Soil characterization from the Rio Grande high basin for preparing a technosol that retains phosphorus to prevent eutrophication in the dam water of the Presa Propósito Multiple Chone

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Abstract. Agriculture and livestock have the most economic significance in the Chone canton. These activities are some of the causes of the phosphorus increases in the Rio Grande basin, making, as a consequence, that there is an excess of nutrients in water so there are many plants growing and leading to eutrophication. So, the objectives of this research were the soil characterization from the Rio Grande high basin for obtaining a Technosol that will retain phosphorus so the eutrophication in the dam water from the PPMCH will be reduced. 17 soil samples were analyzed. The samples were obtained during the rainy season and during the dry season in 2016. The physical characteristics as bulk density, porosity and humidity were used to determine if the soil retains and transmits water to crops while the chemical characteristics as pH, electrical conductivity (EC), Cationic Exchange Capacity (CEC), available phosphorus, exchangeable aluminum and phosphorus retention, were used to determine the capacity of soil to solubilize inorganic phosphorus and the capacity of forming insoluble aluminum compounds that will fix phosphate anions. As a consequence, according to the tests the best soils were the ferric soils, because they have a high potential for preparing a Technosol. The phosphorus fixation percentages for profile 60, 96%, for profile 16 was 54.60% and 79.51% for profile 17. In profile 17 the aluminum content is 5 cmol/kg.

1. Introduction
In Manabi province, the 37.4% of the working population dedicates to agriculture and livestock, and it is the most important economic activity. Chone is the biggest canton of the province with a surface of 3017 km² and its main city is Chone. The economy in this canton is based principally in two activities, stock breading is in first place and then agriculture is in second place. Chone canton has 200 000 heads of cattle and is the most important in Ecuador [1].

Agriculture in Chone canton is the second important activity. The most important crops are in the short cycle: rice, corn, watermelon, papaya, melon and some others and in the long cycle fruit crops. Among the land use in the canton these activities are reflected because the 66.70% of its surface is used for cattle pasture and the 13.2% is used for permanent crops [1]. These activities have increased
the usage of pesticides, herbicides and fertilizers as it’s shown in the work that is titled “Technosols for the eutrophication treatment in the Rio Grande Hydrographic system in the Chone canton” where the PMCH dam is built in the Manabi province in Ecuador [2]. The geology of the Chone canton is characterized by formations of estuarine clay in the quaternary, and formation onzole (shale and limlite) in the polyocene [3]. Due to the presence of clays, they are characterized by a reduced porosity and the presence of ferrous oxides gives rise to the ferric oxide, which gives the brownish tonality to the soils [4]. The shales are rocks consisting mainly of iron oxides, feldspar, etc, qualifying the soils of the canton as ferric soil. The existence of animal organic waste has increased the presence of phosphorus in the Rio Grande basin. Also, the geology of this zone indicates that there are phosphoric rocks and some fossil wastes that has calcic phosphate as main component [5].

Animal and plant decomposition on the soil, since some millions of years and under some special circumstances, can originate petroleum if there are animal wastes and originate carbon if there are vegetable wastes. During this time some processes are made, the most important are; phosphatization, carbonation, silicification, pyritization, and carbonification. The first one has made that there are phosphorus in the research zone. Phosphatization is one of the most usual forms of fossilize vertebrate wastes when there are a lot of them [6], and it makes that these compounds go to the soil, concentrating a lot of nitrogen and phosphorus that with rain produces leaching and transports the elements to the river. Leaching carries many nutrients to water causing fast plant growing. This process is called eutrophication and as a consequence leads to water quality deterioration [7].

Actually, the water from the dam of the PMCH is used as water supply for people nearby during the drought season, as also is used as a transportation way between small towns and the city. Not observing and not following the Environmental Management Plan in the Rio Grande high basin carried many contamination problems, caused mainly by the increase of the agriculture activities. These activities have generated a eutrophic condition in the Rio Grande water because of the high nutrients inflow in the Rio Chone basin [8]. As a consequence of these there are many “lechuguines” (*Eichhornia crassipes*) all over the surface of the dam water affecting directly on its quality.

