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Disposal and reuse of residuals produced at Water Treatment Plants in the Paraíba do Sul River basin

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RESUMO

Population growth increases demand for potable water, which increases the generation of residuals at the Water Treatment Plants (WTPs). During its treatment, water needs to undergo a series of processes that create residuals that must be well managed to avoid environmental impacts. This study analyses the residuals generated at the Paraiba do Sul River basin. We consulted more than 70 documents to identify the plants located in 57 municipalities along the basin. The plants were classified according to the type of water treatment used. We mapped four possible ways to reuse and dispose the residuals in an environmentally friendly way at nurseries, ceramic industries, Sewage Treatment Plants (STPs), and landfills. The results indicate that from the total of WTPs found in the basin, more than 90% produce some waste and that only 7% treat them accordingly. We located more than 200 places as alternative sites for the residuals. From the municipalities analysed, more than 80% could reuse or correctly dispose such residuals when considering at least one of the solutions provided.

KEYWORDS: WTP residuals. Solid residuals. Residual treatment.

1 INTRODUCTION

Sanitation is a fundamental service for health, social and economic reasons. Water is considered a fundamental resource for the human species survival as it is an indispensable asset to our daily needs. The growing demand for products and services increases water consumption, which, in turn, generates more residuals from the water treatment processes. As water is a crucial resource, it is important to understand the current scenario regarding water supply and waste management derived from water treatment (VILELLA, 2011).

In Brazil, the production and disposal of residuals generated by Water Treatment Plants is a clear issue. In 2017, from 1,825 Brazilian municipalities with water supply networks that generate some WTP waste, around 1,300 disposed the waste in bodies of water without prior treatment (IBGE, 2017).

After capturing water at the springs, it undergoes several treatment processes before distribution through the water supply network. These processes generate complex residuals that are challenging to handle and dispose. Some examples are the WTP sludge (WTPS), a dense mass with 1-4% of solid particles, and the filter backwashing water (FBW). Both are highly harmful to the environment if poorly managed (ACHON et al., 2013; DI BERNADO et al., 2012).

Most WTPs fail to quantify the waste generated and few characterize it, making it impossible to employ the appropriate tools to manage the waste (ACHON et al., 2013). According to the Brazilian Standard NBR 10.004, the waste generated at WTPs is considered solid even when it contains more than 95% of water in volume; and due to technical and environmental reasons, they should be treated before disposal (ABNT, 2004).

According to Richter (2001), the most common places to dispose WTP waste are in bodies of water, Sewage Treatment Plants (STPs), soil, and landfill. In order to overcome this problem, Brazilian institutions such as CONAMA (National Environment Council) and SISNAMA (National Environment System) developed the following guidelines: resolution 430, and Federal Law 6.938/81, respectively. These policies convey information regarding the disposal of WTP waste according to the body of water that is receiving the waste. These policies limit the waste disposal according to its composition. The type and quality of the waste generated at WTPs, in addition to its transport and logistics costs, directly influence the disposal site. Therefore, this choice should take into account technical, environmental, and economic factors (JANUÁRIO et al., 2007).

It is important that the environmental sanitation sector has an in-depth view of the water treatment system once there is a global concern about WTP residual reduction, its reuse or recycling, and disposal of only unusable waste (ACHON et al., 2013). Therefore, this work aims at bringing awareness to issues related to the management of waste produced by the water treatment industry to ensure water security in the Paraíba do Sul River basin.

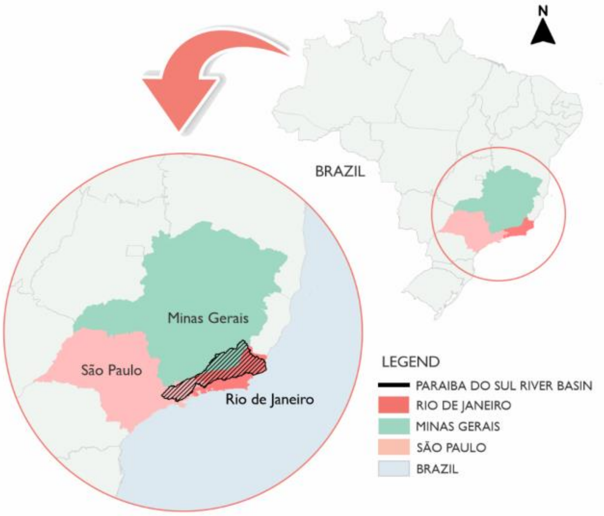
2 OBJECTIVES

Our goal is to investigate the sludge and filter backwashing water produced at Water Treatment Plants in municipalities belonging to the Paraíba do Sul River basin, with over 20,000 people. We assess possibilities to reuse and dispose such residuals.

