ORIGINAL ARTICLE

Water scarcity in the water supply in Tangará da Serra - MT: analysis of the treatability efficiency of different raw waters

Escassez hídrica no abastecimento de água em Tangará da Serra - MT: análise da eficiência de tratabilidade de diferentes águas brutas

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Abstract

Intense and prolonged droughts can cause several economic and social impacts, such as the interruption of water supply to the population.With the significant impact on the levels of water sources, municipal managers are looking for other alternatives to capture water from a new water source. Therefore, the research, combined with the laboratory tests preceding the treatment, guides the definition of the proper operating conditions of the Water Treatment Plant; in other words, they technically improve and reduce costs. The test in static reactors stands out, what allows the evaluation of the coagulation and flocculation processes and their effects in the following phases of treatment. Thus, the aim of this research was to evaluate the efficiency of the coagulation and flocculation process in the treatment of different raw water for public supply in a medium-sized city in the state of Mato Grosso. Water samples were collected from the Queima-Pé stream and the Sepotuba river during different seasonal periods. The methodology was based on the following steps: preparation of a third sample with a mixture of 50% of the waters; raw water characterization and tests in static reactors. The results emphasize that rainfall influenced mainly in the water colors. Regarding the Sepotuba River, during the drought period, mainly in the months of July, August and September, the turbidity of the raw water proved to be inferior and close to the potability standard established by Brazilian legislation. However, the formation of very fine and small flakes was observed, with moderate color removal efficiency and turbidity reaching a maximum value of 37%, which can be justified by the reduced alkalinity of the raw water. That way, it is recommended to add an alkalizing agent in order to make the treatment more efficient.

Keywords: Water Treatment. Jar Test. Water Mixtures. Potability.

Resumo

Secas intensas e prolongadas podem causar diversos impactos econômicos e sociais, como a interrupção do abastecimento de água à população. Com o impacto significativo nos níveis dos mananciais, os gestores municipais

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estão em busca de outras alternativas de captação de água em um novo manancial. Portanto, as pesquisas aliadas a análises laboratoriais que antecedem o tratamento orientam a definição das condições adequadas de funcionamento da Estação de Tratamento de Água, ou seja, melhoram e reduzem tecnicamente os custos. Destaca-se o teste em reatores estáticos, que permite a avaliação dos processos de coagulação e floculação e seus efeitos nas fases seguintes do tratamento. Assim, o objetivo desta pesquisa foi avaliar a eficiência do processo de coagulação e floculação no tratamento de diferentes águas brutas para abastecimento público em um município de médio porte do estado de Mato Grosso. Amostras de água foram coletadas no córrego Queima-Pé e no rio Sepotuba em diferentes períodos sazonais. A metodologia baseou-se nas seguintes etapas: preparação de uma terceira amostra com mistura de 50% das águas; caracterização de água bruta e testes em reatores estáticos. Os resultados evidenciam que as chuvas influenciaram principalmente a cor da água. Em relação ao rio Sepotuba, durante o período de estiagem, principalmente nos meses de julho, agosto e setembro, a turbidez da água bruta mostrou-se inferior e próxima ao padrão de potabilidade estabelecido pela legislação brasileira. Porém, observou-se a formação de flocos muito finos e pequenos com moderada eficiência de remoção de cor e turbidez, atingindo um valor máximo de 37%, o que pode ser justificado pela reduzida alcalinidade da água bruta. Dessa forma, recomenda-se adicionar um agente alcalinizante para tornar o tratamento mais eficiente.

Palavras-chave: *Tratamento de Água. Jar Test. Mistura de águas. Potabilidade.*

1 INTRODUÇÃO

The impurities present in surface waters might cause diseases, and their removal through water treatment is indispensable to adapt them to drinking standards so that they don't affect negatively the health of the supplied population. Among the various water treatment methods, the 5 stages of water treatment employ the largest number of steps, namely: coagulation, flocculation, decantation, filtration and disinfection (LIBÂNIO, 2010; ENNOUHI et al., 2019; SARMA, 2020).

According to Richter (2009), Juneja and Gangacharyulu (2017), the terms coagulation and flocculation are often used as synonyms, both meaning the process of particle agglomeration. However, coagulation is the process in which the coagulants added to water reduce the forces that tend to keep the suspended particles separate. Flocculation is the procedure of agglomeration of coagulated particles to form larger masses or flakes, in order to allow their sedimentation by gravity.

