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DOMESTIC WASTEWATER TREATED BY ANAEROBIC BAFFLED REACTORS AND GRAVEL FILTERS AS A RESOURCE TO BE USED IN AGRICULTURE

AGUAS RESIDUALES DOMÉSTICAS TRATADAS CON REACTORES ANAERÓBICOS Y FILTROS DE GRAVA COMO RECURSO PARA SER USADAS EN AGRICULTURA

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ABSTRACT

Due to limited availability of clean water, treated wastewater is an important resource to reduce water demand through its reuse. In Bolivia, one of the most common practices is the use of wastewater for crop irrigation. Wastewater Treatment Plants (WWTP) must adequate their processes so their effluents are safe for irrigation and for the environment. The intermediate city of Tolata, located at 2720 meters above sea level operates a WWTP with a solids removal pretreatment followed by an Anaerobic Baffled Reactors (ABR) and series of horizontal and vertical gravel filters. The objective of this study is to evaluate its efficiency and determine the potential of the treated effluent for crop irrigation. To assess water quality parameters a series of monitoring campaigns were carried out from August to December 2018. The average concentrations found in the WWTP affluent are as follows: 396 ± 289 mg-BOD_5/l, 795 ± 262 mg-COD/l, 361 ± 113 mg-TSS/l, 66.0 ± 38.9 mg-N-NH_3/l, 11.8 ± 2.2 mg-P/l and 2.73 ± 1.13 m-S/cm for EC. The concentrations found in the effluent on average are: 18 ± 12 mg-BOD_5/l, 95 ± 61 mg-COD/l, 18 ± 10 mg-TSS/l, 41.7±26.5mg-N-NH_3/l, 8.3 ± 2.2 mg-P/l and 2.35 ± 0.75 m-S/cm for EC. The overall efficiencies of the WWTP obtained are: 95 % of BOD_5, 88% of total COD, 95 % of TSS, 37% of N-NH3, and 30% of P. According to these results, it is advisable to restrict irrigation to tall stemmed crops, grass and fodder that have moderate tolerance to salinity and are not eaten raw or without further processing to reduce risks associated with health. In order to use the treated effluent for irrigation of vegetables or other products that are eaten raw, this WWTP needs to implement a disinfection process.

Keywords: Anaerobic Baffled Reactor, Wastewater, Performance, Reuse, Irrigation, Gravel Filters, WWTP Evaluation, Bolivia, Sustainability.

RESUMEN

Debido a la limitada disponibilidad de agua limpia, las aguas residuales tratadas son un importante recurso para reducir la demanda de agua. En Bolivia, una de las prácticas más comunes es el uso de aguas residuales en el riego de cultivos. Las Plantas de Tratamiento de Aguas Residuales (PTAR) deben adecuar sus procesos para que sus efluentes sean seguros para riego y para el medioambiente. La ciudad intermedia de Tolata, ubicada a 2720 metros sobre el nivel del mar, opera una PTAR con un pre-tratamiento para la remoción de sólidos seguido de Reactores Anaeróbicos Compartimentados (RAC) y una serie de filtros de grava horizontal y vertical. El objetivo de este estudio es evaluar su eficiencia y determinar el potencial del efluente tratado para el riego de cultivos. Para determinar los parámetros de calidad del agua, se llevaron a cabo una serie de campañas de monitoreo desde Agosto hasta Diciembre de 2018. Se encontraron concentraciones en el afluente de la PTAR de 396 ± 289 mg-DBO_5/l, 795 ± 262 mg-DQO/l, 361 ± 113 mg-SST/l, 66.0 ± 38.9 mg-N-NH_3/l, 11.8 ± 2.2 mg-P/l y 2.73 ± 1.13 m-S/cm de CE. Las concentraciones halladas en el efluente en promedio son: 18 ± 12 mg-DBO_5/l, 95 ± 61 mg-DQO/l, 18 ± 10 mg-SST/l, 41.7±26.5 mg-N-NH_3/l, 8.3 ± 2.2 mg-P/l y 2.35 ± 0.75 mS/cm de CE. La eficiencia global de la PTAR obtenida fue: 95 % of DBO_5, 88% de DQO total, 95 % de SST, 37% de N-NH3, y 30% para P. De acuerdo con estos resultados, es recomendable usar el agua tratada solo en el riego de cultivos de tallo alto, pasto y forraje que no son para consumo humano directo y que tengan moderada tolerancia a la salinidad para reducir riesgos asociados con la salud a la población. Para utilizar el efluente tratado en verduras y otros productos que se comen crudos, esta PTAR necesita implementar un proceso de desinfección.

Palabras Clave: Reactor Anaeróbico Compartimentado, Agua Residual, Desempeño, Reúso, Riego, Filtros de Grava, Evaluación, Bolivia, Sostenibilidad.