3 METHODOLOGY

The Paraíba do Sul River basin is in the southeast region, one of the most developed regions of Brazil, with an area of 61,000 km^2. The basin spans the regions of Vale do Paraíba Paulista, in São Paulo, Zona da Mata Mineira, in Minas Gerais, and part of Rio de Janeiro, providing water to 184 municipalities as shown in Figure 1 (AGEVAP, 2021). According to the Integrated Water Resources Planning of the basin, there are around 7 million people who depend on its resources. Recent developments have worsened the water quality and reduced its availability, requiring actions from the government and the mobilization of different sectors of society to repair the damages caused by the growing degradation of water resources in the Paraíba do Sul River basin (AGEVAP, 2021).

Figure 1 - Paraíba do Sul River basin location.



Source: Authors, 2022.

We investigated WTPs throughout the basin. Small towns generally present poor urban infrastructure, especially when it comes to sanitation, which is due to the challenges to create universal projects to deliver this service. According to Spósito e Silva (2013), there is less concern with urban areas with less than 20,000 inhabitants, which is evident as these cities are not favoured by the City Statute in terms of urban planning instruments and economic development. Municipalities with more than 20,000 inhabitants were selected, considering the precariousness in the sanitation sector as well as the shortage of data and information in this field. According to Table 1, 51 Municipal Sanitation Plans were consulted, where most information related to the WTPs was collected in addition to the other documentation listed in the table.

Table 1 - Sources used to extract the relevant data.

Consulted Sources	RJ	MG	SP	TOTAL
Municipal Sanitation Plans	29	07	15	51
Technical Studies and Planning for the Universalization of Water Supply and Sewerage	08	-	-	08
Annual Newsletter on Water Quality	02	01	04	07
Inspection Reports	01	06	-	07
Management Plan for Potable Water Supply and Sewerage Services	-	01	-	01
Total	**40**	**15**	**19**	**74**

Source: Authors, 2022.

We have also searched other data sources, such as the Brazilian Institute of Geography and Statistics (IBGE), the National Sanitation Information System (SNIS), and the National Water and Sanitation Agency (ANA). At IBGE (2017), despite having access to the amount of existing WTPs in each municipality, no information was found regarding the generated waste. At SNIS (2022) and ANA (2022), the database was scarce and out of date, and thus no data related to either WTPs or waste generated in them was obtained.

We proceeded to map the area using the ArcGis mapping software together with *Google Maps* to demarcate the WTPs. They were classified based on the drinking water treatment adopted. As a result, it was possible to identify whether the generation of residuals occurred or not at the WTPs as well as if any treatment was performed. The information is presented in Table 2.

Table 2: Water treatment adopted at the WTP, types of generated residuals and treatment used.

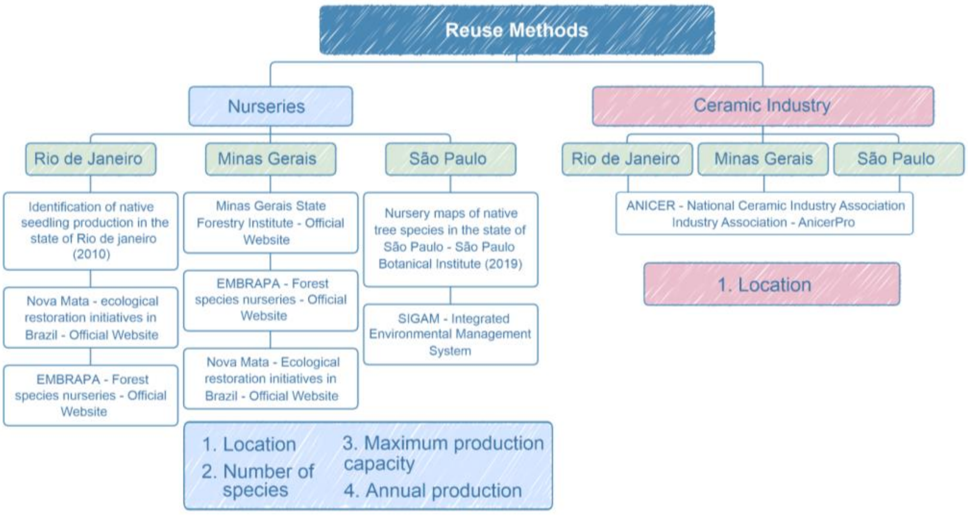
Treatment used by the WTP	Types of residuals	Treatment of residuals
Decantation	Sludge	1. Yes 2. No 3. No information available.
Filtration	Filter backwashing water	
Decantation + Filtration	Both	

Source: Authors, 2022.