Ferreira Filho (2017) points out that the knowledge of raw water and the interaction of the coagulant with the suspended and colloidal particles present in the water is essential to enable the operation of the coagulation processes used in the treatment of drinking water, predominantly in the choice of the coagulant, its dosage and definition of the coagulation pH.

Furthermore, it is worth mentioning that climatic and seasonal conditions, anthropogenic activities and natural phenomena that occur in the body of water, from its source, can quickly influence water quality. Thus, the treatment of surface water for public supply requires an instrument that allows agile decisions to modify the dosage of the coagulant to be used in the coagulation process (MROCZKO; ZIMOCH, 2020).

Sharita, Srinivas and Sriknth Vuppala (2017) affirm that insufficient or excessive dosage of coagulant leads to poor treatment performance. Thus, the treatability tests performed in static reactors (jar test) are of high relevance in determining the ideal dosage of coagulant, so that good floc formation occurs for high treatment efficiency.

It is worth emphasizing that in Tangará da Serra - MT an emergency situation was declared in October 2016 caused by drought, and also in November 2020, caused by severe drought and registered as the biggest in the past years, characterizing a shortage of water. Such events have compromised the water supply for human and animal consumption. In this context, municipal managers are looking for another alternative for water collection from a new supply source. This way, the research combined with the laboratory tests preceding the treatment guide the definition of the proper operating conditions of the Water Treatment Plant (WTP); in other words, they technically improve and reduce costs.

Therefore, this work aims to evaluate the efficiency of the coagulation, flocculation and sedimentation processes in the treatment of different waters for public supply in the city of Tangará da Serra - MT. In addition, it analyzes the feasibility of treating the water mixture (1/1) from two sources.

2 MATERIAL AND METHODS

The municipality of Tangará da Serra is located in the state of Mato Grosso, Brazil, located between coordinates 14º04'38''S and 57º03'45''W, with an area of 11,423.04 km² (Image 1).

The raw water samples were collected in the Queima-Pé stream and in the Sepotuba river, in Tangará da Serra, for 11 months. In addition, a third sample was prepared in the laboratory, comprising a mixture in proportion (1/1) of the waters of the Queima-Pé stream and the Sepotuba river.

Prior to the treatability tests, the characterization of the three raw water samples was carried out following the methods specified in Table 1.

