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Research Article

Soil Exploration and groundwater prospect in Etua, Delta State Nigeria

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Abstract

The various soil types in Etua town were categorized using a soil test. The X-ray fluorescent machine (XRFM) and atomic absorption spectrophotometer (A.A.S.) results show that the soil's natural composition is SiO_2, Fe_2O_3, FeO, Al_2O_3, CaO, Na_2O, and K_2O. When it came to the amount of oxide metals in the soil sample, SiO_2 and Fe_2O_3 came in first. Tests on ion-containing groundwater samples revealed that some parameters had values that were higher than permitted, according to the World Health Organization (WHO). To determine the most suitable and workable groundwater treatment techniques, factors such as soil type and water sample characteristics are taken into consideration. Benin Formation of the Niger Delta sedimentary base of Nigeria contains Etua. It is bordered to the east by Ossissa in the Ndokwa East Local Government Area, to the west by Onicha-Ukwuani, and to the north by Nsukwa in the Aniocha South Local Government Area. Ionic concentrations and elemental oxide compositions of soil and water samples were measured and analyzed. Three types of soil: sand, clay, and laterite are all present in the research area. The link between soil and water components is similar in the examined area. For both soil and water, it demonstrates comparable conductivity in the research areas. As a result of the medium-coarse soil layers in the research region, which have the ability to function as an aquifer, the area offers a considerable deal of groundwater potential.

Keywords: Geochemical analysis, water samples, impact, Etua, Delta State.

INTRODUCTION

In soil science, rock and all soils that originated from parent material—a deposit at the earth's surface—are referred to as soil material or parent material. Rock turns into soil, which is known as soil formation. The rock could be peat, limestone, sand, gneiss, or shale. These names are used interchangeably in soil science. Chemical, physical, and biological factors all contribute to changes in the soil (Sanjay, 2014; Vwavware et al., 2024). The primary determinants of soil formation, parent material, relief, living things, climate, and time, can all exacerbate these changes (Vladychenskiy, 2014).

The transformation of rock into soil is known as soil formation. The rock could be shale, limestone, gneiss, peat, or sand. Soil scientists use the term "parent material," sometimes known as "soil material," to describe rock and other soils that are derived from deposits at the earth's surface. The material weathers to produce smaller materials that are moved by moving glaciers, overflowing rivers, or blowing winds, resulting in soil from the changing parent material (Sanjay, 2014). These effects are caused by the sun, water, wind, ice, and living creatures. The soil profile is divided into three primary horizons: A, B, and C. Leaf litter that is degrading and merging with mineral soil makes up the upper, dark-colored zone of organic accumulation known as the "horizon". The B horizon is composed of minerals that contain very little organic stuff (Bogg, 2016). This is the volume of water that may be progressively taken out of an aquifer without endangering the ecology, quantity, or quality above the aquifer. Groundwater circulation and presence are influenced by geological formations, soil type, rainfall, and lineament density. Ground water is the second-largest intermittent freshwater supply on Earth and the best resource for surface water-related commercial and human development, according to Arabameri et al. (2019).

In several regions of the world, over-exploitation of ground water has led to falling ground water levels, rising stress levels, and diminishing ground water supplies as a result of increased development and intensive agriculture globally to meet rising food and energy demands (Fathi et al., 2021; Priyan, 2021). Information on the soil exposed to the ground surface is quite valuable. In order to gather samples, geotechnical engineers must also drill or excavate exploratory pits in order to evaluate the subsurface conditions. These activities are what we call subsurface exploration. The significance of the building, the intricacy of the soil conditions, and the amount of money allocated for exploration all influence how far exploration can go. Determining, the state of groundwater, identifying the fundamental characteristics of soil that influence the design and safety of structures in terms of compressibility, strength, and hydrological conditions, and analyzing the reasons behind previous work's failures are all part of the goal of soil exploration. A soil study is required to ascertain the soil's carrying capacity, the pace of settling, and the location of the water table. A soil profile is a vertical cross-section of the soil made up of layers that are parallel to the surface. Soil is the topmost layer of the earth's crust and is mostly formed of organic materials and rock particles that support life. We refer to these strata as "soil horizons."

