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USE OF A FILTRATION TITLE SYSTEM FOR SEWAGE DECONTAMINATION IN RELATION TO THE PRESENCE OF FAECAL COLIFORMS

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Abstract: With demographic growth accompanied by greater production needs to keep up with growing demand, water costs have grown exponentially. Every time it is necessary to minimize the environmental damage that is generated and consequently the lack of water for public supply. The lack of basic sanitation, especially in rural areas, leads to a greater need for new studies that allow treating and reusing water from sewage in reuse activities. The present research adopted a filtration trench system of three acrylic boxes with a stone layer of 0.20 m and complementary layers of sand with thicknesses: 0.75 m; 0.50 m and 0.25 m, to monitor the removal of fecal coliforms present. The study was carried out in the FEAGRI experimental field at UNICAMP and allowed the percentage performance to be verified in relation to the layer of sand used. The study lasted five weeks and allowed evaluating that for a sand layer of: 0.75 m; 0.50 m and 0.25 m, the average removal values were: 60%; 50% and 30%, respectively.
Keywords: Environmental Impact, Sanitation, Contamination, Sewage.

INTRODUCTION

With regard to environmental sanitation in Brazil, almost half of the population (83 million people) is not served by sewage treatment systems, 45 million citizens lack drinking water distribution services.

In rural areas, more than 80% of homes are not served by general water supply networks and almost 60% of sewage throughout the country is discharged, without treatment, directly into water courses.

The impact falls on public health, sixty-five percent of hospitalizations of children aged zero to five years old, recorded in Brazil, result from the absence or precariousness of sanitation services. According to Teixeira and Pungirum (2005), the lower the population coverage by sewage systems, the higher the infant mortality.

In urban areas with precarious urban infrastructure, in relation to the lack of sanitary sewage, there is evidence that the greatest risk to children's health is associated, firstly, with the disposal of sewage on the ground, around the house, and, secondly, place, the presence of sewage draining in the street, mainly for feco-oral transmission parasites. For the improvement and implementation of environmental sanitation services, the development of simple, efficient and adaptable treatment systems to the country's economic and structural conditions is required.

According to Van Haandel *et al.* (2004), this simplicity refers to the application of natural, simple, unsophisticated methods with low construction and operation costs, in addition to being viable and environmentally sustainable.

One of the sewage treatment systems that have been researched, currently in Brazil, is the one that uses the anaerobic process, because it is low cost and can generate energy to be reused. However, these systems still require research to achieve a higher degree of efficiency, as they do not meet the limits established for the release of effluents in accordance with CONAMA Resolution 357 (2005) of CONAMA (National Council for the Environment). Therefore, there is a need to improve the final efficiency of the combined systems through other post-treatment units, including filtration ditches, filtration ditches, sand filters, (sinks), absorbent wells and others.

The present research aimed to analyze the behavior of the removal of fecal coliforms in a filtration trench system developed in the experimental field of the Faculty of Agricultural Engineering (FEAGRI) of `` Universidade Estadual de Campinas`` (UNICAMP) during a period of five weeks of sample collection.

LITERATURE REVIEW

FILTRATION DITCHES

According to Norm NBR 13.969 (1997), filtration ditches are a treatment process for the final disposal of anaerobic effluent, which consists of its percolation in the soil, where purification occurs due to physical (solids retention) and biochemical (oxidation) processes due to fixed microorganisms on the surfaces of grains of sand, without the need for complex operation and maintenance.

According to Jordão (2005), the filtration trench system consists of a set of pipes, seated at a rationally fixed depth, in a soil whose characteristics allow the absorption of effluent sewage from the septic tank connected to the system.

The percolation of the liquid through the soil will allow the mineralization of the sewage, before it becomes a source of contamination for the underground and surface waters that one wants to protect.

The filtration trench system differs from the sand filter (Filtration/Percolation) because it does not have a surface area exposed to the weather, which is built in the soil itself, and may have impermeable walls.

The filtration ditch is made up of leaky conduits (usually perforated tubes) surrounded by gravel and lined up inside. They are covered with local soil and have a low slope in their extension.

