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Investigation on the Classification of Soil (Bauxite) at Old Repas Dam, Pahang

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Abstract: *This project mainly focused on current soil classification (bauxite) at Old Repas Dam, Pahang. By identifying the current soil classification, it would be beneficial to researcher and engineers to get a more precise detail and understanding on the current soil at research area. After soil sampling, several tests and experiments were conducted during this project. The experiments were based on the objectives which were going to be achieved. Firstly, would be alumina testing, silica testing, pH test of soil below 50cm, electrical conductivity (EC) test of soil below 50cm, pH test of surface soil, electrical conductivity (EC) test of surface soil. These experiments are used to observe the current state of soil at Old Repas Dam, Pahang. Based on the result obtained in these experiments, the soil classification is then observed. Remedial measurement advice will be given based on soil classification.*

Keywords: Soil Classification, Bauxite, Soil Texture, Electrical Conductivity

1. Introduction

Considering the practicability on any kind of civil construction especially constructing structure dam or agricultural activities, soil will be major components on determining either the structure will be on stable condition or contaminated on ground soil. All of the workability soil by through-out on soil test in various method and this can void tragedy cause avoiding the consequences of soil. (Robert L. Peurifoy, P.E.; Clifford J. Schexnayder, 2018). Soil quality in specifically the stability and strength depending on its physical properties on the soil performs, functions of maintaining biodiversity and productivity on how good soil reflects. These reflections include also the nutrient cycling, buffering and filtering, partitioning water and solute flow. (Deborah Aller, 2017).

Some important factor to-be considered during civil construction is value of soil pH and soil type on selected construction site project on where to build and what the building to-be constructed are. Physical properties of soil and soil characteristics on selected site project conduct soil testing to find the soil texture. By the soil results get, geotechnical engineer can make sure the soil stability and ability to support the building structure before constructing. It crucial for geotechnical engineering engineers to prove on preferred method, or structural design suitable based on soil data gathered. The ideology on conducting soil test on this project is to decide the value pH on the soil and to verify either the soil tested is bauxite? Identify the various soil types at the dam of this project is important as part of research.

Anew, downstream of Old Repas dam there is a red brownish stagnant water been found. Value potential of hydrogen or pH value of the muddy soil average at 3 which close as acidic in water. Red brownish soil colour uncertain to-be bauxite. (R. Newman, 2005 Bauxite Soil Colour, the mineral & gemstone kingdom, Minerals.net). All this happen due to tin and sand mining activities nearby cause the disturbance in soil properties. Thus, to check the reasons stagnant red brownish water and soil at the site, disparate experiments to-be conduct lab experiment and in-situ experiments. Intellect knowledge on soil classification in soil properties is crucial for geotechnical engineer by allowing them to verify the soil state at Old Repas dam. Four sample location specifically was name as Point A, Point B, Point C and Point D with total of six samples of soil to-be collected for soil tests in lab. Providing an alternate plan on preventing acidic water or red brownish soil flowing to downstream at dam only can-be done after conducting the soil lab experiment with data that been verified by lab experiments.

Old Repas dam is one from three dams that was designed and constructed by Department of Irrigation and Draining Malaysia in year 1925. The construction was a part of integrated tailing retention scheme for bentong area. Approximately of 8.8 acres of total size of dam and around 47- 50% of it been used for agricultural, Tin Mining and Sand Mining. Height if the dam is 13400mm with 210000mm of crest length. Elevation of the crest is 143290mm. Vertical shaft spillway type with six compartments in this dam. Old Repas dam placed about 14km from Bentong old town along the side of Raub – Bentong Road. Preceding to this scheme, tailings and silts from tin and sand mind in Bentong hills used to flow down to Repas, Perting and Leboh tributary, fill the stream until town of Bentong flooded after heavy pour. Severe erosion and seepage problems emanate up the dam, a draft was proposed by raising the spillway inlet by its designed level had to-be abandoned by the year 1950. Instead of constructing a new dam at suitable tributary, Department of Irrigation and Draining Malaysia build New Repas dam located 610000mm downstream of Old Repas dam. (Official Portal for Department of Irrigation and Drainage, Ministry of Water, Land and Natural Resources, Old Repas Dam).

Essentially three aim was design for this project narrow down as 1st to determine the soil classification (bauxite) at red brownish stagnant spot in Old Repas Dam, Pahang. 2nd to determine the current pH value of the soil at red brownish stagnant spot and 3rd to measure soil salinity of the selected spot by using electrical conductivity test.

2. Literature Review

Sedimentary rock where has aluminium high classified as Bauxite. It form to bauxite when laterite soils will leached out from silica bedrock with low iron in wet tropical climate as Malaysia. This is the principal ore of aluminium in determining the rock. Occupational health risks in mining especially in alumina refining or bauxite mining require aggressive maintenance and effective control measures (Donoghue, A, 2014).

