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The Role of Coagulation-flocculation in the Pretreatment of Reverse Osmosis in Power Plant

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ABSTRACT

The objective of this work is to simulate pretreatment steps on a laboratory scale with the purpose of producing a higher quality permeate for feed reverse osmosis process. Pretreatment steps involved in this work are a combination of physical and chemical processes, such as coagulation-flocculation, sand filtration, and microfiltration. Samples of seawater next to Itaqui thermoelectric power plant in Maranhão, State of Brazil, powered by coal, were collected and characterized. The characterization indicated high levels of turbidity, which is unusual for seawater, indicating the need of pretreatment to reverse osmosis. The combination of polyaluminum chloride dosages of 30 mg/L and 0.3 mg/L of Nalclear 8,173 anionic polymer allowed the reduction of turbidity values to below 1 Nephelometric Turbidity Unit (NTU). The use of coagulation and microfiltration membranes provided values of silt density index next to 3, while with sand filter, the silt density index values were higher than 4.

KEYWORDS

Reverse osmosis, Salinity, Coagulation, Desalination, Membranes, Microfiltration.

INTRODUCTION

Brazilian thermoelectric plants account for about 30% of the national energy matrix and require a significant amount of water, mainly for the steam cycle and cooling systems, reaching 1,843 m^3/h/MW of water [1]. Water treatment is an integral part of the generation of electric power (coal-fired thermoelectric plants). There are two cycles

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associated with thermal energy generation, the steam/water cycle, which uses demineralized water for the production of steam and the cooling water system, which is used to condense the steam back into liquid form. The two cycles are isolated from each other and exchange heat through a condenser [2]. Therefore, thermoelectric plants demand significant quantities of water for their full operation. However, throughout the world, water scarcity is being recognized as a present and also a future threat to human activity. A trend of development of alternative water resources, such as desalination of sea water is observed [3].

Currently, the two most commonly used desalination technologies are thermal distillation and Reverse Osmosis (RO) [4]. Distillation is a process in which salts are removed from water by evaporation and condensation [5]. For this process, the cost of energy can be up to 2 to 3 times higher than the operation cost of the RO treatment [3].

RO is another technology for desalination process [5]. It can reject almost all of the colloidal or dissolved matter from an aqueous solution, producing a stream of concentrated brine and a permeate stream consisting of almost pure water [6]. Although it is used to concentrate substances, its most frequent use is in desalination applications [7].

RO presents itself as a promising alternative for desalination of seawater or brackish water, suiting its quality for use as water makeup in boilers, cooling towers and reuse in industrial processes, reducing the consumption of drinking water [8].

One of the major problems in desalination operations is fouling which adversely affects separation performance. It leads to decline in permeate flow and quality [9], and an increase in operating pressure over time [7, 10].

The Itaqui thermoelectric power plant is the first Eneva project in Maranhão, State of Brazil. Located in the São Luis Industrial District and powered by coal, the plant has been in commercial operation since February 2013, with a capacity to generate 360 MW of electric power. Seawater is used as water source for Itaqui thermoelectric power plant after treatment process, which includes coagulation-flocculation steps, multimedia filter, cartridge filter and RO. However, the cartridge filter system is replaced several times throughout the year, generating a cost for the process, in addition to the fact that osmosis membranes have a shorter operating life than the one projected due to the presence of aluminum silicates attacking its structure, and the silt density index to feed RO membrane is between 4 and 5, being necessary to lower to less than 3.

Proper pretreatment of the RO feed stream minimizes the occurrence of scaling on the membranes and helps to maintain permeate flow and ensure membrane life [11].

From the aspects of chemistry and contaminants in seawater, coagulation is an essential pretreatment for RO [12]. The main function of coagulation is to prevent RO membrane from the deposition of particulate matter [6]. Coagulation can be used as a method for the removal of many substances that cause turbidity, including oils [13], clays [14], and microorganisms [15]. Usually, coagulation is followed by sedimentation. Conventional sand filtration may be used as polishing step to remove the remaining solids after the sedimentation step. Coagulation-flocculation prior to sedimentation [16] or filtration [17] has shown good results in the removal of colloids [18], reducing the potential of membrane incrustation [19]. The choice of pretreatment depends on the feed water quality [17]. Pretreatment along with innovative technological strategies, such as Microfiltration (MF) or Ultrafiltration (UF) with conventional techniques (coagulation, filtration, etc.), have been studied [20].