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1. INTRODUCTION

Water resources are under pressure in many parts of the planet. The effects of global warming, unexpected floods and droughts, have had a significant economic and environmental impact in the last thirty years, restricting the availability of fresh water for urban development and agriculture. Accelerated population growth, surface and underground water pollution and changes in weather patterns at a global scale are forcing us to pursue more innovative ways to optimize the use of water. In order to obtain the water necessary for agriculture and industrial production we must therefore resort to alternative sources, including wastewater. In a report, the UN recognized the special situation that exists in poor countries, where only 8% of those waters receive some treatment and insisted on the need to reduce discharges and increase the treatment of wastewater to meet the growing needs triggered by population growth. Currently, worldwide, it is estimated that there are around 20 million hectares irrigated with wastewater (treated, raw or mixed) [1]. The World Health Organization [2] states that the reuse of wastewater should be addressed from different angles that complement each other, in order to reduce public health risks, among which we can mention: the treatment of domestic wastewater itself, the restriction of crops, the use of irrigation application techniques that avoid the contamination of products, the management of the times between the last irrigation and the harvest, as a multiple-barrier approach. The reuse of treated water for irrigation is a common practice in Bolivia, particularly in areas with water deficit where this strategy is essential to guarantee agricultural production. Recent studies have identified 105 population centers where wastewater is reused for agriculture in Bolivia [3], mainly in arid and semi-arid zones. In the Andean region, in the departments of Oruro, Potosí and La Paz, main crops are potatoes, quinoa, beans, wheat and barley, while in the sub-Andean region, the departments of Cochabamba, Chuquisaca and Tarija mainly cultivate corn, wheat, fruit trees, vegetables and fodder crops such as alfalfa, barley and oats [4]. A great majority of nations use approximately 92% of the available water in agricultural irrigation, where 56% goes to the production of food. In this context, the future perspective is that by 2050, at least 50% of the water that agriculture will require should come from wastewater and, ideally, it should be treated water that meets the quality parameters required for reuse in agriculture, according to the different regulations [5]. Wastewater treatment involves the use of appropriate technology for plant design. Among these, anaerobic treatment technologies are widely used in our context. Some researchers have investigated the performance of anaerobic reactors combined with other treatment processes and under different operating conditions [6] finding that they are suitable for wastewater treatment under the perspective of sustainable development. Among the preferred anaerobic processes, are the so-called Upflow Anaerobic Sludge Blanket reactors (UASB). Some authors like Saavedra *et. al* [7] have found that in decentralized systems these processes operate effectively even at low temperatures. Among these processes, the Anaerobic Baffled Reactors (ABR) seem to be suitable for the treatment of domestic wastewater. ABRs were developed for the first time by Bachmann *et. al* [8] and are described as a series of UASB reactors where water is forced to flow up, down and through a series of separate compartments with deflectors. Bacteria inside the reactor tend to grow and settle out producing gas and moving horizontally at a relatively slow rate. The wastewater can then come into prolonged contact with the active biomass as it passes through the ABR, and an effluent relatively low in biological solids is obtained [9]. Anaerobic reactors have advantages such as: simplicity in the design, use of non-sophisticated equipment, high yields, low sludge production and low operating expenditures [10]. The most significant advantage of the ABR is its ability to separate acidogenesis and methanogenesis longitudinally down the reactor, which allows different populations of bacteria to dominate each compartment. Acidification predominates in the first compartment and methanogenesis dominates in the subsequent compartments [11].

Although the ABR have been widely used, they alone are not able to meet effluent quality requirements, so their use requires a combination with another treatment technologies. There are combinations of anaerobic and aerobic processes in the literature, such as the aerobic ABR biofilm reactor [12] and the anaerobic-aerobic stage of a modified ABR [13], among others. Some authors also have studied its performance combined with other treatment processes such as hybrid constructed wetlands [14] and duckweed ponds [15] finding that the combination of processes significantly improves the quality of the effluent in terms of organic matter and nutrients. Some geometric ABR variations are also been studied, such as five identical compartments [15] or nine identical compartments arranged in 3 parallel sets [16] that have proved to be efficient at treating wastewater. Even though there are several studies about different configurations of wastewater treatment processes that include ABR, these are still being proved under different climatic conditions, especially under low temperatures. Moreover, some geometric variations of ABR in which the number of compartments is the variable are still being tested.

