# Design of a hospital laundry effluent clarification system

## Concepção de um sistema de clarificação de efluente de lavanderia hospitalar

## Diseño de un sistema de clarificación de efluentes de lavandería hospitalaria

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**Abstract**
Approximately 20% of the mineral coal ash (MCA) generated worldwide, during the combustion of this fossil fuel, has been used to produce Portland cement. Other applications include soil improvement, ceramic industry, catalysis, and an application with special interest for this work which is the synthesis of zeolites. A hospital effluent clarification system was developed using MCA as an adsorbent for substances responsible for the color of the effluent generated by the laundry. A perfect mix tank promotes intimate contact between MCA and the effluent. At the exit of the mixing tank, a pH sensor correlated the value of this variable with the concentration of MCA in the mixture inside the tank. The information about the pH of the mixture was then sent to a programmable logical controller (PLC), which regulated the motor speed of a screw conveyor, with the aid of a frequency inverter. A color removal efficiency of the order of 99.8% was achieved. The proposed clarification system can operate both in batch and continuous. In the first case, the ideal operating conditions can be set. The strategy for adjusting operating conditions is to obtain an adequate nominal capacity for the system by reducing or increasing the number of cyclones per battery or the number of cyclone batteries.
**Keywords:** Laundry service hospital; Coal ash; Zeolites; Waters clarification; Adsorption.

**Resumo**
Aproximadamente 20% da cinza de carvão mineral (MCA) gerada mundialmente, durante a combustão deste combustível fóssil, tem sido utilizada para a produção de cimento Portland. Outras aplicações incluem melhoramento de solos, indústria cerâmica, catálise e uma aplicação com especial interesse para este trabalho que é a síntese de zeólitas. Foi desenvolvido um sistema de clarificação de efluentes hospitalares utilizando o MCA como adsorvente de substâncias responsáveis pela cor do efluente gerado pela lavanderia. Um tanque de mistura perfeito promove o contato íntimo entre o MCA e o efluente. Na saída do tanque de mistura, um sensor de pH correlacionou o valor desta variável com a concentração de MCA na mistura dentro do tanque. As informações sobre o pH da mistura foram então enviadas para um controlador lógico programável (CLP), que regulava a velocidade do motor de uma rosca transportadora, com auxílio de um inversor de frequência. Foi alcançada uma eficiência de remoção de cor da ordem de 99,8%. O sistema de clarificação proposto pode operar tanto em lote quanto contínuo. No primeiro caso, as condições ideais de operação podem ser definidas. A estratégia para ajustar as condições de operação é obter uma

capacidade nominal adequada para o sistema, reduzindo ou aumentando o número de ciclones por bateria ou o número de baterias de ciclones.
**Palavras-chave:** Serviço hospitalar de lavanderia; Cinza de carvão; Zeolitas; Clarificação de águas; Adsorção.

**Resumen**
Aproximadamente el 20% de las cenizas de carbón mineral (MCA) generadas a nivel mundial, durante la combustión de este combustible fósil, se han utilizado para producir cemento Portland. Otras aplicaciones incluyen la mejora de suelos, la industria cerámica, la catálisis, y una aplicación de especial interés para este trabajo que es la síntesis de zeolitas. Se desarrolló un sistema de clarificación de efluentes hospitalarios utilizando MCA como adsorbente de sustancias responsables del color del efluente generado por la lavandería. Un tanque de mezcla perfecto promueve el contacto íntimo entre el MCA y el efluente. A la salida del tanque de mezcla, un sensor de pH correlacionó el valor de esta variable con la concentración de MCA en la mezcla dentro del tanque. Luego, la información sobre el pH de la mezcla se enviaba a un controlador lógico programable (PLC), que regulaba la velocidad del motor de un transportador de tornillo, con la ayuda de un convertidor de frecuencia. Se consiguió una eficacia de eliminación de color del orden del 99,8%. El sistema de clarificación propuesto puede operar tanto en lote como en continuo. En el primer caso, se pueden establecer las condiciones ideales de funcionamiento. La estrategia para ajustar las condiciones de operación es obtener una capacidad nominal adecuada para el sistema reduciendo o aumentando el número de ciclones por batería o el número de baterías de ciclones.
**Palabras clave:** Servicio de lavandería en hospital; Ceniza del carbón; Zeolitas; Clarificación de aguas; Adsorción.

## 1. Introduction

The reuse of effluent water is a way in which treated water is returned to the process from which it originated. The criteria established for the practice of reuse are mainly based on public health and environmental protection items. The reuse must involve the minimum necessary treatments, the quality standards required by Organs environmental and health surveillance agencies for certain uses and the efficiency required for the treatment. For the reuse of effluents from hospital laundries, the monitoring of the activity that will use the reuse water and the purpose of the reuse must be considered (Khery et al., 2022; Zanetti; et al., 2010). When handling these types of effluents, special care must be taken, and careful monitoring of physicochemical and microbiological parameters must be carried out. The techniques used in the hospital laundry effluent treatment program must ensure that such parameters do not exceed the maximum recommended concentrations.

According to information provided by ANVISA - National Health Surveillance Agency, through personal communication, for the reuse of effluents from hospital laundries, the recommendations of the Health Services Clothing Processing Manual (ANVISA, 2009) must be observed. In addition to reuse in the hospital laundry itself, if the parameters that characterize the water obtained do not meet ANVISA's recommendations, less noble reuse can be made within the institution itself, such as use in toilet flushing, floor washing and other purposes. It appears that there are few works in the scientific literature that have studied the possibility of reusing effluents from hospital laundries, which are generally discharged into sewage collection networks; not recommended practice, since these effluents may contain microorganisms, in addition to compounds from the products used in washing (Hopson, 2022).

