Biochemical Oxygen Demand (COD) performance in slow filtration technology

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ABSTRACT

Sanitary engineering is an important arm in the sustainable development of the planet. To solve the environmental problems generated by the unbridled growth of cities and production and supply systems, this branch of engineering has been studying new methodologies and creating new technologies to combat environmental pollution. One of the most worrisome areas of pollution today is with water resources. Well, there is no life without water and with that it becomes important to maintain water bodies on the planet. Faced with this challenge, sanitary engineering has been studying and developing new tools for controlling the aquatic biome, known as alternative sewage treatment systems. Among the systems that make up this follow-up is the slow filter system. Slow filters are technologies based on the use of sand and gravel of different dimensions that, when united in a single chamber, form a system that, through physicochemical processes, enables the removal of polluting agents from contaminated water. The present research used a pilot system developed at UNICAMP to analyze the parameter related to Biochemical Oxygen Demand (COD). The installed system has two conventional filters, in which there is an additional layer of activated carbon to enhance the purification process. During the study period, from August 22 to August 26, 2022, the results achieved in relation to the improvement in the COD parameter were 59.15% and 73.51%. Having that values comprise to slow filters – conventional and with additional layer of activated carbon, respectively.

Keywords: Reuse, Sewage, Environmental impact, Environment.

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INTRODUCTION

Humanity had its resurgence thanks to water, an important resource for the existence of life.

It is not for nothing that the great civilizations of the past: Egyptian, Macedonian, Babylonian among others, owe their emergence and development thanks to the adjacent water resources.

However, the current strong industrialization has led to the problem of scarcity of this important resource on the planet, especially in developing countries.

In Brazil, for example, there are often not enough financial conditions or information for adequate treatment. Consequently, there is a poor use of large amounts of water that could be reused.

Filtration, as part of the treatment of water for human consumption, must have been created by man because of the observation of the clarity of groundwater, which was attributed to its passage through natural soils, and the use of filtration for clarification has been reported since the sixteenth century (Di BERNARDO, 1993).

Filtration is a process that is necessary because water is notoriously a vehicle for the transmission of infectious diseases such as cholera and typhoid fever, and the main victim of these diseases is the child population (Di BERNARDO, 1989).

The first treatment systems appeared in the last century through John Gibb in Paisley (Scotland) and James Simpson in London (England). In London, the process was mainly based on the removal of suspended solids from raw water. In 1850, John Snow showed that cholera was transmitted by water (the pathogenic bacterium that transmitted it was not yet known) and the solution found to prevent this transmission and the presence of other undesirable solids would be the filtration of the water or the abandonment of contaminated springs (PATERNIANI, 2003).

According to Di Bernardo (1993), slow filtration has been attracting the attention of professionals in the area due to the fact that it is a system of simple construction, maintenance and operation, as well as very high efficiency, especially in the removal of microorganisms and suitable for small rural properties, due to the low cost of implementation (Di BERNARDO, 1989).

The aim of this research was to evaluate the performance of the Biochemical Oxygen Demand (COD) present in wastewater (sewage) of a slow filter pilot system developed on the campus of the Faculty of Agricultural Engineering (FEAGRI) of the State University of Campinas (UNICAMP).

SLOW FILTRATION AND ITS OPERATION

Slow filtration is a relatively simple water treatment process where high-tech equipment or chemicals are not used, and skilled labor is not required for its monitoring. It is known that the filtering process is cheaper when units such as rapid mixing, flocculation and decantation, among others, are dispensed with, which are present in a complete treatment plant. The construction of these slow filters is feasible, especially in Brazil today, due to the great proliferation of diseases that are transmitted to water.

Slow filtration is nothing more than the removal of physical, chemical and biological impurities through the passage of water through a granular medium.

The first slow filter for industrial purposes was built in Scotland in 1804 by John Gibb. At that time, it was believed that these filters were only effective for the removal of impurities from the water through a natural sieving process, producing water without color, turbidity and taste, and the mechanisms and processes involved were not known (Di BERNARDO, 1989).

Slow filtration today is the result of the combination of three actions which are:

(a) transport of particles from the suspension to the grain surfaces;
(b) Adhesion of the particles to the grains or previously retained matter;
(c) Biological activity.

