Electrokinetic Remediation Assisted Phytoremediation to Remediate Barren Acidic Soil

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Abstract. Electrokinetic has proven to be alternative technique to remediate pollution and increase soil strength for soft soil. This remediation method has been applied to remediate the hydrocarbon and heavy metal contaminant. Phytoremediation is a technique used to remediate the hydrocarbon and heavy metal contaminant. Both of this remediation technique has been proven as attractive alternative to clean up polluted soils. Although barren acidic soil is not categories as hazardous, the necessity of covered soil surface is on demand in order to minimize the surface erosion. Other than that, this remediation technology also helps in horticulture in order to enlarge the plantation and farming area. This paper will explain the formation of barren acidic soil, principles electrokinetic remediation for remediation of barren acidic soil and application of phytoremediation in order to sustain the process of remediation. Correlation of both remediation methods will minimize the acidic ion migration and sustain the pH value on soil surface for grass, vegetable or palm oil plantation.

Introduction

Modernization via construction give bad impact to the environment especially to the concept of sustainability when the developer ignoring it. According to Gordon (2012), the major cause for soils to become acid are rainfall and leaching, acidic parent material, organic matter decay and also harvest of high yielding crops.

Soil acidifications have major impact to the landscape environment since acidification of soil can infertile the soil which causing the surface become barren and unfavorable. Most soil acidification from construction process is when the subsoil or parent material is exposed to the atmosphere.

Problem faced from barren acidic soil is surface erosion. These problems not only occur on flat surface but also in slope surface. According to Zachar (1984) in extreme cases the bedrock exposed to the atmosphere where it should be covered by sparse or low vegetation. The destruction of this type of land is a consequence of overgrazing and increase the acceleration of erosion.

Term “barrens” is used to describe regions that have nutrient-poor but supports vegetative species that are adapted to their ecology [1]. The term “barrens” expressed a term for poor farmland, or that it lacks aesthetic landscape. The ecologists most debated on this barren soil are edaphic drought and soil infertility [2].
To minimize this problem, remediation of barren soil need to be done. This paper will discuss the remediation process using electrokinetic and phytoremediation. Both remediation techniques are a laboratory scale with control environment.

**Barren Acidic Soil**

All barren lands are notable for their critical ecological environment with insufficient protection against destructive agents. Zachar, (1984) state that barren land shows a shallow soil profile, the nature of the bedrock is of considerable importance of their classification and identification. Barren acidic soils are shallow, sandy and acidic (Homoya, 1994 after Cranfill, 1991). From study conduct by Faizun (2014), Malaysian barren acidic soils located at Ayer Hitam, Johor characterize differ with Homoya (1994) and Cranfill (1991). Faizun (2014) state that the soil are clayey and silt with depth of 5 to 10 m from surface and extremely acidic with pH value of 2.36 to 2.80.

![Figure 1: Location of barren acidic soil at Ayer Hitam, Johor (After Faizun, 2014)](image)

Tufail, Akhtar and Waqas (2006) mention that the electric conductivity of barren soil is decrease with depth compared to cultivated soils found in Faisalabad, Pakistan. This behavior indicates that the mineral accumulate at the upper surface for barren soil and the mineral is keep mixings at the cultivated soil. Other than that, the pH value of barren soil and cultivated is increasing with depth where the cultivated soil is less acidic.

| Author            | Description                                                                 |
|-------------------|-----------------------------------------------------------------------------|
| Morse (1983)      | steep, south-facing slope...treeless openings of shale-flake talus           |
| Wherry 1963       | land underlain by sand or gravel, from the upper levels of which mineral    |
|                   | constituents other than silica have been leached...deficiency of mineral   |
|                   | nutrients...markedly dry                                                    |
| DeSelm 1990       | acid, infertile, and droughty                                               |
| Cranfill 1991     | Soils are shallow, sandy and acidic                                         |
| Keith 1981        | severe soil moisture depletion                                              |
| Winterringer and  | unfavorable to plant growth                                                 |
| Vestal 1956       |                                                                             |
| Forman 1979       | sandy or shallow soil with frequent fire, high acidity and scarce nutrients,|
|                   | and abundant heaths and crooked pines                                       |
| Frost and Musselman 1987 | open canopy, small stature of vegetation, and exposed patches of sand |
FORMATION
Many barren soils are contains pyrite. According to Brady and Weil (2008) formation of barren acidic soil is based on the oxidation of sulphur element found in the soil. Product of oxidation sulphur is sulfuric acid. These oxidation processes normally occur with presence of pyrite element. Chemical reaction for oxidation of pyrite minerals:

\[
\text{FeS}_2 + 3 \frac{1}{2} \text{O}_2 + \text{H}_2\text{O} = \text{FeSO}_4 + 2\text{H}^+ + \text{SO}_4^{2-}
\] (1)

From the equation \(\text{FeS}_2\) is the empirical formula for pyrite. Presence of excess oxygen and water produce product of \(\text{FeSO}_4\) which is ferrous sulfate and \(2\text{H}^+ + \text{SO}_4^{2-}\) which stand for dissociated sulfuric acid. This dissociated sulfuric acid is then exposed to the water catchment area will influence the water become acidic.