Complexion of soil where contain high aluminium (Bauxite) can-be color as white, grey reddish, pink, red brownish, dark red or beige. Soil or monohydrated bauxite occurred in red brownish or grey green. (Bauxite Soil Color, the mineral & gemstone kingdom, Minerals.net). The color of monohydrated bauxite can be in grey green or reddish brown is because it mainly consists of boehmite (aluminum oxide hydroxide) and diaspore. (Arindam Guha, Vivek Kr. Singh, Reshma Parveen, K. Vinod Kumar, A.T. Jeyaseelan, E.N. Dhanamjaya Rao, 2013).

2.1 Classification of bauxite deposits

Bauxite generally has several mixture example calcium oxides, iron oxides, magnesium, phosphorus and 27 – 80% of aluminium oxide. Moisture content within bauxite has range between 10 – 28% (Yan Li, H.H Zhao, G.L Yan, 2012). Minerals such as alumina commonly found in Monohydrated bauxites are Boehmite and dispersal (diaspore). Diaspore is solid and rigid even will break the glass with specific gravity range between 3 – 3.5 (Maddi Karthik Reddy, Vipparla Swarup Kumar, Vadde Ramesh, 2015).

2.2 Bauxite soil pH value

Red brownish mud of bauxite indicate value pH in acid range from 2 – 4, at edge of values of 2 in pH, there was a significant increase in aluminum extraction while it is pH values of 2 (Wm. VL and AF. Mackenzie, 2012, S.M Shaikh, Z.S Khan, A.B Ade, 2010).

2.3 Environmental impact of bauxite

Unfavourably impact from mining example sand mining or bauxite mining can impact on water sources, soil and air. Environment pollution strain indirectly effect on the nearby communities or occupational health issue to miners. In sand or bauxite mining, activities or process such as blasting using explosion or water gun, site clearance, open-pit drilling, opening road track, heavy vehicle movement, loading and hauling, ore handling and rocks wastage create significant dust pollution to air. (Van, Sangyan, 2016). Heavy metals in the sediments and red brownish mud can-be absorbed into soil and surface water. This source cause impact to animals, wild life, plants and numerous level of food chain. (Lee KY, Ho LY, Tan KH, Tham YY, Ling SP, Qureshi, Ponnudurai, Noordin R, 2017).

2.4 Determination of soil pH

To get the current soil pH value at research area, soil pH value test will be conducted in lab. Sample location preferential selected to conduct soil pH value test. By penetrating the metal probe directly to soil pH meter into the moisture soil, values of soil can-be measured in the laboratory or in-situ. Then, record the soil pH level shown on display after the meter probe stabilized. (Ali Bozkurt, Cengis Kurtulus, 2009).

2.5 Salinity Soil

Salinity soil term used to elaborate the content of salt in the soil. Salinization soil usually arise when water-soluble salts which pile up in the soil reach to a certain level and it will bring severe impact on economics, occupational health, environmental communities health, agricultural production. The aftermath of salinity soil is revamp productive land and fertile land into barren lands and desert. (S.R. Imadi, Parvaiz Ahmad, 2016). Salinity soil can-be determined in the laboratory or in-situ by measuring the electrical conductivity (EC). (Marcus, H. and Richard, D. 2012).

2.6 Mining Activities

Sand mining or bauxite mining activities cause major severe to local environment. Substances of chemical used to segregate target mineral substance during mining extraction. This mining extraction activities will pollute the soil surrounding and causes the pH value in soil to-be acidic. Abandoned mine will cause potential environment risk to surface water and soil surrounding if no legitimate precautions measure take place into abandoned mine. pH occasionally below 3 enhances heavy metal mobilization leaching (Low leachate) from the rocks. (Cristina Postigo, Pere Emiliano, Damià Barceló, Fernando Valero, 2018).

2.7 Alumina

Alumina oxide Al_2O_3 is a chemical compound which aluminum binds with oxygen. It is released by weathering process (E.O. McLean, 2008). The higher the content of aluminum in the soil, the lower the pH of the soil. Soil been classified as bauxite if content in soil high in alumina and low in silica (The Bauxite Index, Bauxite formation and process). Normal soil does not contain too high percentage of aluminium content. Bauxite generally has several mixture example calcium oxides, iron oxides, magnesium, phosphorus and 27 – 80% of aluminium oxide. (Maddi Karthik Reddy, Vipparla Swarup Kumar, Vadde Ramesh, 2015).

2.8 Silica

Silica oxide SiO_2 is a chemical compound which silica binds with oxygen. Silica is a colorless, white chemical compound. The soil pH increase throughout the reaction range pH 4 to pH 9 if concentration of silica in soil decreased (J.A. McKeague, MG Cline, 1962). Soil been classified as bauxite if content in soil high in alumina and low in silica. (Gifford, R., & Frugoli, D, 1964)). The higher the content of iron and aluminium oxides in the soil, the higher the silica content in the soil. The dominant component of sand is mineral quartz, which is mainly composed of silica.

