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OPTIMIZING FILTRATION AT ETA ARAPIRACA: LEAN SIX SIGMA IMPLEMENTATION

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Abstract: Filtration is a physical-chemical process used to remove colloidal particles present in the liquid phase by passing them through a granular medium. It is essential for this layer to be of adequate height and granulometry to ensure effective removal of solid particles. However, it was found at the Arapiraca Water Treatment Plant (WTP) that the level of the filter bed had been reduced, having been replaced 10 years ago. As a result, the efficiency of the filtering system has been compromised. With this in mind, the aim of this work is to apply the Lean Six Sigma method to the refurbishment of the filters at the Arapiraca WTP. In addition, the aim is to describe the systemic operational process that was applied in this intervention and assess the impacts from a quality management perspective. To this end, the activities were planned based on the principles of Lean Six Sigma with an emphasis on the DMAIC cycle. The steps related to revitalizing the filtration system were then carried out. Finally, it should be noted that the method studied in this research proved to be a viable alternative for improving process efficiency and quality. It was also observed that the recovery of the filtration system at this WTP showed favorable results, with an increase in filter performance and a reduction in turbidity.
Keywords: Efficiency, Filtration, Lean Six Sigma.

INTRODUCTION

According to Libânio (2010), filtration is a physical-chemical process used to remove the colloidal particles that give color and turbidity to the liquid phase of water. It is important to note that the presence of these solids can compromise the effectiveness of disinfection, impairing the ability to inactivate pathogenic microorganisms. From this perspective, it is clear that the filtration stage has a substantial influence on water quality, since it is during this process that any failures in coagulation, flocculation and decantation can be corrected.

Thus, the filters used in conventional water treatment are designed to allow the water to pass through a granular medium with a specific height and granulometry (FERREIRA FILHO, 2017). This filter layer must be adequately sized and maintained to ensure the effective removal of solid particles, guaranteeing the efficiency of the filtration system (NBR 12216, 1992). However, it is common for the level of the filter layer to decrease over the years of operation due to the backwashing process, which is carried out periodically to remove trapped particles and maintain filtration capacity.

This problem was highlighted at the Water Treatment Plant (WTP) located in Arapiraca-AL, where the filter bed material had been replaced ten years ago. It was observed that the level of the filter layers had been reduced, as material was lost during the backwashing process. As a result, the efficiency of the filtering system had been compromised. Therefore, in order to adapt the filtration system, the filters at the Arapiraca WTP were refurbished, based on the Lean Six Sigma methodology, the applications of which will be assessed in this work.

LEAN SIX SIGMA METHODOLOGY

The Lean Six Sigma methodology is aimed at continuously improving the performance and quality of activities, resulting in improved profitability and a significant reduction in errors, which helps to minimize losses during processes (ISO 13053-1, 2011). It is important to note that Six Sigma methods are aligned with the quality principles outlined in the ISO 9000 and ISO 9001 quality management system standards.

In this context, the Lean Six Sigma method combines the principles of Lean Manufacturing, which aim to eliminate waste and opti-