SLOW FILTER – OPERATION AND MAINTENANCE

Paterniani (20003) reports that at the beginning of each filtration period, the filter is filled with clean water through the drainage system, in order to expel the air bubbles contained in the pores of the bed, ensuring a complete contact surface of the grains with the water, which is introduced until it covers the filter bed, at a height of 10 cm, at this point, admitting the entry of raw water, so that there is no turbulence and consequently damage to the purification process.

Di Bernardo (1989) comments that when the design level is reached, the inlet valve of the influent is opened and the filter starts to work with a filtration rate that must be between the values of 2 and 5 m3.m-2.d-1, during the maturation period, with effluent discharge.

It is during the maturation period that the process of stabilization of the wastewater occurs in order to allow the particles present in the effluent when adhered to the grains of sand in a filter bed, through the mechanisms already described, a very solid structure is formed (Di BERNARDO, 1989).

The sand that is to be used in slow filters should be cleaned of impurities by washing with ordinary water. Even after several filtration paths, the beginning of the system's operation is characterized by the production of effluent with unsatisfactory quality for a period that can reach weeks until the "ripening" layer (*schmutzdecke*) is fully developed (MELO JÚNIOR, 2005).

Di Bernardo (1989) informs that another operability factor that should be considered is the option of covering these filters in order to avoid the action of sunlight in the excessive production of algae in the upper part of the filters. The sand removed during cleaning is washed soon after and scraped, avoiding anaerobic conditions, due to the consumption of oxygen by microorganisms, producing substances that cause taste and odor, which are difficult to remove.

WATER QUALITY PARAMETERS IN SLOW FILTRATION

The size and size distribution of particles present in the influent and effluent of slow filters is a relatively new parameter that has been used mainly to estimate the removal of *Giardia lamblia cysts* and helminth eggs. Althoughthe knowledge of the number of particles and the distribution of their sizes provides additional information about the performance of slow filters, the turbidity can vary considerably for the same total number of particles and vice versa. Also, for each water, there seems to be a relationship between turbidity and suspended solids content, which should also be considered (TATE, 1990).

According to Di Bernardo (1993), water turbidity is due to the presence of colloidal and suspended particles, finely divided organic and inorganic matter, plankton and other microscopic microorganisms.

Its determination is made in a calibrated turbidity meter with formazin solutions. The little shape is a heterocyclic polymer produced by the reaction of hexamethylenetetramine with hydrazine sulfate. The tetrahedral cage-like structure of hexamethylenetetramine, similar to adamantane, serves as the molecular building block to form a three-dimensional polymer network.

The turbidity of raw water in general ranges from 7 to 12 UT (Turbidity Unit), despite the maximum recommendation of 10 UT. In general, the lower the turbidity of the filtered water, the lower the number of coliforms, there are indications that the lower the turbidity, the greater the efficiency of removing viral agents (PROSAB, 1999).

BIOLOGICAL ACTION ON THE SLOW FILTER

Biological activity is considered the most important action that occurs in slow filtration, being more pronounced at the top of the filter medium, where there is the formation of biofilm (gelatinous layer), consisting mainly of organic matter and a wide variety of microorganisms, such as bacteria, algae, protozoa and metazoans. In addition, when there is the presence of iron and manganese in a soluble state in raw water, the formation of precipitates of these metals can occur, which also end up participating in the formation of this layer (Di BERNARDO, 1991).

Biological activity exhibits interdependent purification processes, which are usually described in combination with each other. The most important are chemical oxidation and microbiological oxidation, as well as biological processes involving animal and plant life forms (Di BERNARDO, 1991).

The organic matter that is deposited in the filter is used as food by the microorganisms, forming a true ecosystem that has been developed with the maturation of the filtration career.

Through microbial oxidation, part of this food provides cellular material for its own growth and part is used as energy for its metabolism, allowing dead organic matter to be converted into living organisms (PROSAB, 1999).

IMPORTANCE IN THE REUSE OF TREATED WASTEWATER

According to Carvalho *et al.* (2014) Wastewater reuse consists of the reuse, after adequate treatment, of treated sewage composed of effluents from, for example: tanks, bathtubs, showers, washbasins and washing machines, among others.

According to ABNT NBR 15527/2007, the use of treated wastewater for non-potable purposes is a promising alternative that should be developed and encouraged. However, recently, the use of treated effluent reuse has been used for less noble purposes, such as: supplying toilet tanks; floor washing; garden irrigation, among others. Such use leads to a decrease in the use values of drinking water and consequently in the preservation of drinking water.

