Agronomy Research **19**(X), xxx–ccc, 2021
https://doi.org/10.15159/AR.21.129

Technical and economic pre-feasibility study for the construction of septic tank-filter-sinkhole with alternative material

P.H.N. Martins[1], D. Cecchin[1,*], A.R.G. de Azevedo[2], D.F. do Carmo[1], R.A. Danagemma[1], R.M.M. Waite[1], N.F. Rodrigues[1], F.A. Sousa[3], P.I.S. Amaral[4], C.M. Hüther[1], C.R. Pereira[1] and V.M.F da Cruz[5]

[1]Federal Fluminense University (UFF), Department of Agricultural Engineering and Environment, Street Passo da Pátria, n.156, Boa Viagem, Niterói-RJ, Brazil
[2]North Fluminense State University (UENF), Civil Engineering Department, Avenida Alberto Lamego 2000 - Parque Califórnia, Campos dos Goytacazes BR28013-602 Rio de Janeiro, Brazil
[3]SEMAG/Aracruz, Av. Morobá, n.20, BR 29192-733 Bairro Morobá-ES, Brazil
[4]José do Rosário Vellano University (UNIFENAS), Department of Veterinary Medicine, Rodovia MG-179 km 0, s/n -Bairro Trevo, BR 37130-000 Alfenas-MG, Brazil
[5]Évora University (UE), Pólo da Mitra, PT 7002-554, Évora, Portugal
[*]Correspondence: daianececchin@id.uff.br

Received: February 2nd, 2021; Accepted: August 3rd, 2021; Published: August 24nd, 2021

Abstract. The study of the different materials used in the construction of septic tanks aims to facilitate and spread the use of this sewage treatment system in places that are not assisted by municipal sewage systems and in the rural area, which despite having a smaller number of inhabitants compared to the urban area This study aims to carry out a technical and economic evaluation of the concrete and tires using in the construction of septic tanks-filter-sinkhole. The wastewater treatment systems were built according to the recommendations in NBR 7229/93 and 13969/97. To evaluate the efficiency of each system built, the following parameters were analyzed: chemical oxygen demand (COD), the potential of hydrogen (pH), alkalinity, acidity, and temperature. In the economic evaluation, the materials and labor required to install the systems were considered using the Brazilian cost database (SINAPI), and an economic and financial feasibility study was carried out. According to the technical and economic analysis of construction, both systems showed the same technical performance, however, the concrete design proved to be more advantageous than the tire design, considering the difficulty in acquiring the tires and the high cost if it is necessary to buy them, in addition to the greater difficulty in handling and installing the tire system compared to the concrete one.

Key words: rural buildings; sanitary sewage; anaerobic treatment; decentralized wastewater treatment.

INTRODUCTION

The lack of basic sanitation is a problem faced by many countries, and in Brazil, 33.5% of households do not have access to the sewage system (IBGE, 2018). The absence of sewage collection and disposal in the environment influences society in different ways, bringing negative consequences and also being one of the main causes of environmental degradation, due to the inadequate management of waste (Martinetti et al., 2007). The lack of investments in sanitation worsens the situation of soil and water contamination once, without the treatment of the generated sewage there is a continuous degradation of the springs, and consequently, limits the availability of this resource, which can lead to scarcity, due to the quality of the water resources to meet multiple uses (Sautchúck, 2004).

The 2018 data from the National Sanitation Information System (Brasil, 2019) point out that although there are 662.6 thousand kilometers of water supply networks, there are only 325.6 thousand kilometers of sewage collection networks. Sewage treatment occurs for only 46.3% of the generated sewage and not all the collected sewage is treated, which occurs for only 74.5%. In terms of the increase in households with access to the sewage network, Brazil has evolved (33.5% in 2000, to 66.5% in 2018), with a 2.9% increase in treatment, from 2017 to 2018 (Brasil, 2019). But there is still much to do, especially in rural areas. The Brazilian population living in rural areas is equivalent to 15% of the national total, there are approximately 31 million people living in almost nine million households (IBGE, 2015). Most of this rural population lives in cities where the economic base is predominantly family farming, and the basic sanitation for these residents is still insufficient, as 68.7% of households in rural areas use rudimentary systems, such as rudimentary cesspits, ditches, holes or throwing directly into rivers and soil (IBGE, 2015). According to Cheng et al. (2018), rural areas without a sewerage network depend on local sanitation services, such as septic tanks.

The use of decentralized systems for the treatment of sewage reduces the environmental footprint in rural environments, contributing to sustainability, which, as highlighted by Tihomirova et al. (2019), is one of the key factors in the management of the intelligent environment. Raukas (2010) stresses the importance of offering environmental services in rural communities contributing to the reduction of differences between urban and agrarian inhabitants.

As such, it becomes necessary studies on alternatives for the construction of decentralized sewage treatment systems, which can collect and treat sewage in rural areas or in places where the public network is unable to supply. One of the simplest systems applied, in terms of implementation and operation, is the septic tank. The cost of installing a septic tank to serve a residence with five people varies from 2,000 to 4,000 reais on average, depending on the type of material used (Habitissimo, 2020), and it can be made of polyethylene (average cost of 1,600 reais), masonry (average cost of R $ 3,500), among other materials. However, the use of tires stands out as an alternative material for this construction, allowing the reuse of a material that is difficult to dispose of, minimizing the cost, both of the tires and domestic wastewater. This technique has been widespread by Uberlândia Department of Water and Sewage since 2014 (DMAE, 2016). In the quest for sustainability, systems such as conventional septic tanks have become a subject of critical research from all developing countries around the world (Singh et al., 2019).

Thus, this study aims to analyze the technical and economic feasibility of installing septic tanks-filter-sinkholes built with tires, compared to those of concrete treating black waters.