MF guarantees low Silt Density Index (SDI) value for the feed water of the RO process, even with a substantial fluctuation of the raw water quality [20], allowing a high and stable permeate flow even in long term operation [18].

Since MF inherently capable of removing more foulants than media filtration, the inclusion of coagulation in the treatment train is expected to surpass the performance of conventional pretreatment [20].

MF may be competitive to granular media filtration based on costs and performance when designed appropriately and operated by well-trained staff [21]. There is no study about MF with Maranhão (State of Brazil) seawater, which presents distinct characteristics from other seawaters. Maranhão has many variations through the day on the tide [22]. Maranhão tide variation is the world's third major one, consequently this seawater presents high turbidity and dissolved organic carbon. Because of these facts, the thermoelectric plant undergoes several operational problems in RO membrane, needing an appropriate pretreatment. Thus, the study of this area comes to contribute to the dissemination of knowledge.

The objective of this work is to simulate pretreatment steps on a laboratory scale in order to produce a higher quality permeate for RO process. Pretreatment steps involved in this work are combination of physical and chemical processes, such as coagulation-flocculation, sand filtration, and MF.

MATERIALS AND METHODS

In November 2015, seawater samples were received from the Itaqui thermoelectric power plant, located in Maranhão State, São Luis industrial district, Brazilian northeast (Figure 1). Seawater was sampled during low and high tide. The volumes obtained were 150 L of the seawater at low and high tide. The characterization of the samples and the preliminary treatment were carried out in the Laboratory of Water Treatment and Effluent Reuse (LabTare), located in the School of Chemistry, Federal University of Rio de Janeiro (RJ).

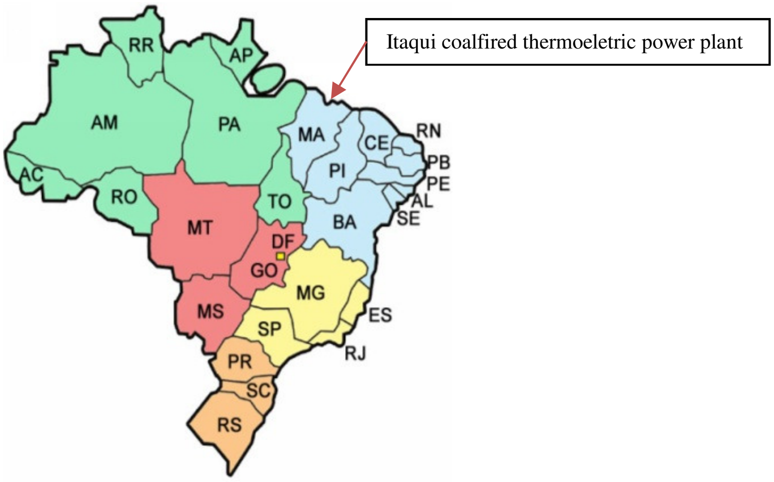


Figure 1. Itaqui localization

Characterization

The samples were characterized in accordance with the procedures laid down in APHA methods [23]. The Total Solids (TS) and Suspended Solids (SS) were determined by gravimetric analysis. The turbidity was evaluated with the aid of a turbidimeter Poli Control-AP 2000. The conductivity and pH were determined by the potentiometric method, while the alkalinity analysis was performed using a titrimetric method. The free and total residual chlorine, color, silica reactive and aluminium were obtained with the aid of a HACH DR 2800 spectrophotometer. The Dissolved Organic Carbon (DOC) was determined using a Vario TOC Cube Analyser by Elementar. Sodium, potassium, calcium, magnesium, chloride, sulfate and total hardness were estimated by liquid chromatography (930 Compact IC Flex 1). The oil & grease was determined by the spectrophotometric technique in the Infrared region using the Infracal TOG/TPH, model HATR-T, brand Wilks Enterprise.