The clarification phase in the effluent treatment process is basically composed of 3 (three) steps (Wang; Serventi, 2019): coagulation, flocculation, and decantation. When properly carried out, clarification enables the elimination of particles of organic and inorganic origin in suspension in the water. These particles provide color and turbidity and are formed by colloids and pigments, algae and plant organisms, odor-generating substances of chemical and biological origin, chemical precipitates, and pathogenic microorganisms. It begins with coagulation, an operation in which chemical products, called coagulants, are added, which when reacting reduce the forces that tend to keep the suspended particles separate. As the suspended material does not easily separate from the water, an attempt is made to destabilize the colloidal material through the addition of ions having a charge opposite to those of these particles, which are generally anionic. This causes them to aggregate, forming floccules (flocculation), and are separated from the aqueous phase by physical processes of sedimentation and filtration (Lima et al., 2022).

To adapt industrial liquid effluents to the standards established by current legislation, many tertiary effluent treatment programs have been developed for new, more specific removal mechanisms for persistent contaminants. Among these technologies, the zeolitic microstructures of some materials have stood out due to their adsorption and ion exchange properties. Zeolites are microporous crystalline hydrated aluminum silicates whose structure corresponds to three-dimensionally arranged polymers (Liu; et al., 2019). They are composed of tetrahedral structures of the TO4 type (where T = Si, Al, Fe, P, Co, ...) joined at the vertices by oxygen atoms. This microporous structure allows mass transfer between the crystalline space and the external environment. However, this transfer is limited by pore diameters. It is, therefore, due to this characteristic that Zeolites are called molecular sieve, that is, they can retain molecules by adsorption.

The synthesis of zeolites is conventionally carried out by alkaline hydrothermal treatment, which is why some MCA's do not require this procedure to exhibit zeolitic properties as they already receive this type of treatment to reduce the sulfur content – at the request of cement industries. Thus, a MCA with a pH above 11.5 has zeolitic properties and can be used for effluent clarification (Novais et al., 2019). The use of MCA as a clarifying substance for hospital effluent allows a large solid environmental liability to be used for the benefit of the environment itself.

## 2. Methodology

### 2.1 Correlation of mixture properties with MCA concentration

This study was carried out in a laboratory, where the potential of coal ash, obtained after hydrothermal treatment, to be used as an adsorbent in the removal of color from an effluent from a hospital laundry of a hospital located in the Agreste region of Pernambucano, Brazil, was quantitatively analyzed (Zahoor, 2022; Bisht et al., 2021).

To better understand the characteristics of the hospital laundry effluent, physical-chemical and bacteriological analyzes of the effluent entering and leaving the effluent treatment plant (ETP) were carried out. The methodology followed to carry out these analyzes was as follows: Standard Methods for the Examination of Water and Wastewater (APHA, 1985).

To identify any property that correlates MCA with its adsorbent power, experiments were carried out using a synthetic effluent, a dye solution of methylene blue at a concentration of 5 $mg.L^{-1}$. Two experiments were carried out to verify the efficiency of MCA in removing the color of the effluent. In the first experiment, 6 125 mL Erlenmeyer flasks were used, one containing the control solution (c. sol.), which consists of a dye solution of methylene blue at 5 $mg.L^{-1}$, and the others the dye solution added at concentrations of 10 (A1), 20 (A2), 30 (A3), 40 (A4) and 50 (A5) $gL^{-1}$ of MCA. The volume of dye solution worked was 25 ml. The pH of the solutions was checked after shaking in the shaker. All tests were performed in triplicate. In the second experiment, 5 125 mL Erlenmeyers were used, one containing the control solution, and the others the dye solution added at concentrations of 5 (A1), 10 (A2), 15 (A3) and 20 (A4) $gL^{-1}$ of MCA. The worked volume was also 25 mL. The pH of the solutions was checked after shaking in the shaker, as for the conditions containing MCA, it was checked after shaking. All tests were performed in triplicate (Balji et al., 2022; Eteba, et al., 2021).

The experimental solutions were shaken in a shaker, at 250 rpm, 31°C, 10 min, previously defined in mixing time tests. The solutions were transferred to Falcon tubes to carry out centrifugation to separate the liquid phase from the solid phase, the conditions were as follows, 5,000 rpm, 10 min and 23°C. 2.0 mL aliquots of the solutions were also collected to verify the absorbance (Abs) in a spectrophotometer programmed at 660 nm. Before reading the equipment, the aliquots were centrifuged under the following conditions, 9,000 rpm, 5°C, 6 min. The calculation to verify the color removal efficiency (E%) was done as follows:

$$E\% = \frac{c.sol.(Abs) \times sample(Abs)}{c.sol.(Abs)} \times 100 \quad (1)$$

Were:

E% - Color removal efficiency

*c.sol.(Abs)* – Control solution absorbance

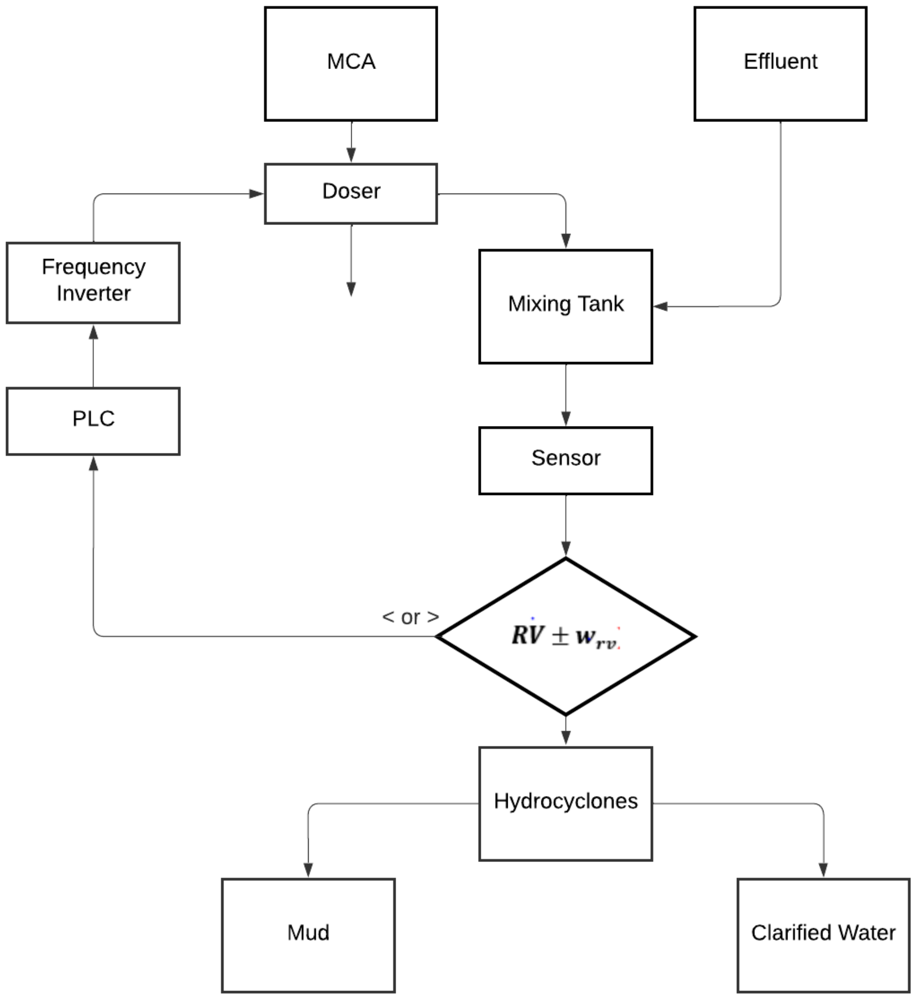
*sample(Abs)* – Sample absorbance

**2.2 Components of a clarification system with hydrocyclones**

The operation of the wastewater clarification system must be since it should be verified, experimentally, that the effluent clarification efficiency varies with the concentration of MCA, and that in turn this concentration of MCA within the perfect mixture provides a variation in the value of some property of the mixture inside the tank. Thus, said property must be correlated with the concentration of MCA (g.L-1) inside the mixing tank with optimized dimensions (minimum mixing time). The Figure 1 illustrates the configuration preliminarily proposed for the referred clarification system. A sensor of the identified property, installed at the outlet of the mixing tank, monitors the response due to the addition of MCA inside the tank, as it was sized based on perfect mixing conditions (Triwibowo, et al., 2018). From this information a transducer transmits the information to the PLC circuit. In turn, the PLC transmits to a frequency inverter, responsible for the rotation speed of the motor of a helical conveyor, obtaining a new adsorbent feed rate (MCA) for the mixing tank.

The system employs hydrocyclones because it is a separator equipment without moving parts, with high solid-liquid separation efficiency and simple operation. The system configuration in terms of the number of hydrocyclones, per battery, will depend on the desired operating conditions and in terms of flow rate per hydrocyclone battery (Lamskova et al., 2019).

**Figure 1 -** Flowchart for designing a hospital effluent clarification system using MCA.




Were: $W_{RV}$ – uncertainty of response variable. Source: Prepared by the autors (2021).

### 2.3 Test of toxicity

For the toxicity test, the microcrustacean Artemia sp. test organisms used in the ABNT NBR 16530:2016 standard and in several studies (Diaz-Sosa et al., 2020; Da Fontoura et al., 2020; Cavion et al., 2020; Ianna et al., 2020). The experiment was repeated with the MCA working with a volume of 50 mL of synthetic effluent. The tested solutions were obtained from a mixture of synthetic effluent, dyeing solution of methylene blue at 5 mg·L-¹, with MCA at four different concentrations (5(A1), 10(A2), 15(A3) and 20(A4) gL-¹). The control solution of the experiment, also known as positive control (C+), was the dye solution of methylene blue at 5 mg·L-¹. As the test was performed in triplicate, the total volume obtained for each solution was 150 mL. The reference control (C) of the experiment was the solution with sodium dodecyl sulfate ($NaC_{12}H_{25}SO_4$) at 100 mg·L-¹.

The determined working volume for the toxicity test was 20 mL. Then, for conditions A1, A2, A3, A4, C+ and C, dilutions were prepared with sea water, working with 100, 50, 25, 12.5 and 6.25% of each solution. For the test, nauplii with 48 hours of life were collected. The test was done in triplicate. The count of individuals who survived and who died was made at 24 and 48 hours. The results were analyzed using the ANOVA test. The assessment of acute toxicity (CL50) was performed for C, C+, and for conditions A1 and A4.