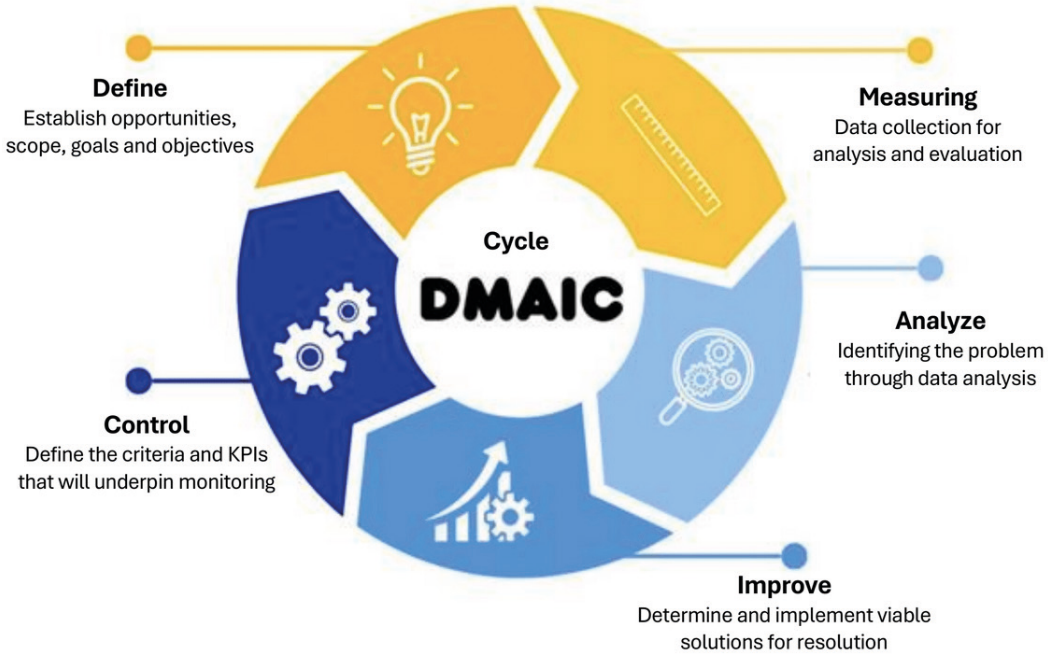

Figure 1 - DMAIC

Source: Authors, 2024.

mize workflow, with the statistical methods of Six Sigma, which aim to reduce variation and improve process quality. In addition, the DMAIC cycle is used - Define, Measure, Analyze, Improve and Control. This cyclical approach allows problems to be identified, relevant data to be collected, causes to be analyzed, solutions to be implemented and results to be monitored over time (Figure 1).

With this in mind, it was decided to use the methods supported by this systematic approach in order to ensure the optimization of processes in an effective and sustainable way. More precisely, the Lean Six Sigma methodology was applied to the refurbishment of the filters at the Water Treatment Plant located in the municipality of Arapiraca, in the state of Alagoas.

CHARACTERIZATION OF THE ARAPIRACA WATER TREATMENT PLANT

The Water Treatment Plant (WTP) located in the municipality of Arapiraca is part of the Agreste Adductor System (SAA), whose catchment is on the banks of the São Francisco River. This WTP is responsible for water treatment, operating in a complete cycle (conventional treatment), in which the stages of coagulation, flocculation, decantation, filtration and final chlorination are carried out (Figure 2).

Figure 2 - Arapiraca Water Treatment Plant (WTP)

Source: Agreste Saneamento, 2023.

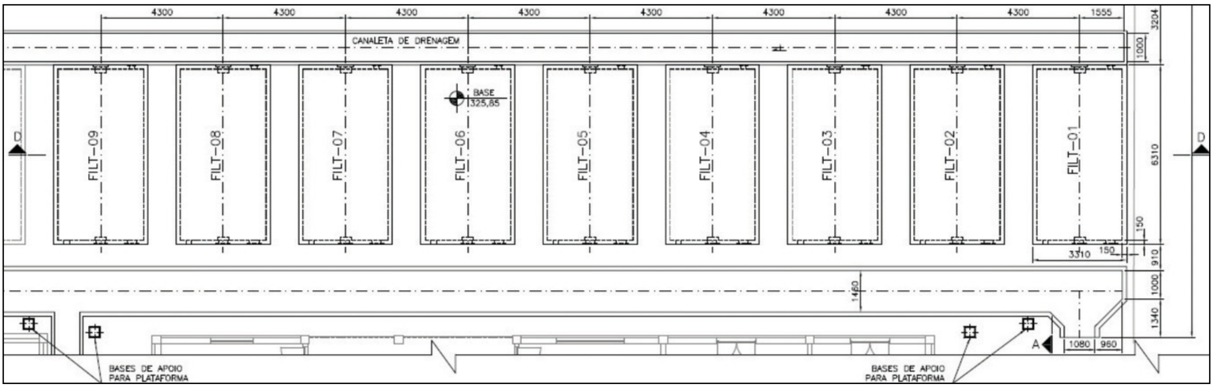

Figure 3 - Top view of the filters

Source: Agreste Saneamento, 2023.