Coagulation-flocculation

Coagulation tests were carried out with the coagulant polyaluminum chloride (PACl, Al_2O_3 – 18% m/m) because it is used in the industrial unit and has been widely used in water and wastewater treatment to remove contaminants. Also, it does not consume much alkalinity when added in the water and consequently causes little variation in pH [24].

Ferric chloride ($FeCl_3$) is commonly related as coagulant in most studies for seawater [16-19], but the residual Fe could cause much danger to thermoelectric plants. The water used for steam boilers must not contain residual iron, because the presence of hydrogen and oxygen causes corrosion [25].

The experiments were conducted in a jar test to evaluate the effect of pH, coagulant and flocculant polymer concentrations on turbidity. No prefilter was used.

The jar test with six beakers containing 500 mL of sample were performed at the same operational conditions of Itaqui power plant, such as: fast stirring speed = 100 rpm, fast stirring time = 1 minute, slow stirring speed = 40 rpm, slow stirring time = 15 minutes, sedimentation time = 20 minutes, with the coagulant concentrations of 20, 30, 40, 50, 60 and 70 mg/L, and the flocculant polymer concentrations of 0.1, 0.2 and 0.3 mg/L. The supernatant were collected and characterized by turbidity after the sedimentation time.

The assays to evaluate the effect of pH on clarification were conducted adding 60 mg/L of PACl. The pH of the samples was corrected to 5.0 to 10.0 range, using 0.1M sulfuric acid or 10% sodium hydroxide solution, the assays to evaluate the effect of coagulant concentration on clarification were conducted adding PACl at a concentration ranging from 20 to 70 mg/L. Coagulation was evaluated through the turbidity measurements of the clarified sample, where the goal was to reach turbidity values below 5 NTU, the assays to evaluate the effect of flocculant polymers on clarification were conducted with the polymers anionics Nalclear 8173, Magnafloc LT 27 and polymer cationic Nalco 8110, varying their concentration from 0.1 to 0.3 mg/L. The use of auxiliary flocculation polymers was to increase the efficiency of the process by evaluating its turbidity at the end of the Jar test. The flocculation polymer was added in slow stirring time. The optimal conditions of clarification were defined to the next experiments. Clarified samples were tested individually on sand filtration and MF. Tests of SDI_{15} were realized after coagulation-flocculation, after coagulation-flocculation + sand filtration and after coagulation-flocculation + MF to analyse the quality of water.

Sand filter

This experiment was conducted to mimic the real process where the coagulation/flocculation is followed by any type of filtration, e.g. multimedia filter, cartridge filter. The column was packed with dry sand over two supporting layers. The lower layer was glass wool and the other one was gravel to support the sand.

After establishing the optimal conditions of clarification, the samples were filtered through a sand column with a mean particle size of 1.00 mm, using a peristaltic pump with an operating flow of 0.1 L/min, a bed diameter of 2.8 cm and a height of 57 cm. The sample filtered will be tested on RO.

Microfiltration

After establishing the optimal conditions of clarification, microfiltration with MF KTM-618 (Koch) flat membrane was performed with pore size of 0.1 μm at 1 bar in individual short time tests. Until the permeate flux was stabilized, no backwash was done.

The planar membranes form a “plate and frame” configuration, i.e., they are arranged in parallel, spaced apart by spacers and porous supports. The cross flow filtration in flat membrane module is a viable option for testing in laboratory scale, since after its use the membrane can be discarded and replaced, and presents lower cost than the spiral module [26].

The assay was carried out with samples after selecting the best coagulation-flocculation conditions. The study aimed to evaluate the quality of the permeate in comparison to the sand filtration process. Figure 2 shows the MF system used in the permeation assays. It consisted of a power tank with the capacity of 5 L, current rectifier, rotor, manometer, thermometer, flow indicator and gear pump. The sample filtered will be tested on RO.