In Ecuador there are many soil kinds from volcanic origin, some of them called Andosol, with low particle density, high porosity, high water retention capability, and also a high permeability as physical characteristics. When we are talking about chemical characteristics this type of soil has the capacity for phosphorus retention as high as 85% [9], that is why the maximum use of the physical and chemical characteristics can be useful for preparing Technosols that will help to reduce the phosphorus concentration in water and to reduce the eutrophication process in the Rio Grande basin.

Technosols are a new group of soils that were created between 2006 and 2007, developed in the Santiago de Compostela University (USC) in Spain by experts that have developed an application technique, and creating alternative soils for rehabilitating deteriorating or contaminated environment. Technosols work with the same edaphological processes and their reactions are the same as the ones in natural soil, as acid-base process, redox reaction, ionic exchange, adsorption, mineral alteration, humification, biological activity, etc. As they are specifically designed, with the appropriate components and properties, can do efficiently and quickly all the processes to solve one or some soil, water or ecosystem quality limitations [10].

Table 1 shows the parameters for measuring and evaluating the soil potential based on the physical and chemical properties. The physical properties reflect the way that soil retains and transmit water to plants, by permeability and porosity that depends on the particle size. The chemical properties are the conditions that affect the relation between soil and plant. It is related with the quality, availability of water, nutrients for plants and microorganisms [11].

| Property     | Relation with soil function and condition                                                                             |
|--------------|-----------------------------------------------------------------------------------------------------------------------|
| Physical Properties Texture | Water retention, water and chemical compounds transportation, soil erosion.                                                                 |

Table 1. Soil physical and chemical indicators.
| Property                        | Description                                                                 |
|--------------------------------|-----------------------------------------------------------------------------|
| Particle and bulk density      | Leaching potential; productivity and erosion                                  |
| Humidity percentage            | Water retention, transport and erosion relations; useful humidity, texture and organic matter |
| Porosity                       | Water transport, particle size                                              |
| Chemical Properties            | Define chemical and biological activities                                    |
| pH                             | Define vegetal and microbial activities                                      |
| Electrical Conductivity (EC)   | Electron activities                                                          |
| Redox Potential (Eh)           | Available nutrients for plants, potential N loss, productivity and environmental quality indicators. |
| Nitrate (NO$_3$)$_3$, Phosphate (PO$_4$)$_3$ | Soil’s potential for retaining and exchanging vegetable nutrients, through the capacity valuation for retaining cation (cation = elements with positive charge) |
| Cationic Exchange Capacity (CEC) | Soil fertility, having a narrow relation with crop response |
| Available Phosphorus           | Soil capability for retaining phosphorus                                      |

Source: [11]

The objective of this investigation is to characterize soil samples from the Rio Grande high basin, Chone canton, located in the northeast Ecuadorian coast at the Pacific Ocean, for designing a Technosol that can retain phosphorus and that prevents eutrophication in the water from the dam of the PPMCH.

2. Methods and materials

2.1. Research area

![Figure 1. Location of the Proyecto Proposito Multiple Chone Dam.](image-url)
Chone canton is located in the Manabi province in the Pacific coast. Its climate is warm and dry in summer, between June and November with temperature that goes from 23 to 28°C, while in winter, from December to May it goes up to 34°C, describing as an extreme and unstable climate condition zone. Sometimes the annual rainfall goes over 3500 mm when the El Niño weather condition is present and sometimes it goes down to 500 mm when there is a dry season (La Niña weather condition). Because of the rainfall intensity, Chone is an area at high risk of flooding during the rainy season [12]. For this reasons the Ecuadorian Government built and inaugurate on December 2015 the Proyecto Proposito Multiple Chone Dam. It is located in the confluence of Rio Grande as is shown in figure 1. One of the main purposes of this project is to mitigate the flood effects in Chone canton and the area under the influence of Rio Grande, and supplying water for people in the canton. This is a very important project for the canton [13].