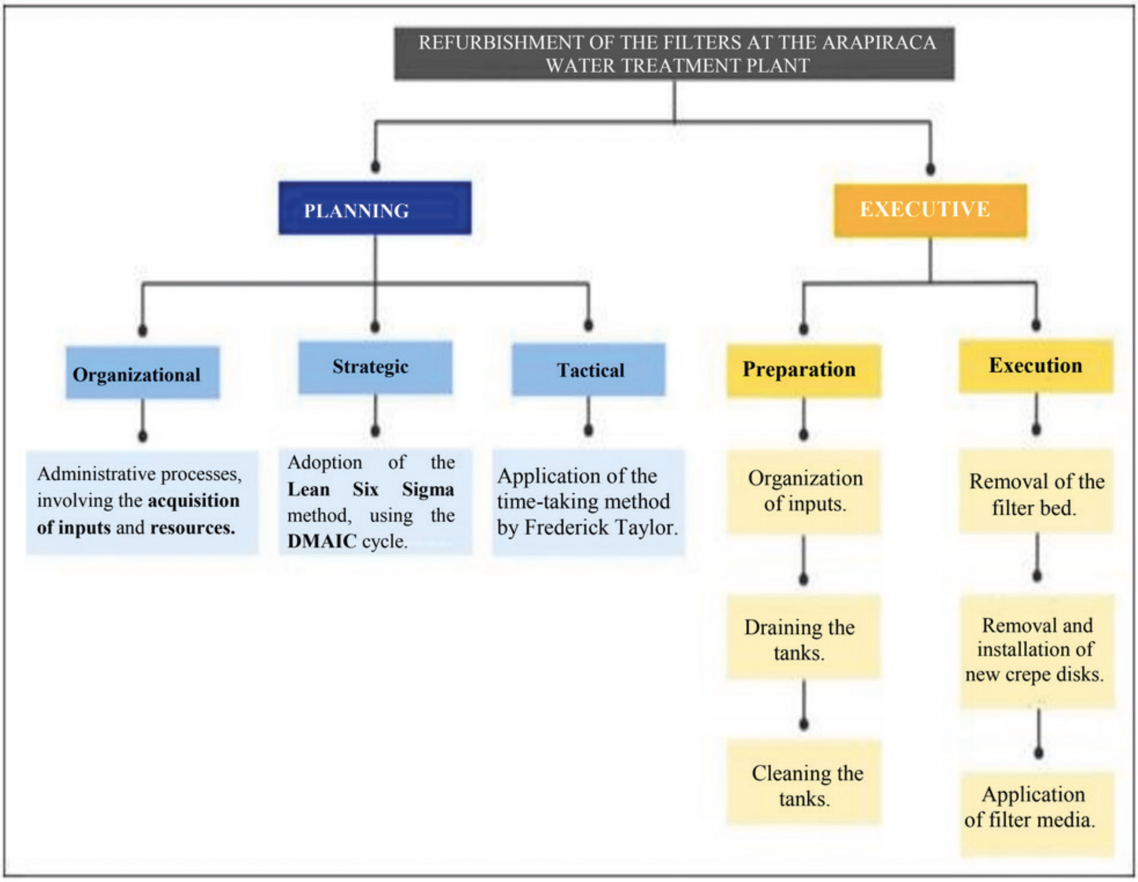

Figure 5 - Process flowchart

Source: Authors, 2024.

CHARACTERIZATION OF FILTERS

The water filtration process is carried out by 9 filters, which are contained in tanks measuring 3.05m x 6.05m, totaling an area of 18.45m² for each filter. They are also structured in metal modules with a height of 4.18m. It should also be noted that the existing filter bed is made up of sand and anthracite, operating in rapid downward flow. The layout of the filters can be seen in figure 3.

ANALYSIS OF THE PROBLEM SITUATION

Filtration takes place by means of water percolating through a filtering material, which is responsible for retaining solid particles. Often, after years of operation, the level of the filtration layer is reduced due to the backwashing process that is carried out periodically. As a result, the filtration efficiency rate is minimized, compromising water treatment. This problem was highlighted at the Arapiraca WTP, whose filter bed material had been replaced ten years ago (Figure 4).

Figure 4 - Arapiraca WTP filters

Source: Authors, 2023.

It was then observed that the level of the filter layers had been reduced, as material was being lost during the backwashing process. As a result, the efficiency of the filtration system was compromised and reduced. Therefore, in order to adapt the filtration system, the filters at the Arapiraca WTP were refurbished using Lean Six Sigma methods, the influence of which will be highlighted in this work.