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## 3. Results and Discussion

### 3.1 Hospital laundry efluente characteristics

The results of the physicochemical and bacteriological analyzes of the hospital laundry effluent are illustrated in Tables 1a, 1b, 2a and 2b. As can be seen in Table 1b and Table 2b the value of the apparent color parameter, which refers to the determination of color in samples with turbidity (with colloidal material or in suspension), was 12 at the entrance to the ETP and 10 at the exit of the ETP , that is, there was a reduction of only 2 in apparent color. Therefore, the implementation of an effluent clarification system is justified, enabling these waters to be reused in the hospital clothing cleaning process itself, or if it does not meet ANVISA's recommendations, a less noble reuse of these waters can be done, using -those in toilet flushing, floor washing and other purposes.

**Table 1a -** Bacteriological analysis of effluent from the entry point of the ETP.

| REHEARSAL | RESULT | REFERENCE VALUE (MAV)[1] |
|---|---|---|
| TOTAL COLIFORMS | ABSENT | ABSENCE IN 100 mL |
| *Escherichia coli* | ABSENT | ABSENCE IN 100 mL |
| HETEROTROPHIC BACTERIA | 153 UFC.mL$^{-1}$ | STANDARD COUNT UP TO 500 UFC.mL$^{-1}$ |

[1]MAV – Maximum Allowed Value. Source: Prepared by the autors (2021).

**Table 1b -** Physicochemical analysis of the ETP entry point.

| REHEARSAL | RESULT | REFERENCE VALUE (MAV) |
|---|---|---|
| pH | 7.60 | 5.0 – 9.0 |
| TEMPERATURE | 23.2 ºC | < 40.0 ºC |
| TURBIDITY | 1.54 | < 5.0 µT[1] |
| ORGANIC LOAD | - | - |
| APPEARING COLOR | 12 | < 15 µH[2] |
| FLOW RATE | - | - |
| TOTAL ALKALINITY (mg/L in $CaCO_3$) | 0.00 | - |
| CHLORIDE (mg/L in Cl) | 300.00 | < 250.00 |
| COPPER (mg/L in Cu) | 0.00 | < 2.00 |
| BIOCHEMICAL OXYGEN DEMAND (BOD) 5/20ºC | 201.00 mg.L$^{-1}$ | - |
| CHEMICAL OXYGEN DEMAND (COD) | 236.40 mg.L$^{-1}$ | - |
| TOTAL HARDNESS (mg/L in $CaCO_3$) | 100.00 | < 500.00 |
| TOTAL IRON (mg/L in Fe) | 2.04 | < 0.30 |
| MANGANESE (mg/L in Mn) | 0.04 | < 0.10 |
| TOTAL OILS AND GREASES | 97.34 mg.L$^{-1}$ | < 20 mg.L$^{-1}$ |
| SULFATE (mg/L in $SO_4$) | 181.74 | < 250.00 |
| SEDIMENTABLE SOLIDS (SD60) | 0.50 mL.L$^{-1}$ | < 1.0 mL.L$^{-1}$ |
| TOTAL SUSPENDED SOLID | 244.00 mg.L$^{-1}$ | - |

[1] µT – Turbidity Value. [2]µH – Microhenry. Source: Prepared by the autors (2021).

**Table 2a -** Bacteriological analysis of the ETP exit point.

| REHEARSAL | RESULT | REFERENCE VALUE (MAV)[1] |
|---|---|---|
| TOTAL COLIFORMS | ABSENT | ABSENCE IN 100 mL |
| *Escherichia coli* | ABSENT | ABSENCE IN 100 mL |
| HETEROTROPHIC BACTERIA | 9 $UFC.mL^{-1}$ | STANDARD COUNT UP TO 500 $UFC.mL^{-1}$ |

Source: Prepared by the autors (2021).

**Table 2b -** Physicochemical analysis of the ETP exit point.

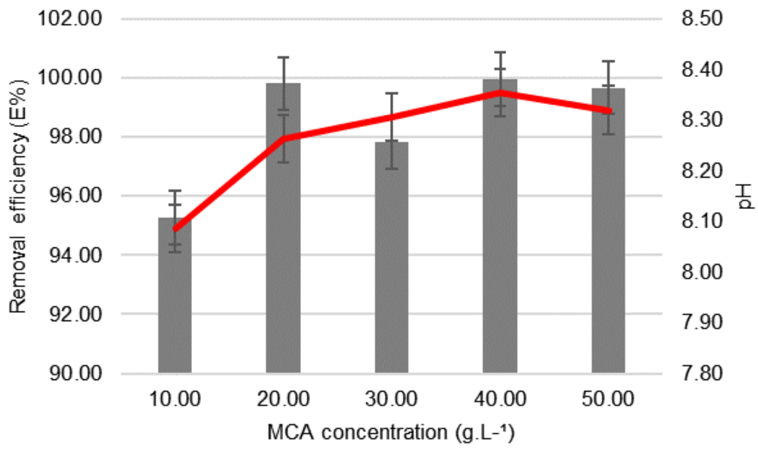
| REHEARSAL | RESULT | REFERENCE VALUE (MAV) |
|---|---|---|
| pH | 6.60 | 5.0 – 9.0 |
| TEMPERATURE | 23.1 ºC | < 40.0 ºC |
| TURBIDITY | 0.09 | < 5.0 µT[1] |
| ORGANIC LOAD | - | - |
| APPEARING COLOR | 10 | < 15 µH[2] |
| FLOW RATE | - | - |
| TOTAL ALKALINITY (mg/L in $CaCO_3$) | 120.00 | - |
| CHLORIDE (mg/L in Cl) | 180.00 | < 250.00 |
| COPPER (mg/L in Cu) | 0.00 | < 2.00 |
| BIOCHEMICAL OXYGEN DEMAND (BOD) 5/20ºC | < 2.00 $mg.L^{-1}$ | - |
| CHEMICAL OXYGEN DEMAND (COD) | 25.30 $mg.L^{-1}$ | - |
| TOTAL HARDNESS (mg/L in $CaCO_3$) | 160.00 | < 500.00 |
| TOTAL IRON (mg/L in Fe) | 0.20 | < 0.30 |
| MANGANESE (mg/L in Mn) | 0.12 | < 0.10 |
| TOTAL OILS AND GREASES | 51.34 $mg.L^{-1}$ | < 20 $mg.L^{-1}$ |
| SULFATE (mg/L in $SO_4$) | 90.26 | < 250.00 |
| SEDIMENTABLE SOLIDS (SD60) | < 0.10 $mL.L^{-1}$ | < 1.0 $mL.L^{-1}$ |
| TOTAL SUSPENDED SOLID | < 10.00 $mg.L^{-1}$ | - |