During its formation, the soil is structured into layers or horizons. The soil profile is made up of these horizons, or layers. It is the portion of the soil that is exposed vertically by a soil pit. The size of the soil profile and the color of the soil make it easy to identify the soil layer. Top soil, subsoil, and parent rock are the various soil layers. Every soil layer has unique qualities, and the soil profile aids in understanding the function of the soil. It aids in distinguishing the donor soil sample from other soil samples according to characteristics such as color, texture, thickness, structure, and chemical makeup.

A sequence of horizons, or soil layers layered on top of one another, make up the soil profile. These layers or horizons are represented by the letters O, A, C, B, and R. The top soil, or A-horizon, is referred to as the "human layer" and is abundant in organic minerals. Both minerals are present in the stratum. To hold enough water and air, the top soil is porous and soft. Nutrients that have leached from the O and A horizons make up the E horizon. This stratum is more prevalent in wooded areas and contains less clay. The uppermost layer of the topsoil, known as the O-horizon, is primarily made up of organic elements such as dead leaves, dried grass, twigs, small boulders, and dried leaves. Because of the presence of organic matter, this soil horizon has a color that is darker than dark brown. The B-horizon, or subsurface, is located immediately below. Under the topsoil and over the bedrock is the B-horizon, or subsoil. In comparison to topsoil, it is more compact and tougher. It has less organic content, soluble minerals and humus in it. It is a byproduct of the deposition of some metals and minerals, like iron oxide. Because clay soil is present, the layer is lighter brown and retains more water than the top soil. The saprolite, also known as the C-horizon, is composed of fractured bedrock and contains no organic material. Soprolite is another name for this stratum. This zone contains cemented geological material. A stratum that is compacted and cemented is the R-horizon. This area contains a variety of rocks, including limestone, granite, and basalt.

Depending on the method, a few key components appear in the development of the soil. These elements, which are primarily released from parent soils that are primarily covered in igneous or sedimentary rocks, include calcium (Ca), magnesium (Mg), iron (Fe), sodium (Na), potassium (K), chlorine (CL), and phosphorus (P) (Zakir, 2013). According to Ayandiran et al. (2018) and Ogunseye et al. (2022), groundwater has a specific and unique significance in human life. It should be drinkable, devoid of contaminants, minerals, and other organic materials that could harm human health, and suitable for human consumption (Shabanda and Shabanda, 2015). The subterranean water that exists in the voids and fissures of rock, sand, and soil is known as groundwater. Aquifers are sand, soil, and rock geologic formations where water is held and moved slowly (Frank and Spellman, 2012). Over the past few years, groundwater and soil contamination in Etua have steadily grown in importance as environmental issues, which has had an impact on local residents' health. Groundwater and soil vulnerability have become critical environmental and public health issues as a result of the growing demand for drinking water and agricultural products (Mohamed et al., 2009). The drinking water supply in Etua can be substituted by groundwater sources. According to Malik and Khan (2016), there are high concentrations of heavy metals dissolved in water as groundwater flows beneath the surface due to a variety of sources, including animal dung, car emissions, excessive fertilizer application, sewage sludge, petrochemical spills from rapidly expanding industrial areas, pesticides, residue from coal combustion, high metal waste disposal, contaminated paints, and contaminated lead-acid batteries (Harvey et al., 2015).

To prolong human and animal life and to fend off disease, clean drinking water is crucial. By understanding the type of soil and the elements or heavy metals present in both the soil and the groundwater, one may anticipate the quality of the groundwater. Therefore, the purpose of this research is to examine the components of soil and groundwater and their detrimental effects on the residents of the area under investigation in order to provide insight into appropriate and sufficient groundwater treatment. In order to determine the soil profile and potential for groundwater, this study project involves mapping the Etua region of Ndokwa, West L.G.A. of Delta State.