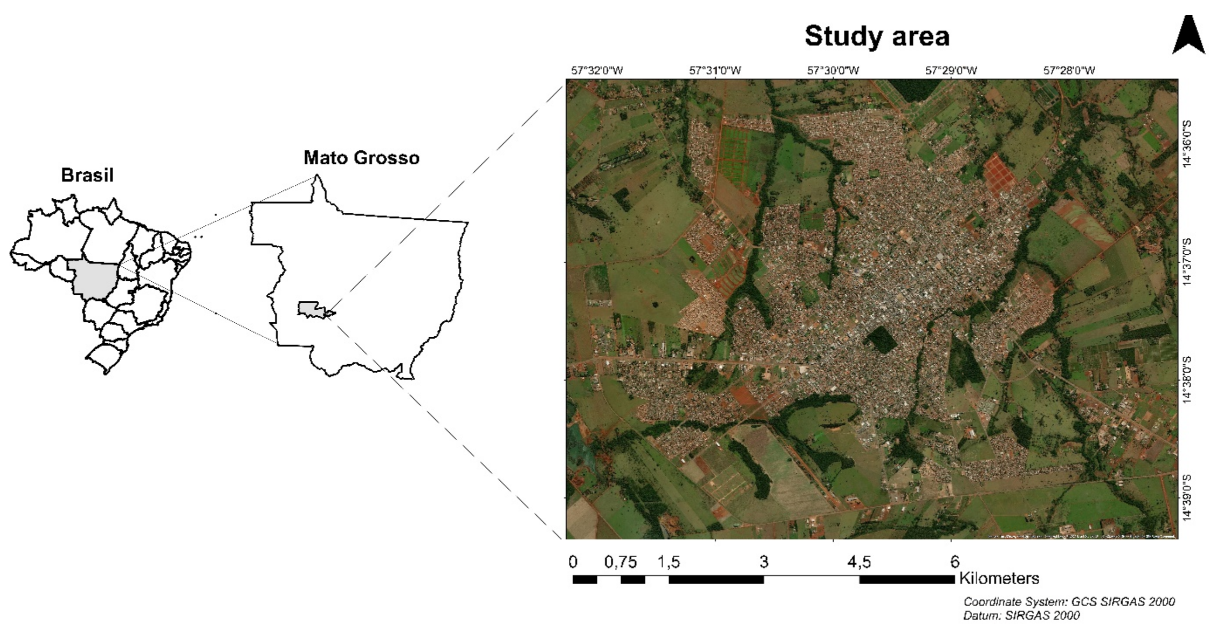

Image 1 - Location of the study area.

Table 1 - Parameters analyzed for raw water characterization.

Parameter	Unit	Methodology/ Equipment
Temperature	ºC	Thermometer Mercury
pH	-	HQ40D Digital multimeter
Apparent color	mg PtCo L^{-1}	Spectrometry/ Spectrophotometer (Hach DR 6000)
Turbidity	NTU	Nephelometry/ Turbidimeter (Hach MD 40)
Electric conductivity	µS cm^{-1}	HQ40D Digital multimeter
Total alkalinity	mg $CaCO_3$ L^{-1}	Titration

In order to verify the treatability of the water, tests were carried out in static reactor equipment, with jar test, using aluminum sulfate (Al2(SO4)3) as a coagulant, since it is used in the Water Treatment Plant of Tangará da Serra. Therefore, the fast and slow mixing times, as well as the agitation speed, were fixed according to the speed gradient, being specified in Table 2:

Table 2 - Conditions adopted for jar test tests.

Process	Time (minute)	Rotations per minute (RPM)	Velocity gradient (s^{-1})
Coagulation	1	180	270
Flocculation	5	70	70
	5	50	40
Sedimentation	15	-	-

The test procedure was carried out in line with proposed by Di Bernardo, Di Bernardo and Centurione Filho (2002). The tested coagulant dosages were between 2 and 40 mg L-1 and pH values between 4 and 10. The following parameters were used as control parameters: pH, apparent color and turbidity.

3 RESULTS AND DISCUSSION

3.1 Raw water characterization

The results of the physical and chemical analysis of the raw water carried out during the rainy and dry periods for the three water samples are shown in Table 3.

Table 3 - Raw water characteristics

Parameter	Unit	Mean ± Standard deviation		
		Queima-Pé Stream	Sepotuba River	Water mixtures
Total alkalinity	mg $CaCO_3$ L^{-1}	25.8 ± 9.5	13.5 ± 7.3	18.5 ± 6.4
Electric conductivity	µS cm^{-1}	37.1 ± 11.8	21.1 ± 7.2	27.7 ± 3.0
Turbidity	NTU	11.2 ± 4.8	9.9 ± 7.1	11.6 ± 4.8
Apparent color	mg PtCo L^{-1}	108.2 ± 47.7	85.4 ± 50.5	101.6 ± 39.3
pH	-	6.8 ± 0.4	6.9 ± 0.4	6.8 ± 0.3
Temperature	ºC	24.8 ± 2.1	25.2 ± 1.6	24.6 ± 1.8

As shown in Table 3, the color presents a greater standard deviation for the three samples, that is, the results showed greater variability in relation to the average obtained. Exemplifying these changes, the color can be influenced by the rainy season, as the increase in precipitation raises the transport of organic and inorganic material drained in the margins of water bodies and, consequently, boosting the amount of dissolved or colloidal substances in the aquatic environment (PIRATOBA; RIBEIRO; MORALES; GONÇALVES, 2017). Still Rocha, Freitas and Silva (2014) and Alencar et al. (2019) state that precipitation influences the flow and also the quality of the water, consequently monitoring the physical, chemical and biological parameters of the water is necessary to properly manage this resource aiming at your knowledge, ensuring its availability and quality.

It is worth mentioning that the excessive variation in the color of raw water may imply in its treatment, that is, with changes in the dosages of coagulants in a way that allows an effective coagulation and flocculation of the particles as well as the frequent cleaning of the filters.