MATERIALS AND METHODS

Characteristics of the study place

Decentralized sewage treatment systems were built in two cities in the state of Rio de Janeiro, Arraial do Cabo and Nova Friburgo. The tire system was built in Nova Friburgo, a mountainous region of the state, the system was installed in holes dug in the ground. The concrete system was installed in Arraial do Cabo, a coastal town, located in the Lakes Region of Rio de Janeiro, a place with rocky soil that did not allow the excavation of the soil to install the tanks, thus the tanks were installed above ground level.

Construction of water treatment

The dimensioning of both systems was based on NBR 7229 (ABNT, 1993) and NBR 13969 (ABNT, 1997), considering households with a contribution of three people (number of inhabitants in the households where the project was developed).

Only blackwaters (wastewater collected from toilets, therefore consisting of faeces, urine and toilet paper) according to Gonçalves et al. (2006) were destined for septic tanks since this segregation into smaller stations helps to stabilize the operation and lower generation of by-products, according to Gonçalves et al. (2006). According to NBR 7229 (ABNT, 1993) each person generates 150 L of domestic sewage per day, of this volume, approximately 30% is blackwater (Rebouças et al., 2007). With this information, it is estimated that the volume of sewage destined for the built systems was 135 liters per day, thus, with an estimated detention time of 17 days.

The septic tanks-filter-sinkhole systems (concrete and tires) were installed at about 15 meters away from the house, in order to avoid gases from the system, and also to prevent the pipes that would connect the house to the treatment system did not have many curves, avoiding future problems in the network.

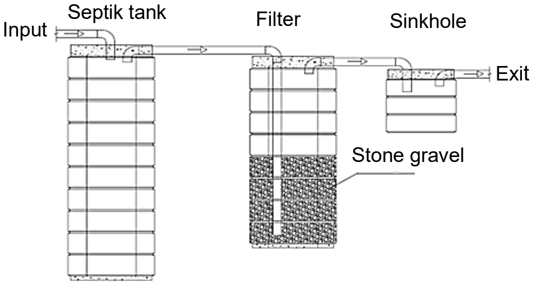

Figure 1. Section of the septic tank-filter-sinkhole of tires.

Source: the authors.

Tires with a diameter of around 1 meter and a weight of 60 kg each were reused, such characteristics made handling and transporting the material a little difficult. Twenty bus/truck tires were required for the complete system (10 tires for the pit, 7 tires for filter and 3 tires for sinkhole, Fig. 1).

For the installation of the tires, which was made below the level of the soil surface, it was necessary to dig (with the help of diggers, hoe, and shovel) the place where the tanks would be installed. Three holes were dug with depths of 2.00; 1.70 and 1.00 m to install the septic tank, the filter, and the sinkhole respectively. Each tire is approximately 105 cm in diameter, and the excavation was carried out with a diameter of approximately

125 cm so that it was possible to handle the sides of the tires at the moment of inserting them in the final location.

After the excavations the tires were lowered tire by tire. The sealing between the tires was made with a cast aluminum blanket through the heat generated by a portable torch (Figs 2, a and 2, b).

For the concrete treatment system, concrete staves (Fig. 3) were used, this material is traditionally used in the construction of tanks and wells. Each stave was 120 in diameter (D120). Even with a high weight in each stave, handling it was easier than handling the tire since there were fewer units of staves per tank (three for each tank).

Figure 2. Overlapping tires (a), application of a bituminous layer (b).
Source: Personal collection.

Figure 3. Concrete staves.
Source: http://www.tubolarpremoldados.com.br/

The tanks were made with overlapping precast concrete rings, joined by a 3:1 mixture of sieved sand, Portland II cement, and Sika waterproofing admixture.

Since they were installed from the ground level, it was possible to observe that some points with leakage of residue appeared during the use of the system, which occurred at the seams of the concrete rings and on the surface of the precast concrete ring, and they were repaired. It is noteworthy that this problem delayed the filling of the pit and that if the system were buried it would not be possible to identify it. Withers et al. (2011) warn about the contamination risks that these buried systems can cause to the subsoil and nearby water bodies without proper maintenance.

In both wastewater treatment systems, concreting of approximately 10 cm in height at the bottom of the tanks was carried out, in order to guarantee the tightness of the systems. For that, a 3:1 mixture of sieved sand, Portland II cement, and Sika1 waterproofing admixture was used (in the proportion suggested by the manufacturer). The concreting was carried out after the installation of the tanks, for better sealing avoiding the escape of residues.

The entrances of the systems (concrete and tire) were made through a 100 mm diameter PVC pipe that connected the sanitary of the houses to the sewage treatment systems. After the first tank was completed (septic tank), the liquid passed to the next tank through a pipe placed just below the entry level of the first tank. In the second tank (filter), the residue was taken through the pipeline to the bottom of this compartment, and through ascension, it passed through the layer of crushed stones, being filtered. When reaching almost the maximum level of this tank, the residue found the pipe and went to the sink. In this last stage of the process, the residue seeped through the bottom of the tank to the ground.

At the top of each tire tank, a 15 cm high precast concrete ring was added (Fig. 4). The sealing was done with an aluminized blanket to allow the pipes to enter/exit, as well as to support the lid. In order to close the tire tanks, lids made of precast concrete were used.

Figure 4. Tanks prepared to receive the lid.
Source: Personal collection.

Systems monitoring

In each system, the local temperature was monitored by consulting the data generated by the meteorological station of the National Institute of Meteorology - INMET (INMET, 2019).

The samples were collected on the surface of the septic tank and sinkhole and placed in transparent glass containers, wrapped in aluminum foil so that there was no incidence of light when carrying the samples to the laboratory. The control and care standards set out in NBR 9898 (ABNT, 1987) and at the National Guide for Collection and Samples Preservation of the National Water Agency (ANA / CETESB, 2011) were followed for storage and transportation.