According to CETESB (2012), it can be explained that this process occurs through direct or indirect reuse, resulting from planned or unplanned actions, so the forms of wastewater use are:

- Unplanned indirect water reuse: This occurs when the water used is discharged into the environment and reused, in its diluted form, in an unintentional and uncontrolled manner.
- Planned indirect reuse of water: The process of discharging effluents in a planned manner into surface or groundwater bodies, which in turn are used in a controlled manner, to meet some need.
- Planned direct reuse of water: It is the one whose effluents, after being treated, are sent directly from their discharge point to the reuse site.
- Water recycling: Internal reuse of water, prior to its discharge into a general treatment system or other disposal site. It functions as a supplementary source of supply from the original use. Water recycling is a particular case of planned direct reuse.

CHEMICAL OXYGEN DEMAND (COD)

According to SOUZA (2018), the Chemical Oxygen Demand (COD) is an indispensable parameter in characterization studies of sanitary sewage and industrial effluents, it evaluates the amount of dissolved oxygen (DO) consumed in an acidic medium that leads to the degradation of organic matter.

The analysis of COD values in effluents and surface waters is one of the most expressive for determining the degree of water pollution, this analysis reflects the total amount of oxidizable components, whether carbon or hydrogen from hydrocarbons, nitrogen (from proteins, for example), or sulfur and phosphorus from detergents (SOUZA, 2018).

Chemical oxygen demand can be considered as a process of chemical oxidation, where potassium dichromate (K2Cr2O7) is employed.

During the process, the organic carbon in a carbohydrate, for example, is converted into carbon dioxide and water.

It should be noted that the oxidation power of potassium dichromate is greater than that which results through the action of microorganisms.

As a result, the resistance of substances to biological attacks led to the need to make use of chemical products, with organic matter in this case being oxidized by a chemical oxidant (SOUZA, 2018).

That is why COD differs from Biochemical Oxygen Demand (BOD), where the amount of oxygen needed for the oxidation of biodegradable organic matter is measured, that is, in BOD it is not necessary to use chemicals, while in COD there is a need (SOUZA, 2018).

MATERIAL AND METHOD

CASE STUDY

The study was carried out in a slow filtration system set up in the experimental field of the Faculty of Agricultural Engineering (FEAGRI) of the State University of Campinas (UNICAMP), in which wastewater samples were collected from August 22, 2022 to August 26, 2022.

Samples were collected weekly before (affluent) the wastewater enters the system and after (effluent) treatment in the set of the two filters themselves, with and without charcoal added to the granular system.

The samples were packaged and preserved in 500 ml deionized PET bottles and frozen at -5oC to maintain their initial properties.

SLOW FILTER SYSTEM

The slow filtration mechanism has a set of three plastic reservoirs, consisting of:

- Prefilter
- Sand and gravel filter, and
- Sand filter, gravel and additional layer of activated carbon.

Figure 1 shows an overview of the assembled slow filtration complex.

Figure 1 – FEAGRI/UNICAMP Slow Filtration System.

Figure 1 shows the presence of a reservoir that functions as a pre-filter for the initial stabilization process and two subsequent reservoirs for the final treatment, in which one of them consists of its usual design composition composed of sand and gravel of different granulometry. While the other reservoir, in addition to the usual composition, there is an additional inner layer formed by activated carbon.

The hydraulic system assembled with 3/4 inch PVC pipes was developed with taps for taking wastewater (sewage) samples for evaluation of purification parameters.

SLOW FILTRATION SYSTEM HYDRAULIC DETENTION TIME

Each reservoir of the slow filtration complex has a useful height (h) of 1.20 meters and a diameter (D) of 60 centimeters.

With the dimensions presented, using the concepts of spatial geometry determined by equation 1, it results in a volume of 0.34 m3.

$$V = \frac{\pi . D^{2}}{4} . h$$

Equation 1

The determination of the volume characteristic of the filters is important to estimate the hydraulic detention time (ɵh) that represents the stabilization behavior of wastewater (sewage).

According to Porto (1999), the hydraulic detention time (ɵh) represents the potential for agility in the stabilization of the organic compounds present in the sewage when residual treatment is performed.