Considering the National Policy on Solid Waste (PNRS, 2010) and the appropriate disposal methods, we identified four possible destinations for the waste generated at WTPs around the Paraíba do Sul River basin: nurseries, ceramic industries, landfills, and Sewage Treatment Plants (STPs). As mentioned above, the disposal of such waste was mapped in municipalities with over 20,000 people. Figure 2 presents a summary of the sources used to collect data regarding the reuse methods for the residuals at the WTPs. In terms of nurseries, several databases were consulted whereas the National Ceramic Industry Association database (AnicerPro) was employed to identify potential ceramic industries.

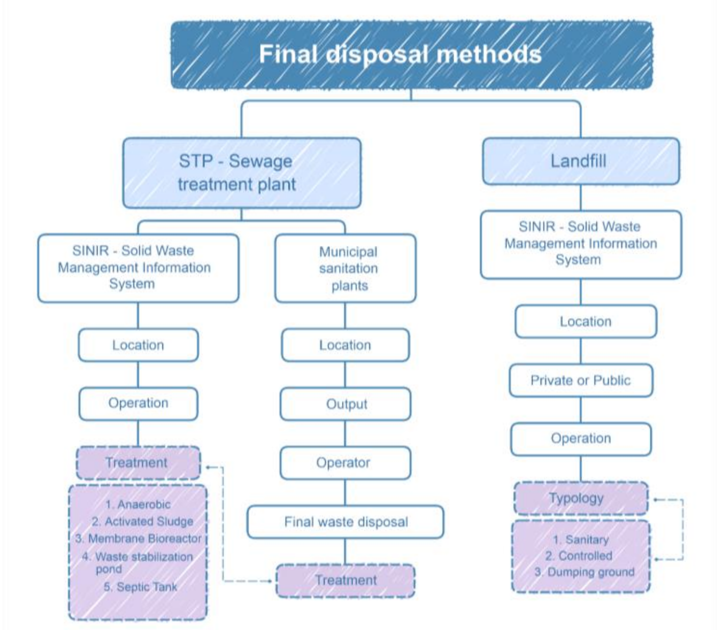
In terms of environmentally friendly methods to dispose residuals, we used the National Information System on Solid Waste Management (SINIR) (2019) database to identify landfills, controlled landfills, and dumping grounds. To collect information regarding the STPs, we also investigated the documents used to identify the WTPs (Table 1) in addition to the SINIR (2019) database. We then analysed the viability and compatibility of these processes as means to dispose the waste generated at WTPs (Figure 3). We considered only STPs that used waste stabilization ponds, anaerobic, and activated sludge processes. We also considered landfills and as a possible destination since it is an environmentally friendly alternative.

Figure 2 - Chart with the sources and information about the reuse methods explored in this work.



Source: Authors, 2022.

Figure 3 - Chart with the sources and information about the waste disposal methods explored in this work.



Source: Authors, 2022.