The parameters analyzed in the samples was: pH, Method Electrometric 4500 B; Temperature, Method Electrometric 2550 B; Alkalinity: Titulação 2320 B; COD: Closed Reflux, Colorimetric Method. 5220 (SMEWW- 22st Edition, 2012).

The sample temperature was measured at the time of collection, with the aid of a thermometer of the Incoterm brand. The pH of each sample was measured at the time of collection with the aid of a pH measuring tape for control and reduction to values less than two, preparing them to be preserved for COD analysis, as recommended in NBR 9898 (ABNT, 1987). The pH reduction was done with 1 mol L^{-1} sulfuric acid (H_2SO_4).

The system made with tires started operating on April 9, 2018, and the first sample collection was carried out with 140 days of operation, in order to characterize the effluent. The second collection of samples was performed after 196 days of this system operation. The system built with concrete, on the other hand, started operating on July 12, 2018, and after 47 days of operation, it was verified that the first tank was full and, thus, it was possible to carry out the first sample collection to characterize the effluent. The second collection was made with 103 days of operation. As in the other installed system, the first two collections were carried out only in the first tank, because there was still no residue in the third tank.

Four collection campaigns were carried out (they were carried out in August, October, February, and April), and in each one, six samples were taken per tank. To carry out the collections, it was necessary to wait for the tanks to be full.

It was not possible to install both systems in the same period, there was a gap of three months between the start of the operation of the systems. In the system made with tires, after 141 and 197 days of operation, the material was collected only from the first tank (three samples with pH adjusted for COD analysis and three samples without pH adjustment by the system). The same procedure was done in the first two campaigns carried out for the concrete system when the system had 47 and 103 days operating. In the last two campaigns, both systems had residue in the three tanks, making it possible to collect material to compare between the first and last tanks of each system. The collections took place with 302 and 372 days of the experiment for the tire tank and with 208 and 278 days for the concrete tanks. Six samples were also collected from each tank, three of these samples had pH corrected, and the other three samples with no correction, a total of 48 samples. Throughout the experiment (310 days) 72 samples were collected.

The built and evaluated systems, in this study, did not have any type of inoculum to accelerate the acclimatization of organisms that act in the decomposition of organic matter.

Economic and financial feasibility study (EVEF)

The costs for construction of each system were acquired, based on the National System of Costs Survey and Indexes of Construction - SINAPI widely used in Brazil, referring to March 2019 (SINAPI, 2019).

The economic and financial feasibility study (EVEF) was carried out in order to evaluate the investment plan that should be carried out before and after the installation of both systems, showing or not the feasibility of the project. For that, the following methods were used according to Waite et al. (2020): Minimum Attractive Rate; Simple Payback; Discounted Payback; Internal Rate of Return and Net Present Value.

To apply the aforementioned methods, the was necessity of the cash-flow statements of the project. By being a home effluent treatment project, and considering that the sewer and water bills come together in the state of Rio de Janeiro, the fact that the use of the system frees the owner of paying fines. Taking into account the specificity of the fine, which considers mitigating factors, among other factors, it was proposed, based on State Law No. 2661 (Rio de Janeiro, 1996), three different scenarios for the fine, namely: an optimistic scenario in which the fine would be less and therefore 10 UFIR-RJ; a normal scenario, with a fine of 50 UFIR-RJ, and a pessimistic scenario, with a larger fine, 100 UFIR-RJ. UFIR is the Fiscal Reference Unit of the state of Rio de Janeiro, considering the exercise unit in the year of 2020, which is R $ 3.5550 (three reais and five thousand, five hundred and fifty-tenths of thousandths) according to Sefaz (2019).

In addition to the costs of installing the system, the cost of maintenance was considered, according to the analysis of current values in the market.

RESULTS AND DISCUSSION

Systems monitoring

Tires system

During the period of the experiment, the absolute minimum temperature (2.3 °C) was observed with 149 days of the system operation, at 9 am, the absolute maximum temperature (31.8 °C) was observed with 320 days of operation, at 6 pm. The average temperatures recorded in this period in the city of Nova Friburgo oscillated within the range of 10 °C and 25 °C, with an average in the entire period of 17.2 °C. As can be seen in Fig. 5, on some days, the average temperature was below that mentioned by Luostarinen et al. (2007) as being the ideal, considering that the microbiological activity depends on this variable, which can compromise the performance of biological reactors in the degradation of organic matter in extreme values.

Throughout the collections, the average temperature of the effluent sample in the tank outlet of the tire system was 19.7 °C. Thus, it was found that the temperature measured at the outlet of the system is within the limits allowed by CONAMA resolution 357, which establishes a temperature below 40°C of the treated effluent when released into the environment. Luostarinen et al. (2007) conducted a study comparing anaerobic systems for treating domestic sewage, at different temperatures and periods of the year. The authors found that, although there is little microbial activity in the period of low temperatures (5 °C <T <13 °C) these systems can be used in houses because the degradation of organic matter occurs when there is an increase in temperature.

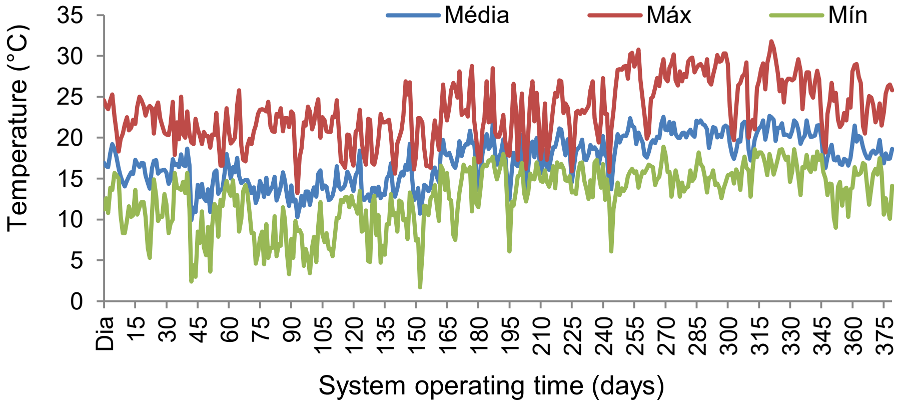

Figure 5. Temperature variation during the experiment - tire system (Nova Friburgo - RJ).