As well as color, turbidity can be easily influenced by the erosion of riverbanks during rains (PIRATOBA et al., 2017). From the standard deviation results, we noted that there is variation in the turbidity of the three water samples; however, it is not so significant. Average turbidity resulted in 11.2 NTU for the Queima-Pé stream and 9.9 NTU for the Sepotuba river and 11.6 for the water mix.

Queima-Pé, Queiroz and Zanini (2017) specifically studied the water quality of the stream, carrying out analysis between the months of July to December 2013 and obtained turbidity results between 17.7 NTU to 23.8 NTU. Thus, the authors highlighted that there is no statistical difference between the data, revealing a pattern of turbidity along the course of the Queima-Pé stream during the two periods. Still Queiroz and Melo (2017), in another study (also in Queima-Pé stream, this time carried out in mid-October 2016), obtained an average turbidity of 19 NTU.

The electrical conductivity was higher in the Queima-Pé stream, resulting in an average value of 37.1 $\mu S\ cm^{-1}$. However, these results are expected for natural and surface waters. Melo, Queiroz, Vinaga and Ferreira (2020), in order to carry out the physical-chemical and biological characterization of the water used for irrigation in the Queima-Pé hydrographic basin, point out that the stream waters and their tributaries are of low salinity, because the results of electrical conductivity were low. Still, the authors found an increase in electrical conductivity along the basin (from source to mouth), indicating the supply of nutrients along the route, which could come from several sources, among them urban (sewage), industrial or agricultural ones.

Regarding the alkalinity, this indicates the number of ions in the water that react to neutralize hydrogen ions, and in surface waters they rarely exceed 500 mg $CaCO_3\ L^{-1}$. So, according to the results obtained, it can be considered low for the three samples. Of the three samples, the Sepotuba river had the lowest average for alkalinity, with 13.5 mg $CaCO_3\ L^{-1}$. Considerably low values, such as 7 mg $CaCO_3\ L^{-1}$ were obtained during the dry period in the Sepotuba river. It should be noted that alkalinity is an extremely important factor in the coagulation and flocculation process, and a minimum amount is necessary to enable the formation of the flakes. According to Eckenfelder (1989), the treatment of water with low alkalinity has been a challenge, as it requires the use and application of an alkalizing agent in order to have an efficient treatment.

The natural pH of the water was relatively constant, with the average value close to neutrality in the three types of raw water. That way, it will probably not be a necessary correction factor, since it is one of the main factors involved in the coagulation process. Di Bernardo et al. (2002) stated that high pH values suggest correction in the coagulation by adsorption / neutralization of charges, because in this mechanism, coagulation with aluminum sulfate usually occurs with a pH less than 6.

As well as the pH, the temperature showed a small dispersion of the results, with an average value of between 24.6 to 25.2 °C for different water samples during the two analyzed periods. This small uniformity of data is positive for the treatment, as according to Di Bernardo and Dantas (2005) the temperature influences the viscosity of the water and, consequently, the reaction speed of the aluminum sulfate during the coagulation process.

In general, analyzing the parameters, the water mixture showed close results between the sample of the Queima-Pé stream and the Sepotuba river, which was already expected, as it is a two-water composition.

3.2 Coagulation diagrams

3.2.1 *Queima-Pé stream*

Image 2 shows the diagrams containing the efficiency of removing turbidity and color as a function of the aluminum sulfate dosage as well as pH for the water samples from the Queima-Pé stream in rainy and dry periods.

Regarding the removal of color during the rainy season (Image 2b), the tests showed that the optimal dosage of coagulant is approximately 17 mg L^{-1}, with a pH close to neutrality and removal efficiency equal to 85%. It was possible to obtain the same removal, with a dosage of 14 mg L^{-1} and a more alkaline pH. Regarding the removal of turbidity (Image 2a), for the dosage of 17 mg L^{-1}, the efficiency is 55%. However, with a pH close to 8, there is an improvement in the efficiency of removing turbidity, with approximately 65%. According to Di Bernardo et al. (2002), at elevated pH, the prevailing coagulation mechanism is sweeping, in which the particles behave as condensation nuclei, being subsequently removed by sedimentation. Although there is a tendency for high turbidity removal to pH above 8, this is not the most viable alternative to the operational routine of a Water Treatment Plant due to the costs of chemicals for pH changes (BARTIKO; JULIO, 2015).