OBJECTIVES

This project aims to apply the principles of the Lean Six Sigma methodology to the revitalization of the filtration system of the WTP located in the municipality of Arapiraca, with the aim of guaranteeing continuous improvement and process quality. In addition, it seeks to highlight the construction system used in the aforementioned intervention and assess the impacts of this revitalization from the perspective of quality management, with a view to reducing costs, operational efficiency and increasing the performance indices of the filter tanks.

METHODOLOGY USED

The methodology adopted is based on the application of the Lean Six Sigma method, with a technological emphasis and an approach that encompasses both quantitative and qualitative aspects. Figure 5 illustrates the flow of activities implemented in this work.

As shown in the flowchart above, the planning of filter refurbishment activities is divided into organizational, strategic and tactical stages. The organizational phase is integrated into the strategic level, based on the principles of Lean Six Sigma and applying the DMAIC cycle. On the other hand, tactical planning is based on the premises of Frederick Taylor's time-taking method. Furthermore, the executive phase comprises two related stages: the preparation phase and the subsequent execution.

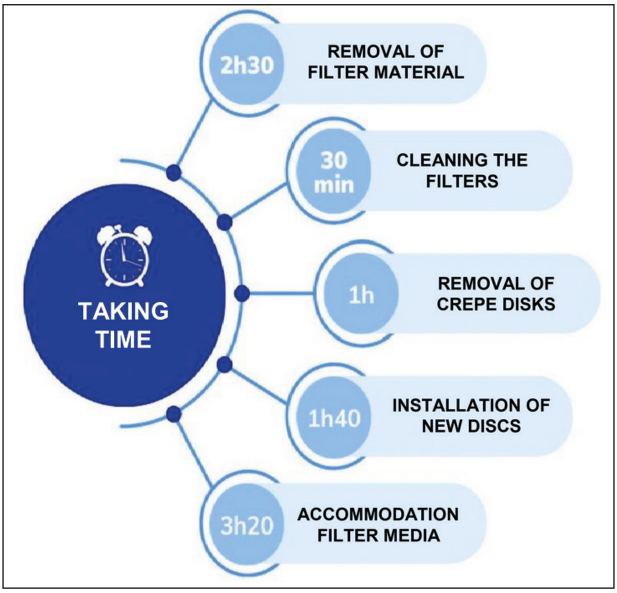

Figure 6 - Task division flow
Source: Authors, 2024.

TASK	HOME	END	TOTAL TIME
Draining the tank	07:30	08:00	30 minutes
Removal of the filter bed	08:00	10:00	2 hours
Cleaning the tank	10:00	10:30	30 minutes
Testing the operation of the crepes	10:30	10:40	10 minutes
Removing the disks	10:40	11:30	50 minutes
Application of the new crepe discs	11:30	13:00	1 hour 30 minutes
Testing the operation of the crepes	14:00	14:10	10 minutes
Application of the 1st layer of filter media	14:10	14:30	20 minutes
Application of the 2nd layer of filter media	14:30	14:50	20 minutes
Application of the 3rd layer of filter media	14:50	15:10	20 minutes
Application of the 4th layer of filter media	15:10	15:40	30 minutes
Application of the 5th layer of filter media	15:40	16:10	30 minutes
Application of the 6th layer of filter media	16:10	16:50	40 minutes
Application of the 7th layer of filter media	16:50	17:30	40 minutes

Table 1 - Time-taking method
Source: Authors, 2024.

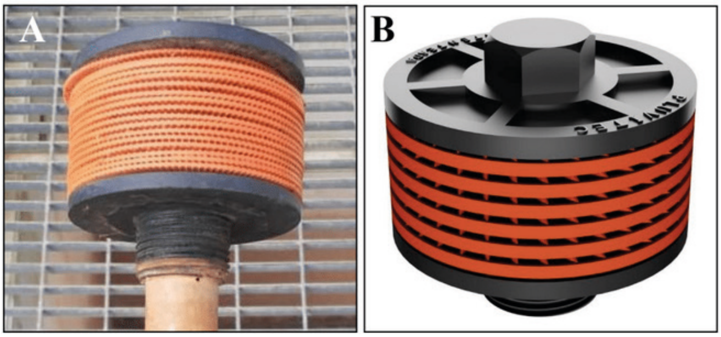

Figure 7 - A) Old disk layout; B) New configuration adopted.
Source: Authors, 2024.