The conduit distributes the effluent along the trench, providing its subsurface filtration. As it uses the soil as a filter medium, its performance depends on the characteristics of the soil, as well as its degree of water saturation.

According to Coraucci Filho *et al.* (2001), filtration ditches are advantageously applied when the surface layer of the soil has greater filtration capacity than the lower layers, or when the aquifer is at great depth, providing greater health protection. Taking into account the use of the soil as a filtering medium, the performance of the trenches depends on the characteristics of this medium.

For disposal in the soil, two analyzes of the site must be carried out: the first is qualitative and serves to determine the type of soil and the depth of the water table and impermeable layers. The second is quantitative, which is a measure of the soil's filtration capacity, that is, its permeability.

Sandy soils (very permeable) allow the rapid passage of the effluent, without the correct and sufficient treatment of the effluent; clayey soils are not very permeable, not allowing sufficient absorption for treatment (NBR 13,969,1997). This method can be used for the final disposal of liquid effluents from septic tanks, anaerobic filters and other domestic reactors that produce little suspended solids. For its installation, you need places with good area availability and with a remote possibility of aquifer contamination.

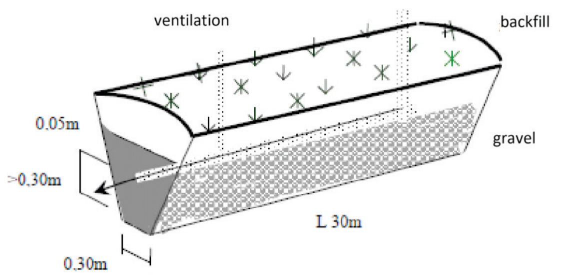

Figure 1: Process of using the Filtration Ditch. (JUNIOR, 2006).

Therefore, its use must be preceded by a technical evaluation to observe the following parameters (CORAUCCI FILHO *et al.* 2001):

- The characteristic of the soil where the filtration trench will be installed;
- The maximum aquifer level and its minimum vertical distance;
- Maintaining the aerobic condition inside the trench;

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- The minimum distance from the water catchment well; It is,
- The rainfall index.

Soils that over time have reduced absorption capacity and can quickly clog, mainly due to the high concentration of solids in the effluent from septic tanks, improve their performance when receiving effluents from filtration ditches, as the removal of solids is high in the sand layer of this system (LOUDON, 1985; *apud* NATALIN JUNIOR, 2002).

APPLICABILITY OF FILTRATION TRENCHES

The filtration ditch is an alternative sewage treatment system, whose technology development started about 100 years ago. Its operation is based on the application of effluents in a sand bed, where physical, chemical and biological processes naturally occur, which carry out sewage purification.

Inside each trench, along the longitudinal axis and at different levels, a distribution pipe and a receiver pipe are installed. The liquid that comes out through the free joints of the distribution pipe crosses the bed of sand to then penetrate the receiving pipe, which is also made up of tubes that leave free joints between them or have a perforated surface (CORRAUCI FILHO et al. 2000*)*.

According to Norm NBR 7.229 (1993), filtration ditches are defined as a complementary biological treatment system for the liquid effluent from the septic tank, which consists of an ordered set of distribution box, inspection boxes, upper perforated pipes to distribute the effluent over a filtering biological bed, and lower perforated pipes, to collect the filtrate and send it to final disposal.

According to NBR 13,969 (1997), a trench dug in the ground, filled with sand filter medium and provided with anaerobic effluent distribution tubes and treated effluent collection.

The filtration trench system differs from the sand filter (Filtration/Percolation) because it does not have a surface area exposed to the weather, being built on the ground itself, and may have its impermeable walls with waterproofing canvas on the sides and back, when it is not desired to escape the effluent to the soil, or when the water table is shallow.

Figure 2 presents an illustration of a simplified operating system for a filtration trench.

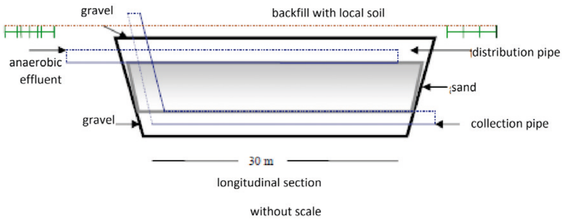

Figure 2: Schematic representation of the Filtration ditch (JÚNIOR, 2006).