2.2. Sampling and parameter analysis
The methodology used for the soil analysis is based on the Mexican regulation [14]. Seventeen soil sampling points were located using the zig-zag method. These samples were collected during two seasons: 6 in the rainy season and the other 11 during the drought season. From each sampling point almost 2 kg of soil was collected at 20cm deep in the cultivated zone and al 10cm deep where there are pasture and no crops. In figure 2 the sampling points are shown.

![Figure 2. Location map of the sampling points in relation with the dam and the irrigation zone.](image)

For the first analysis there were used saturation extracts of 15 soil samples. The saturation extracts were used because they are representative for salt analysis using an electrolytic probe and because the electrical conductivity is directly related with plant growing [15]. Once the first analysis of the 15 soil samples was finished, three samples were picked up according to the physic and chemical characteris-
tics, their light bulk density, high porosity level, good water retention, hydraulic conductivity and pH below 6.6 and mainly observing the aptitude to retain phosphate. The samples were analyzed in the environmental technologic laboratory of the Universidad de Santiago de Compostela (USC), according to the crop of each sample and previous characterization. To be sure of the potential to retain phosphorus in the three samples were analyzed: available phosphorus, exchangeable aluminum, phosphorus retention percentage, CEC and pH. One of them has higher potential for phosphorus retention and with similar characteristics of the andic soils, as iron and aluminum oxides (Profile 1).

From another sampling of this kind of soils from Chone canton there were collected sample 16 and profile 17 (figure 3) and were again analyzed as the other samples because from the previous analysis the aluminum and iron soils have the best characteristics for designing a Technosol. In the table 2 there is a description of the 17 soil profiles with their locations.

![Figure 3](image-url) Location map of the three soil profiles of aluminum iron soils in the Rio Grande micro basin.

| N°  | DESCRIPTION                                    | SEASON | DATE         | X    | Y    |
|-----|-----------------------------------------------|--------|--------------|------|------|
| 1   | Ferric soil                                   | Rain   | February 2016| 620626| 9925232 |
| 2   | Crop: Oranges                                 | Rain   | February 2016| 607437| 9931488 |
| 3   | Main crop: banana                             | Rain   | February 2016| 606688| 9928274 |
| 4   | Crop: creole cocoa                            | Rain   | February 2016| 604226| 9924482 |
| 5   | Crops: cocoa and banana                       | Rain   | February 2016| 604054| 9924446 |
| 6   | Crop: banana. Partially flooded zone          | Rain   | February 2016| 604054| 9924446 |
| 7   | Pasture                                       | Drought| August 2016  | 607434| 9930652 |
| 8   | Crop: maize                                   | Drought| August 2016  | 607306| 9930518 |
| 9   | Universidad Católica Campus                   | Drought| August 2016  | 607395| 9930554 |
| 10  | Crop: orange and mandarin                     | Drought| August 2016  | 606742| 9926056 |
| 11  | Crop cocoa (mosquito)                         | Drought| August 2016  | 606723| 9926132 |
| 12  | El Guabal zone, crop: citrus fruit            | Drought| August 2016  | 604105| 9924346 |
| 13  | Citrus fruit                                  | Drought| August 2016  | 604007| 9924364 |
| 14  | Crop: cocoa                                   | Drought| August 2016  | 603558| 9922510 |
| 15  | Soils with production problems (zorilla)      | Drought| August 2016  | 603552| 9922472 |
In table 3 there is a description of the analysis that were used to characterize and evaluate the soil samples with each method and regulation. The analyses were: humidity, bulk density, particle density, porosity, texture, pH, electric conductivity (EC), soluble cations (Na⁺, K⁺, Ca²⁺, Mg²⁺), available phosphorus, exchangeable aluminum, CEC and phosphorus retention.