3. Methodology

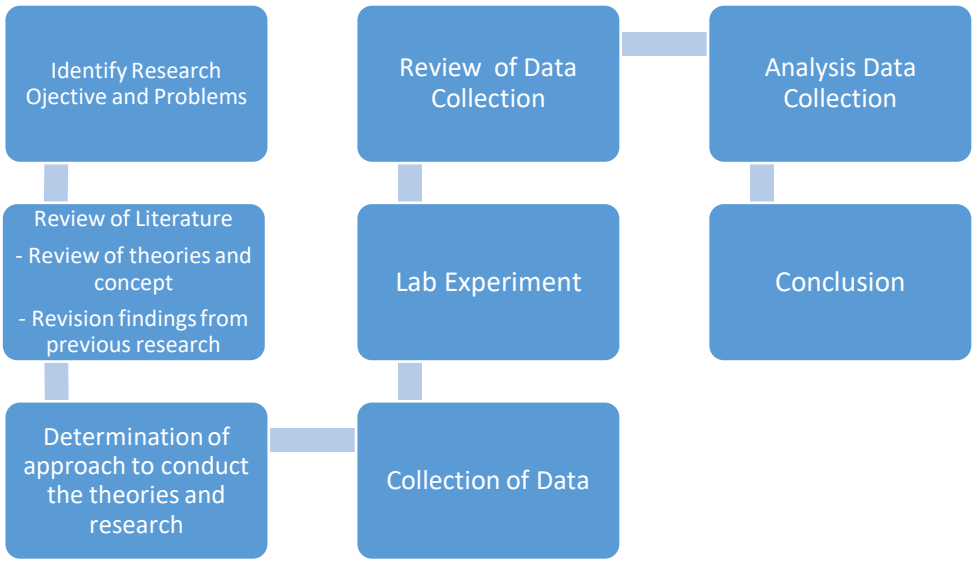

Figure 1.0: Project Flow Chart

Soil auger is used to drill a 50cm depth hole to obtain the soil below 50cm. Soil sampling bag which marked A(lab), B(lab), C(lab) and D(lab) will be sent to the laboratory to check for two parameters. Each of the soil sampling bag must contain at least 1kg of soil. First parameter is alumina in soil testing. Second parameter is silica in soil testing.

3.1 Soil test (pH value)

To obtain the pH value of the soil below 50cm, soil auger is used to drill the hole until 50cm below the surface soil. To conduct soil pH value test, the ratio of soil to distilled water is 1:1, which is 50gram of soil are put in a clean and dry plastic container, filled with 50ml of distilled water and mechanically stir for 10 minutes and formed muddy soil. Then, penetrate the head of pH meter into the soil to get the reading. To gather the pH value of soil surface, metal probe

need to-be penetrate into muddy soil and make sure it submerged into soil. Record the value once the value appear on-screen.

3.2 Electrical conductivity (EC) test for measuring salinity soil

Salinity soil will be amplitude by using electrical conductivity (EC) test. Conductivity of electric measure in a solution using an electrical conductivity (EC) meter. Proper ratio determination of soil salinity suggested which is 1:5 where soil: distilled water. This ratio was suggestion because the ratio of 1:5 soil: distilled water produces larger quantity of solution for smooth measurement. (Hardie M., Doyle R. (2012). The ambient temperature for conducting soil salinity test is 25 Degrees Celsius. Prepare a 1:5 soil: distilled water. For example, 50g of air dry soil into a vial and add 250 mL of distilled water. Mechanically shake it for 30 minutes at 25 degrees Celsius in a closed system to dissolve soluble salts. Allow the soil to settle for 15 minutes.

4. Results and Discussions

4.1 Silica and Aluminum analysis

All the soil sample of four sampling points is sandy soil. Based on result obtained, the silica content for soil sampling point A is 52.48%, point B is 47.08%, point C is 88.80% and point D is 63.24%. The result shown that the percentage of silica content at soil sampling point C is 88.80% which is the highest among the four sampling points. Bauxite content is the mixture of silica and different kind of iron oxides. Soil been classified as bauxite if content in soil high in alumina and low in silica (The Bauxite Index, Bauxite formation and process). The higher the content of iron and aluminium oxides in the soil, the higher the silica content in the soil. The dominant component of sand is mineral quartz, which mainly composed of silica.

The result shown the aluminium content at soil sampling point A is 10.75%, soil sampling point B is 20.21%, soil sampling point C is 10.70% and soil sampling point D is 23.71%. At soil sampling Point B and Point D, the aluminium content in the soil is 20.21% and 23.71% which is both more than or equal to 20%. Normal soil does not contain so high percentage of aluminium content. Bauxite generally has several mixture example calcium oxides, iron oxides, magnesium, phosphorus and 27 – 80% of aluminium oxide. (Maddi Karthik Reddy, Vipparla Swarup Kumar, Vadde Ramesh, 2015).