According to Jordão (2005), the filtration trench is used when the soil filtration time is high, in the case of an almost impermeable soil or saturated with water, and not allowing to adopt another more economical system (filtration ditches or sinks); when groundwater pollution must be avoided; when high pollutant removal is required; or when the receiving body can receive this contribution.

CONSTRUCTIVE CHARACTERISTICS OF FILTRATION DITCHES

Norm NBR 13.969 (1997) determines that the construction of a system of filtration trenches presents the following recommendations as shown in the illustrations of Figures 3 and 4, below.

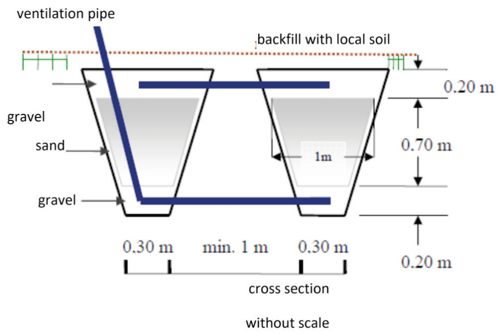

Figure 3: Cross section of a filtration trench (NBR 13.969/97).

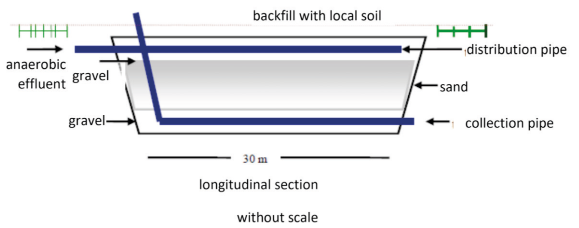

Figure 4: Longitudinal section of a filtration ditch (NBR 13.969/97).

Regarding the design of filtration trenches, the NBR 13.969/97 standard uses the following requirements:

- An elevation of the soil must be foreseen when backfilling the ditch, in order to avoid its erosion due to the rains, giving a slope between 3 and 6% on its sides;

- In places where the terrain has a steep slope, such as on the slopes of hills, the ditches must be installed following the contour lines;

- The layer of gravel or crushed stone, located above the sand bed, must be covered with permeable material, such as a fine mosquito screen, before backfilling with soil, so as not to allow the mixture of this with the stone, and at the same time to allow the evaporation of moisture;

- With coefficient of uniformity [1] less than 4. For, a medium with high coefficient of uniformity is characterized by inequality in particle size. This way, sand beds with this characteristic will have particles very close to each other, reducing the porosity and the average pore area, in addition to the permeability to the effluent (WILLMAN et al., 1981) to USEPA (1999*)* ;

- Depending on the geological characteristics of the site, the filtration trench must have the bottom and side walls protected with impermeable material, such as PVC blankets, so as not to contaminate the water table;

- The sand bed must be 0.70 m high and its particles must have an effective diameter [2] in the range of 0.25 mm to 1.2 mm. Therefore, the effective diameter of the sand affects the filtration rate of the influent in the bed and the depth of penetration of the insoluble solid matter. The adoption of a medium with very coarse particles provides a low liquid retention time, insufficient for complete biological decomposition. This fact provides a low yield, but high application rates can be adopted (USEPA, 2002). The use of finer sand enables effective nitrification and removal of organic matter, however the amount of effluent applied is small and the filter clogs quickly (USEPA, 1999);

- The drainage and distribution pipes must be involved in a layer of gravel nº 4, have a minimum diameter of 100 mm, be perforated and have a slope between 1 and 3%; It is,

- The availability of local material must be taken into consideration, to reduce the cost of implementing the system, but always with reference to the parameters of the ABNT Standard.

TOTAL COLIFORMS

According to Jordão (2005), bacteria from the total coliform group were the first to be adopted as indicators of human pollution. However, the presence of bacteria from the total coliform group in wastewater does not necessarily mean that it is a human or animal contribution, as these organisms, although associated with fecal matter, can also develop in vegetation, in the soil, and be carried with the wash water. Because they contain thermotolerant coliforms and a wide variety of species, specific tests have been developed to measure total coliforms and other groups.