Source: Prepared by the autors (2021).

### 3.2 Response variable as a function of MCA concentration

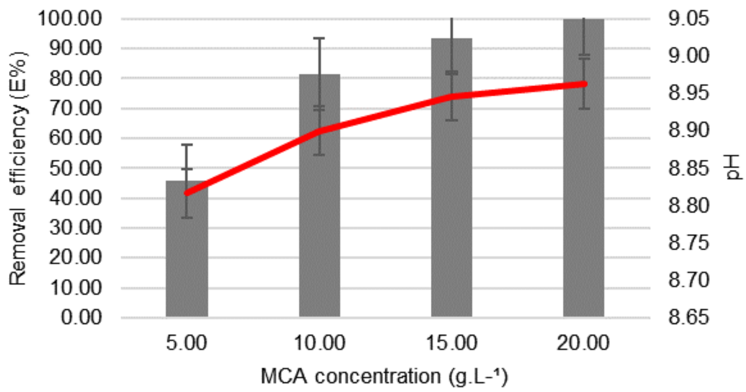
During the experiments to clarify the effluent tested, a considerable variation in the pH of the effluent-MCA mixture was observed. As pH is a variable in which there are sensors and transducers for monitoring and reporting through PLC-type circuits, such variations were the focus of observations during the experiments. Figure 2 and Figure 3 show correlations between MCA concentration (g.L-1), clarification efficiency (*E*%) and pH of the mixture from experiments 1 and 2. The clarification efficiency could also be monitored. However, depending on the type of effluent, this variable could present correlation difficulties, as it would depend on the type of contaminant present in the mixture. It is observed in that table that up to the dosage of 20 g.L-1 the pH measurements can be discriminated as a function of the measurement uncertainty. From this value, the calculated uncertainties do not allow a distinction to be made between concentration levels above 20 g.L-1. Fig. 2 and Figure 3 show the bar graphs with indication of uncertainties, demonstrating the possibility of using pH monitoring to dose MCA in the mixing tank. Note that at the concentration of 20 $g.L^{-1}$ the color removal efficiency reaches values close to 100%. Soon there was a need to study the removal efficiency working with lower values of CCM concentration. Then, a new experiment was carried out where CCM concentrations were tested at values of 5, 10, 15 and 20 $g.L^{-1}$.

**Figure 2 -** Behavior of pH and Clarification Efficiency as a function of MCA concentration in experiment 1.




Source: Prepared by the autors (2021).

**Figure 3 -** Behavior of pH and Clarification Efficiency as a function of MCA concentration in experiment 2.




Source: Prepared by the autors (2021).

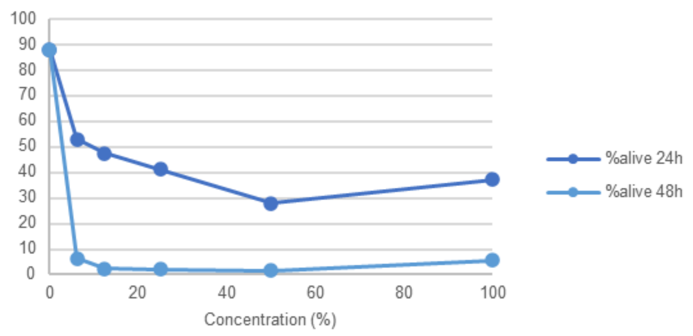
In experiment 2, lower concentrations of MCA were worked. As can be seen in Figure 3, with only 5 $g.L^{-1}$ of CCM the color removal efficiency value was 45.67%. With 10 $g.L^{-1}$, the efficiency was 81.38%. At the concentration of 20 $g.L^{-1}$ the efficiency reached values very close to 100%, 99.86%. It is possible to notice a correlation between the concentration of MCA and the pH of the solutions.

With the definition of the pH response variable to control the MCA dosage, a block flowchart was used as a second step to define the automation and control strategies for the clarification system.