The collection of the regulated flow of sewage that passes through the slow filter complex is worth 5.10-5 m3.s-1. With the value of the volume (V) obtained by equation 1 and the flow rate (Q), the interchamber detention time can be determined by equation 2.

$$\theta_h = \frac{V}{Q}$$

Equation 2 (PORTO, 1999).

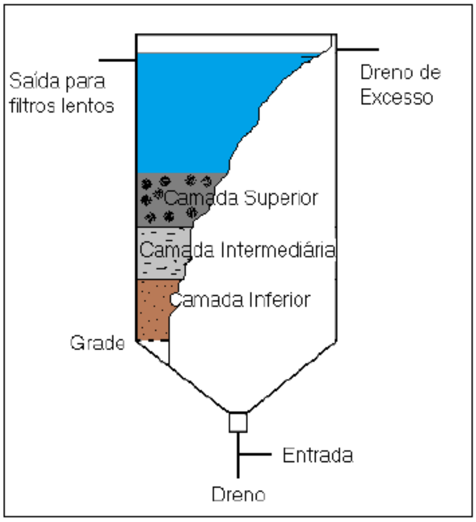
From equation 2 we can see that the detention time (ɵh) was 7.87.10-2 d. This value, if normalized by the dimensional analysis process, shows that the detention value was 2 hours of sewage stabilization.

COMPOSITION OF THE PRE-FILTER

The pre-filter installed at the beginning of the slow filtration system has the function of starting the purification process in a preliminary way.

Figure 2 shows a sketch of the internal division of the pre-filter, where the composite layers can be seen.

Figure 2 - Pre-filter cut. (MELO JÚNIOR, 2005).



The pre-filter, as shown in figure 2, works with stratified layers, in which each region has a support material of different granulometry (MELO JÚNIOR, 2005).

Table 1 shows the constitution of the pre-filter with the divisions of each distinct layer.

Table 1 – Variability of layers *versus* pre-filter thickness.

	Material Bracket (mm)	**Thickness (cm)**
Top Layer	3.2 to 6.4	25 cm
Middle Layer	6.4 to 19.0	25 cm
Bottom Layer	19.0 to 31.0	25 cm

The system of sample collection valves can be seen in figure 3, being made of PVC and which allows the pre-filter and subsequent filters to remove wastewater and also for the process of water extraction when there is a need for cleaning in the three filters.

Figure 3 - Pre-filter view.

COMPOSITION OF SLOW FILTERS

The filters were developed adopting the recommendations of Ferraz and Paterniani (2002), where each filter has a characteristic composition.

Table 2 shows the filter dimensions and composition.

Table 2 – Variability of layers with different particle size and thickness.

	Backing material	**Grain size**	**Thickness (cm)**
Top Layer	Sand	0.05 mm	40
Middle Layer	Gravel 1	5.0 mm	20
Bottom Layer	Gravel 2	31.5 mm	20

In one of the filters there is also an additional layer of 10 cm thickness with activated carbon of 8.5 mm granulometry.

COD METHODOLOGY

The Biochemical Oxygen Demand (COD) test is an indispensable analysis in the characterization studies of sanitary and industrial sewage.

The methodology adopted used the NTS 004 standard of SABESP, with the following ingredients:

- Silver sulfate (Ag2SO4);
- Sulfuric acid (H2SO4);
- Keeping track of the Storm;
- Ferrous sulphate heptahydrate (FeSO4.7H2O);
- Amoniacal ferrous sulfate (Fe(NH4)$_2$(SO4)2.6H2O;

- Biftalato de potássio (KHC8H4O4);
- Mercury sulfate (HgSO4).

Preparation Procedure (COD)

Add 10 g of silver sulfate (Ag2SO4) to 1 liter of sulfuric acid (H2SO4). The dissolution of Ag2SO4 can be done by leaving the solution to rest for 1 to 2 days or with the help of a magnetic stirrer, until total dissolution is verified.

Then, dissolve 12.2590 g of potassium dichromate (K2Cr2O7), previously dried at 103°C for 2 hours, in deionized water and dilute the volume to 1000 mL. It is stored in an amber jar.