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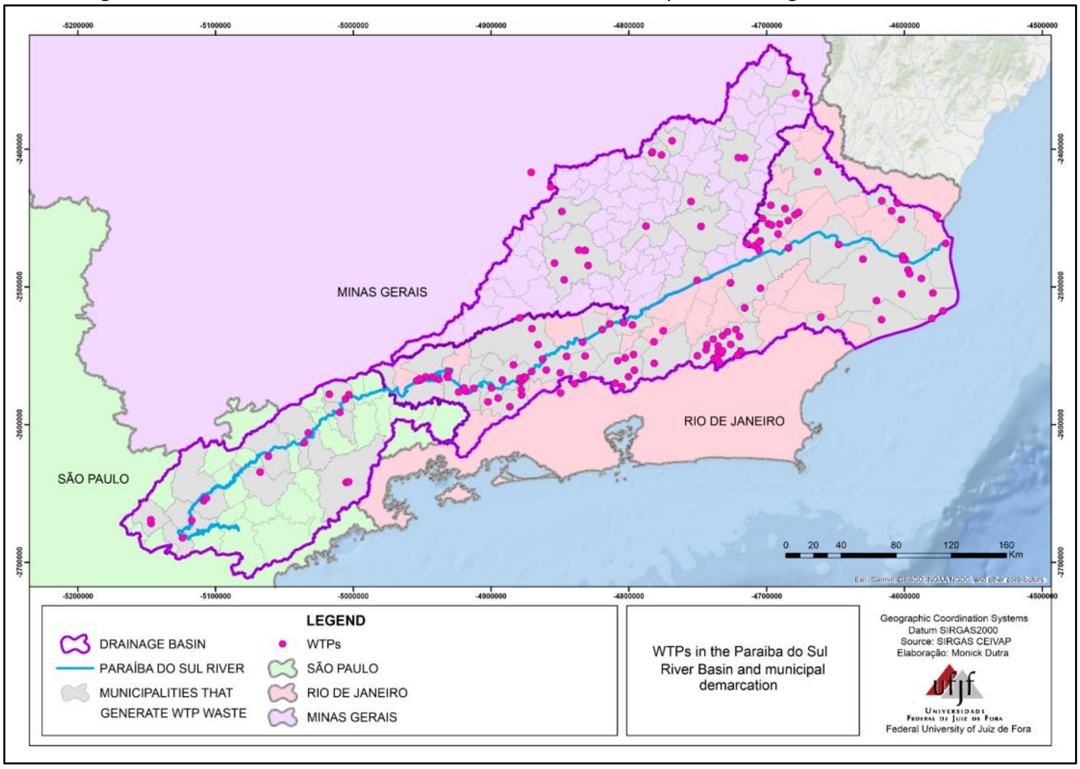
After analysing the data, we identified possible applications for the WTP waste in the municipalities surrounding the Paraíba do Sul River basin. We considered the distance between the WTP and disposal sites as well as the accessibility and applicability for each WTP. Technical, economic, environmental, social, and political aspects of each Water Treatment Plant should be assessed for each applicability, with the main criteria being the distance between the WTP and the disposal site. Finally, it was possible to analyze the reduction of contaminants in bodies of water if the aforementioned disposal options were adopted.

4 RESULTS

After surveying 184 municipalities in the Paraíba do Sul River basin (AGEVAP, 2021), we found 57 with a population higher than 20,000 inhabitants, with 50 generating WTP waste. From these, we located 153 plants, where 117 are in Rio de Janeiro, 20 in Minas Gerais, and 16 in São Paulo as observed in Figure 4.

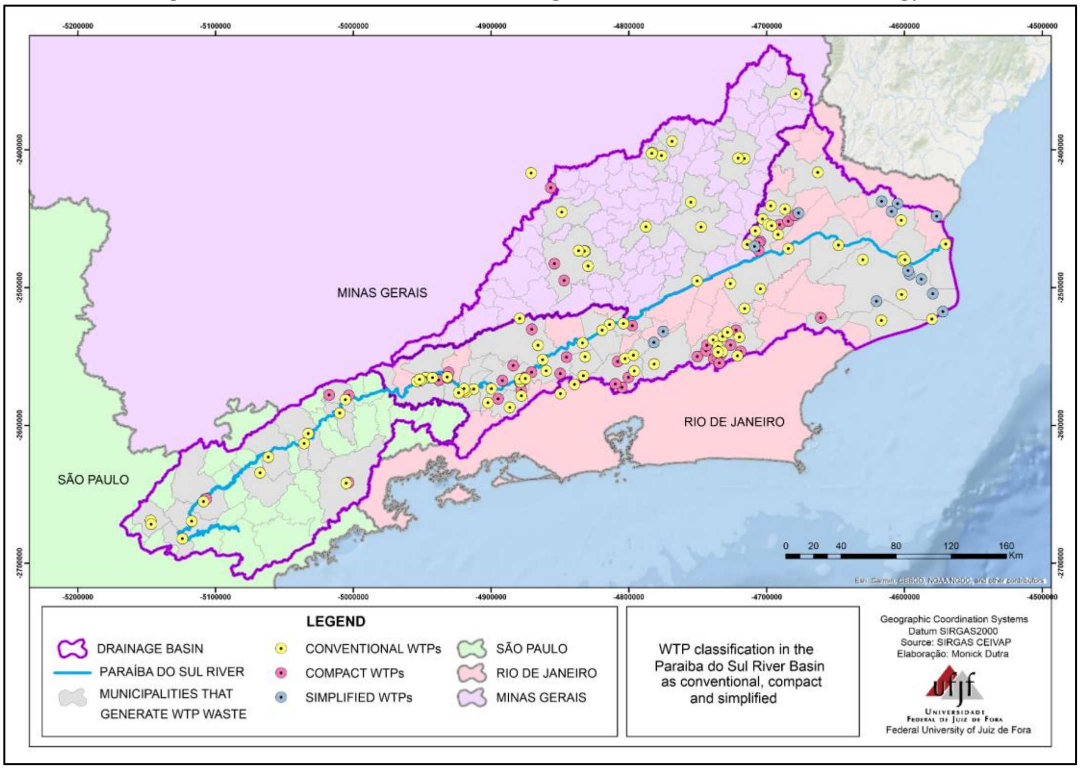
Figure 4 - WTPs in the Paraíba do Sul River basin and municipalities that generate WTP waste.