### 3.3 Analysis of the toxicity test

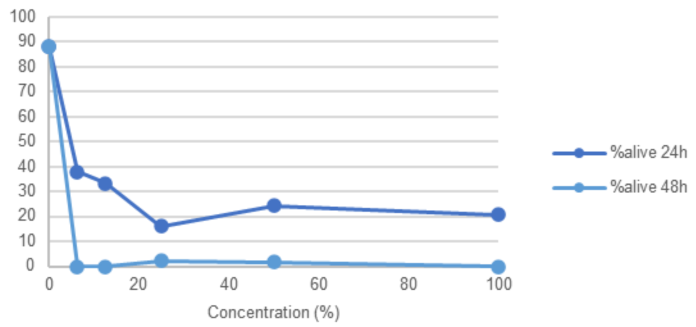
Based on the data collected in the toxicity test with Artemia sp, the ANOVA test was performed to compare the relationship between conditions A1, A2, A3 and A4 with 100% concentration within 24 hours, the sample results showed a significant difference in relation to the percentage of individuals who survived, with value (p=0.003225), as shown in Figures. 4, 5, 6 and 7.

**Figure 4 -** Relation of the concentration of solution A1 with the percentage of survival at 24h and 48h.




Source: Prepared by the autors (2021).

**Figure 5 -** Relation of the concentration of solution A2 with the percentage of survival at 24h and 48h.




Source: Prepared by the autors (2021).

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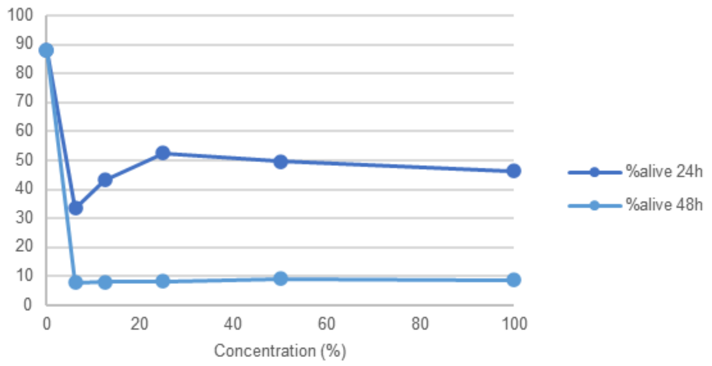
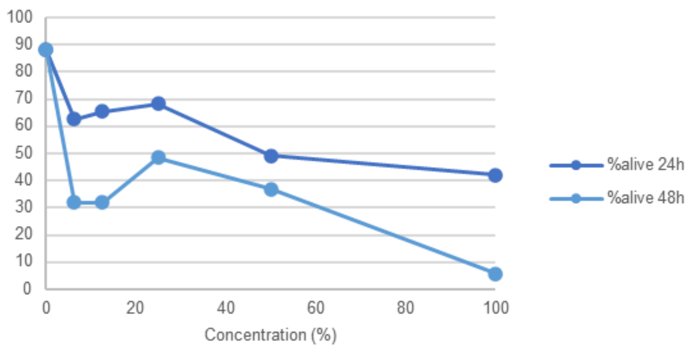
**Figure 6 -** Relationship of the A3 solution concentration with the percentage of survival at 24h and 48h.




Source: Prepared by the autors (2021).

**Figure 7 -** Relationship between the concentration of the A4 solution and the percentage of survival at 24h and 48h.




Source: Prepared by the autors (2021).

The relationship between the solutions in concentration at 6.25% within 24 hours also showed a significant difference in relation to the percentage of individuals who survived, with value ($p=0.006038$). When comparing the toxicity values, it is possible to notice that there was a reduction in the level of toxicity from the treatment with coal ash.

Sample A1, a solution with a CCM concentration of 5 $g.L^{-1}$, showed a reduction in toxicity when compared to the positive control and the reference control. In sample A4, solution with the greatest amount of ash, 20 $g.L^{-1}$, there was a greater reduction in the level of toxicity, as can be seen in Figures 8, 9, 10 and 11. The assessment of acute toxicity (LC50) for sodium dodecyl sulfate (100 $mg.L^{-1}$) of 10.84 $mg{\cdot}L^{-1}$. The control solution (C+) showed a level of toxicity twice as much low. The solution with a concentration of MCA 5 $g{\cdot}L^{-1}$ (A1) showed a level of toxicity twice as low as the control solution, whereas the solution with a concentration of MCA 20 $g{\cdot}L^{-1}$ (A4) had a toxicity level four times lower than the control solution. Thus, it is concluded that the treatment with the application of coal ash reduced the toxicity levels of the solutions.

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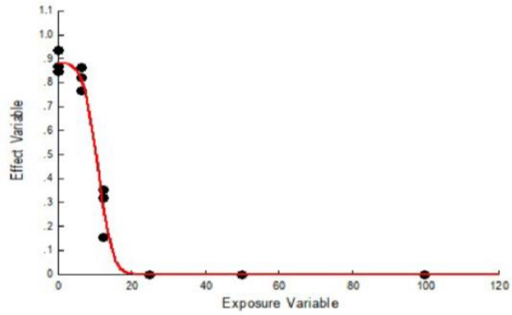
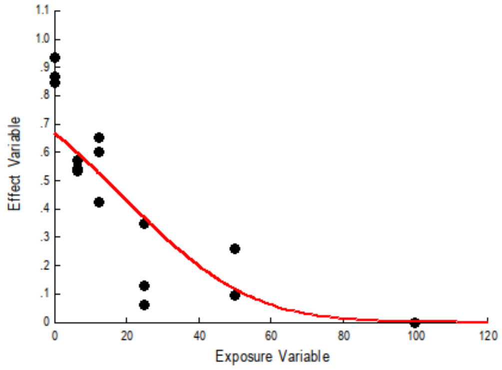
**Figure 8 -** Relation of the toxicity of sodium dodecyl sulfate (100 mg.L$^{-1}$).