2. MATERIALS AND METHODS

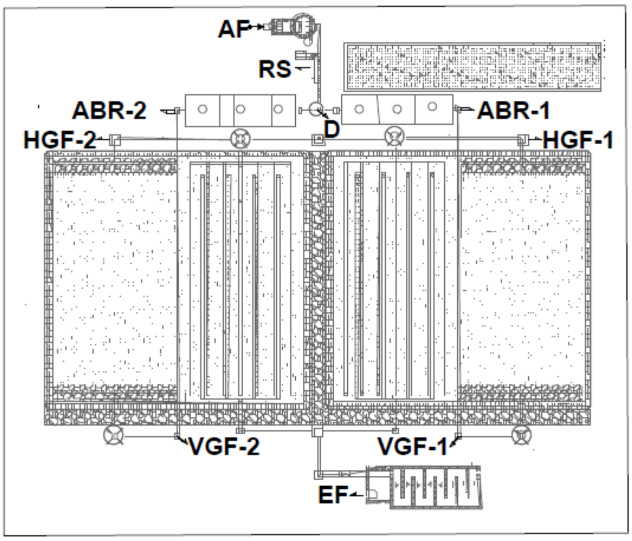
2.1 Description of the treatment plant

2.1.1 Location

Tolata city is located approximately 30 km south of the city of Cochabamba (Bolivia). It has a population of 2705 inhabitants according to the Statistics National Institute [17]. The wastewater treatment plant (WWTP) of Tolata is placed at an altitude of 2720 meters above sea level. The average temperature is 16.5ºC. The hottest month of the year is November with an average temperature of 19.3 °C and the coldest month is July with an average temperature of 12.7 °C. The average annual rainfall is 457 mm. The economy of this area is based on agriculture and farming. Its calcareous soil is ideal for the production of prickly pear [18]. The WWTP was built by the AGUATUYA Foundation and, to date, the operation and maintenance are carried out by them.

2.1.2 Configuration of the wwtp

This WWTP is made up of two treatment trains that function in parallel. The whole process is designed to have a hydraulic retention time HRT of 31 h from the influent to the effluent. The treatment plant shown in Figure 1, has been designed to treat a flow rate of 351.4 m^3/d for a design period of 20 years.



REFERENCES		
AF: Affluent	ABR: Anaerobic Baffled Reactor	VGF: Vertical Gravel Filter
RS: Rotating Screen	HGF: Horizontal Gravel Filter	EF: Effluent

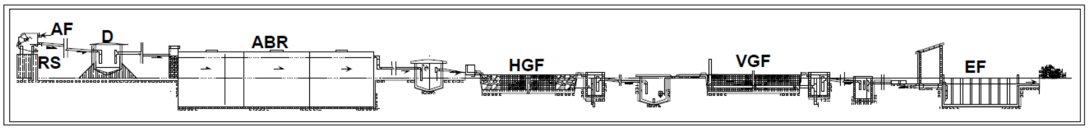


Figure 1: Configuration of Tolata's WWTP.

The treatment train is composed of the following processes: Wastewater enters a pumping station equipped with a grid chamber placed before the pumping well where larger solids are retained. The pumping station receives all wastewater coming from the public sewer systems and then elevates the wastewater in the direction of the rotating screen (RS). This station also works as an equalizer that allows maintaining a uniform flow to be sent to the plant. However, the flow that currently enters the WWTP is less than the average design flow, so the pumping is intermittent. The RS filters solids with a size greater than 3 mm, then the wastewater is conduced to a grease trap (D) where fatty material is separated by natural flotation and then removed manually. The design retention time of the degreasing chamber is 2 minutes. The primary treatment is carried out in 2 ABRs in which organic matter is decomposed into simpler compounds under anoxic conditions. The process generates sludge deposition in the bottom of the ABR, where digested

sludge can be extracted periodically through relief valves. The ABRs are designed to have a retention time of 9 h. The walls and their deflectors have been built with fiberglass reinforced polyester (FRP).
Secondary treatment is carried out in a configuration that combines horizontal-flow gravel filters (HGF) and vertical-flow gravel filters (VGF). At the outlet of the ABR, collecting chambers are arranged to direct the flow to two HGFs with a total area of approximately 509 m^2 (11 x 22.5 m each) and a depth of 0.8 m. The walls and bottom of the filter is lined with high density polyethylene geomembrane.

At the entrance area of the HGFs, the solid media is composed of coarse gravel while in the treatment area there is gravel with a mean porosity between 36 and 40%. The wastewater is conducted to the VGFs through a perforated pipe installed at their entrance. The effluent from the HFGs goes through an aeration chamber before entering the VGFs. These comprise an approximate area of 508 m^2 (11 x 22.5 m each) and are packed with medium size gravel. The distribution of wastewater to the media is carried out by sprinklers. The treated wastewater from both trains is collected in a chamber; from there it is subsequently directed to a chlorination chamber. The chlorination chamber is used only in emergency situations in order to avoid the formation of toxic organochlorine compounds.
The sludge accumulated at the bottom of the ABRs is removed by means of a pump and deposited in the sludge drying area. The sludge drying area is approximately 194.5 m^2 (8.5 x 22.8 m) with a depth of 0.15 m. Excess water in the drying area returns to the inlet of the plant.

2.1.3 SAMPLING

To evaluate the performance of the treatment plant, composite samples (collected during 8-hour periods) were taken at 10 treatment points which are described and codified in Table 1 (the same codes, that refer the monitoring points, are observed in Figure 1). Six monitoring campaigns were carried out between August and December 2018.

