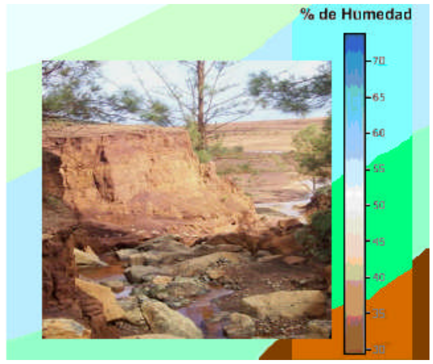

The influence of precipitation on soil moisture at the Ferronickel Mining plant S.A

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Summary: The objective of this investigation is to assess the effect of precipitation patterns on soil moisture in the Mining Ferronickel plant area to establish the basis for pre-drying treatment methods to be used in the industrial process. To achieve this, a temporal statistical study was carried out based on the determination of seasonal nature using additive method. This method is based on a 21-year series of rainfalls measured by using 5 rain gauges in the localized area of study and an analysis of variance using the simple determination method. This provides an accurate determination of wet and dry periods in the locality. This allows establishing the relation between rainfall indexes with soil moisture.

Keywords: pluviometry; precipitation soil; ferronickel mining plant S.A.

Influencia de las precipitaciones en la humedad natural de los suelos de la planta Ferroníquel Minera S.A.

Resumen: La presente investigación tiene como objetivo valorar la influencia de las precipitaciones en el comportamiento de la humedad natural de los suelos en el área de la Planta Ferroníquel Minera S.A. lo que permite establecer criterios sobre el método de pre-secado a emplear en el proceso industrial. Para ello se emplea un estudio estadístico de series temporales que se basa en la determinación de la estacionalidad por el método aditivo que sigue una serie de 21 años de datos pluviométricos registrados por 5 pluviómetros del área del estudio y un análisis de varianza por método de determinación simple; cuya aplicación se traduce en la definición con precisión de los períodos húmedos y secos que se manifiestan a nivel local y que permiten obtener la relación de la pluviometría con la humedad natural de los suelos.

Palabras clave: Pluviometría; precipitación; suelo; planta Ferroníquel Minera S.A.

Introduction

The volume of rainfalls reported in the region of Moa is a key factor in exposing ore bodies which are the product of an intense weathering process in which water plays an important role. Due to these conditions of heavy rainfalls, intense evaporation, high temperatures and continuous fluctuations in underground water tables, soils are subjected to different cycles of drying and moistening throughout the year due to the reloading they experience in the locaty and region.

Soils are originated from the pre-existing rock massifs that make up the bedrock that is subjected to disintegration by erosion in its three phases: physical, chemical and biological processes. These processes result in the disintegration and alteration of a rock, thus forming a meteorization profile. The soil that remains at the place of formation without being transported is called residual soil and when it has been carried is called transported soil. (González de Vallejo, 2002).

The soils in the area of study constitute all the material to be extracted, where Ferronickel mining S.A is being built. Their thicknesses are varied; approximately 30 meters (Ferronickel report). They belong to the materials forming the laterite meteorization crust; specifically on the saprolite zone of the laterite profile. According to physical-mechanical properties, these soils are classified into: plastic clayey silts (MH), silty sands (SM) and clayey gravel (GM).

Silty sands with gravels (SM) and silty gravels with sand (GM)

Generally, these types of soils are characterized by the predominance of either gravel or sand as their other characteristics the same; such as matrix with high plasticity, high specific weights, among others. The content of some gravels and sands are serpentine relicts so they are occasionally represented by fragments of hydroxide of iron and quartz to a lesser degree.

Plastic clayey silt (MH)

Partly, they are simply plastic silts (clayey) or with sand or sandy. But they are generally plastic clayey silts with sand. The average grain size is 3% gravel; 15% sand; 51% lime; 32$ clay; 18% colloid. Plasticity is high with liquid limit of 70%, plastic limit of 41% and plasticity index of 29%. The specific weight is very high (3,51). In normal conditions, they have: 54,8% humidity; specific humid and dry weights are 17,0 kN/m^3 and 11,3 kN/m^3 ; respectively. In particular, they have low shear strength; although logically, their parameters improve, although very slightly, for the different trial schemes, from saturated to humid (with natural moisture content or optimum moisture) and from quick to slow.

Because of their composition, these soils may be expansive but both controlled and free swell factors are somewhat offset in their natural state by high moisture and silt and sand contents. It can be observed that depending on the optimum humidity, compacted soils are somewhat expansive, with an average value of 0,097 MPa.

Based on their consolidation, these soils may be deformed with a module of deformation below 20 MPa for all the tested loads. The specific weights of these compacted materials from standard proctor compaction are improved so it would be needed to dry approximately 13,0%. At an optimum humidity of 42,2 %, specific dry and humid weights are 18,1 kN/m^3 and 12,8 kN/m^3, respectively. Consolidation and strength behaviors also improved as opposed to the swelling which is increasingly unfavorable.

