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DIRECTIONAL DRILLING AND DEVIATION CONTROL TECHNOLOGY

ADITYA TRIPATHI

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Preface

Directional Drilling and Deviation Control Technology examines and explains techniques for development drilling through directional wells. It has been written by operating company field engineers assisted by drilling consultants. Illustrations show how measuring and guidance devices work, and general procedures and recommendations for equipment are given for each deviation method. Intended for drilling engineers and supervisors in charge of development operations involving deviated wells, the book may be profitably consulted by project and design engineers working in well siting.

Editor

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Chapter 1

Assessment of Potential Location of High Arsenic Contamination Using Fuzzy Overlay and Spatial Anisotropy Approach in Iron Mine Surrounding Area

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ABSTRACT

Fuzzy overlay approach on three raster maps including land slope, soil type, and distance to stream can be used to identify the most potential locations of high arsenic contamination in soils. Verification of high arsenic contamination was made by collection samples and analysis of arsenic content and interpolation surface by spatial anisotropic method. A total of 51 soil samples were collected at the potential contaminated location clarified by fuzzy overlay approach. At each location, soil samples were taken at the depth of 0.00-1.00 m from the surface ground level. Interpolation surface of the analysed arsenic content using spatial anisotropic would verify the potential arsenic contamination location obtained from fuzzy overlay outputs. Both outputs of the spatial surface anisotropic and the fuzzy overlay mapping were significantly spatially conformed. Three contaminated areas with arsenic concentrations of 7.19 ± 2.86, 6.60 ± 3.04, and 4.90 ± 2.67 mg/kg exceeded the arsenic content of 3.9 mg/kg, the maximum concentration level (MCL) for agricultural soils as designated by Office of National Environment Board of Thailand. It is concluded that fuzzy overlay mapping could be employed for identification of potential contamination area with the verification by surface anisotropic approach including intensive sampling and analysis of the substances of interest.

INTRODUCTION

Arsenic contamination to the environment can cause an adverse environmental problem that further impacts health. Exposure to arsenic can result in a variety of human health problems, including various forms of cancer (e.g. skin, lung, and bladder), cardiovascular and peripheral vascular disease, and diabetes. Humans may be exposed to arsenic through inhalation, dermal absorption, and ingestion of food, water, and soil [1, 2]. Arsenic is a naturally occurring element present in both inorganic and organic forms in different environmental and biological samples and its concentrations may be increased by anthropogenic contamination [3]. The major sources of arsenic pollution may be natural process such as dissolution of arsenic containing bedrock/minerals and anthropogenic activities, for example, percolation of water from mines, wood preservatives, agricultural chemicals, and discharge from an uncontrolled mining and metallurgical industry. It is estimated that about 60% of arsenic present in the environment is of anthropogenic origin [4–10].

Regarding arsenic occurrence in nature, it geologically occurs in soil. Besides gold mine activities, arsenic-bearing hydrothermal minerals frequently occur in ores containing copper, iron, tin, nickel, lead, uranium, zinc, cobalt, or platinum [11]. Mine drainage refers to surface water or groundwater becoming contaminated with heavy metals, arsenic, and/or sulfuric acid as the water infiltrates into the mine shafts, pits, coal piles, ores processing structures, and wastes impoundments, such as mine tailings piles and disposal ponds [12, 13]. On January 22, 2001, USEPA published a final arsenic rule in the Federal Register that revised MCL for arsenic from 0.05 mg/L to 0.01 mg/L (10 μg/L) for drinking water [14]. Office of National Environment Board of Thailand (NEB) specified MCL of arsenic in soils as 3.9 mg/kg and 27 mg/kg for agriculture and other usages, respectively [15].

In Thailand there is some evidence of arsenic contamination in the area of Wangsaphung district, Loei province. The line governmental agencies had investigated both surface water and groundwater, revealing that arsenic concentration was less than the MCL of 0.01 mg/L specified by USEPA. However, there are still some findings of sick peoples due to arsenic exposure even though the iron mine had been already closed since 2005. With this suspicion, more extensive investigation in the whole area and in environmental medium such as soils and plants is required. In addition, the site contamination assessment in the catchment where the abandoned iron mine is situated is actually needed.

In order to identify the potential location of high arsenic contamination in the iron mine surrounding area, the major approach included fuzzy overlay mapping in ArcGIS and surface interpolation of the data derived from field sampling and analysis of arsenic content by spatial anisotropy approach.