Location/Geology of Study Area

The study area (Etua town) is located in the northern part of Delta State, Nigeria (Figure 1). It is composed of soil layers, some of which might be good aquifers. In the studied region, confined and unconfined aquifers can be identified. The study region is characterized by the Benin, Agbada, and Akata Formations, which are part of the Niger Delta formation sequence (Esi et al., 2023; Esi and Akpoyibo, 2024; Molua et al., 2024; Akpoyibo and Vwavware, 2024). The sands of the Somebreiro-Warri Deltaic Plain, the uppermost portion of the Benin Formation, immediately underlie Etua. Numerous authors (Short and Stauble, 1967; Okolie and Akpoyibo, 2012; Ofomola et al., 2017; Akpoyibo et al., 2022; Esi and Akpoyibo 2023, Anomohanran et al., 2023; Akpoyibo et al., 2023) have thoroughly examined and documented the Niger Delta's geology. According to studies, the sand in the Somebreiro-Warri Deltaic Plain is 120 m thick and is quaternary to recent (Wiber and Daukuro, 1975). The sediments have an uneven texture and range in size from medium-grain sand with occasional pebbles to thin plastic clay. The Benin Formation is mostly composed of loose sand, gravel, and sporadically intercalated shale. It is the primary freshwater supply for the Niger Delta region and is approximately 2000 meters thick, with ages spanning from the Oligocene to the Pleistocene.

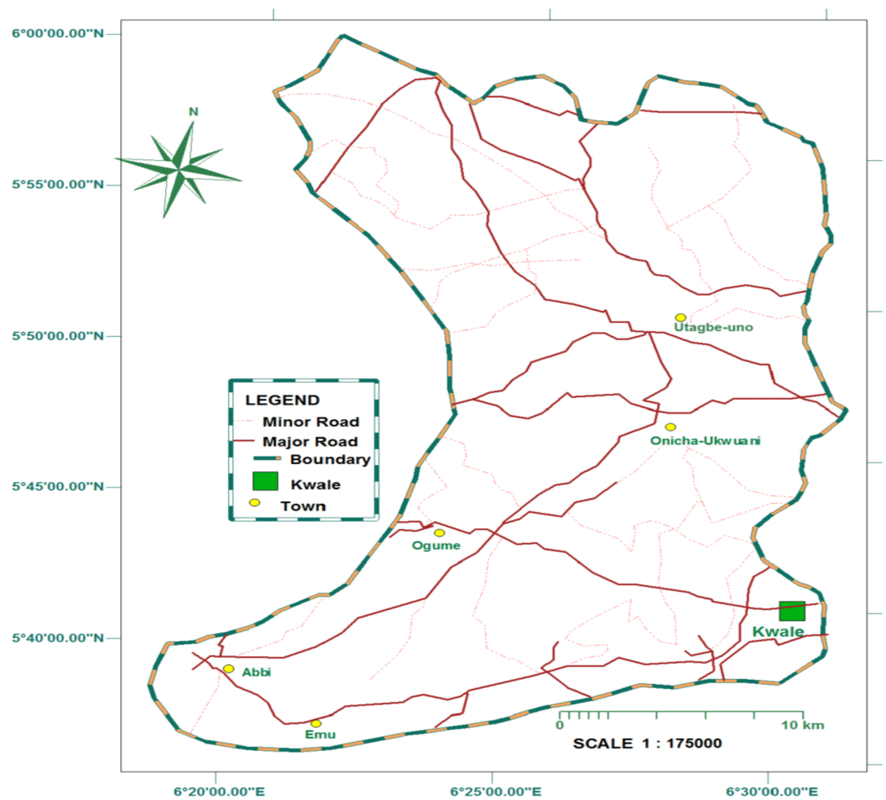

Figure 1: Map of Ndokwa West unveiling Etua Region (Ndokwa West Local Government Council, 2015)

MATERIALS AND METHODS

In the vicinity of Etua, Nigeria, ten sites near oil companies, gas stations, local soap industries, palm oil factories, and mechanic workshops provided soil samples and fresh boreholes that were labeled and collected for laboratory studies at the Federal University of Technology Akure (FUTA) laboratory. There, different metals and compounds were examined to ascertain their concentrations and assess their potential effects on the groundwater in the region. When a crucial area is being researched, the investigation exercise is conducted using the random sample method. This is accomplished by physically surveying the type, color, and structure of the soil. The following basic equipments were used: measuring tape, pen, pencil, empty bags, hammer, masking tape, note book, and jerry cans. The sampling places in Etua, Delta State, include Etua-Uno (EUn), Etua-Oliogo (EOl), Etua-Etiti (EEt), and Etua-Ukpo (EUk), with locations designated as EUn1, EUn2, EUn3, EO_L1, EO_L2, EO_L3, EEt1, EEt2, EEt3, and EUk1. The samples come from several soil horizons in various locations within the investigation region's soil profile. The primary component concentrations that determine them include SiO_2, Fe_2O_3, FeO, Al_2O_3, CaO, Na_2O, and K_2O, and the outcomes were contrasted with the WHO recommended benchmark. The atomic absorption spectrophotometer (A.A.S.) method was used to determine these. Eight (8) samples from various locations within the study region were used for the water analysis. The samples include WEUn1, WEUn2, WEEt1, WEEt2, WEO_L1, WEO_L2, WEU_{k1}, and WEUk2. The ionic concentrations of both soluble and insoluble compounds in water were measured as part of the analysis. Among the determined compositions are Ca, K, Na, HCO_3, SO_4, CL, and Mg.