For soil sampling Point D, the aluminium content is 23.71 % and the silica content is 63.24%. The percentage of aluminium content in soil sample Point D is 23.71% which is very near to bauxite content. Bauxite is the most important ore of aluminium which contains only 30% to 54% of alumina Al_2O_3. The rest of the bauxite content is the mixture of silica and different kind of iron oxides. Soil been classified as bauxite if content in soil high in alumina and low in silica. (Arindam Guha, Vivek Kr. Singh, Reshma Parveen, K. Vinod Kumar, A.T. Jeyaseelan, E.N. Dhanamjaya Rao, 2013).

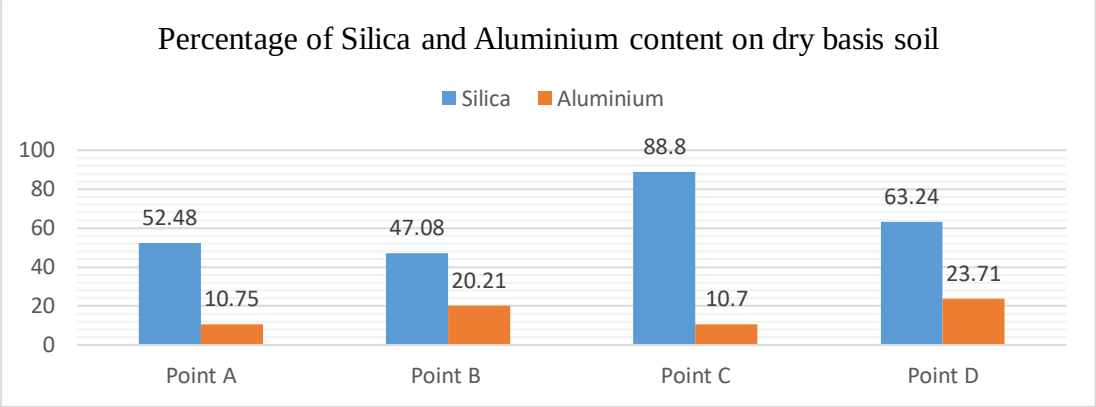

Figure 2.0: Silica and Aluminium content on dry basis soil

4.2 pH test analysis for soil below 50cm

The results obtained were all acidic and at the pH range between 5.21 - 6.7. The pH value for soil sampling Point A is 5.21, Point B is 6.60, Point C is 6.00 and Point D is 6.71. The most acidic sampling point is Point A which is 5.21. Point A occurred to be the most unusual pH value among these four points and point A is classified as acidic. Optimal soil pH range for most plants is between 5.5 and 7.0. At first soil sampling trip, there was 5 minutes of rainfall prior to the sampling. The runoff due to the rainfall caused the concentration of the acidic compounds to enter the soil and make the soil become more concentrated and muddier, thus increasing the acidity of the soil.

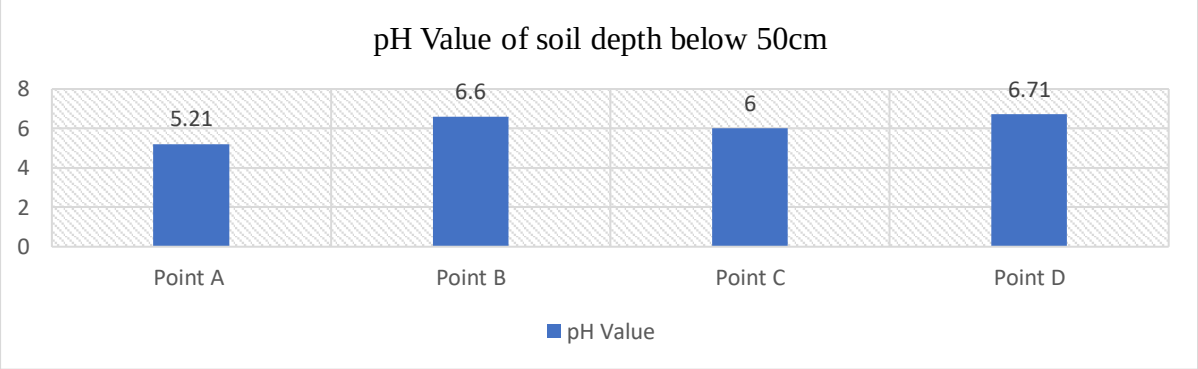

Figure 3.0: pH value on soil sampling

4.3 EC test analysis for soil below 50cm

Sand has a lower electrical conductivity value which is 1 – 10 mS/m. (Chakravarty, P., Deka, 2021). At this case, the four sampling points are all sand. In the electrical conductivity test, the result for Point A is 12.6 mS/m, Point B is 10.4 mS/m, Point C is 8.4 mS/m and Point D is 12.6 mS/m. In the electrical conductivity test, the highest electrical conductivity value obtained were Point A and Point D which is 12.6 mS/m for both the point. Too low of electrical conductivity value indicate low available nutrients in the soil but too high of electrical conductivity indicate excess of nutrients in the soil. (Chakravarty, P., Deka, 2021).