TABLE 1 - SAMPLING POINTS AT WWTP TOLATA

	Code	Description
Affluent to the WWTP	AF	Wastewater collector
Effluent of the rotary screen	RS	Inlet pipe to degreaser D
Effluent from the grease trap	D	Flow distribution chamber to ABR-1 and ABR-2
Effluent from ABR-1	ABR-1	Flow distribution chamber to HGF-1
Effluent from ABR-2	ABR-2	Flow distribution chamber to HGF-2
Effluent of the HGF-1	HGF-1	Entrance to VGF-1
Effluent of the HGF-2	HGF-2	Entrance to VGF-2
Effluent of VGF 1	VGF-1	Flow output chamber in VGF-1
Effluent of VGF 2	VGF-2	Flow output chamber in VGF-2
Effluent from the WWTP	EF	Inlet pipe to treated water tank

2.1.4 MEASUREMENT OF PARAMETERS FOR WASTEWATER CHARACTERIZATION

In this evaluation, on-site measurements were carried out using a multiparameter HANNA HI 98136 for the following parameters: pH, temperature (T) and electrical conductivity (EC). Biological oxygen demand (BOD) was determine by the Center for Water and Environmental Sanitation (C.A.S.A-UMSS); total chemical oxygen demand (CODTotal) and dissolved Chemical Oxygen Demand (CODdis), nitrogen as amonia $N\text{-}NH_3$ and phosphorus P were measured using a multiparameter photometer HANNA HI 83099; Total Solids TS and Total Suspended Solids (TSS) were analized using gravimetric methods from the Standards Methods for Examination of water and wastewater [19]. In addition, the flow rate was measured at the entrance to the pumping station using the volumetric method.

3. RESULTS AND DISCUSSION

3.1 WASTEWATER CHARACTERISTICS

Table 2 presents the average wastewater characteristics and their standar deviations, measured at different treatment points during six monitoring campaigns carried out from August to December 2018. Based on these results, a more detailed analysis is presented in the next section for the following parameters: pH, EC, COD, TSS, $N\text{-}NH_3$, P; that were chosen to evaluate the potencial of treated wastewater for reuse in irrigation.

TABLE 2 - CHARACTERISTICS OF WASTEWATER IN THE TREATMENT

		AF		RS		D		ABR		HGF		VGF		EF	
Parameter	**n**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**
BOD (mg O_2/l)	6	396	289	624	223	407	116	217	57	64	25	25	6	18	12
COD (mg O_2/l)	6	795	262	962	368	919	313	392	153	169	53	90	63	95	61
COD (dis) (mg O_2/l)	2	306	11	346	10	346	15	223	91	71	48	32	30	40	24
TS (mg/l)	6	2191	629	2292	382	2140	297	1754	484	1632	328	1573	378	1475	376
TSS (mg/l)	6	361	113	441	133	556	264	127	68	31	19	24	25	18	10
pH	6	7.81	0.19	7.85	0.27	7.73	0.26	7.05	0.16	7.22	0.17	7.32	0.15	7.38	0.16
Electrical conductivity (mS/cm)	6	2.73	1.13	2.54	0.80	2.46	0.86	2.60	1.25	2.75	0.93	2.33	0.94	2.35	0.75
T (ºC)	6	21.09	2.1	20.94	2.29	20.93	2.53	21.26	2.16	20.7	2.69	20.71	2.18	20.58	2.05
$N\text{-}NH_3$ (mg/l)	6	66.0	38.9	71.1	39.5	76.9	42.6	79.9	42.7	66.2	37.2	39.6	21.6	41.7	26.5
P (mg/l)	6	11.8	2.2	11.8	2.4	12.4	1.9	11.7	2.3	10.6	2.0	9.2	1.4	8.3	2.2

Wastewater coming from the Tolata's WWTP could be classified as high-strength wastewater according to parameters established by Metcalf and Eddy [20]. The high concentration of parameters can be due to low consumption of water in the area and the relatively short length of the collection system in this type of decentralized wastewater sewer systems.

The COD/BOD ratio calculated for the affluent during the sampling period is approximately 2.0. This value is compatible with the typical COD/BOD ratio range 1.5-2.0 established by Metcalf and Eddy [20] indicating that wastewater can be treated by biological processes.

3.2 PERFORMANCE OF THE TREATMENT SYSTEM OF THE WWTP AT TOLATA

From the data presented in the Table 2, we observe a considerable reduction in concentration of all the parameters chosen for the characterization of the WWTP. The removal efficiencies of the parameters were calculated from the percentage difference between the values recorded at the influent and the effluent of the Tolata's WWTP. The obtained overall efficiencies are: 95 % of BOD_5, 88% of total COD, 95 % of TSS, 37% of $N\text{-}NH_3$ and 30% of P.

A set of parameters from Table 2 were selected and they are described in the following section. These parameters were chosen in order to evaluate whether the processes carried out in this WWTP are adequate to obtain an effluent that can be re-used for crop irrigation.

3.2.1 pH

Figure 2 shows the variation of the average pH values throughout the treatment in the monitoring campaigns carried out between the months of August and December 2018.