**Table 3. Physical and chemical parameters for soil analysis.**

| PARAMETER                  | METHOD/EQUIPMENT                      | REFERENCE REGULATION          |
|----------------------------|---------------------------------------|--------------------------------|
| Humidity content           | Gravimetric                           | NOM-021-RECNAT-2000           |
| Particle density           | Pycnometer                            | NOM-021-RECNAT-2000           |
| Bulk density               | Test tube                             | NOM-021-RECNAT-2000           |
| pH                         | Portrait pH meter, model Orion 3-STAR, Termoelectric | Direct measuring with electrode |
| Electric Conductivity      | Conductivimeter model HQ14D, Hach.    | NOM-AA-93-1984                |
| Soluble cations (Na⁺, K⁺, Ca²⁺, Mg²⁺) | Atomic absorption                  | NOM-021-RECNAT-2000           |
| Available phosphorus       | Colorimetric                          | NOM-021-RECNAT-2000           |
| Exchangeable aluminum      | Volumetric                            | NOM-021-RECNAT-2000           |
| CEC                       | Atomic absorption                     | NOM-021-RECNAT-2000           |
| Phosphorus retention       | Colorimetric                          | NOM-021-RECNAT-2000           |

Source: [14,16]

3. Results and discussion

3.1. Physical and chemical analysis of the first soil samples

3.1.1. Soil physical properties. In table 4 there are the results of the 15 soil profiles physical characterization: humidity, density, porosity and texture.

**Table 4. Soil physical properties.**

| Nº | Humidity % | Bulk density g/cm³ | Particle density g/cm³ | Porosity % | Texture    |
|----|------------|--------------------|------------------------|------------|------------|
| 1  | 47.49      | 1.04               | 2.10                   | 50.44      | Clay       |
| 2  | 28.18      | 1.19               | 2.07                   | 42.62      | Loamy soil |
| 3  | 29.43      | 1.22               | 2.23                   | 45.17      | Loamy soil |
| 4  | 32.98      | 1.04               | 2.08                   | 49.79      | Loamy soil |
| 5  | 39.21      | 1.22               | 2.04                   | 40.08      | Loamy soil |
| 6  | 54.03      | 1.06               | 1.90                   | 44.21      | Loamy soil |
| 7  | 29.60      | 1.18               | 2.39                   | 50.56      | Clay       |
| 8  | 38.60      | 1.14               | 2.34                   | 51.00      | Clay       |
| 9  | 50.64      | 1.1                | 2.15                   | 48.91      | Loamy soil |
| 10 | 42.27      | 1.00               | 2.28                   | 56.14      | Clay       |
| 11 | 36.59      | 0.98               | 2.27                   | 56.56      | Clay       |
| 12 | 29.51      | 1.18               | 2.45                   | 51.62      | Clay       |
| 13 | 36.96      | 1.14               | 2.18                   | 47.47      | Loamy soil |
| 14 | 24.69      | 1.20               | 2.25                   | 46.60      | Loamy soil |
| 15 | 21.39      | 1.11               | 2.41                   | 54.00      | Clay       |

- Rainy Season

As shown in table 4, the profiles from 1 to 6, were sampled in rainy season. The profiles number 1, 5 and 6 have humidity percentages as 47.49%, 39.21% and 54.03% indicating that these soils have an acceptable humidity content, while the profiles 2, 3 and 4 have low humidity percentages, 28.18%,
29.43% and 32.98% having an average low humidity.

The results of the bulk density of the 6 soil profiles show values less than 1.70 g/cm³ and according to [17] they are a good indicator of hydraulic conductivity. This hydraulic conductivity is directly associated with porosity. When the soil has low bulk density value, the porosity percentage is higher, and it also can be concluded that according to the bulk density this soils have a high content of organic matter, values are lower than 2.65% g/cm³ and indicate high soil fertility and contributes local crop growing.