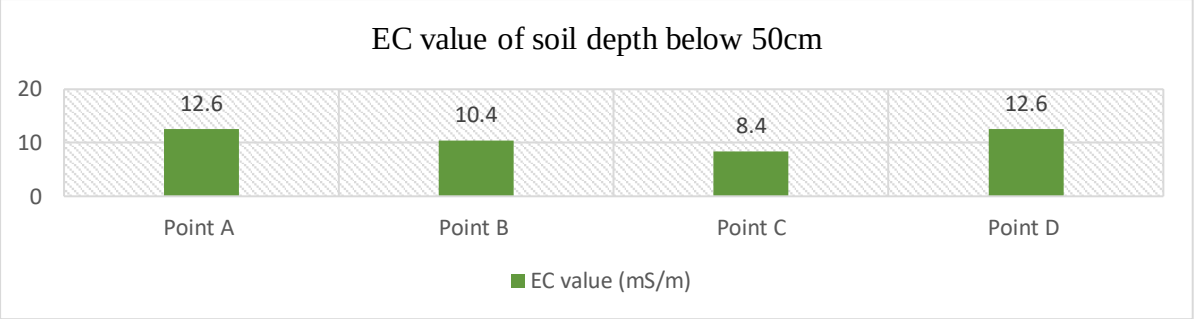

Figure 4.0: Electrical conductivity value on soil sampling

4.4 pH test analysis for surface soil

The pH value for soil sampling Point A is 6.37, Point B is 6.27, Point C is 6.55 and Point D is 6.78. Eventually Point A, Point B, Point C and Point D occurred to be acidic. The most acidic sampling point is Point B which is 6.27. pH value which is below 7 is classified as acidic. pH value of 7 is being neutral. Above 7 is alkalinity. Soil pH is a measure of the alkalinity and acidity of the soil. The optimal soil pH range for most plants is between 5.5 and 7.0.

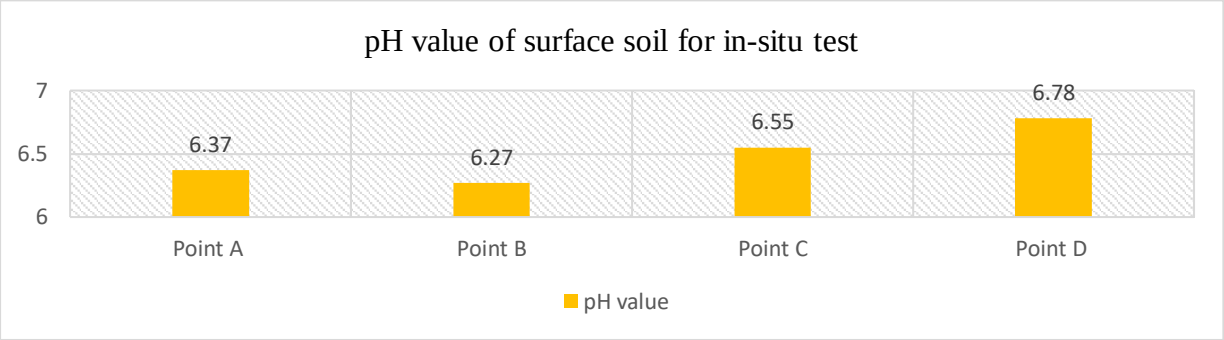

Figure 5.0: pH value of surface soil

4.5 EC test analysis for surface soil

Four sampling points are all sand. In the electrical conductivity test, the result for Point A is 21.2 mS/m, Point B is 3.8 mS/m, Point C is 8.6 mS/m and Point D is 11.4 mS/m. In the electrical conductivity test, the highest electrical conductivity value obtained were Point A which is 21.2 mS/m. Too low of electrical conductivity value indicate low available nutrients in the soil but too high of electrical conductivity indicate excess of nutrients in the soil. (Chakravarty, P., Deka, 2021).