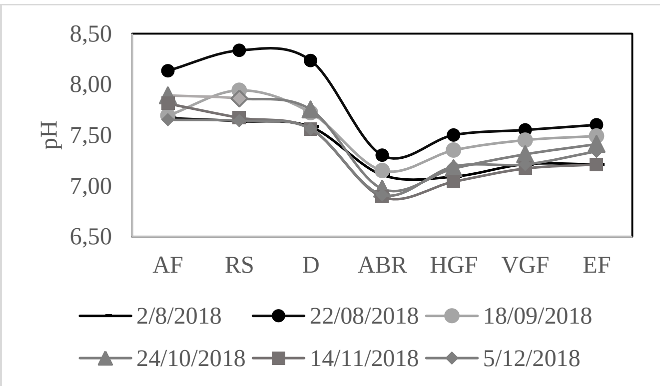


Figure 2: pH variation throughout the treatment.

A decrease in pH values can be observed at the output of the ABR, however these values are not less than 7.1, which indicates the correct performance of the anaerobic reactor. In anaerobic compartmentalized reactors, pH tends to fall because acidogenesis and acetogenesis occur in the first compartments, resulting in methanogenesis in subsequent compartments [11]. The pH is an index upon which irrigation water is quickly assessed for its suitability. Normally, the pH of irrigation water ranges from 6.5 to 8.4. The pH outside of the normal range might be suitable for irrigating, but has the potential to cause an imbalance of nutrients or contain poisonous ions. The biggest hazard related to an abnormal pH in water is its effect on irrigation equipment. Exceptionally low pH in irrigation water can increase corrosion. On the other hand, irrigation water containing high levels of alkalinity can lower the efficiency of the trickle irrigation system [21]. Based on the results obtained during the monitoring, the pH value found at the effluent indicates the suitability to reuse the treated effluent in irrigation.

3.2.2 ELECTRICAL CONDUCTIVITY

Salinity has been considered as the most important factor of water quality in agriculture because the high salinity in the soil can create a hostile environment for the crop to absorb nutrients and cause toxicity [2]. It is important and necessary to evaluate the concentration of salts in wastewater because when it is applied for irrigation, in excess and with a large amount of salts, it could cause soil salinization gradually which leads to low productivity [5]. Electrical Conductivity (EC) is an indirect measure of the content of dissolved salts in wastewater. The average results of the EC measurements at Tolata's WWTP are presented in Figure 3.

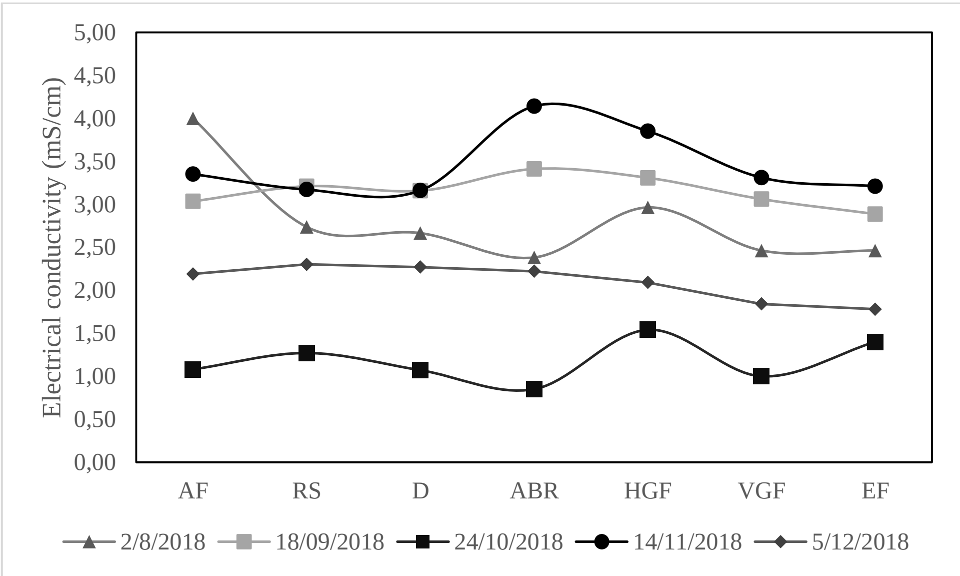


Figure 3: Variation of Electrical conductivity throughout the treatment.

From Figure 3, it is observed that there is not a considerable variation in the concentration of dissolved salts throughout the treatment; however, significant variations are observed in the average values of the conductivity in the different monitoring campaigns. That may be due to different sources of water supply for consumption that the population of Tolata uses. The average value recorded during six monitoring campaigns for the effluent is 2.35±0.75 mS/cm. Ayers and Westcot [22] mention the guidelines to interpret the quality of irrigation water that are very useful to select the appropriate crops based on the degrees of restriction that water presents for its use. They established that if irrigation water has an EC of <0.7 mS/cm, almost all crops can be cultivated, except for those very sensitive to salts. On the other hand, if the EC is in the range of 0.7 to 3.0 mS/cm, it is only recommended to cultivate those crops that have accepted to moderate tolerance to salinity. The value for EC found in this study suggests that the wastewater could be used only for irrigation of plants that have tolerance to salinity; however, the microbiological quality is a parameter that must also be considered for its use.