- **Dry Season**

As shown in table 4, the profiles from 7 to 17 were sampled in the dry season. The humidity percentage significantly reduces in profiles 7, 8, 11, 12, 14 and 15, showing values from 21.00% to 38%. In profiles 9 and 10 the values are 42.27% and 50.46%, higher than the other results. The explanation can be that some different anthropogenic activities are developed on each sample profile, where there is an agricultural zone with banana, cocoa and orange plantations that requires high humidity during the rainy season. During the rainy season the phosphorus concentrations increase and accelerating the eutrophication process on the dam. Their pH values are less than 6.6, so they are acidic soils.

### 3.1.2. Soil chemical properties

Once the physical characterization was finished, the chemical parameters were determined using the saturation extracts. The chemical parameters evaluated were: pH, electrical conductivity and soluble cation (Na⁺, K⁺, Ca²⁺, Mg²⁺). The results are shown in table 5.

| N°   | pH   | EC dS/m | Na⁺ cmol/kg | K⁺ cmol/kg | Ca²⁺ cmol/kg | Mg²⁺ cmol/kg |
|------|------|---------|-------------|------------|--------------|--------------|
| Profile 1 | 4.90 | 0.05100 | 0.026474    | 0.00095    | 0.00114      | 0.00221      |
| Profile 2 | 6.50 | 0.16800 | 0.025113    | 0.02177    | 0.03281      | 0.02430      |
| Profile 3 | 7.39 | 0.28500 | 0.039083    | 0.04062    | 0.02653      | 0.02803      |
| Profile 4 | 7.52 | 0.31000 | 0.047610    | 0.02257    | 0.05662      | 0.02416      |
| Profile 5 | 6.41 | 0.10400 | 0.022750    | 0.00777    | 0.01473      | 0.01109      |
| Profile 6 | 7.43 | 0.15300 | 0.026268    | 0.02141    | 0.01832      | 0.01231      |
| Profile 7 | 6.91 | 0.33800 | 0.007313    | 0.00304    | 0.00630      | 0.00287      |
| Profile 8 | 6.64 | 0.65700 | 0.008191    | 0.00444    | 0.01015      | 0.00432      |
| Profile 9 | 7.17 | 0.63400 | 0.009040    | 0.00682    | 0.00965      | 0.00646      |
| Profile 10 | 6.93 | 0.26200 | 0.005610    | 0.00325    | 0.00529      | 0.00236      |
| Profile 11 | 6.84 | 0.30700 | 0.006325    | 0.00330    | 0.00484      | 0.00275      |
| Profile 12 | 6.60 | 0.24900 | 0.005635    | 0.00178    | 0.00541      | 0.00167      |
| Profile 13 | 7.10 | 0.33300 | 0.004030    | 0.00221    | 0.00519      | 0.00151      |
| Profile 14 | 6.60 | 0.54200 | 0.008520    | 0.00456    | 0.01560      | 0.00432      |
| Profile 15 | 6.60 | 0.30200 | 0.008000    | 0.00185    | 0.00355      | 0.00180      |

As shown in the table 5 and according to the regulation NOM-021-SEMARNAT-2000 [14], the pH values in 9 samples indicate that the soil is neutral. The values from 6.60 to 7.30 show that the soils have a good assimilation of nutrients, because they have inorganic phosphorus higher solubility [18]. The other 6 profiles are from moderately acidic to strong acidic as in profile 1. These conditions diminish the solubility of compound phosphate, forming chemical insoluble compounds in the soil. The Electrical Conductivity values are less than 1.00 dS/m indicating that they are low salinity soils, and the soluble cations show low concentrations on all the profiles that were analyzed.

As a result of these analysis, profiles 1, 2 and 5 were chosen because of their bulk density less than 1.20 g/cm³, and with humidity percentage values 50%, 42% and 40% for each one and were sampled during the rainy season. During the rainy season the phosphorus concentration increases and accelerates the eutrophication process on the dam. Their pH values are less than 6.6, so they are acidic soils.
with an important amount of aluminum (Al³⁺). What this work searches is that the soil forms insoluble aluminum compounds so they can immobilize the phosphates anions, that causes eutrophication on the dam water [18].