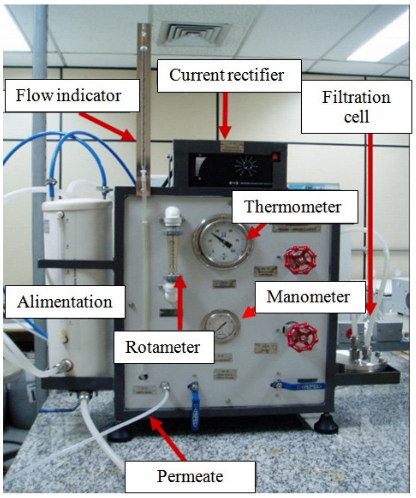


Figure 2. MF system

Reverse Osmosis

Samples from sand filtration and MF were tested individually on RO system in short-time tests. The RO test was performed with a BW30-4040 (Dow) flat membrane at 35 bar with cross flow filtration and 50% recovery rate. Until the permeate flux was stabilized, no backwash was done. Figure 3 shows the RO system using permeation assays. The RO unit consisted of a power tank of a capacity of 10 L, with capacity of operation up to 40 bar.

Figure 3. RO system

RESULTS

All the characterizations and experiments showed below were realized in triplicate at controlled temperature of 298 K.

Characterization of raw seawater

Table 1 shows that little variability was observed in the vast majority of parameters analyzed independently of day and tide. Parameters most influenced by the day and tide are turbidity and solids, which exhibit a close relationship between them. It is observed that there are no significant variations in Total Dissolved Solids (TDS) that are related to the presence of dissolved salts. However, there are significant variations in Total Suspended Solids (TSS) and turbidity that are related to the presence of suspended solids.

The degree of turbidity in raw water can be classified into four classes: low-turbidity (less than 50 NTU), medium turbidity (50-100 NTU), high turbidity (100-200 NTU) and very high turbidity (greater than 300 NTU) [27]. The characterization indicated high levels of turbidity, which is unusual for seawater, indicating the need of pretreatment to RO.

Table 1. Characterization of raw seawater samples collected during the high and low tide (SD – standard deviation in 5 samples)

Parameters	Unit	Sample			
		High tide		Low tide	
		Values	SD	Values	SD
Condutivity	[mS/cm]	45.72	0.13	46.04	0.1
Turbidity	[NTU]	124	2	135	1
Silica	[mg/L]	3.47	0.16	3.54	0.04
Silicium	[mg/L]	3.7	0.1	4.7	0.1
Apparent color	[CU]	288	6	235	3
Real color	[CU]	24	2	60	10
Salinity	[%]	35.1	0.6	31.2	0.9
Freechlorine	[mg/L]	0.12	0	0.13	0.04
Total chlorine	[mg/L]	0.13	0.03	0.26	0.03
Alkalinity	[mg/L]	116.3	1.2	119.3	1.2
TS	[mg/L]	33,008	1,163	35,556	1,251
TSS	[mg/L]	317	28	328	38
TDS	[mg/L]	32,691	1,626	35,228	1,551
pH	[-]	7.42	0.03	7.32	0.02
DOC	[mg/L]	6.1	0.3	4.3	0.2
Aluminium	[mg/L]	0.023	0.001	0.02	0.002
Sodium	[mg/L]	10,929	180	10,804	198
Potassium	[mg/L]	441	32	418	25
Calcium	[mg/L]	368.4	28.3	369.1	38
Magnesium	[mg/L]	1,253.7	47	1,264	14.7
Chloride	[mg/L]	19,430	314	19,297	498
Sulphate	[mg/L]	1,883.2	40	2,402.1	20
Hardness	[mg/L $CaCO_3$]	6,073.6	100.4	6,117.8	144.8
Oils & Greases	[mg/L]	0.65	0.05	0.6	0.05

Particulate fouling generally refers to fouling by suspended particles in water. Particulates make up the primary source of the TSS and turbidity constituents in a water quality analysis. If not removed in the pretreatment process, particulate fouling will build up as a physical occlusion on the membrane surface and feed spacer. Particulate fouling is most severe in the lead RO elements in the pressure vessels. This type of fouling is usually easily mitigated by improving the coagulation/flocculation/filtration steps in the pretreatment system. The mechanism of particulate fouling is well understood relative to the other types of fouling [28].