3.2.3 COD

An analysis of the COD was carried out to determine the behavior of the removal of organic matter in each of the processes throughout the treatment. Figure 4 shows the concentration of COD throughout the treatment, reaching an average of 95 ± 61 mg O_2/l for the treated effluent.

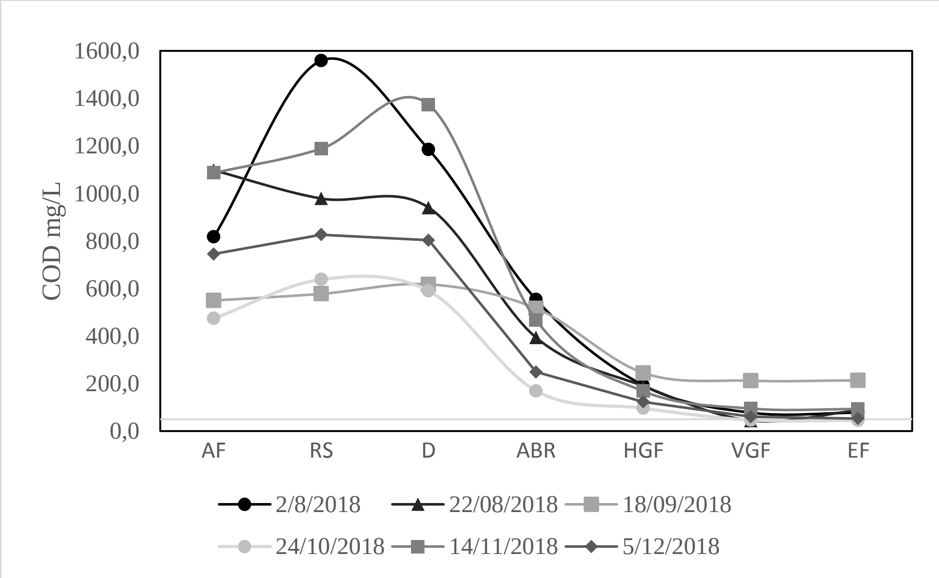


Figure 4: Variation of COD concentration throughout the treatment.

As it is observed in Figure 4, an accumulation of COD was found at the outlet of the rotating screen and at the outlet of the grease trap, which may be due to the dragging of solids by the action of suction of the pump from the pump station to the rotating screen, and to the accumulation of suspended and floating organic matter in the grease trap for lack of maintenance. Generally, COD is used as a measure of organic matter, biodegradable and non-biodegradable. Oxygen in water is consumed for decomposing organic matter to create an anaerobic state. During the decomposition process, oxides in soil such as Fe_2O_3, Mn_2O_5 and sulfates consume oxygen to lower the oxidation-reduction potential. In the end, the generated iron, manganese and sulfide along with organic acids can disrupt the crops to absorb nutrients [21]. There are very few guidelines that establish standards for COD concentrations in wastewater for its use in irrigation. However, some countries such as France has established that a concentration below 60 mg/l-COD permits an unrestricted irrigation. On the other hand, Israel and Italy has established a value below 100 mg-COD/l for water reuse in irrigation [21]. Based on these parameters, it can be considered that the effluent obtained in the Tolata's WWTP is suitable for reuse for crop irrigation.

3.2.4 Total Suspended Solids

The variation of the concentration of TSS throughout the treatment it is shown in Figure 5.