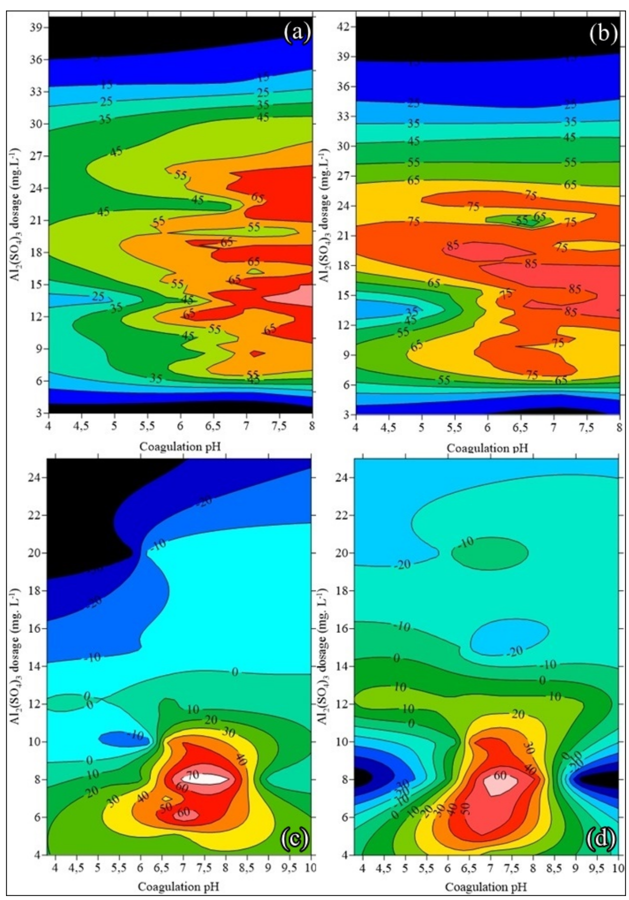

Image 2 - Coagulation diagrams containing the turbidity and color removal efficiency of the Queima-Pé stream.
a) Efficiency of removing turbidity (%) during the rainy season; b) Color removal efficiency (%) during the rainy season; c) Efficiency of removing turbidity (%) during the drought period; d) Color removal efficiency (%) during the dry season.

In view of the results obtained in the tests performed during the dry months (Image 2c, d), it is possible to observe a similarity between the two diagrams, with an optimal coagulation range corresponding to a dosage of aluminum sulfate between 7.5 e 8 mg L^{-1}. This average dosage refers to a pH close to neutrality. efficiency of removing turbidity by 70% and color equal to 60%.

An increase in color and remaining turbidity is observed at the ends of the diagrams (with up to -20% removal efficiency), corresponding to dosages higher than 15 mg L^{-1}. This can be justified by a possible charge reversal, that is, negatively charged particles become positive by adsorption of excess hydrolyzed aluminum ions (YANG et al., 2019), making unable colloid aggregation and increasing the amount of material suspended in water.

Comparing the results of the hydrological periods, for the treatment of water in the Queima-Pé stream, a lower dosage of aluminum sulfate was required for the dry period, with approximately 8 mg L^{-1}, while for the rainy period it resulted in 17 mg L^{-1}. This fact was probably due to the quality of raw water during the drought period, when there is less concentration of solid particles suspended in the water.

3.3 Sepotuba river

Image 3 shows the diagrams containing the efficiency of removing turbidity and color as a function of the aluminum sulfate dosage and pH for the water samples from the Sepotuba river in the rainy and dry periods.