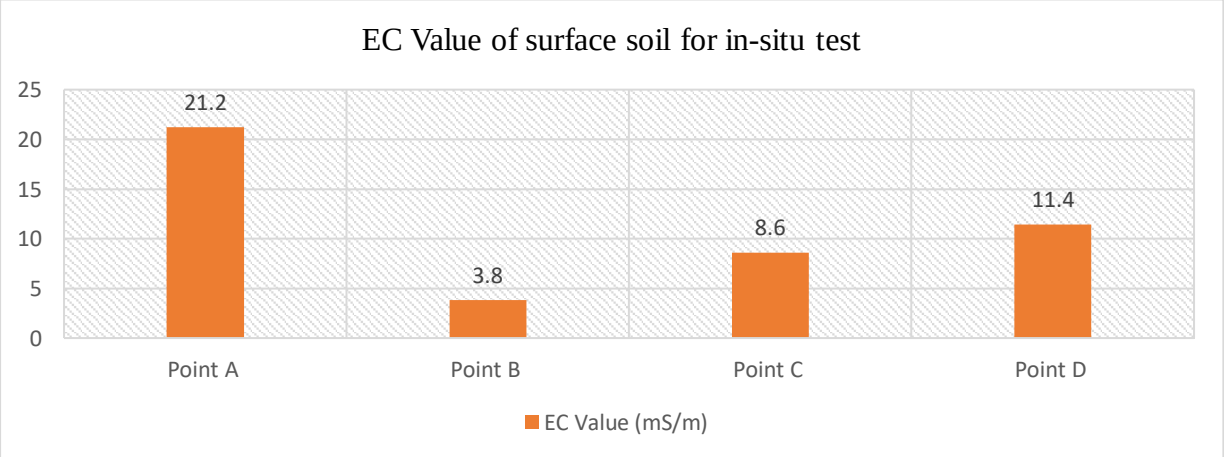

Figure 6.0: Electrical conductivity value of surface soil

4.6 Comparison of the pH value of the top soil and the soil below 50 cm.

The pH value of surface soil and soil below 50cm were all acidic. There was a slightly difference in between the pH value of the surface soil and soil below 50cm. The results were similar when it is compared. The recorded pH value for both sampling day lies within the pH range 5.2 to 6.8. The average data of soil samples that taken on first sampling were more acidic when compared to second sampling. At first soil sampling, the soil had a lower pH value due to 5 minutes of rainfall prior to the sampling. The runoff due to the rainfall caused the concentration of the acidic compounds to enter the soil and make the soil become more concentrated and muddier, thus increasing the acidity of the soil. The result obtained prove that the occurrence of acid mine drainage (AMD) on the sampling points. For point A, it had a range of pH between 5.21 to 6.37. For point B, it had a range of pH between 6.60 to 6.27. For point C, it had a range of pH between 6.00 to 6.55. For point D, it had a range of pH between 6.71 to 6.78. Based on the comparison, Point D has the least difference in the pH value.

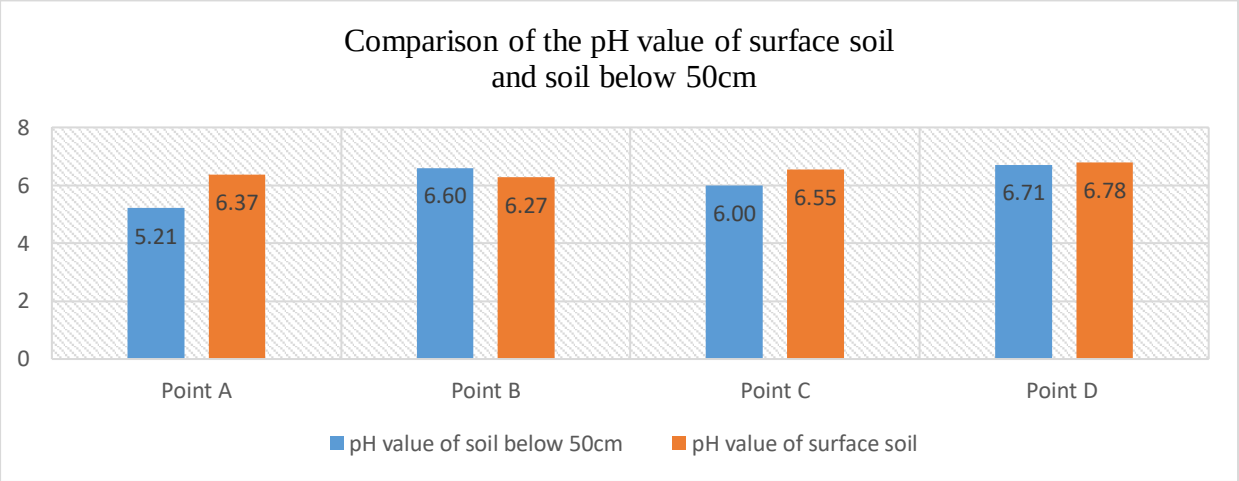

Figure 7.0: Comparison of the pH value of surface soil and soil below 50cm

4.7 Comparison of the EC value of the surface soil and the soil below 50 cm

The type of soil sample at four sampling points are all sandy soils. Sandy soil has a lower electrical conductivity value which is 1 – 10 mS/m. (Chakravarty, P., Deka, 2021). EC value for Point A soil below 50cm is 12.6 mS/m and for surface soil is 21.2 mS/m. EC value for Point B soil below 50cm is 10.4 mS/m and for surface soil is 3.8 mS/m. EC value for Point C soil below 50cm is 8.4 mS/m and for surface soil is 8.6 mS/m. EC value of Point C is in the range of sandy soil 1 to 10 mS/m. This means that sandy soil has a poorer capacity to store cations and lose nutrients easier than silty and clayey soil. EC value for Point D soil below 50cm is 12.6 mS/m and for surface soil is 11.4 mS/m. based on the result shown in Figure 8.0, for Point A and Point D, the EC value of surface soil and soil below 50cm are more than 10 mS/m. Therefore, Point A and Point D considered as high electrical conductivity value.

