Effect of Hydraulic and Organic Load, in the Removal of Biochemical Oxygen Demand in Wastewater using Biofilter with Vegetable Carbon, in High Andean Climate

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Abstract. Generating new sustainable alternatives in the design of trickling filters for rural populations is necessary to improve the quality of discharges and optimize the design of secondary treatment units. The study determined the impact of hydraulic and organic charge on the removal of BOD in the environment charcoal biofilter. Biofilters prototypes were implemented at scale with charcoal filter medium on different surfaces that vary from 0.12 to 0.25 m², carried out at an elevation of 2100 meters above sea level, the final concentration most effective in removing BOD obtained hydraulic load of 2.34 to 4.76 m³m⁻²d⁻¹ and the organic load between 0.27 to 0.56 kg DBO m⁻³. The results of the Biofilter experiments determined that the hydraulic load generated a better distribution and mixing of the residual water throughout the trickling bed, achieving a good reaction and effective combination between the water that entered and the amount of air required to complete the aerobic process. and to achieve the removal of BOD, the organic load obtained in the measurements concentrates enough biomass that helps in the formation of the biofilm, for which it is concluded that this criterion has a determining effect on the reduction of organic matter in domestic wastewater, it is confirmed that the charcoal biofilter is efficient and can be used in small systems of wastewater treatment plants.

1. Introduction
Domestic wastewater generated in developing countries is discharged directly into bodies of water without any adequate treatment, causing potential dangers to the environment and public health of nearby populations. [1] With the growth of urban areas and peri-urban populations, there is a demand to expand the sanitary sewer networks that are of appropriate costs, including wastewater treatment plants with conventional technology that is improved to continue reducing pollution to the environment of families and risk of contracting water-borne diseases.[2]. In these current treatment plants in rural and urban areas, a large amount of odours are generated due to poor management and operation of the primary and secondary process units, thus causing damage to people's health and even more so if they are very close to the systems.[3]. For that reason, it is proposed to design improved systems with new alternatives since those that were mainly installed do not demonstrate effectiveness in biological percolation technologies in gas and BOD purification, and as they are secondary treatment systems, these processes should be improved.[4] With these improvements, what is intended
is to favour the formation of more robust biofilms with a very close relationship between the fixed material or support and the amount of air that the microorganisms need to carry out the aerobic process.[5]. It is known that the reactors that operated under similar conditions with suitable support materials and with the necessary dissolved oxygen (DO), made the aerobic process take place properly and this was evidenced in results and studies where they generated a positive impact. [6], the different materials used were also studied treated with trickling filters such as polyurethane foam filter bed [7], peat and glass beads[8], stone-based media[9] compost[10], wood charcoal[11], cylindrical pieces of yellow-grain (Cajanus cajan) stalk[12], coal[13], perlite[14], Likewise, subsidence problems have been known in some types of support beds, this due to a greater pressure drop, which causes an increase in operating costs and maintenance of biofilters made of compost.[15], It is also known that the use of charcoal in the clarification of water sources is feasible in Hindu cities.[16]. It is necessary to know that substances similar to proteins and humic substances usually dissolve the components of organic matter, these are well fixed in support materials such as those mentioned above, which is useful to use them to treat wastewater effluents and generate their biological degradation that will be directly affected by various parameters, [17]. Including the effect of temperature on the start-up of the filter and the influence of temperature, pH value, and recirculation rate on the treatment effect of the filter.[18] the efficiency of various biological filter technologies such as bench-scale up-flow anaerobic sludge blanket (operated at hydraulic retention time or HRT of 1–10 days) and anaerobic biofilter (HRT of 0.25–3 days) study were conducted for 188 days,[19], additionally using a continuously operated trickling filter. The system efficiency ranged up to 60–70% for a hydraulic loading of 1.1m³/m² day and up to 80–85% for a hydraulic loading 0.6 m³/m²/day. A stable chemical oxygen demand (COD) removal efficiency of 60–70% was achieved even in the case of undiluted wastewater at a hydraulic loading of 1.1m³/m² day.[20]. The biofilter was operated continuously for ~110 days and at four different flow rates (0.069, 0.084, 0.126, and 0.186 m³/h), corresponding to toluene loading rates of 160–8759 g/m³/h. The maximum elimination capacity (EC) achieved in this study was 6665 g/m³/h, while the removal efficiency (RE) varied from ~70 to >95%[15], also The results showed a high removal efficiency for suspended solids (>95%) and organic matter as determined by total organic carbon (>98.5%) and dissolved organic carbon (>70%),[21]