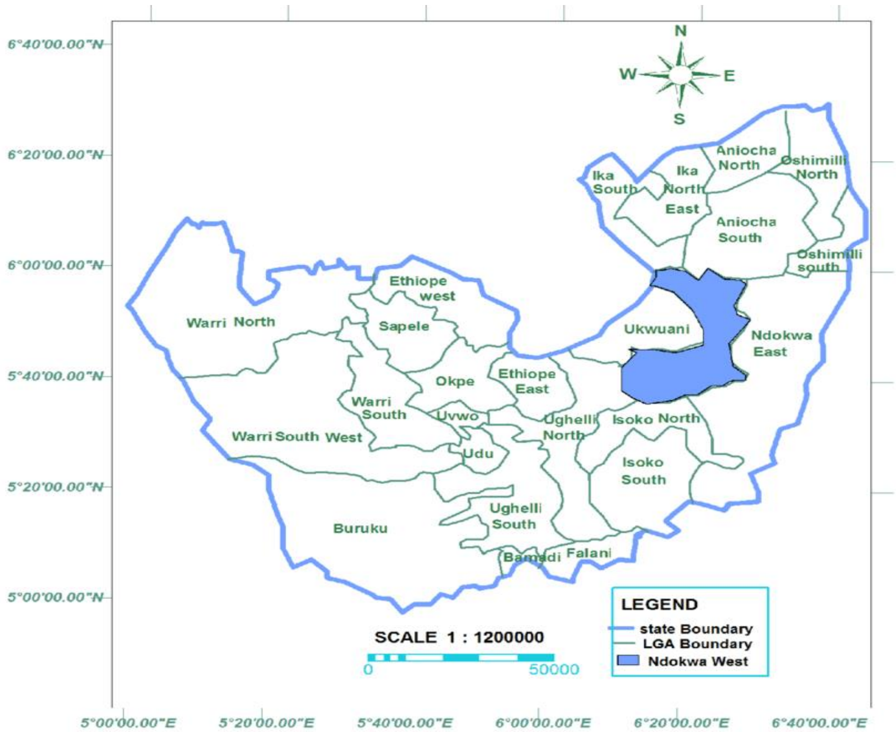

Figure 2: Map of Delta States displaying Ndokwa West (the study area). Source: Ministry of Land and Survey Asaba, Delta State, (2015).

RESULTS AND DISCUSSION

The table below displays the data that was analyzed for the soil sample. The process was carried out based on composition by percentage.

Table 1. Geochemical analysis of soil samples based on percentage composition

location	SiO_2	AL_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Cr	Ni	CL	Sum	S/R
EUn 1	61.40	17.01	44.0	37.0	17.0	24.0	33.0	50.0	01.0	10.1	294.5	1.01
EUn 2	60.20	18.40	30.0	41.0	24.0	31.1	45.0	45.0	11.1	20.0	325.8	1.24
EUn 3	63.00	16.10	22.2	45.0	30.0	10.0	24.0	31.0	11.2	10.0	262.5	1.65
EO_L 1	58.12	17.11	50.0	92.0	18.0	25.0	34.0	1.0	02.0	11.1	308.3	0.87
EO_L 2	60.10	17.70	34.0	47.0	10.5	11.0	21.2	3.0	05.0	13.4	222.9	1.16
EO_L 3	48.40	19.00	25.0	66.0	10.0	67.0	24.5	20.0	01.0	12.5	293.4	1.10
EEt 1	53.30	17.10	34.0	70.0	23.0	11.7	31.0	11.0	11.0	11.0	273.1	1.04
EEt 2	57.90	18.70	28.1	20.0	81.0	21.1	20.8	10.0	12.0	01.0	270.6	1.24
EEt 3	51.10	20.40	29.0	14.0	11.0	25.0	20.0	01.0	01.0	10.3	182.8	1.03
EUk1	52.00	22.10	22.0	10.0	21.0	28.0	11.0	21.0	11.0	12.0	210.1	1.18