APPLYING LEAN SIX SIGMA METHODOLOGY

Initially, a technical consultancy was carried out to assess the filters. Following this assessment, the existing scenarios were analyzed, identifying opportunities and establishing the technical scope for carrying out the service. This stage is part of the first phase of the DMAIC cycle. Next, the filter refurbishment activities were mapped out, which will be detailed in section 3.2. Spreadsheets were then drawn up to monitor the stages of the service, as well as metrics for analyzing and evaluating the data. Management consisted of detailed management of time and activities, which were subdivided and controlled through precise measurement of the time used, following Taylor's time-taking method. Figure 6 shows the process of dividing up activities according to this method, broken down in Table 1.

In addition, it is worth mentioning that during the execution of the services, it was noted that the employees faced challenges when dealing with the filter bed material. Following this analysis, it was found that using machinery to remove and apply the filter media increased employee productivity and led to a notable reduction in execution time. In addition, it is important to note that the following were defined criteria for monitoring and maintaining the improvements implemented, thus guaranteeing the continuous efficiency and quality of the processes. These steps are part of the other items in the DMAIC cycle.

CONSTRUCTION SYSTEM

The construction method begins with draining the water from the filtration tank. After this process, the filter layer material and the crepe discs were removed and replaced with new ones. With regard to this procedure, it is worth noting that a new configuration was adopted for the crepe discs, which now uses 6 discs in each crepe (Figure 7 A and B).

The tanks were then cleaned and backwashed in order to test the crepe disk system. After these procedures, the support layer and filter bed were installed, characterizing a double-layer rapid filter (Figure 8). Table 2 shows the half-granular arrangement for water percolation.

RESULTS OBTAINED

The results obtained in this study can be presented as a quantitative sample, relating to the construction process and quality indicators, and as a qualitative sample, which is associated with the results after the renovation.

QUANTITATIVE RESULTS:

- Savings of approximately **R$ 330,967.43** in labor costs for the refurbishment of the filters;
- Completion of **9 filters in just 25 days,** representing a **75%** reduction in execution time;
- Reduced turbidity and increased filter performance.

QUALITATIVE RESULTS:

- Increased efficiency in removing impurities, sediments and contaminants from the water, resulting in higher quality treated water;
- Improved efficiency in terms of energy consumption, chemicals and maintenance, leading to a reduction in long-term operating costs;
- Ensuring more consistent and reliable filtration, resulting in more stable and predictable treated water quality over time;
- Increased production capacity of the filtration system, allowing the water treatment plant to meet growing demand without compromising water quality;

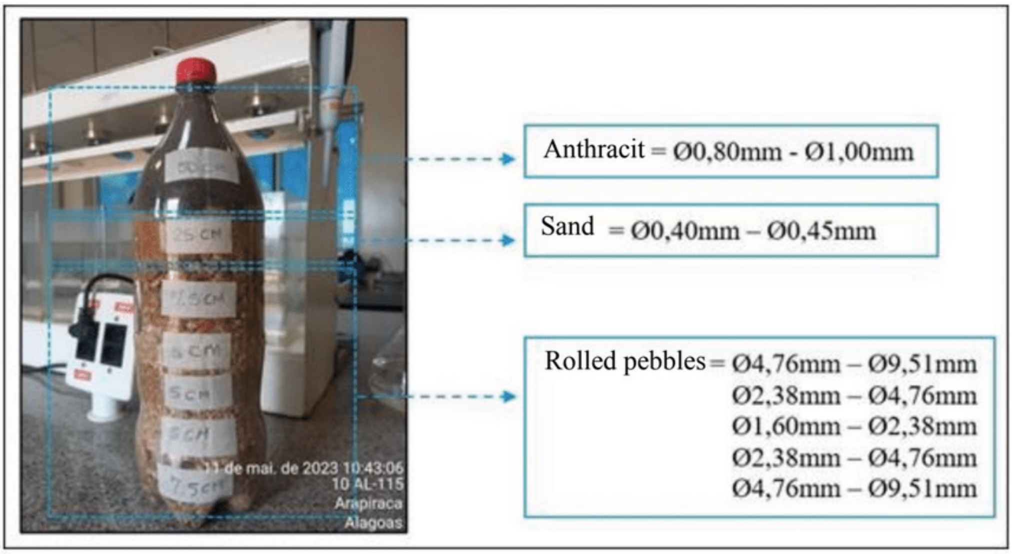

Figure 8 - Filter bed configuration

Source: Authors, 2024.