2. Material and methods

2.1. Design and installation

The investigation according to its nature, depth, and/or scope is explanatory, because the investigation consists of obtaining data that is obtained from the measurement of the processes studied in the experimentation.[22]

Biofilters were sizing with the input BOD data of 150 mgL⁻¹ and a depth of 1.00m, and three pilot trickling filters were installed, shown in table 1:

Table 1. Design and dimensions of Biofilters.

| Filter | Depth (m) | Length and width (m) | Filter area (m²) |
|--------|-----------|----------------------|------------------|
| F-A    | 1.00      | 0.500                | 0.250            |
| F-B    | 1.00      | 0.400                | 0.160            |
| F-C    | 1.00      | 0.350                | 0.120            |

Block 01, 02, 03, and 04; correspond to the different organic loads of the domestic wastewater coming from the effluent of the septic tank 01, 02, 03, and 04 respectively.

In each block, there were 03 units of analysis (F). One of the blocks did not have the treatment (P), that is, it will be in the absence of charcoal. Instead, gravel was used as a filter medium; In the remaining units of analysis, treatment (C) will be carried out using charcoal, and with a different hydraulic load. Measurements were made weekly.
According to figure 1, it is indicated that F-A, B, and C: Filter type A (0.50mx0.50m); Type B (0.40mx0.40m) and Type C (0.35mx0.35m), as can be seen in figure 1.

The measurements of the indicators according to each variable of the study were measured at the entrance and exit of each filter, the identification acronyms for the pilots were placed like this; P: Stone filter bed and C: Charcoal filter bed.

2.2. Operation and measurement

Measurements were made at the entrance (04 points) and exit (12 points) of the following parameters taking punctual samples.

The parameters in the effluent were: Wastewater flow (m$^3$ d$^{-1}$), Hydrogen potential, temperature ($^\circ$C), Biochemical Oxygen Demand (mgL$^{-1}$), and the effluent parameters are: Hydrogen potential, Temperature ($^\circ$C), and Biochemical Oxygen Demand (mgL$^{-1}$).

Four analysis groups have been installed, each one has primary treatment and different surface areas of each of the filters have been assigned as shown in the following figure:

3. Results and discussion

3.1. Determination of hydraulic and volumetric load

Once the systems are installed flows and initial operation concentrations of the reports which gave the following were measured, for example in figure 2, shown, it can be deduced that the average work volume was: Block 1 is 0.57 m$^3$/day; Block 2 is 0.54 m$^3$/day; Block 3 is 0.53 m$^3$/day and Block 4 is 0.58 m$^3$/day; very different from the design flow of the Biofilters is 0.43 m$^3$/day.

The organic load in the removal of pollutants from wastewater in a biofilter with charcoal in Tuyururi, a high Andean locality, gave the average values which can be seen in figure 3, for block 1: 0.326; 0.512 and 0.737 Kg BOD / m$^3$.day; for block 2: 0.285; 0.448 and 0.597 Kg BOD / m$^3$.day; for block 3: 0.310; 0.473 and 0.651 Kg BOD / m$^3$.day; for block 4: 0.309; 0.477 and 0.651 Kg BOD / m$^3$.day. It was also possible to understand the values obtained from the removal of BOD for block 1 of 32.5%; 35.5%; 44.4%; that corresponds to each one of the pilots subjected to the treatment, for block 2 of 42.2%; 34.7%; 37.8%; for block 3 of 37.7%; 44.4%; 40.3%; for block 4 of 43.8%; 46.6%; 46.1%.