These related reactions are responsible for producing large amount of acidity and reduce the present of sulfur in soil. Oxygen level increase by drainage or excavation of the soil surface.

\[
\text{H}_2\text{SO}_4 = 2\text{H}^+ + \text{SO}_4^{2-}
\] (2)

From equation (1) and (2), formation of hydrogen ion has increase the availability to react with other acid functional group which then can be dissociated. From x-ray photoelectron data observed by Faizun (2014) the percentage of aluminum oxide, \(\text{Al}_2\text{O}_3\) is 26.90% is contribute to cations acid.

Electrokinetic Remediation

Electrokinetic is a process of treatment on soil without disturb the soil through excavation or deep-mixing. Electrokinetic remediation is conducted by inserting two electrodes known as anode and cathode into the soil through drill and application of direct current to mobilize ion between those two electrodes at the specified treatment area. Three parameters that control the electrokinetic process is type of electrode, type of electrolyte and direct current (DC) voltage with duration of current applied. Electrokinetic can be categories as 2 which are electrokinetic remediation (EKR), and electrokinetic stabilization (EKS).

ELECTROKINETIC REMEDIATION SETUP

During electrokinetic remediation, electrode provide and electric field across the soft soil. Electrode promotes migration of electrolyte in the soil media. Electrodes establish the point where current change from an ‘electronic character’ to the ‘ionic’. Electrodes electrons exchanged between the metallic phase and electrolyte in solution. In order for this to occur, reactions will base on Faraday’s law which formulated as “When 96485 Coulombs pass through solution, at both the electrodes a gram equivalent of 45 substances is released”.

Corrosion in electrochemical process is nature. It involves the unprompted oxidation reaction in the presence of an aqueous environment. This process is also known as metal-dissolution reaction and the product of is ionic species: authorities where the work was carried out.

\[
\text{Me} \rightarrow \text{Me}^{n+} + n\text{e}^-
\] (3)
Where Me refer to metal used as electrodes, Me$^{n+}$ is ions of the metal and n is the number of electrons (e$^{-}$). This metal ion is then acting as cementing agent when it precipitates during interparticle contact and increase media strength.

Figure 2: Electrokinetic remediation setup at laboratory scale (Jamil, 2014)

Electrolyte is a solution placed at the anode and cathode that used to extract contaminant as the contaminant changes into ionic form. Researcher used anode as chemical liquid and cathode as distilled water.

Electrolyte conditioning enhanced removal of contaminant and decreased energy consumption from enhancement in dissolution of soil mineral and supply of ions (Baek et al., 2009). Electrolyte conditioning with strong acidic or basic solution decreased dramatically with energy consumption which is a critical factor.

Nowadays, different solutions are being studied to enhance the transport and extraction of contaminants and to prevent the formation of precipitates (Vereda-Alonso et al., 2007). The present of electrolyte increase the applied voltage up to 70% compared to to about 30% without electrolyte (Ahmad Tajudin, 2012). This result show that the electrolyte function as a medium for the electric field pass through and ion mobilization (electromigration) can take place.

According to Ahmad Tajudin (2012) direct current is applying continuously with range of 20 to 60V/m. These voltage gradients control the magnitude of electrokinetic. Maximum voltage of 30 volts and a maximum current of 2 amps with constant voltage gradient of 50 V/m was used for all electrokinetic treatment that have been suggested by many researchers as an optimum voltage gradient for geotechnical purposes and also in the range of 40 – 60 V/m which proposed by Mitchell & Soga (2006). According to Hamir (1997), there is no difference between applying of constant current or constant voltage could be found to the properties of treated soil.

Phytoremediation

Phytoremediation is the used of plant to eliminate the presence of heavy metal, hydrocarbon contaminant and mineral in soil or slurry thus reducing the risk for environmental degradation from leaching to groundwater (Salt et al., 1995). This technique is successfully applied in foreign country and also used to remediate radioactivity pollution in Japan 2011.
Phytoremediation techniques for barren acidic soil using Dieffenbachia as native plants show that there are increasing in pH value from 2.36 to 4.30 on sample from Ayer Hitam, Johor (Faizun, 2014). It is shown that this technique is suitable to be applied at barren acid soil in Malaysia.

Summary

Remediation of natural contamination using both remedial techniques can be applied. The electrokinetic remediation is used to increase the pH where the phytoremediation takes place after electrokinetic remediation for continuous remediation process. Phytoremediation also act as soil surface protection which decrease the velocity of surface water run-off during heavy rainfall.

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