Layer	Material	Layer granulometry		Layer height
		Minimum	Maximum	
Filter media	Anthracite	0.80 mm	1.00 mm	50.0 cm
Filter media	Sand	0.40 mm	0.45 mm	25.0 cm
Support Layer	Rolled pebbles	4.76 mm	9.51 mm	7,5 cm
Support Layer	Rolled pebbles	2.38 mm	4.76 mm	5.0 cm
Support Layer	Rolled pebbles	1.60 mm	2.38 mm	5.0 cm
Support Layer	Rolled pebbles	2.38 mm	4.76 mm	5.0 cm
Support Layer	Rolled pebbles	4.76 mm	9.51 mm	7,5 cm

Table 2 - Filter bed configuration

Source: Authors, 2024.

- Guaranteed reliability and less need for maintenance, reducing unplanned downtime in the water treatment plant;
- Improving the efficiency of the filtration system beyond the initial design, thus increasing its filtration capacity and service life;
- Guarantee of the Water Quality Index (IQA);
- Ensure availability and sustainable management of drinking water and sanitation for all - Sustainable Development Goal (SDG 6) Drinking water and sanitation;
- Ensuring sustainable consumption and production patterns - Sustainable Development Goal (SDG 12) Responsible consumption and production.

ANALYSIS AND DISCUSSION OF RESULTS

The adoption of a methodology based on the quality principles of ISO 9000 and ISO 9001 optimized the execution processes inherent in the renovation services, promoting an improvement in workflow and reducing errors. As a result, it was possible to save approximately R$ 330,967.43 (three hundred and thirty thousand, nine hundred and sixty-se-

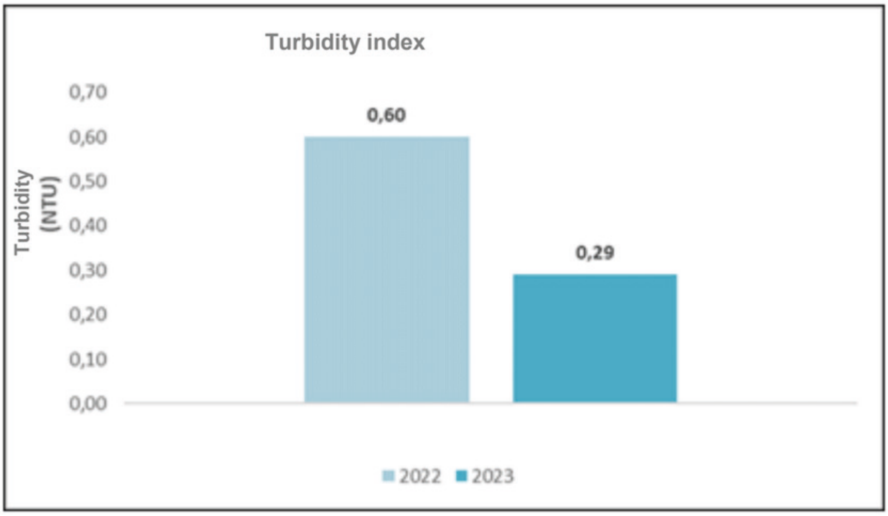

Figure 9 - Reduction in turbidity after renovation
Source: Authors, 2024.