The geochemical analysis result is displayed in Table 1. The main total chemical elements found in the examined soils in decreasing order are SiO_2, Fe_2O_3, and Al_2O_3, with averages of 56.55%, 31.82%, and 18.36%, respectively. The investigated soil samples are described by a high quantity (levels) of silica (48.4–63.0%), a reasonable amount of sesquioxides (Al_2O_3 and Fe_2O_3), in the range of 16.10–22.10% for Al_2O_3, 22.0–50.0% for Fe_2O_3, and a significant number of bases (MgO, K_2O and Na_2O). The soil sample is enriched with a high concentration of SiO_2 (43.90%) and Al_2O_3 (12.10%). The silica/sesquioxide ratios (S/R) (Table 1) range from 0.87 to 1.65, and according to Onana et al. (2017), soils are classified as laterite if their ratio of silica to sesquioxides is not greater than 1.33, lateritic if the ratio varies from 1.33 to 2, and also non-lateritic if it exceeds 2.0. This categorization indicates that silicates leak into iron and aluminum oxides since nearly all of the investigated soil samples are categorized as both lateritic and laterite soils. The soil's other geochemical components range in CaO from 10 to 81.0%, K_2O from 10 to 67.0%, and Na_2O from 11 to 45.0%. The minor component comprises chromium (Cr), nickel (Ni), and chlorine (CL), with Table 2 displaying their corresponding percentages.

Table 2. The data analyzed for water sample expressed in mg/l

Location	Ca	Mg	Na	K	HCO_3	SO_4	CL	NO_3
WEUn 1	310.0	1.40	7.10	1.51	78.00	84.00	107.00	4.6
WEUn 2	286.0	12.61	6.22	20.1	61.40	76.31	130.41	8.6
WEEt 1	236.0	10.21	7.81	24.0	51.22	80.44	125.61	13.0
WEEt 2	165.9	11.80	8.00	25.0	45.33	161.11	12.00	9.6
WEO_L 1	262.7	13.00	6.31	31.1	76.00	50.43	10.11	10.1
WEO_L 2	211.1	10.20	5.44	27.6	28.11	80.00	14.00	8.5
WEU_k 1	102.4	14.61	6.66	21.1	34.66	565.03	285.61	11.2
WEU_k 2	240.0	28.2	8.11	10.2	76.45	555.41	133.00	10.3
WHO acceptable limit (mg/L)	200.0	50.0	200.0	12.0	120.0	500.0	250.0	50.0

Chemical analysis of water samples

Analysis yielded the following water contents: Ca, Mg, K, HCO_3, SO_4, CL, and NO_3. The calcium concentration in the Etua region was 226.76 mg/L on average, with a range of 102.40 mg/L to 310.0 mg/L. 200.0 mg/L is the highest amount that can be legally present in drinking water (WHO, 2017). The research area's calcium concentration is both within and beyond the allowable range. The area's high percentage of calcium in the drinking water may be caused by nearby cow bones. A calcium deficiency may result in intestinal, bone, and renal problems. The water sample had a mean magnesium value of 226.76 mg/L and a range of 1.40 mg/L to 28.2 mg/L. 200.0 mg/L is the highest amount that can be legally present in drinking water (WHO, 2017). The study area's magnesium concentration is within allowable bounds. Vegetables, chocolates, and coffee in the oil industry may be the cause of the magnesium concentration in drinking water. Hereditary heart attacks, diabetes, strokes, and even elevated blood pressure are linked to low magnesium levels.

The salt (sodium) concentration in the study area ranged from 5.44 mg/L to 8.11 mg/L, with a 6.96 mg/L mean. According to WHO (2017), the highest permissible amount in drinking water is 200.0 mg/L. The average salt concentration is less than the legal drinking limit.

Sodium content in groundwater in low quantity results in underactive thyroid, diarrhea, and heart failure.