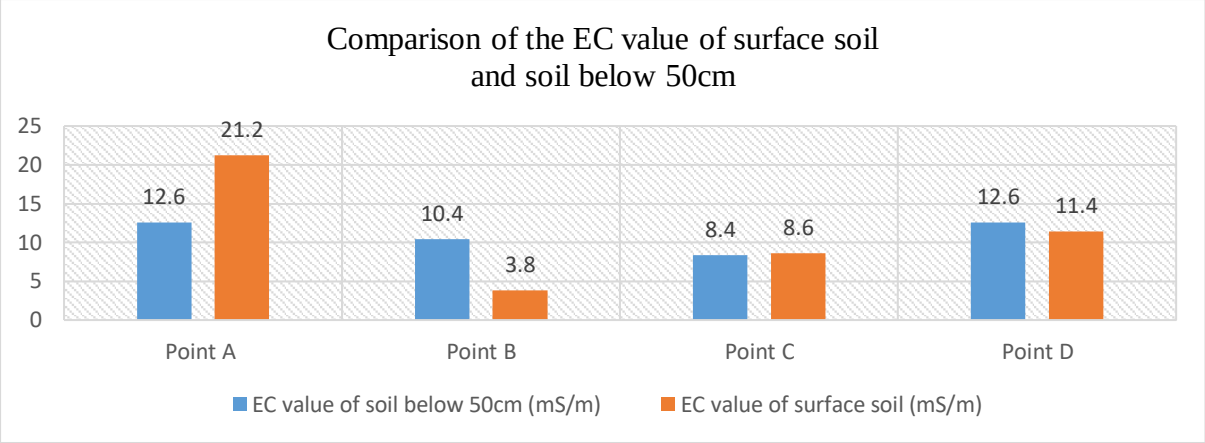

Figure 8.0: Comparison of the EC value of surface soil and soil below 50cm

5. Conclusion

The experiments were carried out to determine the soil classification (bauxite) of Old Repas Dam, Pahang. According to the test result, all the soil sample of four sampling points are sandy soil. At first soil sampling, there was 5 minutes of rainfall before taking the soil sampling. At second soil sampling, there was no rainfall on the day. Based on the result obtained by conducting the alumina testing of soil, the highest alumina content of soil is Point D and followed by Point B. Point D contains 23.71% and Point B contains 20.21% of aluminum. Soil been classified as bauxite if content in soil high in alumina and low in silica. (Chakravarty, P., Deka, 2021).

Normal soil does not contain so high percentage of aluminum content. Normal soil does not contain too high percentage of aluminium content. Bauxite generally has several mixture example calcium oxides, iron oxides, magnesium, phosphorus and 27 – 80% of aluminium oxide. (Maddi Karthik Reddy, Vipparla Swarup Kumar, Vadde Ramesh, 2015). The content of alumina in Point D and Point B is bordering on the range of bauxite soil which is 27% to 80% of aluminum oxide. Based on the result obtained by conducting the silica soil test, the highest silica content of soil sampling point is Point C which is 88.80%. The alumina content of Point C is 10.70%. Soil been classified as bauxite if content in soil high in alumina and low in silica. (Chakravarty, P., Deka, 2021). It can be concluded that Point C is not bauxite soil.

For soil pH test on the first soil sampling, the soil samplings were carried out by collecting soil below 50cm. The soil had a lower pH due to rainfall prior to the sampling. Soil sampling Point A has the lowest pH value on the first soil sampling day which is pH 5.21. Soil sampling Point D has the highest pH value on the first soil sampling day which is 6.71. The rainfall caused the runoff on surface of soil to flow from upstream to downstream, soil sampling point is at downstream. The water particles penetrate the soil and contribute to a lower pH value.

A lower pH value of soil contributes to a higher soil electrical conductivity. However, bauxite soil has the pH value range between 2 to 4. (S.M Shaikh, Z.S Khan, A.B Ade, 2010). The soil pH test result obtained at both soil sampling range between 5.21 to 6.78. For soil pH test on the second soil sampling, the soil pH tests were carried out in-situ on the surface of soil of Point A, B, C and D. Point B has the lowest pH value which is 6.27 and Point D has the highest pH value which is 6.78. For second soil sampling, the pH of the soil range between 6.27 to 6.78. Based on the result obtained on the both soil sampling day, it can be concluded that first soil sampling day has a lower pH value compared to second soil sampling due to rainfall prior to

first soil sampling and the depth of the soil does not bring up a big effect on the pH value of soil.

For soil electrical conductivity test on first soil sampling, the soil samplings were carried out by collecting soil below 50cm. The soil below 50cm had a higher EC value when compared to the surface soil. The soil had a lower pH due to rainfall prior to the sampling. The lower the soil pH, the higher the soil electrical conductivity. Point A and Point D had the highest electricity conductivity value which is 12.6 mS/m and 12.6 mS/m. Point C has the lowest EC value which is 8.4 mS/m. Sandy sand has a lower electrical conductivity value which is 1 – 10 mS/m. (Chakravarty, P., Deka, 2021). Based on the result obtained on first soil sampling, it can be concluded that the EC value of Point A and D is very high because the EC value of Point A and Point D more than 10 mS/m. For soil electrical conductivity test on second soil sampling, the electricity conductivity tests were carried out in-situ on the surface of the soil. Point A had the highest EC value which is 21.2 mS/m and followed by Point D which is 11.4 mS/m. Point B has the lowest EC value which is 3.8 mS/m. Based on the result obtained, it can be concluded that Point A and Point D is very high because the EC value of Point A and Point D more than 10 mS/m. According to the electricity conductivity test result for both soil sampling day, Point A and Point D were the highest EC value among the four soil sampling points.