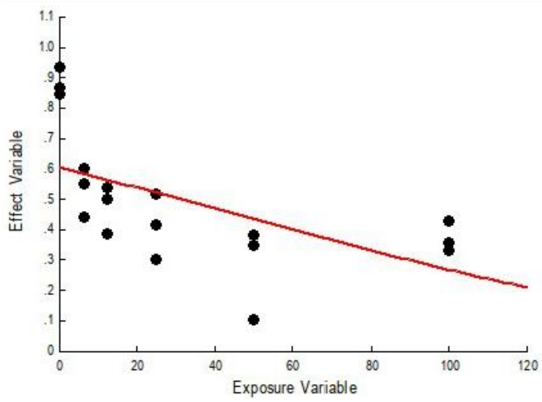

Source: Prepared by the autors (2021).

**Figure 9 -** Relation of the toxicity of control solution (C$^{+}$).



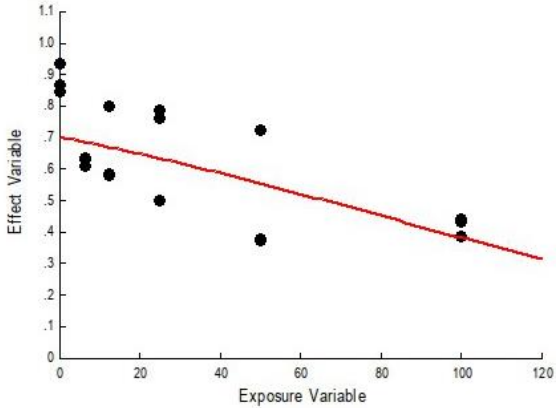

Source: Prepared by the autors (2021).

**Figure 10 -** Relation of the toxicity of the A1 solution (5 g.L$^{-1}$ of MCA).




Source: Prepared by the autors (2021).

**Figure 11 -** Relation of the toxicity of the A4 solution (20 g.L$^{-1}$ of MCA).

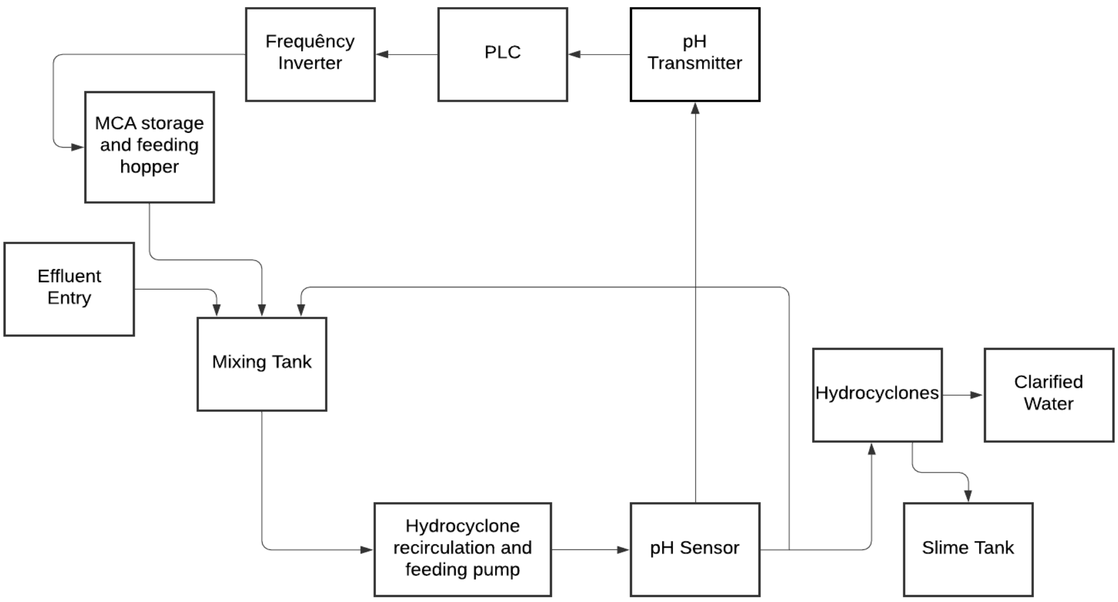



Source: Prepared by the autors (2021).

### 3.4 Strategies for control and automation of the hospital effluent clarification process using CCM

The Figure 12 illustrates the afore mentioned block diagram, which indicates the pH information for manipulating the control variable (CCM) of the effluent clarification process. The starting point of the treatment is 1. inlet of the effluent, which will be passed to a 2. mixing tank, where the effluent will be mixed with the ash and then the 3. pH measurement, which from a 4. PLC system, will give the command to start, maintain, increase or decrease the ash dosage in the mixing tank, in order to obtain the best pH of the solution, to, then, be pumped to the 5. hydrocyclone system and thus obtain the 6. clarified water. The sludge generated in the hydrocyclone system will be sent to a 7. slime tank.

**Figure 12 -** Block diagram for control strategies and automation of the hospital effluent clarification process using CCM.

