

Evolution of the LUSI mud volcano: Fluid chemistry and remote sensing

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The LUSI mud volcano near Sidoarjo in East Java, Indonesia has been erupting since May 2006. It discharged as much as 180,000 m³/d at the peak of its activity [1, 2], destroyed thousands of homes, and displaced tens of thousands of people. The solids in the mud can be traced with some certainty to the blue-gray clays of the Upper Kalibeng formation, found 1600-1800 m beneath the LUSI main vent. The erupting fluid is a mixture of water, clay, and other minerals at near-boiling temperatures that is accompanied by venting of hot gases, primarily H₂O vapor, CO₂, and CH₄ [2]. The origin of the LUSI fluids remains a matter of speculation.

LUSI is an evolving and complex dynamic system, thus, we take a multi-disciplinary approach to assess both the fluid provenance and eruption behaviour. Our effort includes both geochemical analyses of aqueous and solid-phase components (elemental and isotopic composition) as well as ground-based (FLIR) and satellite-based (MODIS, ASTER) thermal remote sensing data for the LUSI main-vent region. Preliminary geochemical results (IC, ICP-MS, Sr isotopes) indicate the water in the LUSI mud may have multiple sources (Fig. 1). Solid-phase analyses (XRD, ICP-MS) confirm the mud has an elemental composition and mineralogy very similar to that of the Kalibeng formation. The satellite-based thermal remote sensing data are used to calculate the radiant heat-flux from LUSI over time. We compare these estimates with ground-based flow rate and thermal flux estimates to establish and calibrate a remote-sensing proxy for mud emission rate.

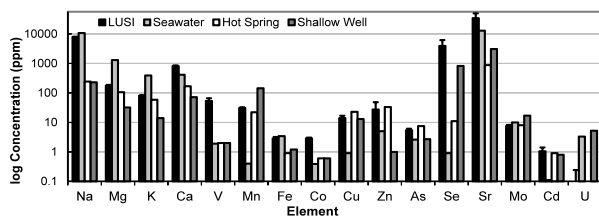


Fig. 1. Metals (ppm) in LUSI fluid (black), and a selection of potential source fluids; LUSI fluid is likely a mixture of multiple water sources that may include hydrothermal fluids.

[1] Zoporowski & Miller (2009) *Mar. Petrol. Geol.* **26**, 1879-1887. [2] Mazzini, *et al.* (2007) *EPSL* **261**, 375-388.

The leaching of arsenic and heavy metals from pyrite slags depots in the upper banks under conditions of highly dynamic groundwater-surfacewater interaction

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Pyritic waste slags from mining activities in Germany were used “free-of-charge” in The Netherlands. This occurred in the 1970’s to fill former clay pits in the largely unsaturated upperbank deposits within the drainage area of the river Rhine. The original clay pits in part extended down to the confined sandy aquifer beneath. The present-day groundwater flow patterns within this aquifer are highly dynamic. Variation in surface water levels, causing alternating infiltration and drainage periods, in combination with hydraulic heterogeneity are the main controls. The flow dynamics are reflected in the erratic temporal evolution in groundwater observation wells of both contaminant concentrations (arsenic and heavy metals) and main elements. While weathering of the pyritic slags is the controls the release of contaminants, secondary reaction strongly influence overall contaminant behavior. High arsenic concentrations appear to be associated with the occurrence of drainage conditions, when arsenic mobility is probably enhanced by reductive dissolution of secondary ironhydroxide precipitates at to redox and pH boundaries below the pyritic slags. Mobility of zinc and nickel is probably controlled by pH-dependent adsorption to the sediment under the carbonate-buffered conditions. Geochemical modeling using PHREEQC corroborates that the oxidation of pyrite with oxygen and subsequent pH-buffering by carbonate dissolution are the main geochemical processes. In addition, acid buffering by K-feldspar under conditions in or close to the pyrite slags seems to occur when carbonate buffer is consumed. The extent to which nickel and zinc will be transported further off site will depend in particular on the depletion of sediment acid-buffering capacity, the concentrations of zinc and nickel evolving from the pyriteslags, and the adsorption capacity for nickel and zinc in the sediment. The main control for arsenic transport will be the development of redox conditions in the pyrite slag as well as future alteration of the hydrological situation.