Consequently, the primary objectives of this research were (1) to identify the most potential locations of high arsenic contaminant and (2) to verify the most potential locations by surface interpolation of the studied arsenic content in such identified area.

Study Area

The study area covered the area surrounding the abandoned iron mine situated at the catchment in Wangsaphung district, Loei province, the northeastern region of Thailand as shown in Figure 1. Most area in this catchment is plateau area with the elevation of about 250–300 meters above mean sea level (mmsl). Iron mine is situated in the east of the catchment at the elevation of 250 mmsl. Within three-kilometer radius of the iron mine, there are four villages, including Ban Na Nong Bong, Ban Huai Phuk, Ban Nam Huai, and Ban Tio Noi, as shown in Figure 2. Based on the iron mine location, Ban Tio Noi is the nearest village and Ban Huai Phuk is the farthest village located 3.5 kilometers in distance at 251 mmsl elevation and located about 4.5 kilometers in distance at 271 mmsl elevation, respectively. Most of land use in the study area is paddy rice field and crop cultivation such as banana, tapioca, nut, and rubber.

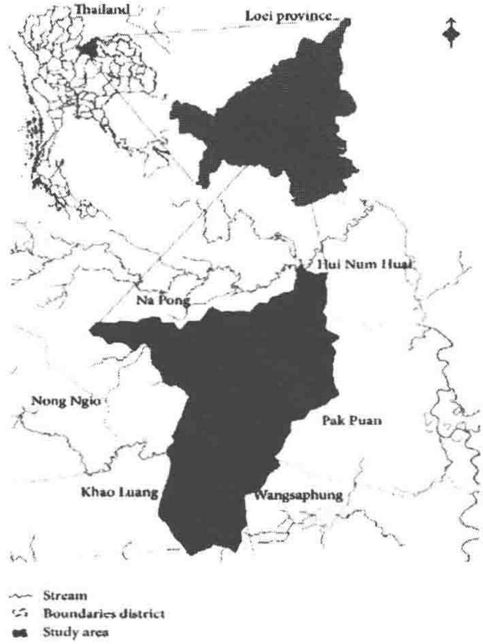

Figure 1: Study area at Wangsaphung district, Loei province, northeast Thailand.

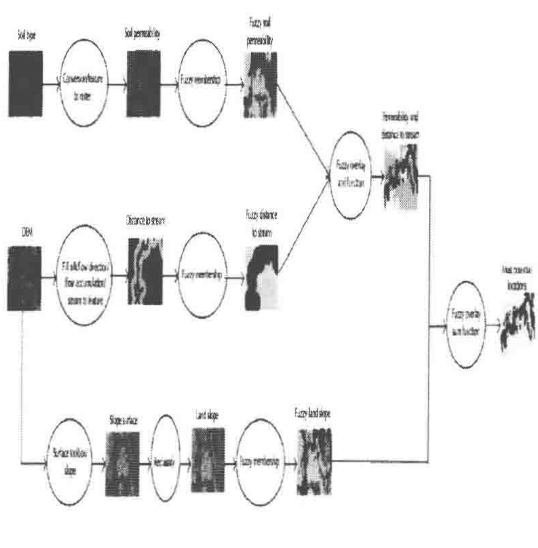

Figure 2: Methodology chart for fuzzy overlay approach.

Within the study catchment there are many small waterways flowing from the high elevation at the top of plateau, about 500–650 mmsl, flowing to the low elevation area and merging to be one stream, namely, Huai stream, passing through the villages downward the Loei River which then joins the Mekong River.

MATERIALS AND METHODS

The conceptual framework of this study is approached with fuzzy overlay mapping to identify the potential arsenic contamination locations and verification of such potential locations with field sampling and analysis of arsenic content in conjunction with the surface interpolation by spatial anisotropy.

Fuzzy Overlay Approach

The source maps selected for fuzzy overlay approach in ArcGIS are based on the factors determining the most potential locations of arsenic contamination which were as follows.

- Land slope: the raster layer of elevation variability is used for slope steepness classification, which affects the rate of lateral movement.
- Soil type: the percentage of sand in soil significantly determines the rate of percolation of water into the groundwater.
- Distance to stream: the raster layer representing the distance from the main stream of each grid cell in the map is used to examine how far the movement is required for the water body.