References

Wm. VL and AF. Mackenzie, (2012), Soil pH Measurement and its application to organic soil in *Canadian Journal of Soil Science.*

Maddi, K.R. and Vadde, M. (2015), Mode of occurrence and distribution of bauxite deposits in Andhra Pradesh and feasibility of aluminium industry. *Procedia, Earth and Planetary Science.*

Van, Sangyan. (2016), Soil pollution: causes, effects and control. *Tropical Forest Research Institute*, 3, 1.

Ali, Bozkurt. and Hasan, E. (2009), Measurements of apparent electrical conductivity and water content using a resistivity meter. *International Journal of Physical Science,* 4,12.

Marcus, H. and Richard, D. (2012), Measuring Soil Salinity. *Article in molecular biology.*

Lee, K.Y., Ho, L.Y., Tan, K.H., Tham, Y.Y., Ling, S.P., Qureshi, A.M., Ponnudurai, T. and Nordin, R., (2017). Environmental and Occupational Health Impact of Bauxite Mining in Malaysia: A Review. *International Medical Journal Malaysia*, *16*(2). Michael Donughue, (2015). Bauxite mining and alumina refining. *Process description and occupational health risks.*

Yan Li, H.H Zhao, G.L Yan, (2012). Study on Mineral Composition and Main Mineral Morphology of Bauxite from ZhongXiang, HuBei Province.

S.R. Imadi, …Parvaiz Ahmad, (2016). Phytoremediation of Saline Soil for Sustainable Agricultural Activity. *Plant Metal Interaction.*

S.M Shaikh, Z.S Khan, A.B Ade, (2010). Effect of pH on Metal Extraction from Bauxite Ore by Thiobacillus Ferrooxidans.

E.O.McLean, (2008). Chemistry of soil aluminium. Communication in Soil Science and Plant Analysis.

Donoghue, A.M., Frisch, N. and Olney, D., (2014). Bauxite mining and alumina refining: process description and occupational health risks. *Journal of occupational and environmental medicine*, *56*(5 Supply), p.S12.

Gifford, R., & Frugoli, D. (1964). Silica Source in Soil Solutions. *Science, 145*(3630), 386-388. Retrieved February 25, 2021, from http://www.jstor.org/stable/1714435

Robert L. Peurifoy, P.E.; Clifford J. Schexnayder, P.E., Ph.D.; Robert L. Schmitt, P.E., Ph.D.; Aviad Shapira, D.Sc. Construction Planning, Equipment, and Methods, Ninth Edition (McGraw-Hill Education: New York, Chicago, San Francisco, Athens, London, Madrid, Mexico City, Milan, New Delhi, Singapore, Sydney, Toronto, 2018).

Deborah Aller, Ross Mazur, Kenneth Moore, Roger Hintz, David Laird, Robert Horton, Biochar Age and Crop Rotation Impacts on Soil Quality, Soil Science Society of America Journal, 10.2136/sssaj2017.01.0010, **81**, 5, (1157-1167), (2017).

R. Newman, 2005 *Bauxite Soil Colour, the mineral & gemstone kingdom, Minerals.net*

Arindam Guha, Vivek Kr. Singh, Reshma Parveen, K. Vinod Kumar, A.T. Jeyaseelan, E.N. Dhanamjaya Rao, Analysis of ASTER data for mapping bauxite rich pockets within high altitude lateritic bauxite, Jharkhand, India, International Journal of Applied Earth Observation and Geoinformation, Volume 21,2013, Pages 184-194, ISSN 0303-2434,

Cristina Postigo, Pere Emiliano, Damià Barceló, Fernando Valero, Chemical characterization and relative toxicity assessment of disinfection byproduct mixtures in a large drinking water supply network,Journal of Hazardous Materials,Volume 359, 2018,Pages 166-173,ISSN 0304-3894,https://doi.org/10.1016/j.jhazmat.2018.07.022.

Hardie M., Doyle R. (2012) Measuring Soil Salinity. In: Shabala S., Cuin T. (eds) Plant Salt Tolerance. Methods in Molecular Biology (Methods and Protocols), vol 913. Humana Press, Totowa, NJ. https://doi.org/10.1007/978-1-61779-986-0_28

Chakravarty, P., Deka, H. Enzymatic defense of *Cyperus brevifolius* in hydrocarbons stress environment and changes in soil properties. *Sci Rep* **11,** 718 (2021). https://doi.org/10.1038/s41598-020-80854-5**.**