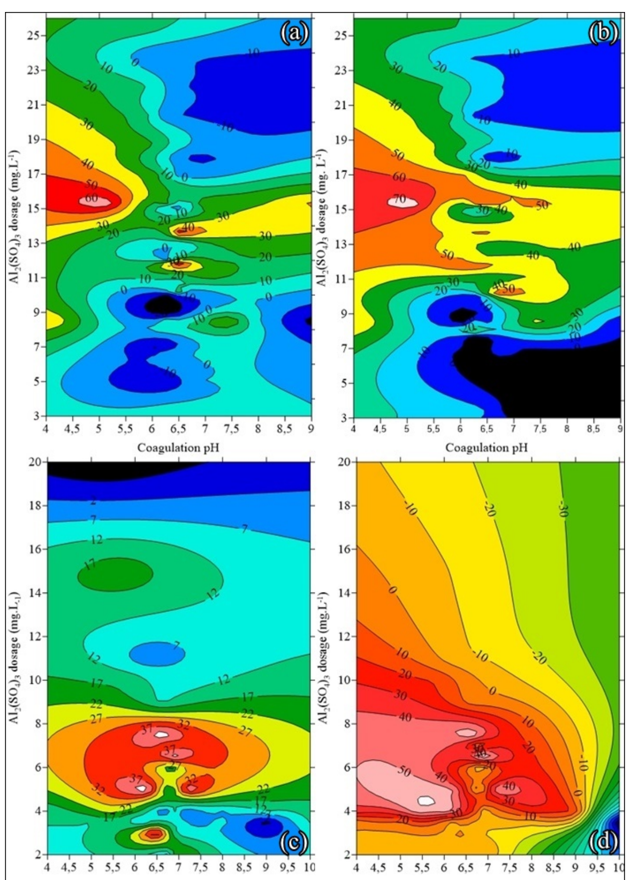

Image 3 - Coagulation diagrams containing efficiency to remove turbidity and color for the Sepotuba river.
a) Efficiency of removing turbidity (%) during the rainy season; b) Color removal efficiency (%) during the rainy season; c) Efficiency of removing turbidity (%) during the drought period; d) Color removal efficiency (%) during the dry season.

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A reasonable similarity between the turbidity and color removal diagram is noticeable during the rainy season (Image 3a, b). Both have good removal efficiency (between 60 and 70%) with aluminum sulfate dosage in the range of 15 to 16 mg L^{-1} and slightly acidic pH (between 4 and 6).

Regarding the drought period (Image 3c, d), the presence of several areas with optimal coagulation bands is noticeable, represented by the lightest color, with neutral pH and aluminum sulfate dosage between 5 to 8 mg L^{-1}. In comparison to the rainy season, there are significant differences in the efficiency of removing turbidity, in which the dry season obtained a value of only 37%. This modest removal rate can be justified by the characteristics of raw water, which showed low alkalinity and turbidity even more reduced during the dry season.

Regarding the removal of color during the dry period (Image 3d), a large part of the diagram represented the increase in color after the treatability tests, and in extreme conditions with a pH equal to 10 there was an increase in the color of the water by 160%.

The reduced gross turbidity for the Sepotuba river observed during this study may justify the not-so-high water clarification efficiency. The initial turbidity interferes with the removal efficiency, since raw waters with higher amounts of solid particles in suspension (without commas) have a high amount of nucleation sites, which gives greater density to the formed flake and, consequently, greater efficiency in sedimentation (BATISTA, FURTADO JUNIOR; FRANCO, 2018).

In addition, another factor that may justify the moderate clarification efficiency as well as the increase in turbidity and color in some situations observed in the diagrams was the sample for the month of February, in which the raw water showed low alkalinity and high apparent color.

According to Beyene, Hailegebrial and Dirersa (2017) when aluminum salts are used as a coagulant, there may be a total consumption of the alkalinity of raw water, requiring the addition of an artificial alkalinity with the application of substances such as hydrated lime or carbonate of sodium to elevate and occur reaction with aluminum sulfate and consequently the formation of flakes.

3.4 Water mixtures

Image 4 shows the diagrams showing the efficiency of removing turbidity and color as a function of the aluminum sulphate dosage and the pH for the mixing of the water in the rainy and dry periods.

In the diagram referring to the rainy season presented in Figure 4 (a, b), it can be seen that for dosages of aluminum sulfate between 9 and 22 mg L^{-1} and pH value between 4 and 7, was found the best removal of turbidity and color. The dosage between 16 and 18 mg L^{-1} and pH between 5.5 and 6 with removal efficiency of 65% and 75% for turbidity and color, respectively. This region corresponds to the combination of scanning and adsorption-neutralization mechanisms, since there is also another region with high efficiency, however, under acidic conditions, corresponding to the adsorption-neutralization mechanism (AMIRTHARAJAH; MILLS, 1982; DI BERNARDO et al., 2002).