Source: Authors, 2022.

We classified the WTPs according to the technology employed in the water treatment. 60.14% of WTPs employ the full-cycle technology, generating waste in decanters as well as in filter backwashing. 30.72% of WTPs are compact, utilizing the full-cycle technology or just some units such as fast filtration, flotation, and clarifier. The other 9.14% of WTPs are simplified, with only the chlorination step (Figure 5).

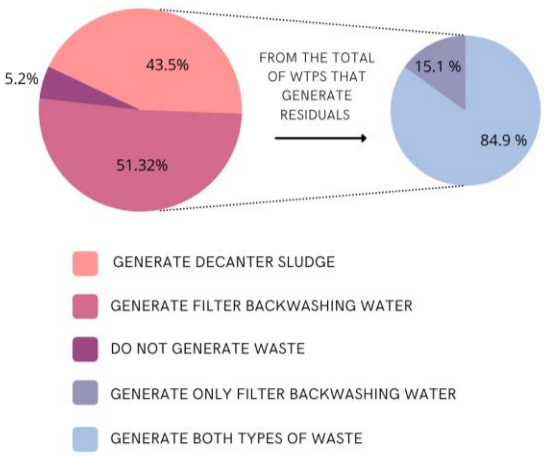
Figure 5 - Classification of WTPs according to their water treatment technology.



Source: Authors, 2022.

Figure 6 shows that, out of 153 WTPs, 139 plants generate some residuals. In Minas Gerais, the 20 analysed plants produce both decanter sludge and filter backwashing water, while Rio de Janeiro has 103 plants producing some waste. In São Paulo, out of 16 WTPs, only one does not generate decanter sludge, whereas all produce backwashing water. Only 9.15% of WTPs do not generate any waste. All of them are simplified plants, performing disinfection and fluoridation, located in Rio de Janeiro.

Figure 6 - Types of WTP waste generated in the basin and its distribution among different states.



MINAS GERAIS: 20 WATER TREATMENT PLANTS

DECANTER SLUDGE	FILTER BACKWASHING WATER	GENERATE BOTH	DO NOT GENERATE WASTE
20	20	20	0

RIO DE JANEIRO: 117 WATER TREATMENT PLANTS

DECANTER SLUDGE	FILTER BACKWASHING WATER	GENERATE BOTH	DO NOT GENERATE WASTE
83	103	83	14

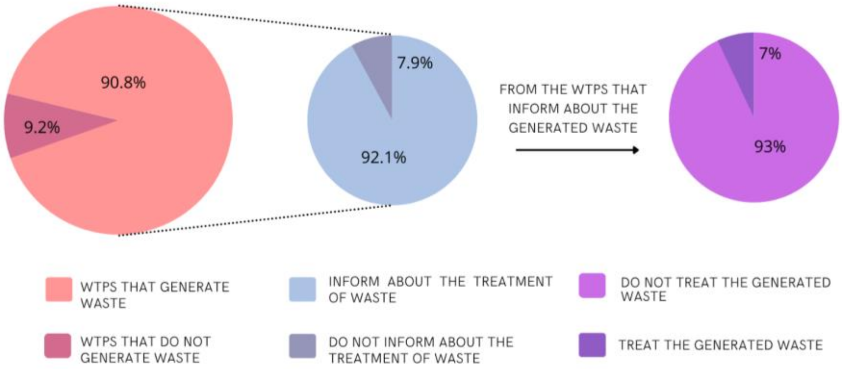
SÃO PAULO: 16 WATER TREATMENT PLANTS

DECANTER SLUDGE	FILTER BACKWASHING WATER	GENERATE BOTH	DO NOT GENERATE WASTE
15	16	15	0

Source: Authors, 2022.

According to Figure 7, out of the 50 municipalities that generate some waste, 42 informed how they manage it, which corresponds to 139 WTPs (92.1%). From those, only 9 plants (7%) treat their waste. The other eight municipalities (14 WTPs or 7.9%) did not disclose whether they perform any treatment or not.