The measurement of coliforms is given by a statistical estimate of their concentration, known as the Most Probable Number of Coliforms (NPM/100 ml), determined by laboratory techniques (APH, 2001).

According to Norma L 5.240 of CETESB (1991), total coliforms are defined as microorganisms belonging to the group of bacteria constituted by gram-negative bacilli, aerobic or facultative anaerobes, not forming spores, oxidizing negative, capable of growing in the presence of bile salts or other surface-active compounds (surfactants).

Coliforms have similar growth-inhibiting properties, and they ferment lactose with aldehyde, acid and gas production at 35ºC in 24-48 hours. The group includes the following genera: *Escherichia, Citrobacter, Enterobacter and Klebisiela.*

THERMOTOLERANT COLIFORMS

According to Norma L 5.240 of CETESB (1991), thermotolerant coliforms are defined as capable of developing and fermenting lactose with acid and gas production at a temperature of 44.5 ± 0.2°C in 24 hours. The main component of this group is *Escherichia coli,* and some coliforms of the genus *Klebisiela,* also have this capacity.

According to CONAMA Resolution 357 (2005) they are gram-negative bacteria, in the form of bacilli, oxidized and negative, characterized by the activity of the enzyme galactosidase. They can grow in media containing surface-active agents and ferment lactose at temperatures of 44-45ºC, producing acid, gas and aldehyde.

In addition to being present in human and homeothermic animal feces, they occur in soils, plants or other environmental matrices that have not been contaminated by fecal material.

MATERIALS AND METHODS

CASE STUDY - FILTRATION DITCH SYSTEM

The experimental study of the fecal coliform's removal performance was carried out in the experimental field of FEAGRI at UNICAMP.

In the FEAGRI field, a pilot project for an alternative sewage treatment system based on a filtration ditch was developed.

The research focused on five weeks in January 2023 with influent (input) and effluent (output) collections of wastewater from the sewage produced at FEAGRI.

The filtration trench system used acrylic plates with the support medium exposed for visual verification of the filtering layers. Three pre-treatment compartments were adopted for the local sewage that was collected in specific tanks.

The treatment compartments represented by the filtration trench system were made in acrylic boxes with height for different layers of: 0.75 m, 0.50 m and 0.25 m.

Figure 5 below presents a general detailing scheme of the acrylic boxes used for the filtration trench system and its 0.10 m diameter pipe.

Figure 5: Detail of one of the acrylic boxes with the drainage tubes.

As each box has a different height, to simulate a certain effective depth, each filtration trench was named according to Table 1, below:

Name of the Filtration Ditch	Sand Support Medium Layer (m)	Hydraulic Rate ($Lm^{-2} d^{-1}$)
V1	0.75	40
V2	0.50	60
V3	0.25	100

Table 1 – Name of the filtration trench system under study.

The hydraulic rate corresponds to the chosen hydraulic detention time in relation to the contact surface area.

Each filtration ditch (V1, V2 and V3) had an application of an internal gravel layer of 0.20 m. The remainder of each infiltration trench is filled with sand, for each filtration thickness: V1 (0.75 m of sand), V2 (0.50 m of sand) and V3 (0.25 m of sand).

SYSTEM PIPING

In the constitution of the filtration ditches, HDPE (High Density Polyethylene) drainage pipes were used in the sewer distribution piping.

The HDPE tubes allow a better distribution of the surface tension generated by the liquid and the adopted support medium and the percolation process (CORAUCCI *et al.*, 2000).

In the adopted support medium, layers of gravel 1 (gravel) and sand with an average grain size of 9.0 mm and 0.183 mm, respectively, were used.

FINAL INSTALLED SYSTEM

In figure 6, tanks A (blue) can be seen, in which the locality's sewage was collected for later dosing in the superficial part of the filtration trench system represented by the acrylic boxes with a support medium. Internal drains of acrylic boxes were used to collect post-treatment sewage, represented by tanks B (brown), as shown in Figure 6 (below).