The first two collections were made only in the first tank, since there was still no residue in the third tank. From the third collection, carried out with 302 days of system operation, it was possible to analyze the reduction of organic load. It can be seen in Table 1 that there was a reduction in COD of 16.69% in the third collection and 21.54% in the fourth collection. Although these values point to an increase in removal efficiency, they are still insufficient to meet the standard NBR 13969 (ABNT, 1997), which is 40 to 70% for COD removal with this type of treatment.

Table 1. Tire tanks, average results of COD (mg O_2L^{-1}), pH and Alkalinity ($mgL^{-1}CaCO_3$) analyzes

Operating time (days)	Sample results from Tank 1			Results of the Sink samples		
	COD	pH	Alcal.	COD	pH	Alcal.
141	620.00	8.07	188	-	-	-
197	656.00	7.93	201	-	-	-
302	607.00	7.69	194	505.67	7.26	145
372	705.67	7.60	216	553.67	7.38	142

In the analyzes performed on the material collected at the outlet of the system (third tank), an average pH of 7.26 was observed in the first collection and 7.38 in the second collection (Table 1). Both values are in agreement with Conama Resolution 357 (Brasil, 2005) which establishes pH in the range of 6 to 9 for the discharge of effluents into bodies of water.

During the experiment period, it was also carried out alkalinity monitoring in the tanks (Table 1). The alkalinity remained relatively stable, with variation between 145 and 142 ($mgL^{-1}CaCO_3$).

The expected pH value for sanitary effluent is within the range of 6 to 9. Withers et al. (2011), and Sousa et al. (2003) treating sanitary effluents in anaerobic reactors found values in the same range.

Concrete system

The average temperatures recorded throughout the experiment in the city of Arraial do Cabo were within the range of 15 °C to 30 °C, with an average temperature over the entire period of 22.8 °C. As can be seen in Fig. 6, most of the time the average temperature remained close to the ideal for a good functioning of the system, which is close to 25 °C (Luostarinen et al., 2007).

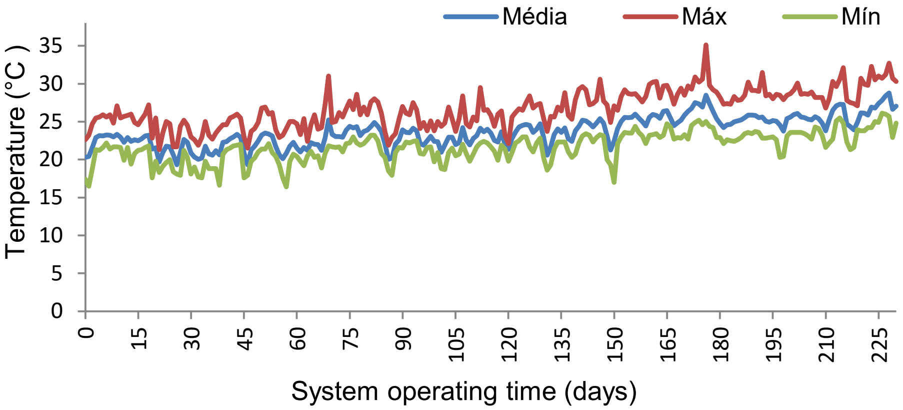

Figure 6. Temperature variation during the experiment - concrete system (Arraial do Cabo - RJ).

The minimum absolute temperature (16.4 °C) was observed with 55 days of system operation, at 10 am, while the absolute maximum temperature (35.1 °C) was observed with 170 days of operation, at 1 pm. Throughout the collections, the average temperature recorded for the effluent in the system outlet tank was 23.5 °C. Thus, as in the tire system, it was found that the temperature of the treated effluent meets the resolution of Conama 357 (Brasil, 2005), which says that the temperature of the treated effluent when released into the environment must be less than 40 °C.

The analysis of the efficiency of COD removal was made from the third collection. According to Table 6, it is noticed that there was a reduction in COD of 12.72% in the third collection and 22.56% in the fourth collection (Table 2). The increase in removal efficiency was considerable, however, the values are still below the removal efficiency expected for the septic tank provided for in the standard NBR 13969 (ABNT, 1997), which is 40 to 70% predicted. However, the values are similar to those found by Colares & Sandri (2013) evaluating different types of post-treatment for systems with septic tanks.

Table 2. Concrete tanks, results of COD (mg O_2L^{-1}), pH and Alkalinity ($mgL^{-1}CaCO_3$) analysis

Operating time (days)	Average value of Tank 1 samples			Average value of sinkhole samples		
	COD	pH	Alcal.	COD	pH	Alcal.
47	581.67	7.50	171	-	-	-
103	617.67	7.21	185	-	-	-
208	540.00	6.86	173	471.33	7.06	130
278	670.77	7.29	204	519.33	6.95	156

Regarding the pH evaluated in the third tank, an average value of 7.06 was observed in the first analysis, and an average value of 6.95 in the second analysis (Table 2). Both values are according to CONAMA Resolution 357/05 (BRASIL, 2005) which establishes for the discharge of effluents into water bodies pH in the range of 5 to 9. Colares & Sandri (2013) when analyzing septic sink, filter, and sinkhole systems constructed of concrete treating domestic sewage found mean pH values similar to these, 7.25 and 7.41 respectively.