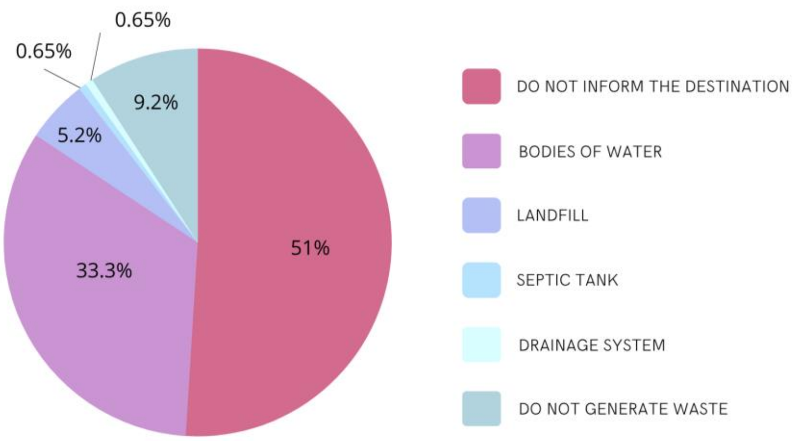
Figure 7 - Information on the numbers of WTPs that generate some waste and whether they treat it or not.



Source: Authors, 2022.

In terms of type of waste treatment, one WTP uses drying beds for sludge dewatering, while seven others employ dewatering bags. One WTP reuses the filter backwash water in addition to a sludge dewatering system, but the exact method was not informed (AGEVAP, 2014). In terms of disposal, eight WTPs dispose their residuals in landfills whereas the others did not declare where their waste is placed after treatment as reported in Figure 8 (AGEVAP, 2014; CEDAE, 2018).

Figure 8 - Disposal sites for waste generated at the basin.



Source: Authors, 2022.

When analysing the entire basin, one notices that more than half of WTPs, generating some waste, do not inform the disposal sites. In addition, most WTPs, which give such information, directly dispose the waste on bodies of water close to their location. The disposed waste is either in its natural form or diluted in water. The residuals disposal in drainage systems was mentioned by one WTP as well as the use of dumping grounds as disposal sites (HABITAT ECOLÓGICO, 2014; FATOR S/A et al., 2019) (Figure 8).

Based on waste production data at the WTPs, we selected four alternative applications to the waste: its reuse in nurseries, ceramic industries, and its disposal in STPs and landfills. From these options, one can select the most cost-effective one. Using the same method to identify WTPs, we mapped 62 nurseries, 61 ceramic industries, 96 STPs, and 11 landfills (Table 2). These locations were marked in the municipalities that are integrated to the Paraíba do Sul River basin whether they generate some waste or not. We also considered the possibility of future investments in the water supply sector.

Table 2: Quantification of nurseries, ceramic industries, STPs, and landfills in the 57 municipalities analyzed around the basin.

Destinos mapeados	RJ	MG	SP	TOTAL
Nurseries	30	19	13	62
Ceramic Industries	61	-	-	61
Sewage Treatment Plants	49	12	35	96
Landfills	05	06	-	11
Total amount of sites in each state	**145**	**37**	**48**	**230**

Source: Authors, 2022.

In São Paulo, we found more options for residuals disposal, with 13 municipalities containing STPs and seven having landfills. In terms of reuse, eight locations could use the waste only in nurseries; no ceramic industry was identified in the region (Table 3).

Although most municipalities around the basin are in Rio de Janeiro, we observed an insufficiency of sewage treatment services, which are present only in seven locations. The number of landfills is also small given the number of places examined, where only five have access to this resource. In terms of reuse, nurseries are in 16 municipalities, whereas ceramic industries are found in six places. It is important to highlight the city Campos dos Goytacazes, an important commercial centre in Brazil, with 56 ceramic industries (Table 3).

As seen in Table 3, Minas Gerais also suffers from sufficient sewage treatment services, present in only 5 of 11 municipalities. In this state, 78.3% of cities have less than 20,000 inhabitants, which contributes to the lack of such services (SPÓSITO AND SILVA, 2013). Similarly, only six locations have landfills. When it comes to waste disposal, eight municipalities have nurseries, and no ceramic industry was located.