Although it is not of interest for this investigation, it is important to mention that the existing serpentinite rock ranges in color from dark green to brownish gray and occurs as cracked or fractured. These serpentinites are distinguished as brecciated, medium to fine grained and schistose. The predominant distribution in the studied area closely corresponds to the order above.

In order to analyze the natural moisture content behavior of the soils above based on the effect of rainfalls on this index, the main results of the investigation conducted in the Ferronickel mining plant S.A area are described below.

Pluviomeric analysis in the studied area. Interpretation of statistical results

The analysis of precipitation is based on data collected from 5 rain gauges distributed irregularly, having an influence in the studied area.

When analyzing the variance to verify if there are significant differences in the amount of precipitation recorded by the rain gauges, it is observed that the F (Fisher) calculated from the data is lower than the critical value of F, which indicates that there is no significant difference in the average gauge readings as their behaviour across all the periods is similar.

Figure 1 shows the average yearly rainfall distributions for the time series. It is observed that the highest amount of rainfall which fell in a year was in 2007 with the least amount received in 1997.

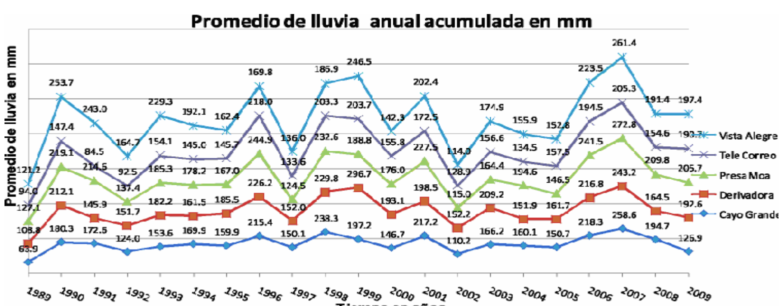

Figure 1. Average rain gauge distribution for the period of 1989 through 2009.

Each rain gauge has seasonality coefficients; which means that the time series is seasonally adjusted; identifying the different dry and wet periods depending on which time of year they occur and therefore precipitation levels will be either higher or lower.

However, when analyzing variance for monthly accumulations as the F calculated is higher than the critical value of F, the hypothesis is ruled out; that is, the average monthly precipitation over 21 years is not the same. In this case, it is necessary to identify what months are accountable for such differences.

When analyzing the rain accumulated during 1989-2009, it is noted that the rainiest months are November, October and December with the least precipitation accumulation in April and July.

Spatial-temporal analysis of the natural moisture content of the soil

Natural moisture content is a parameter that varies with the passage of time. The spatial and temporal behavior of soil moisture content depends, among other factors, on grain size, porosity, cracking, thickness of soil layers and water table depths.

One of the characteristics of these natural soils is that the pore space between solid particles is occupied by water and air in varying amounts; mainly on the upper part, and specifically open pit mines as the cuts facilitate the extraction of minerals The spatial temporal variability in natural moisture content is also due to the granulometric composition and porosity index, drying and wetting cycles the soils are subjected to due to the variation of the climatic conditions (rain and evaporation).

If the weather creates the conditions conducive to the drying process, the water in the pores is evaporated, causing the suction to increase in relation to the hydrostatic distribution, faster at the surface than at depth. The suction gradient will cause the vapour from the meniscus be transported to the external surface by molecular diffusion. This completes the drying mechanism ant then capillary flow occurs from the water table to superficial layers where evaporation takes place (Carmenate, 2006).

These fluctuations are milder in the laterite crust because of its high porosity. The porosity of clayey silts within the studied area ranges from 1,04 to 3.05 for an average value of 2.15; which results in a higher water storage coefficient. A rise in deep water table leads to a capillary rise of water, wetting the laterite crust (saprolite layer).

As shown in figure 2, the moisture content of soils is high; the highest values being (50, 60, 70%) to the NNE and NNW and the lowest contents (35, 40%) to the furthest SE.

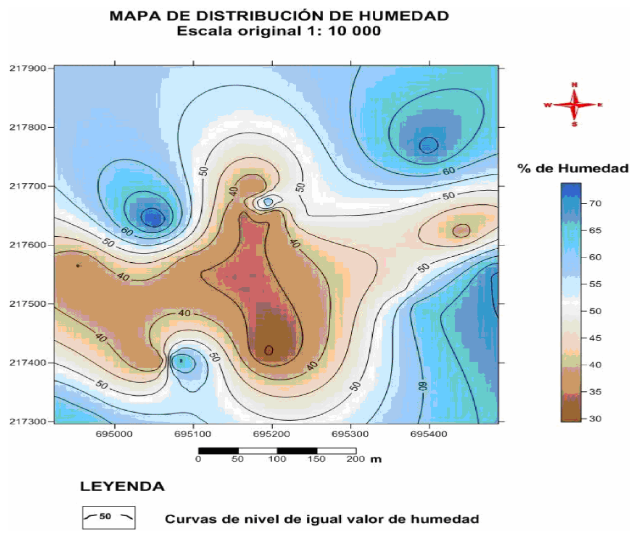

Figure 2. Moisture content distribution map.