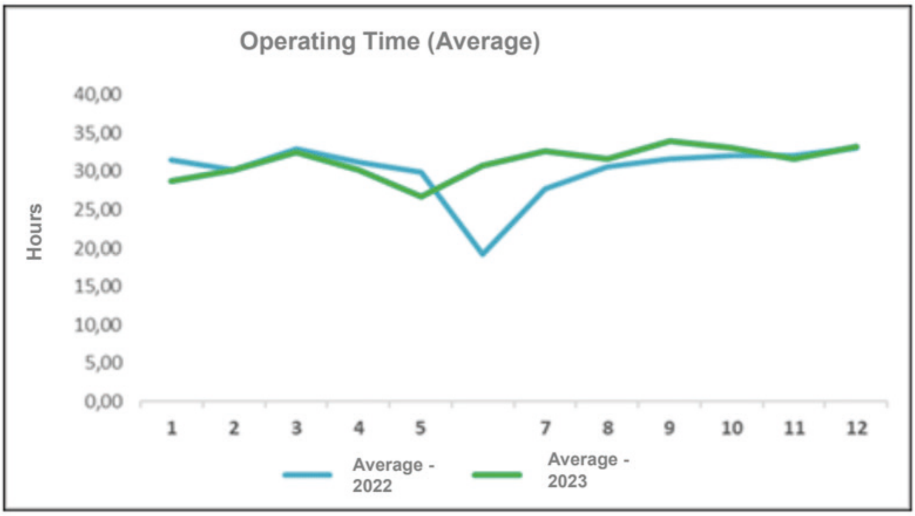

Figure 10 - Comparison of operating time
Source: Prepared by the Treatment sector of the Agreste operation, 2023.

ven reais and forty-three cents) on labor, as well as reducing the time dedicated to activities by 75%, allowing 8 filters to be completed in just 15 days. It should be noted that these practices are in line with SDG 12 - Responsible consumption and production, as they aim to manage resources sustainably and efficiently (UN, 2024).

With regard to the post-reform results, the analysis of the turbidity of the raw, decanted and filtered water is shown in Table 3. It is worth noting that a comparison was made between the months of June and July, considered critical periods due to rainfall, in the years 2022 and 2023. These figures are shown in two columns, indicating the general and average turbidity range.

Location	2022		2023	
	Range (NTU)	Average (NTU)	Range (NTU)	Average (NTU)
Gross	100 - 140	129	100 - 140	121
Decanted	0,19 - 20	2,27	0,5 - 10,6	2,07
Filtered	0,11 - 10,1	0,60	0,11 - 0,5	0,29

Table 3 - Turbidity index comparison

Source: Prepared by the Treatment sector of the Agreste operation, 2023.

It can be seen that the percentages identified in the raw and decanted water remain close, however, when analyzing the turbidity index of the filtered water, a reduction of **48.33%** can be seen. This shows that the intervention carried out on the filter media increased the efficiency of the filtration system, significantly reducing the turbidity index. Figure 9 shows this disparity.

With regard to the water treatment performance index, it was observed that the percentage in the raw/decanted water section remained partially constant. However, when analyzing the decanted/filtered segment, there was a significant improvement. These results are shown in Table 4.

Location	2022	2023
Gross/Decanted	98,24%	98,28%
Decanted/Filtered	73,57%	85.99%

Table 4 - Turbidity index comparison

Source: Prepared by the Treatment sector of the Agreste operation, 2023.

In addition, the filters' career time was evaluated, and the analysis shows that there was a subtle increase after the intervention. These results can be seen in Figure 10.

Finally, it is important to note that these results are in line with SDG 6 - Drinking water and sanitation, as they contribute directly to improving water quality, minimizing the use of chemical products and guaranteeing access to water for consumers served by the Agreste Adductor System.

CONCLUSIONS/ RECOMMENDATIONS

The results of this study indicate that it is feasible to adopt construction methodologies based on quality management and innovation. Thus, it is clear that Lean Six Sigma is an approach capable of improving the efficiency and quality of processes, especially in this context, in civil construction applied to sanitation. Furthermore, the recovery of the filtration system at the Water Treatment Plant (WTP) in the city of Arapiraca showed favorable results. Replacing the filter bed made it possible to increase the performance of the filters, as well as significantly reducing the turbidity index. It is therefore clear that this project has a direct impact on the Sustainable Development Goals established by the UN. The use of high-performance filters guarantees access to drinking water for a greater number of people, in a sustainable way over the long term (SDG 6). In addition, the conscious development of this service, supported by efficient resource management, contributes to SDG 12 (Responsible consumption and production).

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