Regarding the dry period (Image 4c, d), the maximum removal of turbidity and color (equal to and greater than 60%, respectively) occurred with a coagulant dosage of approximately 7 mg L^{-1} and with natural pH of the raw water and close to neutrality.

It can be said that changing the pH has no benefits for the treatment, as there is an increase in turbidity and color. This can be seen in the diagrams (Image 4c, d) in situations where the pH was adjusted between 4 and 5 and between 9 and 10. In addition to that, it also did not show satisfactory results in removing particles with dosages above 14 mg L^{-1}.

In general, the water mixture showed intermediate results in relation to the sample of the Queima-Pé stream and the Sepotuba river. Then, the composition of this mixture of raw water, for a treatment, does not present significant advantages when compared with the other samples.

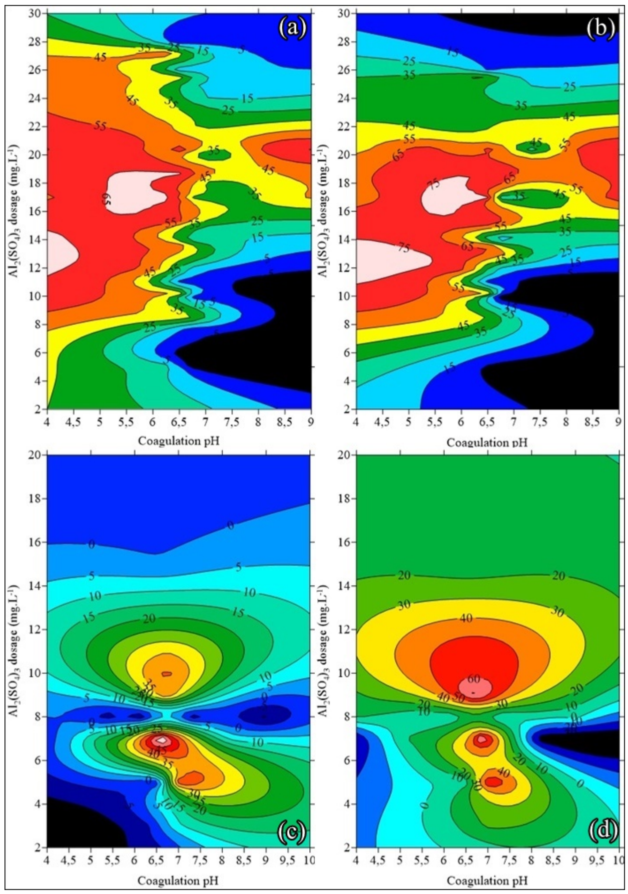

Image 4 - Coagulation diagrams containing turbidity and color removal efficiency for water mixing.
a) Efficiency of removing turbidity (%) during the rainy season; b) Color removal efficiency (%) during the rainy season; c) Efficiency of removing t urbidity (%) during the drought period; d) Color removal efficiency (%) during the dry season.

4 CONCLUSION

The results showed that the three samples of raw water show reasonable qualitative similarity. Regarding the hydrological periods, precipitation influenced, mainly, the color of the samples; during the drought period, there was a slight improvement in water quality.

Specifically, on the Sepotuba River, which would be a source of water for the city of Tangará da Serra during the dry season, during the months of July, August and September, turbidity results were 5.2, 4.2 and 5 NTU, respectively. These results indicate the possibility of a more simplified treatment only during those months, given the low turbidity of the raw water. Thus, treatment with only filtration followed by disinfection can be evaluated by municipal managers in the future.

The elaboration of the coagulation diagrams showed that the Queima-Pé stream has better color removal and turbidity efficiency than the other samples, especially during the rainy season. As we have already elucidated, during some tests of treatability of the water of the Sepotuba river there was the formation of very fine flakes, hindering the flocculation process and consequently having a moderate efficiency of color removal and turbidity. For the water treatment of the Sepotuba river, the addition of alkalizing agents is indicated before the treatment, in order to optimize it, given the low result of the natural alkalinity of the raw water.

In the whole, the mixture did not present a significant advantage, since the dosage of coagulant required for the treatment proved to be close to that of the two waters, consequently, the costs with the acquisition of aluminum sulfate would also be similar.

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6 AUTHORS' CONTRIBUTION

All authors contribute equally.

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