Raster data of land slope and distance to stream could be created from DEM (digital elevation model) of a cell size of 5 × 5 m. Both layers are continually spatial factors for determining how much water is contaminated by surface runoff process at a site where the stream reaches. The higher slope with shorter distance to stream and sandy soil (higher permeability) make more opportunities for movement of arsenic through the soil pore by surface runoff and then to the stream or store at the plain area along the stream bank. Raster layers of DEM and soil type could be collected from Land Development Department, Ministry of Agriculture and Cooperatives of Thailand. Maps overlay is illustrated in Figure 2.

Sampling and Analysis of Arsenic Content

Soil samples were taken from the potential area derived from the fuzzy overlay mapping. A total of 51 soil samples collection are illustrated in Figure 3. At each location, soil samples were taken at the depth of 0.00–1.00 m from the surface ground level. Methods of drilling and collecting soil samples were performed in accordance with the guidance of American Society for Testing and Materials [16]. Each soil sample was wrapped with aluminum foil sheet and coated with paraffin to protect against the moisture loss and oxidizing reaction that might occur during carrying to the laboratory for analysis. Analysis for temperature, pH, and oxidation-reduction potential (ORP) was made on site. All soil samples were analyzed for arsenic and iron content, OC, CEC, soil type, and its associated parameters such as moisture content, and unit weight. Arsenic contents were analyzed using Inductively coupled plasma mass spectrometry (ICP-MS) method. This technique provides high precision determination of substance, even metallic or nonmetallic, from the relatively small amount of samples [17, 18]. Soil type was classified using mechanical sieve analysis and hydrometer test. Soil group name associated with soil symbol was designated as recommended by Unified Soil Classification System [19].

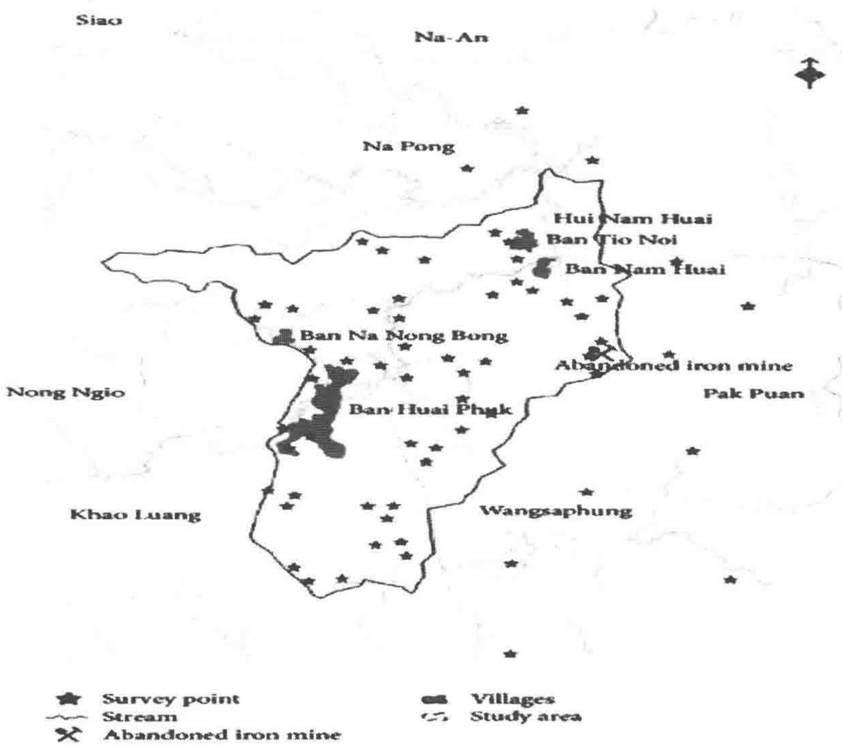

Figure 3: Sampling locations in the study catchment (inside catchment).

Potential Locations Using Fuzzy Overlay

Fuzzy overlay technique employs the principle of fuzzy logic to solve traditional overlay analysis applications in geographic information system (GIS) such as site selection and suitability models. Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0). It is based on the logic of set theory, in which one can traditionally determine whether a value is a member of a set or not. A variation on set theory allows specifying the likelihood that a given value is a member of the set rather than merely specifying whether the value is either in or out of the set [20]. A numeric is used in fuzzy logic with 1 representing full membership in the set and 0 representing nonmembership.