As in the tire system, alkalinity was monitored in the tanks. Even though the pH was lower, the alkalinity remained relatively stable, varying between 130 and 204 ($mgL^{-1}CaCO^{3}$).

Comparison between the two systems

The COD analyzes of both systems were performed with samples collected in tank 1 (after the sewage enters the system) and in tank 3 (after the sewage passes through the decanting of organic matter, microbiological decomposition, and physical filtration). The results presented in both systems show an average COD removal efficiency in the period of 17.64% for the concrete system and 19.12% for the tire system. The similarity of the effluent before the treatment occurred, as both houses where the systems were installed had the same number of inhabitants, and because of that, the volume of sewage produced in each house was similar, with an average affluent COD of 602.53 mg L^{-1} for the concrete system and 647.17 mg L^{-1} for the tire system. The built systems had the same volume, as they were dimensioned using the same calculation procedure and standards, thus storing the same amount of matter in each tank, in addition, for the collection, maintenance, and transport of samples, the same procedures were followed, providing thus a basis for comparison between analyzes. The absence of inoculation may also have contributed to the low efficiency of COD removal since there was an increase in efficiency over time in both systems. It is noticed that inoculation would provide faster acclimatization and acquisition of better results in less time, being of relevant importance (Li et al., 2014; Dhamodharan et al., 2015).

The collection of material for analysis was carried out on the surface of the tanks and because of that, there may have been interference from the input material. It is suggested for the implantation of these systems that some way of shielding be installed, preventing the incoming sample from mixing with the outgoing sample. For sampling in future studies, it is suggested to collect at different depths of the tank to increase the reliability of the analysis results, and the column sampler can be used for that, as showed by Santos (2009).

Considering the results presented in this study, it was found that there was no interference on the type of the tanks walls coating in the results found. The criterion for defining which material to use depends on the availability of tires for usage in the construction of the system, if it’s necessary to purchase all material, the use of concrete rings is recommended, as the difference in the COD reduction efficiency was small, not enough to determine the choice of which material to use. However, if it is considered that the use of used tires contributes to the reduction of environmental pollution, and compatible prices in the purchase of this, of course, the recommendation would be for this option.

Economic and financial feasibility study (EVEF)

Tables 3 and 4 detail the costs for building each system with values obtained through the National System of Costs Survey and Indexes of Construction - SINAPI (SINAPI, 2019). The system built with tires has a higher value of R$ 2,469.29 (Table 3), due to the high value of each tire. For the development of this project, the tires were donated, which did not generate cost and made the system competitive. Without the need to pay for the purchase of tires, the system costs R$ 1,902.31, approximately R$ 500.00 cheaper than the concrete system. Otherwise, the cost of the system becomes higher than the concrete system, approximately twice as much. The shown value in Table 3, for the item 'used tire', was verified in the market. As it is used material there is no standard and the price may vary from region to region and/or according to the condition of the tire. The acquisition of new tires would make the construction of the sewage treatment system unfeasible. However, it should be noted that, for this purpose, used tires must have tightness, no cut or large punctures, because the tires compose the tank wall, and there can be no leakage from the stored sewage. In the region where this study was carried out, it was necessary to seek a partnership to supply the tires. In regions where tires are available at no cost for reuse in these systems, it is advisable to use this material, with a view of the economy with the most expensive part of the construction of tanks, filter and, sinkhole.

Table 3. Cost breakdown of the septic tank built with tires, SINAPI table values March 2019

Item	Unit	Quantity	Unit value (R$)	Total value (R$)	Sinapi code
Portland Cement CPII	kg	50	0.40	20.00	1379
Sand	m^3	0.5	54.64	27.32	370
Gravel	m^3	0,5	82.21	41.11	88549
Waterproofing Admixture	L	2	5.10	10.20	123
Concrete cover d1	m^2	2.36	66.86	157.46	6171
Concrete ring h 15 cm	uni.	3	41.20	123.60	12547
Tube 100 mm	m	6	23.48	140.88	9841
Curve 100 mm	uni.	10	13.77	137.70	1966
Glue for pipe	uni.	1	53.75	53.75	122
Waterproofing membrane	m^2	9	35.42	318.78	4014
Subtotal (materials)			**R$ 526.83**	**R$ 4,030.80**	
Hod carrier	h	32	19.21	614.72	88316
Used tires	uni.	20	150.00	3,000.00	Not found
Plumber Assistant	h	6	18.89	113.34	88248
Plumber	h	6	23.91	143.46	88267
Subtotal (labor)			**62.01**	**871.52**	
Total			**R$ 588.84**	**R$ 4,902.32**	

The system built with concrete had its consolidated advantage by presenting less value for construction, about 50% smaller than in the tire system. Among the materials presented in the cost spreadsheet of the two systems, the difference is the material that makes up the wall of the tanks, the other materials are practically the same.