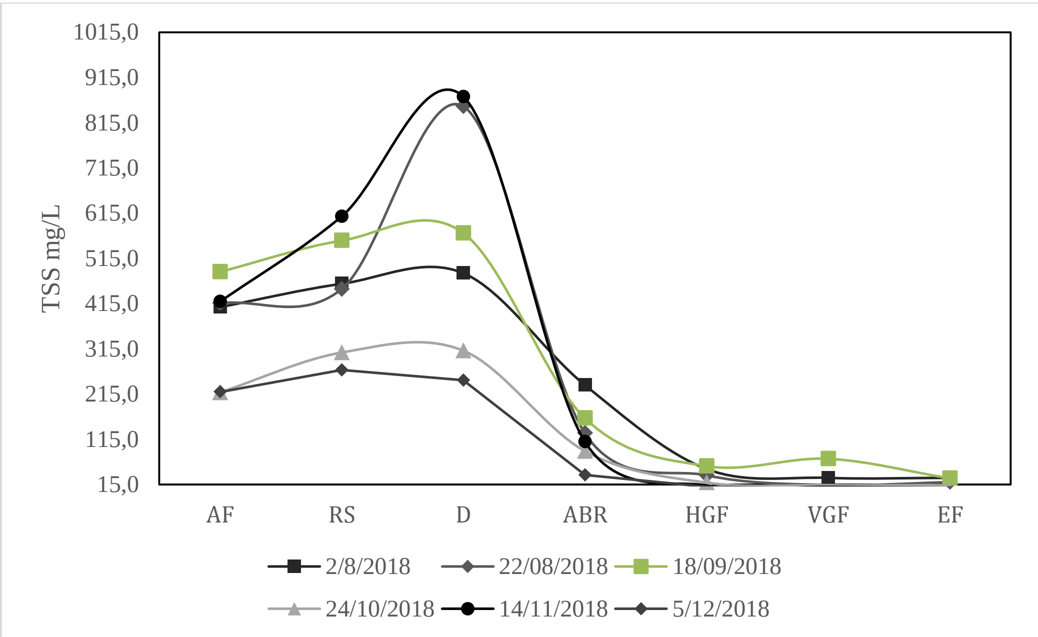


Figure 5: Variation of TSS concentration throughout the treatment

As it is observed from Figure 5, there is a clear relationship with the high values of COD recorded at the exit of the grease trap (Figure 4) and the high values of TSS registered at the same monitoring point (Figure 5), which verifies the accumulation of suspended and floating organic matter in the grease trap that goes to the ABR which could eventually lead to an overload of solids entering the ABR.

The average concentration of TSS in the effluent does not exceed 30 mg/l. The United Nations Food and Agriculture Organization (FAO) has established guidelines to interpret the quality of irrigation water, and they consider degrees of restriction of use based on the concentration of total suspended solids. Accordingly, when the concentration of TSS is less than 50 mg/l, there are no restrictions on its use for crop irrigation [23].

The suspended solids contained in wastewaters can be retained by the soil matrix when they are used in irrigation. This improves the physical and chemical properties, structure and retention of nutrients, in addition to promoting a greater biological activity that favors the mineralization of elements such as nitrogen and phosphorus [24].

3.2.5 Nutrients

Anaerobic reactors do not remove nitrogen and phosphorus, conversely, their concentrations may even increase in the soluble phase due to the hydrolysis of solids. Nitrates and phosphates can stimulate eutrophication when they are present in natural water courses; however, when the treated effluent is intended to be used in the irrigation of crops, these nutrients could be useful for the growth of the plant. In this paper, the content of the nitrogen was measured in form of nitrogen coming from the ammonia nitrogen (N-NH_3) and the values found in different points of the treatment train are shown in the Figure 6.

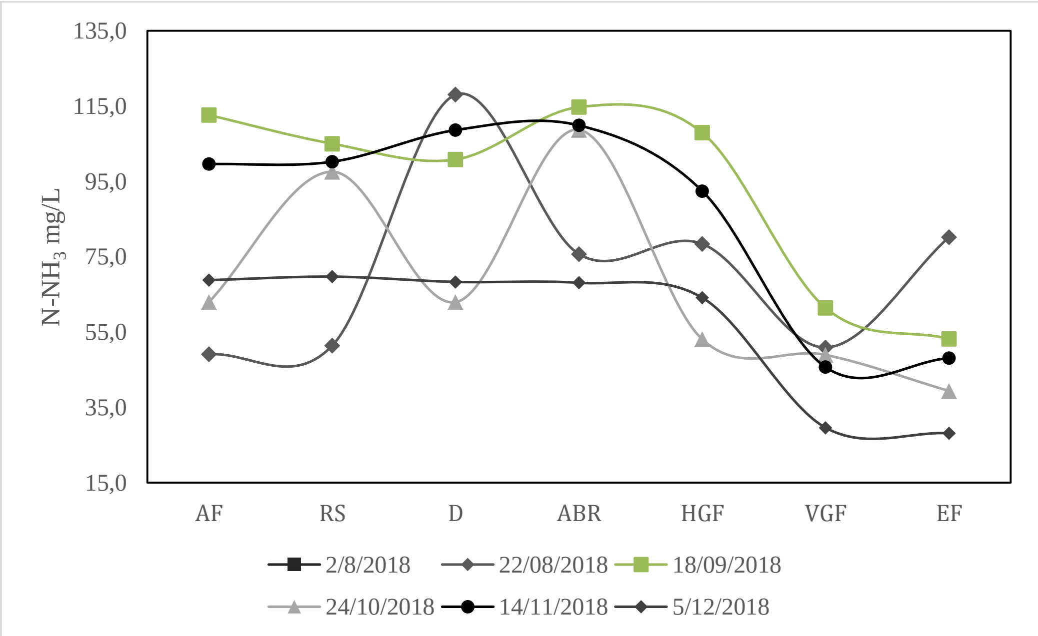


Figure 6: Variation of N-NH_3 concentration throughout the treatment.