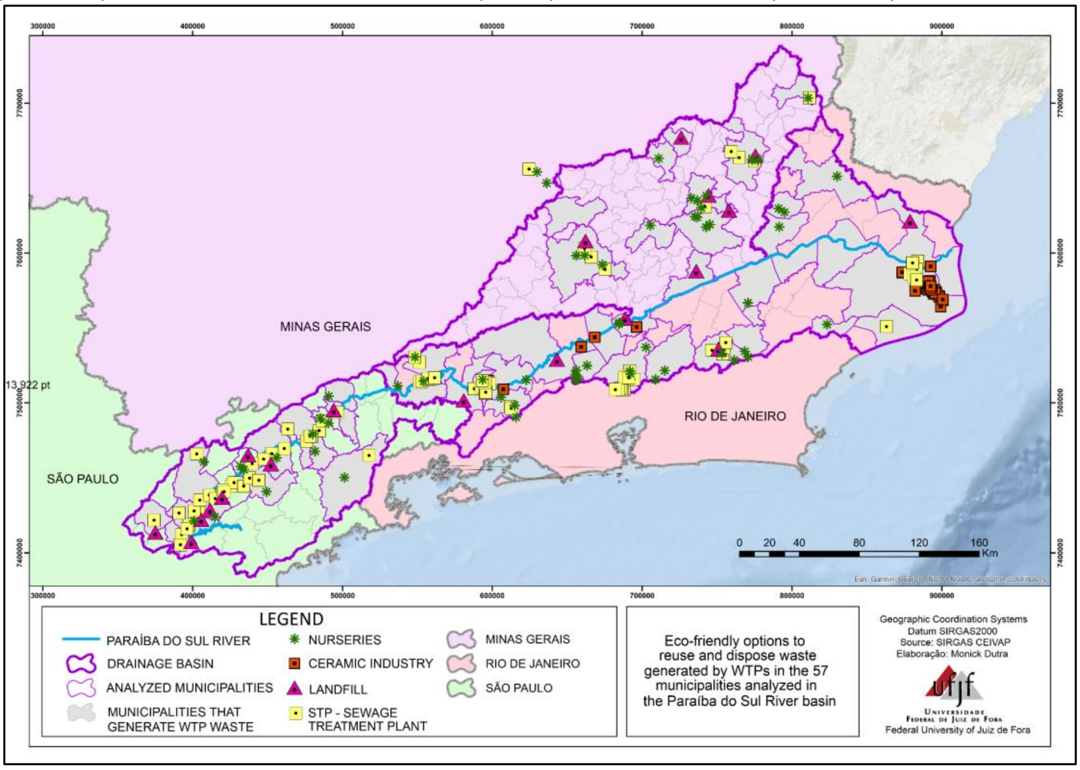
Table 3: Number of municipalities around the basin with disposal sites for WTPs residuals.

Reuse and disposal options	RJ 31 MUN	MG 11 MUN	SP 15 MUN	TOTAL
Nurseries	16	08	08	32 MUN
Ceramic industries	06	-	-	06 MUN
Sewage Treatment Plants	07	05	13	25 MUN
Landfills	05	06	07	18 MUN

Source: Authors, 2022.

Considering the 57 municipalities around the basin, the reuse of WTP waste to grow seedlings in nurseries would be possible in 32 of them. On the other hand, the reuse in ceramic industries would be available only in six places located in Rio de Janeiro. The disposal in STPs and landfills can be implemented in 25 and 18 municipalities, respectively (Table 3) (Figure 9).

Figure 9: Map with the distribution of reuse and disposal options in the 57 municipalities analysed across the basin.



Source: Authors, 2022.