The process continues by dissolving 1.485 g of phenanthroline monohydrate, together with 0.695 g ferrous sulfate heptahydrate (FeSO4.7H2O), in deionized water and dilute to 100 mL, the product is stored in amber vial under refrigeration. Then 98 g of ammoniacal ferrous sulfate ($Fe(NH4)_2(SO4)2.6\ H2O$) is dissolved in deionized water, adding 20 mL of sulfuric acid (H2SO4) together.

The resulting solution is cooled and diluted to 1000 mL with deionized water and stored.

The ammonia ferrous sulfate solution is obtained by diluting 100 mL of the ammonia ferrous sulfate solution, approximately 0.25M, with deionized water up to approximately 500 mL. Then add 20 mL of sulfuric acid and cool the solution.

For the potassium biphthalate standard, 0.425 g of potassium biphthalate (KHC8H4O4) is weighed, previously dried to constant weight at 120ºC.

The standards are added to the water sample in a 500 mL volumetric flask and the dissociation reaction is expected to occur for further analysis of the released oxygen concentrations.

RESULTS

ANALYSIS OF COD CONCENTRATIONS OBTAINED

From the methodology adopted by the NTS 004 standard of SABESP for the samples of the alternative treatment system of inlet sewage (influent), before the treatment and after the purification process (effluent), for the filters with complementary addition of activated carbon and without the addition of activated carbon, it was possible to understand the dynamics in the efficiency of COD concentration gain.

Table 3 shows the behavior of the concentrations analyzed for the inflow (inlet) and effluent (outlet) of the slow filtration process.

Table 3 – Chemical Oxygen Demand in the Slow Filtration System (mg. L-1).

Data	Tributary	Effluent WITH activated carbon	Effluent WITHOUT activated carbon
22/08/22	180	309,5	281,5
23/08/22	175	311,9	281,9
24/08/22	181	307,5	280,5
25/08/22	169,5	303,52	280,52
26/08/22	179	301,45	282,45
AVERAGE	**176,9**	**306,77**	**281,37**

Table 3 shows that the slow filtration system played a relevant role in increasing the biochemical oxygen demand (COD).

This is reflected in the measurement of the mean values during the scientific analysis stage that was employed.

Table 3 shows that the mean inflow of sewage to be treated was 176.9 mg. L-1, while after treatment in each individualized slow filter, the mean COD concentration values were 306.77 mg. L-1 for the filter with extra added activated carbon is 281.37 mg. $^{L-1}$ for the filter without the extra layer of activated carbon.

SLOW FILTRATION SYSTEM EFFICIENCY PERCENTAGE RATIO

From the data obtained in Table 3, it is also possible to verify the efficiency of the process as a percentage of its efficiency, which is presented in Table 4 below.

Table 4 – Percentage of COD elevation in the slow filtration system.

Data	Effluent WITH activated carbon %	Effluent WITHOUT activated carbon %
22/08/22	71,94	56,39
23/08/22	78,23	61,09
24/08/22	69,89	54,97
25/08/22	79,07	65,50
26/08/22	68,41	57,79
MEDIA	**73,51**	**59,15**

Table 4 shows that the increase in efficiency in the presence of biochemical oxygen demand was, on average, 59.15% of COD gain for the slow filter constituted by the conventional construction process based on sand and gravel.

While the slow filter with the addition of an additional layer of activated carbon obtained an average percentage gain of 73.51%.

This mechanism allows us to assess that the addition of an additional layer in the initial tests shows promise with an increase in the efficiency of the treatment and improvement in the quality of the wastewater.

CONCLUSION

The research aimed to verify the efficiency in the use of the alternative slow filtration system for the treatment of sewage collected at the study site.

The values of increase in the concentration of the biochemical oxygen demand were promising and satisfactory for the beginning of operation of the slow filtration system, being obtained values of 59.15% (without coal) and 73.51% (with coal) of increase in the presence of COD in the final state of the treated wastewater.

It should be noted that according to the treatment mechanisms employed, in which by the hydraulic detention process, together with the biological (aerobic) and chemical (adsorption) processes, the system already performs a significant improvement process as the value of 59.15% presented.

However, with the inclusion of an additional mechanism such as activated charcoal to the treatment system, the treatment values have a significant improvement reaching 73.51%.

Techniques such as slow filtration are important for use, since they promote a considerable improvement in wastewater and bring an alternative for the use of this effluent in reuse applicable in activities that do not require noble water, that is, drinking water.

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