3.2. Chemical analysis of the three selected soil samples

3.2.1. Chemical soil properties and their capacity for soil retention. Table 6 shows the chemical analysis of the three chosen soil profiles to measure the potential of retaining phosphorus: phosphorus, aluminum, Cationic Exchangeable Capacity, phosphorus retention.

| N°  | pH  | Phosphorus mg/L | Exchangeable Acidity meq/100g | Exchangeable aluminum meq/100g | K⁺ cmol/kg | Ca²⁺ cmol/kg | Mg²⁺ cmol/kg | Na⁺ cmol/kg | Total Bases cmol/kg | Phosphorus Retention (%) |
|-----|-----|-----------------|-------------------------------|--------------------------------|------------|--------------|--------------|------------|--------------------|--------------------------|
| Profile 1 | 4.90 | 4.40            | 9.33                         | 2.38                             | 0.40       | 10.06        | 4.79         | 0.79        | 16.04              | 60.96                    |
| Profile 2 | 6.59 | 37.00           | 0.00                         | <0.12                            | 4.13       | 21.80        | 4.72         | 0.14        | 30.79              | 12.27                    |
| Profile 5 | 6.40 | 124.00          | 0.00                         | <0.12                            | 1.23       | 22.60        | 5.82         | 0.20        | 29.85              | 13.96                    |

From the 15 samples in table 5, 3 profiles were chosen. Two of them with representative crops of the zone as orange and cocoa and one ferric soil belonging to the rainy season because as [19] shows in his investigation, the Rio Grande basin presents an accelerated eutrophication, over 0.1 mg/l of phosphate during this season. This condition can be explained because the heavy rainfall can produce soil washing that transports all those nutrients to the river basin.

From table 6: Profile 1 has a pH value of 4.90, indicating that the soil is strongly acid, profile 2 has a value of 6.40 indicating that the soil is moderately acidic and profile 5 shows a pH value of 6.6 that indicates a neutral soil.

The presence of phosphorus on profile 1 shows 6.00 mg/l, profile 2 has a value of 37.00 mg/l and 124.00 mg/l on profile 3. There is difference between them, because the available phosphorus must be important for the crops to grow. On profile 1 there are no crops growing. When the soil is cultivated fertilizers add some nutrients that are necessary for plants to grow. The added nutrients are phosphorus (P), calcium (Ca), potassium (K), etc. and that is why the measured values are so high in the cultivated profiles.

The most important point when analyzing the profiles was the phosphorus retention, as shown in the table 6. The profiles number 1, 2, and 5 have values of 60.96%, 12.27% and 13.96%. Profile 1 has five times more phosphorus retention than the other profiles. The presence of Aluminum on these soils increases significantly the phosphorus retention [20]. The values of Aluminum in the profiles are: profile 1, 2.38 meq/100g, less than 0.12 meq/100g on profiles 2 and 5. These values demonstrate the previous statements.

Once the analyses are concluded, the best profile for designing a Technosol is profile 1 because of its capacity of phosphorus retention.

Another sampling in the zone of the ferric soil was made during the dry season (figure 3). On these three ferric soils all the previous analyses were done to establish which one is the best for designing the phosphorus retaining Technsol.

3.3. Physical and chemical analysis of the three new ferric soils

3.3.1. Soil physical properties. To determinate the profile that presents the high rate of compliance of the specified characteristics for a Technosol these analyses were made: humidity, density, porosity and texture as shown in table 7.
Table 7. Physical properties of the red aluminum iron profiles.