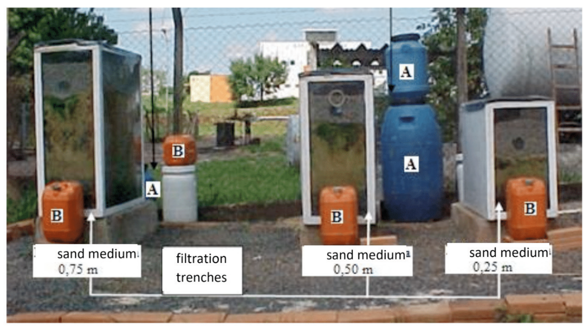

Figure 6: General system of filtration ditches with emphasis on the adopted sand layer.

SAMPLE COLLECTION METHODOLOGY

In the sample collection phase, an aliquot of 500 mL of wastewater from the sewage pumping process generated on site was taken (tanks A) and the same volume after treatment of each filtration trench (tanks B). The samples were bottled in PET bottles at -5 ˚C.

The study was carried out for five weeks with a weekly collection of samples, which totaled 30 samples of PET bottles.

The methodology used for the analysis of fecal coliforms was the Colillert method to be described later.

ANALYSIS OF FECAL COLIFORMS

® method allowed detecting the total concentration of coliforms in waste samples with reasonable accuracy and low sampling error, around 0.5% (OLIVEIRA, 2013).

FECAL COLIFORMS: METHOD – COLILERT ® CARD

The Colilert method consists of quantifying the total and fecal coliforms present in a given sample, by mixing the sample and the patented Colilert reagent, with subsequent transfer of the solution to a sterile card (100 ml), which is sealed and kept incubated at 35±2ºC for 24 hours (1st reading) and 48 hours (2nd reading-confirmation).

The results are obtained by relating the positive values between the largest and smallest squares on the card, with those verified in the standard table for the Colilert test.

For the application of the method were used:

- Sealer for Colilert cards;
- Vertical autoclave;
- Darkroom equipped with UV radiation;
- Thermo-adjustable incubator (35±2ºC);
- Flat bottom flask (sterilized*); It is
- 100 ml test tube.

The time of use in an autoclave was 15 minutes, where the flasks were completely sealed with plugs (prepared with gases), aluminum foil and kraft paper (double layer).

During the fecal coliform analysis procedure by the Colilert ® method, 50 ml of wastewater sample were used, which went through the steps below:

- The sample volume was transferred into a sterile flat-bottomed 100 ml volumetric flask to the desired dilution, so that the final volume was 100 ml;
- In each sample, a Colilert reagent card was added and stirred until complete dissolution;
- The final 100 ml were transferred to a sterile Colilert card, placed on the sealer support and sealed;
- The pack was kept in a thermo-regulated incubator at 35±2ºC;
- After 24 hours in the incubator, positive values were recorded in the large (49 spaces) and small (48 spaces) squares. Positive values were those in which a strong yellow color developed;
- The same procedure was carried out by observing the cards in a dark chamber equipped with UV light, so that, for this case, the large and small squares to be annotated were those that developed a characteristic blue luminescence (Figure 7);
- The registered values were written down; and the procedure was repeated after 48 hours to confirm the results;

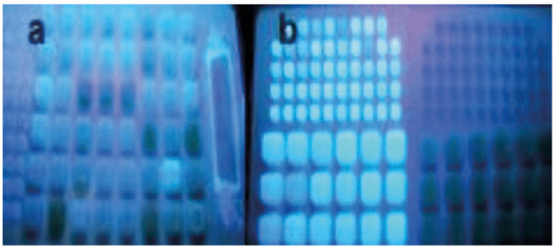

Figure 7: Characteristic colonies of E. coli in 4a and 4b (OLIVEIRA, 2013).

CALCULATION OF THE MOST LIKELY NUMBER OF FECAL COLIFORMS

The results are obtained from the standard chart of the method that correlates the values observed in the large squares with those observed in the small squares. For example, in an analysis that used 50 ml of sample, 10 large positive squares with 15 small positive squares were observed for total coliforms and 5 large positive squares with 3 small positive squares for fecal coliforms (OLIVEIRA, 2013).