The effect of the hydraulic load as seen in figure 4, was determined with the removal of pollutants from wastewater in a biofilter with charcoal in a high Andean climate. The results found for the hydraulic load for block 1 was 2.25; 3.59 and 4.94 m$^3$/m$^2$.day; for block 2 of 2.19; 3.51 and 4.64 m$^3$/m$^2$.day; for block 3 of 2.08; 3.23 and 4.45 m$^3$/m$^2$.day; for block 4 of 2.37; 3.58 and 4.76 m$^3$/m$^2$.day. It was interpreted that the dependence of the COD mass removal on the hydraulic load exists, but with a low level of significance. This shows us that the hydraulic load does not effect on the removal of pollutants[23]. It can also be explained that the increase in hydraulic load causes the thickness of the...
water layer to be greater, which increases the retention of the liquid and the hydraulic retention time [24].

3.2. Removal of a body from wastewater in a filter with vegetable charcoal
Variation of the Biochemical Oxygen Demand (BOD) at the Biofilter Outlet has also been studied in the 04 blocks or analysis groups with 03 biofilters in each block, obtaining average values as shown in table 2.

| Point 1 (mgL⁻¹) | Point 2 (mgL⁻¹) | Point 3 (mgL⁻¹) |
|-----------------|-----------------|-----------------|
| Biofilter 01    | 104.46          | 87.18           | 96.74           |
| Biofilter 02    | 88.27           | 95.70           | 86.64           |
| Biofilter 03    | 97.00           | 88.70           | 101.77          |
| Biofilter 04    | 78.20           | 72.35           | 83.38           |

The pH results are also analyzed, obtaining average values for block 1 of 7.68 for block 2 of 7.69; for block 3 of 7.71; for block 4 of 7.74. The temperature variation of the process developed in each biofilter was also determined, obtaining an average of 17.143°C, 16.921°C, 17.115°C, and 17.181°C respectively in biofilter 1, 2, 3, and 4.

It was also verified that the temperatures in March were from 10 to 26.2°C and in May from 12.2 to 27.9°C; achieving effective organic matter removals.[25]
In figure 5 the variation of the removal of the biochemical oxygen demand was determined as a function of the hydraulic load and the organic load. The darker area represents a percentage of removal of DBO increased to 75% and the lighter area means a percentage of removal of DBO lower to 15%.

**Figure 5.** Contour graph, of appreciation of the efficiency relation of removal of BOD using vegetal carbon comparing the variation of organic load and hydraulic load.

In figure 6 shows the distribution of the charcoal trickling filter pilots, where the results presented were obtained and were processed with statistical models for validation as presented below.

In the first group of analysis or block 1 the correlation between the removal of BOD and the hydraulic load, the Pearson correlation coefficient is $r = 0.088$ and it is a very weak positive correlation.

In the same way, a Pearson correlation coefficient was found for block 4 of $r = 0.051$ and it is a very weak positive correlation, it follows that the increase or decrease of the hydraulic load does not represent a significant change in the removal of the BDO in a Charcoal Biofilter, in the other two blocks the correlation gave negative results.

The relationship was determined in block one, the Pearson correlation coefficient of $r = 0.326$ and it is in a weak positive correlation to Medium. That is, the variation of the organic load has a positive effect on the removal of the BOD, the same also happens with block four having a correlation coefficient $r = 0.299$ from weak to medium, identifying that it has a positive effect on the removal of soluble organic matter in the wastewater.
4. Conclusions
The impact of hydraulic load and organic load on the removal of pollutants from wastewater in a biofilter with charcoal -Tuyururi-2019 was determined. The important thing is that he concluded that there is no effect of the hydraulic load on the removal of pollutants but that there is an effect of the organic load on the removal of pollutants, and it is better observed in block 3 with a correlation of 0.406 and the value of P is 0.021 is less than 0.05. That is, it is shown that there is a significant correlation. This proves that if it is possible to design full-scale Biofilters with a charcoal filter bed in the high Andean area greater than 2,100 meters above sea level, with an organic load of 0.27 - 0.56 kg BOD m⁻³ m⁻² day⁻¹ and with a hydraulic load of 2.10 - 4.35 m³ m⁻² day⁻¹.

The relationship between the hydraulic head and the removal of BOD in a biofilter with charcoal was determined in all the blocks studied, the correlation that was found is very weak for the hydraulic head in its effect of removal of the BOD, this is very insignificant or null. But it can also be concluded that the best behavior of the hydraulic load was block 04, where the hydraulic load varied from 2.34 - 4.76 m³ / m².d. This hydraulic load guaranteed the homogeneous distribution of the residual water in the filter bed.

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