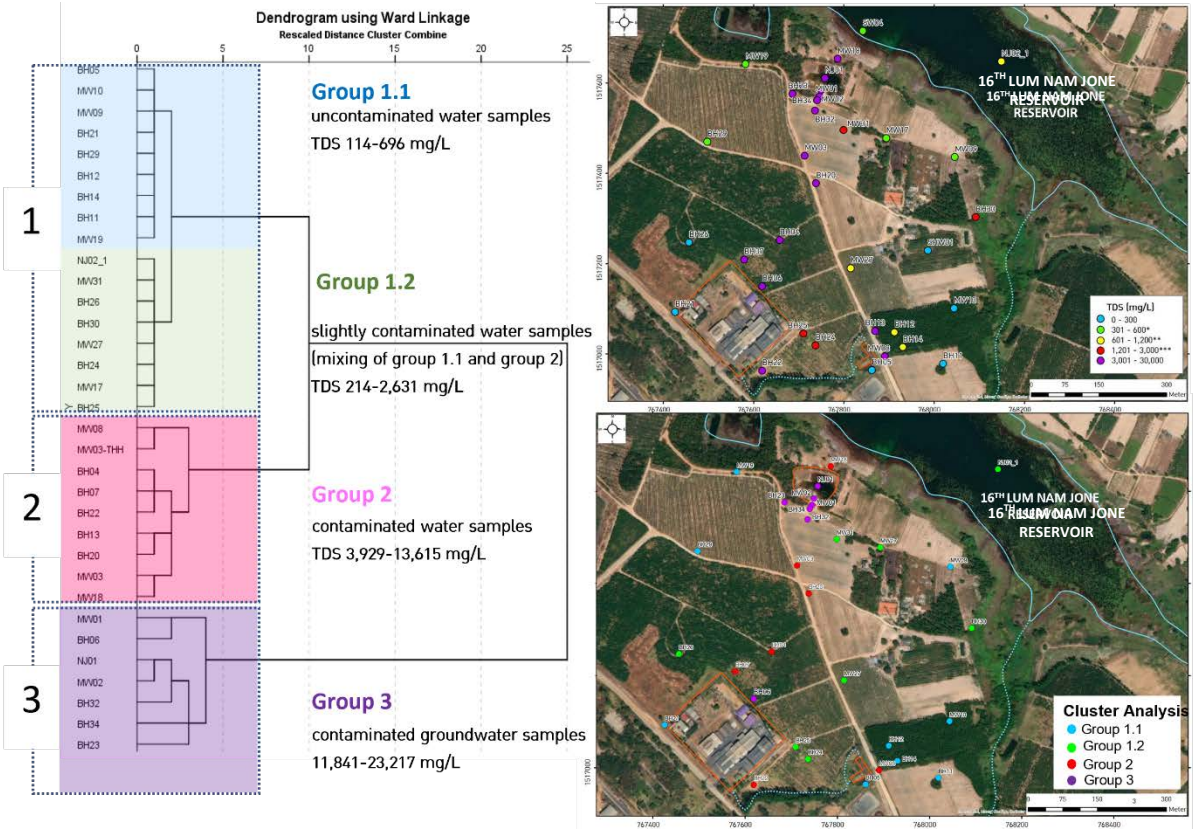

Figure 2 Dendrograms using Ward's method showing three main cluster solutions

A major finding from the combined statistical, hydrogeological, and geochemical assessments confirmed that contaminated water in the 16th Lum Nam Jone reservoir is significantly related to the molybdenum ore processing plant located upgradient. The industrial wastewater from this plant might be illegal discharge into underground and flows due to hydraulic gradient to the 16th Lum Nam Jone reservoir.

Keywords: groundwater, contamination, environmental forensic investigation

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