RESULTS AND DISCUSSIONS

ANALYSIS OF THE PRESENCE OF FECAL COLIFORMS

For the weekly collection of samples and subsequent analysis of the rate of fecal coliforms present, its behavior can be observed in Table 2 (below).

Data analyzed using the Colillert method are presented for each collection week in Table 2.

Note that the influent (inlet) concentration varied due to the wastewater properties for the sampling day.

Thus, showing that the affluent sewage does not have a uniform concentration, this depends on the state and properties of the organic matter contained in the sewage.

In Table 2, it can be seen that the depth adopted for the half support makes the treatment action potentiate.

This allows us to verify that the sand support medium plays an important role in the degree of removal of total fecal coliforms.

Still based on Table 2, it can be evaluated in percentage values which treatment demand the support layers of sand can influence: V1 (0.75 m), V2 (0.50 m) and V3 (0.25 m).

Table 3 presents the effective percentage removal behavior of fecal coliforms.

In Table 3 it is possible to notice that the greatest depth of sand, 0.75 m, caused the percentage performance of treatment, that is, its effectiveness was about 60%, while in the worst application of half support, that is, for 0.25 m, its performance was much lower, fluctuating in the 30% range for the five weeks of the study.

Such reduction values are significant, although the average post-treatment rate is still high, around 7.00 MPN for the largest sand layer.

According to the standards established by CONAMA (Conselho Nacional de Meio Ambiente) for reuse water in Norma 357 for water courses, there must be a decay to at least a range of 1.0 NMP for class 4 in relation to river courses. ‘water (CONAMA, 2005).

However, it must be noted that a system such as the filtration ditch complex brings a great benefit, and can be used in conjunction with other complementary alternative treatment systems for a better reuse of reuse water.

CONCLUSION

The use of alternative treatment methods is of great relevance when thinking about sustainability.

The yields in relation to the purification potential show that the support medium based on sand in the filtration ditch allows a stabilization of the contaminant load.

Undoubtedly based on what was studied, maintaining the level of gravel layer 1 in each filtration trench, the fact that a filtration trench has a greater or lesser complementary layer of sand influences the removal of fecal coliforms by the complementary support medium constituted by sand.

Chemical processes such as the adsorption phenomenon, observed by Von Sperling (1996), allow us to conclude that their demand causes a greater potential for capturing fecal coliforms present in sewage.

Date	Ditch Filtration	layer of sand	Prohibited (MPN/100 mL	Exit (NMP/100 mL)
	V1	0.75 m	25.00	8.90
02/january	V2	0.50 m	25.00	11.90
	V3	0.25 m	25.00	16.75
	V1	0.75 m	22.00	7.85
January 9	V2	0.50 m	22.00	9.90
	V3	0.25 m	22.00	13.50
	V1	0.75 m	23.50	7.79
January 16	V2	0.50 m	23.50	10.50
	V3	0.25m	23.50	15.75
	V1	0.75 m	25.00	8.75
January 23	V2	0.50 m	25.00	10.89
	V3	0.25 m	25.00	15.95
	V1	0.75 m	24.75	7.75 11.05
January 30	V2	0.50 m	24.75	
	V3	0.25 m	24.75	15.75

Table 2 - Fecal Coliforms at the entrance and exit of the Filtration Ditches in 2023.

Date	Ditch Filtration	layer of sand	Percent Removal
	V1	0.75 m	64.40%
02/january	V2	0.50 m	52.40%
	V3	0.25m	33.00%
	V1	0.75 m	64.32%
January 9	V2	0.50 m	55.00%
	V3	0.25 m	38.64%
	V1	0.75 m	66.85%
January 16	V2	0.50 m	55.32%
	V3	0.25m	32.98%
	V1	0.75 m	65.00%
January 23	V2	0.50 m	56.44%
	V3	0.25m	36.20%
	V1	0.75 m	68.69%
January 30	V2	0.50 m	55.35%
	V3	0.25m	36.36%

Table 3 - Percentage of reduction of Fecal Coliforms in Filtration Ditches in 2023.

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