In the study area, potassium concentrations varied from 1.5 mg/L to 31.1 mg/L, with an average of 20.08 mg/L. 12.0 mg/L is the highest amount that can be legally added to drinking water (WHO, 2017). The average potassium concentration in the research region shows that the oil firm, local soap manufacturers, and fertilizers have all contributed to some minor soil contamination. Human consumption of potassium-contaminated water can lead to heart failure and irregular heartbeats (WHO, 2017).

The research area's hydrogen bicarbonate (HCO_3) concentration ranged from 28.11 mg/L to 78.0 mg/L, with a mean of 56.39 mg/L. According to WHO (2017), the highest allowable amount in drinking water is 120 mg/L. The research area's HCO_3 use is within allowable bounds. The compound's rising value is a result of acid rain brought on by gas flaring in the area under investigation.

In the study region, sulfate concentrations range from 50.43 mg/L to 565.03 mg/L, with an average of 144.09 mg/L. 500.0 mg/L is the highest guideline level for drinking water (WHO, 2017). In certain cases, the research area's sulfate content is marginally higher than the uppermost allowable level. But the greater amount of tainted drinking. The concentration of chlorine ranged from 10.11 mg/L to 285.61 mg/L, with a mean strength of 102.22 mg/L. The maximum allowed limit in drinking water is 250.0 mg/L (WHO, 2017). The chlorine concentration in the study area falls within the permissible limit, except for a few cases of high amounts. The high content is due to the occurrence of gas fares in the research area. Deficiency of chlorine causes fluid loss, increases the blood sodium level, and induces asthma.

Concentrations of nitrate differ from 4.6 mg/L to 13.0 mg/L, with a mean concentration of 9.49 mg/L. The maximum permissible limit in drinking water is 50.0 mg/L (WHO, 2017). The concentration of nitrate in the study area is lower than the maximum permissible limit. Nitrate-contaminated drinking water causes methemoglobinemia, headaches, abdominal cramps, and nausea.

These compounds determine many of the properties exhibited by the soil profile in the area. The properties include conductivity, porosity, permeability, and so on. The conductivity of the soil profile in the research area is determined mainly by the above chemical compounds. The mobility of the ions determines the physics of the research region. It is well known that porosity is the amount of empty pore space between the soil profile, while permeability is a measure of the extent to which the empty pore spaces are interconnected to permit water research. The permeability of the soil profile is determined by the soil profile (Hunt 1972). The ionic concentrations of Ca and Mg are higher than those of Na in the research region. Also, HCO_3 and SO_4 are less than CL. The conductivity of water is determined by its chemical component (Linsley, 2021, Ikegu et al. 2024). Water that contains sodium chloride (NaCL) is more conductive than water with a lower concentration of NaCL. Again, sea water is more salty than fresh water; aquifer recharge with sea water tends to conduct electricity more than recharged by fresh water. In the region of research, the aquifer is recharged with fresh water as a result; the conductivity of the ground water is low.

Relationship between soil and water analysis

In the study area, there is a connection between groundwater and the soil profile. Given its ability to store and transfer water, the soil under study in this part of the profile may function as an aquifer. Because there may be lateritic layers above the soil in some places, which may limit the upper surface of saturation, the soil may be a restricted aquifer. Thus, there are similarities between the chemical composition of soil and water. There is a correlation between the chemical makeup of the soil and the groundwater in the research region, according to the analysis done there. Because it has the qualities of water storage and retention, the sandy soil in the profile functions as an aquifer.

CONCLUSION AND RECOMMENDATION

In Etua, Ndokwa West, ten soil samples and eight water samples from various places were examined for a geochemical analysis to determine the groundwater quality suitable for human consumption. The study's findings showed that, in some places, the concentrations of calcium, potassium, sulfate, and chlorine in the boreholes exceeded the World Health Organization's (WHO, 2017) recommended standard for drinking water. Therefore, because it endangers consumers' health, the drinking water is not fit for human consumption. For every sampling location in Etua, the levels of nitrate, magnesium, sodium, and carbonate in water samples were all within WHO guidelines. Therefore, it is advised that groundwater development and additional water treatment be carried out before usage. It could be assumed that the soil in the Etua area contains principal and minor elements of metals. Significant metals are both present in soil and groundwater analyses. There should also be a well engineered dumpsites to prevent groundwater contamination.

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