It is evident that the most significant removal occurs in the VGF stage. Water coming out of the HGF is distributed through a system of perforated pipes with holes arranged longitudinally, towards the VGF where it is sprinklered and infiltrated in the media favoring the partial aeration of the water flow and achieving partial removal of nitrogen. The final treated effluent contains a concentration of 41.7 ± 26.5 mg/l of N-NH_3. Taking this value as a reference it can be assumed that the concentration of total organic nitrogen is even greater or at least equal in magnitude. The Technical Guide for the Reuse of Wastewater in Agriculture [5] establishes that a concentration greater than 30 mg/l of total nitrogen has severe limitations for its use in irrigation considering the type of crop to be irrigated; however no parameters are established for the concentrations of phosphates. On the other hand, the dynamics of organic matter in the soil play an important role as its decomposition allows the availability of nutrients for plants [25], so the contribution of organic matter from wastewater is very appreciated by the agricultural producers. However, it is important to consider the soil capacity for buffering, assimilation and degradation of contaminants present in the residual water, in order not to cause damage that deteriorates its quality.

The content of phosphorus throughout the treatment was also measured. The results are shown in Figure 7.

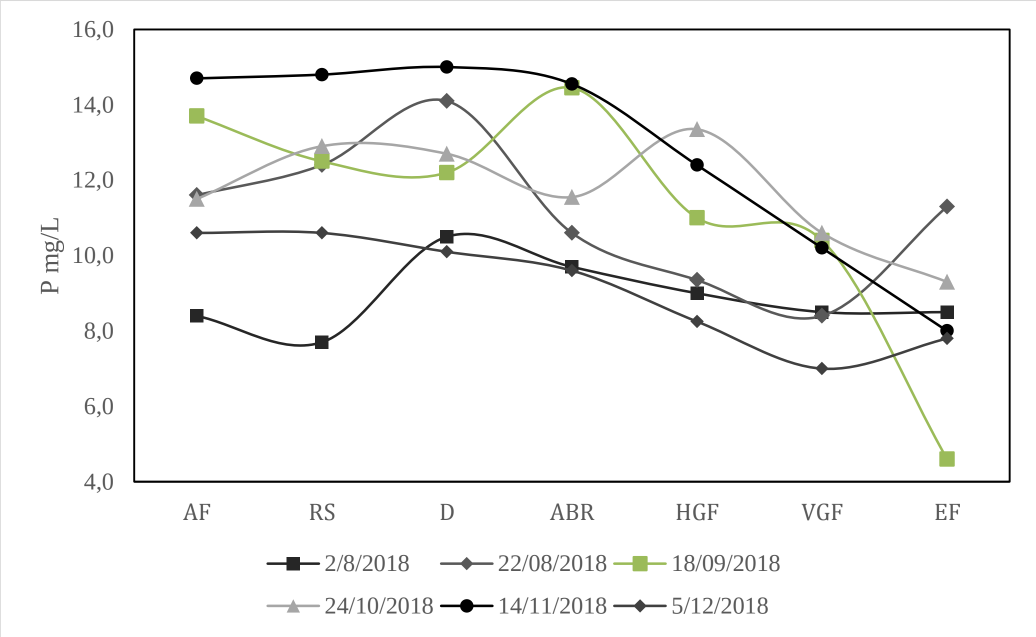


Figure 7: Variation of P concentration throughout the treatment.

In the same way as in the case of nitrogen, a partial removal of P is observed in the VGF stage, which is favored by the aeration suffered by the water flow in the infiltration process to the filter bed. The average concentration reached at the effluent is 8.3 ± 2.2 mg-P/l.

4. CONCLUSIONS

The anaerobic baffled reactor is a simple technology that is effective when combined with horizontal and vertical gravel filters. The concentrations found at the effluent of the Tolata's WWTP were: 18±12 mg-BOD_5/l, 95±61 mg-COD/l, 18± 10 mg-TSS/l, 41.7±26.5 mg-N-NH_3/l, 8.3±2.2 mg-P/l and 2.35 ± 0.75 mS/cm for EC. The obtained overall efficiencies of the WWTP were: 95 % of BOD_5, 88% of total COD, 95 % of TSS, 37% of N-NH_3 and 30% of P. Comparing these results with some parameters established in guidelines to reuse wastewater for crop irrigation, we found that the treated water has the potential to be used with some restrictions on the choice of crops, favoring those which have a moderate tolerance to salinity. Although the concentration of nutrients in the effluent can favor the growth of the plant, it could cause contamination of groundwater or eutrophication in lagoons or lakes if sufficient runoff is generated. On the other hand, one of the main concerns related to the reuse of wastewater is the salinization of agricultural land and the loss of infiltration; therefore, these issues should be analyzed in detail in order to establish a proper irrigation management plan or strategy that should include for instance: the restriction of some crops, the use of appropriate irrigation techniques that avoid the contamination of products and the management of the times between the last irrigation and the harvest. To guarantee the safe use of wastewater due to the microbiological quality of the same, since currently the WWTP does not carry out a disinfection process, it is advisable to use the effluent only in the irrigation of high stem crops such as fodder and other crops that are not eaten raw. Additionally, in the Bolivian context, there is a need to establish water quality standards for the safe and sustainable practice of wastewater reuse in agriculture.

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