Table 4. Cost breakdown of the septic tank built with concrete, SINAPI table values March 2019

Item	Unit	Quantity	Unit value (R$)	Total value (R$)	Sinapi code
Portland Cement CPII	kg	50	0.40	20.00	1379
Sand	m^3	0.5	54.64	27.32	370
Gravel	m^3	0.5	82.21	41.11	88549
Waterproofing Admixture	L	2	5.10	10.20	123
Concrete cover d1	m^2	2.36	66.86	157.46	6171
Concrete ring D120 cm	uni.	3	128.18	384.54	12552
Concrete ring D100 cm	uni.	5	117.71	588.55	12547
Tube 100 mm	m	6	23.48	140.88	9841
Curve 100 mm	uni.	10	13.77	137.70	1966
Glue for pipe	uni.	1	53.75	53.75	122
Subtotal (materials)			**565.31**	**2,176.23**	
Hod carrier	h	32	19.21	614.72	88316
Plumber Assistant	h	6	18.89	113.34	88248
Plumber	h	6	23.91	14346	88267
Subtotal (labor)			42.80	256.80	
Total			**R$ 608.11**	**R$ 2,433.03**	

Based on the amount of the budget presented, and the forecast for the system maintenance about R$ 266.00 per year, and the fine amounts for each scenario based on Rio de Janeiro UFI of R$ 355.50 per month on the pessimist scenario, R$ 177.75 in the normal one and R$ 35.55 in the optimistic one, the annual cash flows were generated for each type of system, shown in Table 5 for the system built with tires and in Table 6, the one built with concrete.

Table 5. Septic tank cash flow built with tires

	Anual cash flow - Septic tank built with tires					
Time	10-year horizon					
Scenario	Pessimistic		Normal		Optimistic	
Years	Cash-inflows (R$)	Cash-outflows (R$)	Cash-inflows (R$)	Cash-outflows (R$)	Cash-inflows (R$)	Cash-outflows (R$)
0	0.00	- 4,902.32	0.00	- 4,902.32	0.00	- 4,902.32
1	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
2	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
3	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
4	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
5	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
6	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
7	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
8	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
9	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
10	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
Total	42,660.00	- 7,562.32	21,330.00	- 7,562.32	4,266.00	- 7,562.32
Diference	R$ 35,097.68		R$ 13,767.68		-R$ 3,296.32	

Table 6. Anual cash flow - Septic tank built with concrete

	Anual cash flow - Septic tank built with concrete					
Time	10-year horizon					
Scenario	Pessimistic		Normal		Optimistic	
Years	Cash-inflows (R$)	Cash-outflows (R$)	Cash-inflows (R$)	Cash-outflows (R$)	Cash-inflows (R$)	Cash-outflows (R$)
0	0.00	- 2,433.03	0.00	- 2,433.03	0.00	- 2,433.03
1	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
2	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
3	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
4	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
5	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
6	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
7	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
8	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
9	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
10	4,266.00	- 266.00	2,133.00	- 266.00	426.60	- 266.00
Total	42,660.00	- 5,093.03	21,330.00	- 5,093.03	4,266.00	- 5,093.03
Diference	R$ 37,566.97		R$ 16,236.97		-R$ 827.03	

It was considered, conservatively, that in both cases, in the first year of operation of the systems there were no cash-inflows. It can be seen that in the optimistic scenario, where the best results are implied, the worst ones are presented, in both cases. However, it should be emphasized that this was already expected, since the scenarios deal with the fine collection, and since it is a value that is expected not to pay, the higher its value, the greater the gain that the system has. Thus, in the pessimistic scenario, more optimistic results are expected for the viability of the system and vice versa. Table 7 presents the results of all methods applied to all projected scenarios, in order to facilitate the comparison of the systems presented.

Table 7. EVEF summary

		Methods	Septic tank built with tires	Septic tank built with concrete
Scenarios	Pessimist	Simple Payback	2 years	1 years
		Discounted Payback	2 years	1 years
		IRR	50.03%	116.48%
		NPV	R$ 20,531.03	R$ 22,803.09
	Normal	Simple Payback	3 years	2 years
		Discounted Payback	3 years	2 years
		IRR	20,87%	47.87%
		NPV	R$ 7,213.60	R$ 9,485.66
	Optimist	Simple Payback	8 years	4 years
		Discounted Payback	9 years	4 years
		IRR	-10.72%	-4.51%
		NPV	-R$ 3,440.34	-R$ 1,168.28

The Minimum Attractiveness Rate (TMA) is a rate that varies according to the beneficiary, with no fixed rate. The Selic rate was used as the TMA, which is the basic interest rate of the economy, and considering that the investment in the Selic Treasury is one of the most stable and secure in the financial market. Therefore, considering the quotation on April 14, 020, a TMA of 4.25% was obtained.

Simple Payback is a calculation that takes into account the return time of the initial investment, where the maximum period for obtaining the recovery of the investment is established. In the pessimistic and normal scenarios, short terms of up to 3 years were obtained for both systems, while in the optimistic one the septic tank that uses tires obtained a return time of 8 years, which is a long time, considering the value of the investment made. However, it should be noted that the purchase of tires was considered and not the donation, which has a high possibility of occurring, reducing the costs of implementation.

Discounted Payback is similar to the simple one, however, it considers an attractiveness or discount rate, so that the value of the investment in time will be considered. In the proposed analysis, large variations in the return time were not obtained when considering the variation in investment over time. Only in the pessimistic scenario of the septic tank built with tires had an increase of one year, thus repeating the same considerations obtained for the analysis of the Simple Payback.

The obtained Internal Rate of Return in the pessimistic and normal scenarios is higher than the established TMA. Thus, the project within these scenarios proves to be economically viable. In the optimistic scenario, as expected, the IRR was lower than the TMA for both systems, so in this scenario, the projects are not viable. In the comparison between both systems, we can see that the IRR value of the septic tank system built with concrete is slightly higher than the double of the septic tank system built with tires, a fact expected when it is observed that the initial investment of the septic tank built with tires is slightly more than double the septic tank built with concrete, and both have the same input value in all scenarios.

The Net Present Value (NPV) as well as the IRR obtained values above zero in the pessimistic and normal scenarios, indicating the economic viability of the projects in these scenarios, and also being below zero in the optimistic scenario, indicating the project's unfeasibility in the optimistic scenario. The NPV reinforces the conclusions obtained by the IRR, and the same observations made in the analysis of the IRR apply.