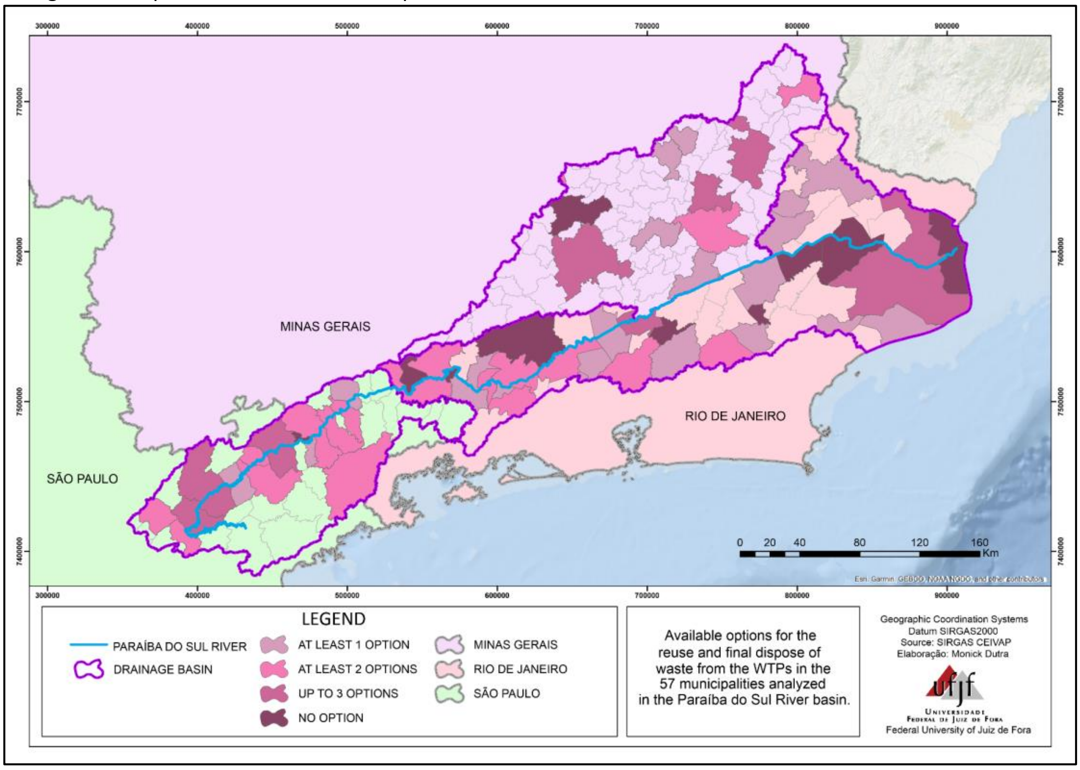
Overall, 46 municipalities could either reuse or adequately dispose the WTP waste using at least one of the options described. Additionally, almost half of the municipalities (26) could use at least two methods and only nine of them have access to at least three. Lastly, 10 locations do not have any option (Table 4) (Figure 10).

Table 4: Number of possibilities to apply WTP residuals in the 57 municipalities analysed across the basin.

Number of possibilities	RJ 31 MUN	MG 11 MUN	SP 15 MUN	TOTAL
No possibility	08	01	01	10 MUN
At least 1	22	10	14	46 MUN
At least 2	09	06	11	26 MUN
At least 3	03	03	03	9 MUN

Source: Authors, 2022.

Figure 9: Map with the distribution of possibilities to use WTP residuals in the Paraíba do Sul River basin.



Source: Authors, 2022.

It is important to notice that STPs and landfills are indispensable to all municipalities and its scarcity lead to inappropriate waste disposal. The reuse of waste in seedling nurseries appears to be a promising alternative given that most municipalities in our study have access to them. On the other hand, few regions have ceramic industries.

For an effective use and implementation of the four aforementioned options, we need to consider two important parameters: distance between sites and transport system. Based on that, we analyzed the best options for the waste disposal in the three states. In Minas Gerais and Rio de Janeiro, the most appropriate sites are seedling nurseries. In São Paulo, however, the STPs are the adequate choice. In addition to the alternatives provided, there are other options such as agricultural soil, recovery of degraded areas, and manufacturing of construction materials (TERTOLINO DA SILVA, 2019). Considering that not all municipalities have the cited options available, this issue becomes even more critical. As a result, 33.3% of WTPs dispose their wastes in bodies of water. This number is likely to be higher as the disposal site for 51% of the WTPs is unknown.

The conservation of water resources improves the efficiency of water supply networks once the conventional treatment improves the effectiveness of impurities removal, and thus water treatment. Pollution issues in some regions of the basin directly affect raw water negatively reflecting on the costs to treat it. Therefore, the lack of treatment of WTP waste and its disposal on bodies of water contribute to worsening water quality. This is mainly due to pathogenic organisms, which increases water treatment costs and biological risk. This affects WTPs that collect downstream water, which is the case for the Paraíba do Sul River basin.

5 CONCLUSION

Residuals generation in the Paraíba do Sul River basin is extremely high as 91% of the WTPs contribute to it, with Rio de Janeiro having 75% of these WTPs. We observed a scarcity in information related to the treatment and disposal of these residuals. More than half of the WTPs did not provide information regarding waste disposal and 33% of them dispose their waste in bodies of water. Only one WTP, in the entire basin, mentioned reuse as part of its waste disposal policy. Therefore, this issue needs to be further addressed.

We conclude that São Paulo presents more disposal and reuse options when compared to the other two states. Around 80% of its WTPs have access to reuse or disposal sites such as nurseries, ceramic industries, STPs, and landfills.

We expect the results herein to bring awareness to mayors and councillors about the adequate reuse and disposal of WTP residuals in the Paraíba do Sul River basin. We suggest future studies on the other cities that integrate the basin to further explore alternatives to WTP waste disposal and reuse.

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