This spatial distribution of moisture content is conditioned by the tectonics. Faults are concentrated with a higher density in the areas with higher moisture content (Figure 3). The direction of cracking is predominantly NE and NW with an angle of dip of approximately 85 degrees; these discontinuities are the means by which water circulates towards the rock where the aquifer is.

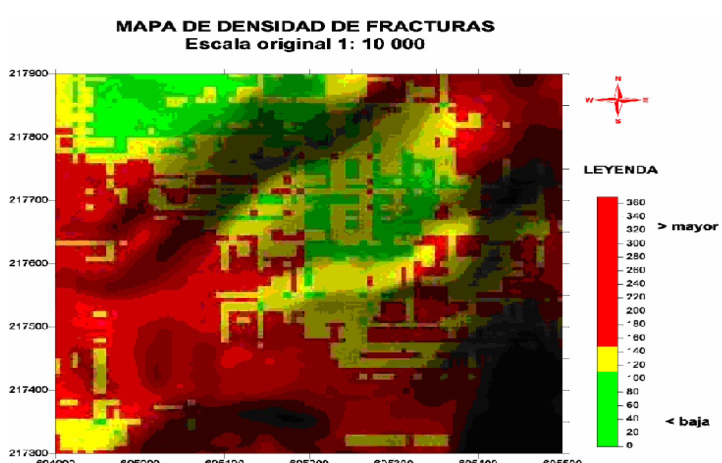

Figure 3. Fault Density Map *(provided by Quality Cuba S.A.)*

These zones are also characterized by a marked development of the fluvial system of different orders carrying the water and maintaining a high soil moisture level in the area due to the existing fine grained soils with high porosity. Another factor influencing the distribution of soil moisture is that the aquifer is a few meters deep (about 10 meters) in the areas with high moisture content and 18 meters deep in the areas with low moisture content.

The higher moisture content is associated with lower soil thickness values (10-12 m) and the lower moisture content with higher soil thickness (30-32m).

Assessment of the relationship between pluviometry and natural moisture content of the soils in the area of the Ferronickel Mining plant S.A during dry and wet seasons

During rain or flood, the suction in the surface becomes zero and the absorption of liquid water by the superficial dry layer occurs because of the suction gradient, creating a wet front that moves downward and it is one of the factors associated with a high moisture content of the soils in the studied area (Carmenate, 2006). This characteristic proves that natural moisture of soils varies over time; during which it does not remain the same, it either increases or decreases. Soils are therefore considered either wet or dry depending on the percentage of moisture; without overlooking the fact that soils will never be 100% dry. It is impossible to remove all the water from the soils. This is why the most commonly used terms are partially saturated soils or unsaturated soils. Thie time-dependent behaviour of natural moisture content is based on the intensity and duration of erosion and meteorization, granulometric composition, porosity and the specific surface area of the grains.

An assessment of the moisture content in the area of study during rainy periods was carried out and it is observed that the moisture content changes with the passage of time and the amount of precipitation.

In general, when assessing the influence of natural moisture content of soils with pluviometry it is inferred that there is a direct relation between high percentage of soil moisture and high precipitation. This is influenced by granulometric composition in which there is predominance of fine particles and a large number of pores that give the material a high porosity and thus the presence of significant percent residual moisture (6%).

Conclusions

The results of the variance analysis show that there is no significant difference in the average rainfall accumulation by rain gauge; however, there is a marked difference between average monthly accumulations; which allows identifying the rainiest or least rainiest months.

The soils constitute all the material to be extracted in the studied area where the Ferronickel Mining plant S.A is being built. The thickness of these soils varies, approximately 30 meters. They belong to the saprolite zone of the laterite profile and according to their physical-mechanical properties, these soils are classified into: plastic clayey silts (MH), silty sand (SM) and clayey gravel (GM).

The highest thickness values of the soils in the area correspond to clayey silt with high average moisture content (54%). This is why they are classified as soils with a very high moisture content which increases with depth.

There is a direct relationship of linear tendency between pluviometry and natural soil moisture content. The higher the precipitation the higher is the soil natural moisture content in the studied area.

Recommendations

Conduct studies of the air-water interphase relationship and soil's saturated permeability in the studied area considering that for fine grained soils and high porosity the height of capillary rise can be significant.

Conduct lab tests to determine natural moisture contents of the soils in the area of study during dry seasons in order to know the behaviour of moisture content.

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