It should also be considered, that comparing these systems built with the sewage collected in the urban area, the amount invested in the construction of the concrete system corresponds to 20 months of collection and treatment of domestic sewage in a household with the same standards studied in this work. In consultation with the fee charged by the concessionaire that operates this segment in the state of Rio de Janeiro, a two-bedroom house produces an average of 30 m^3 of sewage per month, generating an expense for the collection and treatment service of approximately R$ 120.00 per month.

Comparing the costs of collection and treatment between the urban area and the decentralized system proposed in the present work, the implementation of the individual system presents a greater initial investment, but the cost of maintaining the system is low (about 23 Reais monthly). It should also be noted that if, instead of the fine, this rate of 120 Reais was used as input to the EVEF, the payback amount would not be much changed compared to the normal scenario and the IRR of the concrete system would be 28.27% and NPV of R$ 5,158.90 while the tire system would have an IRR of 11.43% and NPV of R$ 2,886.64. Therefore, the results for both systems are attractive. It is also considered that the value used in the construction of the systems should be considered as an investment in order to guarantee people's health and quality of life. According to the World Health Organization (WHO, 2014) for every US $ 1.00 spent on basic sanitation, US$ 4.30 is saved in the population's health costs, a fact that alone demonstrates the importance of investing in this area.

The proposal to use tires for the construction of sewage systems emerged as an alternative solution for the reuse of a material that would be discarded. Doing that, tire reuse and sewage treatment would happen. It should be noted that tires have been used in various activities and proposals in order to reduce the impact on the environment, and they can be used in construction, in playgrounds, in the manufacture of asphalt-rubber, automotive mats, synthetic grass, among others (Lagarinhos & Tenório, 2009).

CONCLUSIONS

Both systems can be implemented in rural homes, without major complications.

The system implementation with concrete tanks was more practical from the acquisition of materials to the installation, also showing greater economic viability.

From the perspective of technical feasibility, according to the results found during the monitoring of the systems, neither of them presented satisfactory results, to comply with the current legislation. The low efficiency may have occurred due to the way the waste was collected for analysis. As mentioned in this study, the collections took place on the surface of the first tank and, thus, it is believed that the collected material had already undergone some treatment, considering that when it reaches the tank, through the pipe, most of the organic matter deposits at the bottom of the tank. It is therefore suggested for future studies that samples should be collected over the entire depth of the tank, which can be done with the aid of a sampling column, thus obtaining a more homogeneous sample and close to the actual situation in which the sewer reaches the treatment system. Still, related to this point, it is suggested that some form of the screen should be installed so that there is no mixing of the input material with the reactor output.

The non-use of inoculum may have contributed to the low efficiency found, considering that with the use of the inoculum there is a better adaptation and development of microorganisms that act in the decomposition of organic matter.

Both projects proved to be viable in the pessimistic and normal scenarios, that is, with higher fines for the release of untreated sewage. And they proved unfeasible in the optimistic scenario, that is, with a lower fine. Even if intuitively opposed, this is the scenario in which the project would be expected to fail. The average turnaround time for the project was between one and three years, considering that a short time within the stipulated horizon. When comparing projects, it was already expected that with the same cash flow inputs, the one with the largest initial investment would have the worst viability indicators.

RECOMMENDATIONS. It is believed, by the results of this work can be adopted, by the public health systems of small city halls, considering in their sewage water sanitation programs.

REFERENCES

American Public Health Association – APHA, 2012. Standard methods for the examination of water and wastewater (SMEWW). 22th ed. Washington.

Ana/Cetesb, 2011. National guide for collecting and preserving samples: water, sediment, aquatic communities and liquid effluents. Companhia Ambiental do Estado de São Paulo; Organizadores: Carlos Jesus Brandão et al.- São Paulo: CETESB; Brasília: ANA. (in Portuguese).

Associação Brasileira de Normas Técnicas, 1987. NBR 9898: Preservation and sampling techniques for effluents and receiving bodies. Rio de Janeiro. (in Portuguese).

Associação Brasileira de Normas Técnicas, 1993. NBR 7229: Design, construction and operation of septic tank systems. Rio de Janeiro. (in Portuguese).

Associação Brasileira de Normas Técnicas, 1997. NBR 13969: Septic tanks - Complementary treatment units and final disposal of liquid effluents - Design, construction and operation. Rio de Janeiro. (in Portuguese).

Brasil, 2005. Conselho Nacional do Meio Ambiente. Resolução n. 357 de 17 de março de 2005. Diário Oficial [da] União, Brasília, 18 mar., pp. 58–63.

Brasil, 2019. Ministério do Desenvolvimento Regional. Secretaria Nacional de Saneamento – SNS. National Sanitation Information System: 24th Diagnosis of Water and Sewage Services – 2018. Brasília:SNS/MDR. 180 pp. (in Portuguese).

Colares, C.J.G. & Sandri, D. 2013. Efficiency of sewage treatment with septic tanks followed by cultivated beds with different support media. *Ambi-Agua* **8**, 172–185.

Cheng, S., Li, Z., Nazim Uddin, S.M., Mang, H., Zhou, X., Zhang, L., Zheng, L. & Zhang, L., 2018. Toilet revolution in China. *J. Environ. Manag*. **216**, 347–356 (in Portuguese).

Dhamodharan, K., Kumar, V. & Kalamdhad, A.S. 2015. Effect of different livestock dungs as inoculum on food waste anaerobic digestion and its kinetics. *Bioresource Technology* **180**, 237–241.

Dmae - Prefeitura Municipal De Uberlândia, 2016. Sustainable Septic Tank. Available in: http://www.uberlandia.mg.gov.br/uploads/cms_b_arquivos/13916.pdf Accessed in: 10 de março de 2017. (in Portuguese).