| N°  | Description    | Season | X     | Y     | Humidity% | Bulk Density g/cm³ | Particle Density g/cm³ | Porosity% | Texture |
|-----|----------------|--------|-------|-------|-----------|-------------------|------------------------|-----------|---------|
| 1   | Ferric soil    | rain   | 620626| 9925232| 47,49     | 1,04              | 2,10                   | 50,44     | Clay    |
| 16  | Ferric soil    | dry    | 619852| 9924982| 40,04     | 1,00              | 2,18                   | 54,09     | Clay    |
| 17  | Ferric soil    | dry    | 618770| 9925319| 40,43     | 1,02              | 2,07                   | 50,72     | Clay    |

As shown in the table 7, the humidity value on profile 1 is 47.49% and on profiles 16 and 17 those values are approximately 40%, although the sampling was made in different seasons, the humidity values are not so different. This is because of their porosity that defines the soil type, the soil humidity retention and the water infiltration. The porosity values of the 3 profiles are between 50.00 and 55.00% that corresponds to clay soil [21].

With this information we can conclude what minerals are part of the soil according to the bulk density that was measured. According to the Table 7, the bulk density values of the three profiles are between 1.00 and 1.19 g/cm³ which corresponds to clay minerals as shown in the regulation NOM-021-SEMARNAT-2000 [1]. The clay soils have thin texture, and have a high anion absorption, and will help to retain phosphorus [22].

3.3.2. Soil chemical properties. On table 8 are presented the values of the soil profiles analysis: phosphorus, aluminum, cationic exchange and phosphorus retention.

Table 8. Chemical properties of the ferric soils profiles and phosphorus retention.

| N°  | pH   | Phosphorus (mg/L) | Exchangeable Acidity (cmol/kg) | Exchangeable Aluminum (cmol/kg) | CEC (cmol/kg) | Total Bases (cmol/kg) | Phosphorus Retention (%) |
|-----|------|-------------------|--------------------------------|---------------------------------|---------------|-----------------------|--------------------------|
| 1   | 3.94 | 4,4               | 9,33                           | 2,38                            | 0,40          | 10,06                 | 60,96                    |
| 16  | 3,74 | < 3,5             | 16,00                          | 3,40                            | 0,24          | 3,44                  | 54,60                    |
| 17  | 4,20 | < 3,5             | 23,40                          | 5,00                            | 0,45          | 2,97                  | 79,51                    |

As shows the table 8, the pH values of the three profiles are between 3.74 and 4.20. The three soils are strongly acid as the Mexican regulation NOM-021-SEMARNAT-2000 [1] specifies. This parameter indicates a high percentage of phosphorus retention when the soil has very high or very low values [22].

The phosphorus analysis shows low values as 6.45 cmol/kg on profile 1 and less than 3.50 on profiles 16 and 17. The same as the values for K⁺ and Ca²⁺, important plant nutrients, are low, less than 0.50 cmol/kg of K⁺ for the three profiles and 10.06 cmol/kg of Ca²⁺ on profile 1 and less than 4 cmol/kg of Ca²⁺ for the other two profiles, 16 and 17. That is why there is no sign of crop, plantation or vegetation on the three profile points [22].

Making an analysis of the phosphorus retention for the three profiles. The results were more than the 50%, as shown on the table 8. All of them have the attitude for retaining phosphorus, profile 17 has the higher value with 75.51% of phosphorus retention and also has the higher value of aluminum that is essential for phosphorus retention [23].

4. Conclusions
From this study we can conclude that the ferric soil from the Chone canton can have all the characteristics for preparing a Technosol that can retain phosphorus and can be used as an environmental reme-
diation method for reducing the eutrophication of the dam water of the Rio Grande basin, helping the people of the zone and diminishing the costs for water treatment so it can be used for human consumption.

From the sampled profiles on the irrigated zone and the PPMCH dam, number 17 was the soil that fulfilled all the characteristics that were the object of this study with a 79.51% of phosphorus retention. This profile will be the best for designing a Technosol. It is recommended to make a new study in the future with this kind of soil and adding some other elements as organic and inorganic matter that will help and increases the natural bonding for improving the soil characteristics and that will raise the capacity for retaining phosphorus and having at last, less eutrophication on the basin water.

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