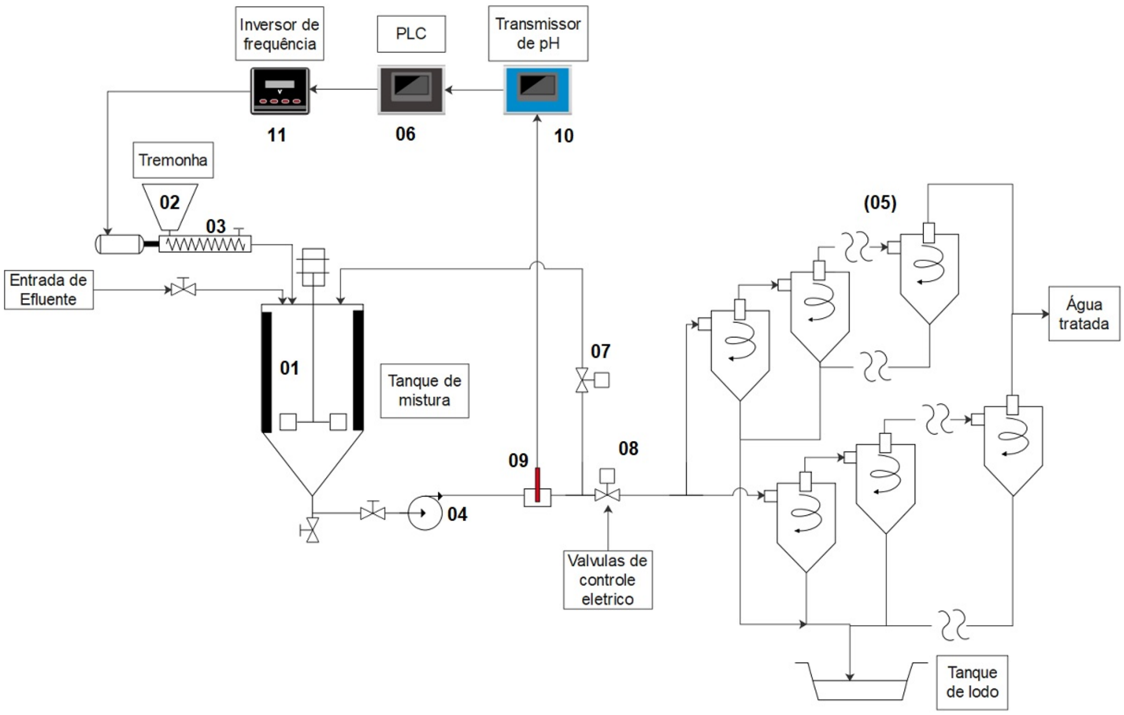



Source: Prepared by the autors (2021).

### 3.5 Hospital efluente clarification system

The efluente clarification system of Figure 13 is presented a process flowchart preliminarily predicted by the block diagram of Figure 12. The basic components of that system are: i) 01 solid-liquid mixing tank (01); (ii) 01 hopper for storage and feeding of MCA (02); (iii) 01 helical conveyor (Popescu; Necula, 2019) for CCM dosage (03); (iv) 01 recirculation pump and hydrocyclone feed (04); (v) 02 hydrocyclone batteries arranged in parallel, each with said separators in series (05); (vi) 01 PLC (06) for controls (Dewanto et al., 2019) of the speed of the MCA metering helical motor and the opening of the return valves and for the mixing tank (07) and hydrocyclone feed (08) ; (vii) 01 pH sensor (09) (Manjakkal et al., 2019); (viii) a pH sensor signal transmitter for the PLC (10) (Yin et al., 2019); (ix) 01 frequency inverter for motor speed control for the MCA dosing helicoid (11) (Yin et al., 2019).

**Figure 13 -** Flowchart of the hospital effluent clarification process using MCA.




Source: Prepared by the autors (2021).

The effluent clarification system varies with the concentration of MCA (up to about 20 g.L-1) inside the mixing tank, whose MCA dosage is controlled by the pH value detected by the sensor at the output of the mixing tank. From this information, a pH signal transducer transmits such information to a PLC, which in turn informs the frequency inverter, responsible for the rotation speed of the screw conveyor motor, and a new MCA feed rate is adjusted to the tank of mixing.

The system can be tested in a discontinuous condition according to the degree of efficiency of liquid-solid separation for which it was adjusted (Svarovsky, 2000). This can be achieved by adjusting the PLC to open one valve and close another, allowing the pump discharge to return to the mixing tank.

The system employs hydrocyclones because it is a separator equipment without moving parts and has high solid-liquid separation efficiency. The system configuration in terms of the number of hydrocyclones per battery will depend on the desired operating conditions in terms of flow rate per hydrocyclone battery (Lamskova et al., 2019).

## 4. Conclusion

MCA subjected to treatment to reduce the level of emission of polluting gases by the gas desulphurization technique (Flue Gas Desulphurization – FGD) was successfully used to clarify hospital laundry effluents. Treatment with MCA also reduced effluent toxicity levels. The strategy of using pH to monitor clarification efficiency, controlling the mass flow of MCA dosing in the mixing tank, gave rise to a system of high efficiency, simple operation and minimizing costs. Furthermore, a large environmental liability such as MCA can allow expenditure on chemical products and commercial zeolites to be replaced by effluent treatment using sustainable techniques.

As suggestions for future work, the construction of the proposed prototype is recommended to optimize the operating conditions of the system. It is recommended to install a thermostat in the mixing tank for temperature control. As well as the development of techniques to synthesize zeolites in ash that has not received FGD-type treatment. In both cases, the lifetime and forms for the synthesis and regeneration of the synthesized zeolites must be evaluated.

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