Gonçalves, R.F., Alves, W.C. & Zanella, L. 2006. Water conservation in urban areas. In: Uso Racional da Água em Edificações. Ricardo Franci Gonçalves (Coord.). Rio de Janeiro: ABES, cap. 2, pp. 29–71 (in Portuguese).

Habitissimo, 2020. Build Septic Tank: Prices and Budgets. Available in: https://www.habitissimo.com.br/orcamentos/construir-fossa-septica. Acesso em abril de 2020. (in Portuguese).

IBGE - Instituto Brasileiro de Geografia e Estatística, 2010. National Basic Sanitation Survey – PNSB, p. 40. (in Portuguese).

IBGE - Instituto Brasileiro de Geografia e Estatística, 2015. National Household Sample Survey - PNAD, p.102. (in Portuguese).

IBGE - Instituto Brasileiro de Geografia e Estatística, 2018. National Household Sample Survey – PNAD. Available in: Instituto Brasileiro de Geografia e Estatística <https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/24532-pnad-continua-abastecimento-de-agua-aumenta-no-centro-oeste-em-2018-mas-se-mantem-abaixo-do-patamar-de-2016> Accessed in: 16 de julho de 2019. (in Portuguese).

IBGE, Instituto Brasileiro de Geografia e Estatística. Synopsis of the Demographic Census. 2010. Available in: Instituto Brasileiro de Geografia e Estatística: <https://censo2010.ibge.gov.br/sinopse/index.php?uf=33&dados=21> Accessed in: 09 de março de 2019. (in Portuguese).

INMET – Instituto Nacional de Meteorologia, 2019. Available in: <www.inmet.gov.br> acesso em: 20 de abril de 2019. (in Portuguese).

Lagarinhos, C. & Tenório, J., 2009. Tire recycling: discussion of the impact of Brazilian policy, *Engevista* **11**, 32–49. (in Portuguese).

Li, Y., Hua, D., Zhang, J., Gao, M., Zhao, Y., Xu, H., Liang, X., Jin, F. & Zhang, X. 2014. Influence of inoculum to substrate ratios (ISRs)on the performance of anaerobic digestion of algal residues. *Annals of Microbiology* **64**, 955–960.

Luostarinen, S., Sanders, W., Kujawa-Roeleveld, K., & Zeeman, G. 2007. Effect of temperature on anaerobic treatment of black water in UASB-septic tank systems. *Bioresource Technology* **98**, 980–986.

Martinetti, T.H., Shimbo, I. & Teixeira, B.A.N. 2007. Analysis of more sustainable alternatives for local treatment of residential sanitary effluents. *In: IV Encontro Nacional e II Encontro Latino - Americano Sobre Edificações e Comunidades Sustentáveis.* Curitiba. 996–1005. Available in: http://www.elecs2013.ufpr.br/wp-content/uploads/2007_artigo_01pdf. Accessed in: 29 ago. 2018. (in Portuguese).

Organização Mundial da Saúde - OMS, 2014. Available in: <https://www.who.int/water_sanitation_health/monitoring/economics/en/> Accessed in: 06 ago de 2019. (in Portuguese).

Rebouças, T.C. 2007. Physicochemical and microbiological characteristics of different types of residential wastewater. In.: Congresso Brasileiro de Engenharia Sanitária e Ambiental, Belo Horizonte, 24, 2007. *Anais... Minas Gerais: Associação Brasileira de Engenharia Sanitária e Ambiental*. (in Portuguese).

Rio de Janeiro (Estado). Lei 2.661, de 27 de dezembro de 1996. Constituição do Estado do Rio de Janeiro, 1996. (in Portuguese).

Raukas, A. 2010. Sustainable development and environmental risks in Estonia. *Agronomy Research* **8**(SII), 351–356.

Sautchúck, C. 2004. Formulation of guidelines for implementing water conservation programs in buildings. São Paulo: USP. Dissertação (Mestrado em Engenharia) - Escola Politécnica, Universidade de São Paulo, São Paulo, 303 pp. (in Portuguese).

SEFAZ – Secretaria De Fazenda do Estado do Rio De Janeiro, 2019. Resolution 101 of December 20, 2019. Diário Oficial do Estado do Rio de Janeiro de 23 de dezembro de 2019. (in Portuguese)

SINAPI, 2019. Civil Construction Indexes. Available in: <http://www.caixa.gov.br/site/Paginas/downloads.aspx#categoria_656>. Accessed in: 19 mai 2019. (in Portuguese).

Singh, R P., Kun, W. & Fu, D. 2019. Designing process and operational effect of modified septic tank for the pretreatment of rural domestic sewage. *Journal of Environmental Management.* **251**, 109552.

Sousa, J.T., Van Haandel, A.C., Cavalcanti, P.F.F. & Figueiredo, A.M.F. 2003. Efluentes tratados utilizados na agricultura. In: Simpósio Brasileiro de Recursos Hídricos. 15. Anais Simpósio brasileiro de recursos hídricos. Curitiba-PR, Brasil, pp. 1–12.

Tihomirova, K, Denisova, V., Golovko, K., Kirilina–Gutmane, O., Mezule, L. and Juhna, T. 2019. Management of wastewater from landfill of inorganic fiberglass. *Agronomy Research* **17**(S1), 1216–1226.

Waite, R.M., Salgado, E.G. & Carmo, D.F., 2020. Economic feasibility for wastewater treatment system composed of wetlands for the wastewater reuse: a case study. *Revista agrogeoambiental* **12**(2). doi: http://dx.doi.org/10.18406/2316-1817v12n220201461 (in Portuguese).

Withers, P.J.A., Jarvie, H.P. & Stoate, C., 2011. Quantifying the impact of septic tank systems on eutrophication risk in rural headwater. *Environment International* **37**, 644–654.