Coagulation-flocculation

Coagulation results are shown in Figure 4 which indicates the desired target of turbidity below 5 NTU. The samples showed turbidity below 5 NTU at pH 5. Experiments to evaluate the influence of pH on coagulation were investigated in this moment only when 60 mg/L PACl was added to observe the course of turbidity decay. Therefore, it was decided not to perform pH adjustment in the future Jar Test, due to satisfactory results with the original pH of the raw sea water samples, that is between 7 and 8 on both tides, besides the fact of using a dispersant in later stages of RO, whose performance is impaired above pH 7.8.

The coagulation is also affected by other factors like salinity, total organic carbon, alkalinity and temperature of the treated water. Inorganic coagulants like ferrous sulfate, ferric chloride and aluminum sulfate (alum) are acid salts. Their addition to the treated water will result in decrease of the pH of this water. To counteract this decrease in pH, an alkali must be added [29]. But PACl did not consume much alkalinity when added in the raw water and consequently caused little reduction in pH.

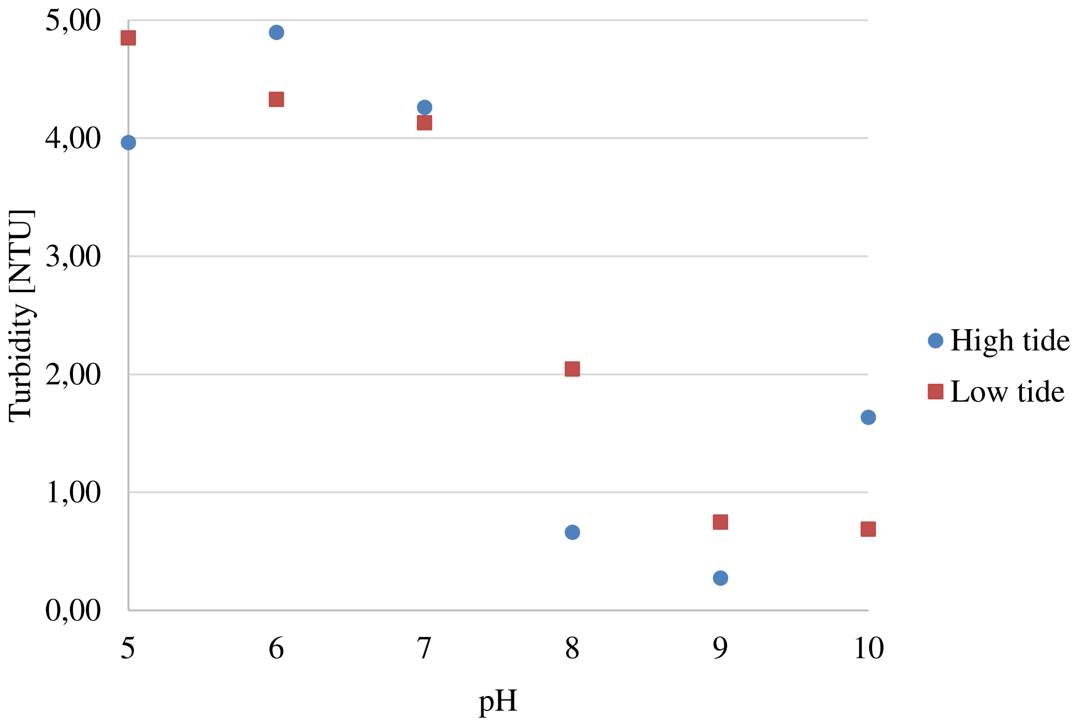


Figure 4. Effect of pH on the turbidity of the samples (dosage of 60 mg/L PACl)

Many other factors may influence the coagulation process, but two factors are considered the most important: coagulant dose and the coagulation pH [29]. Figure 5 shows the results found varying the dosage of PACl. It is observed that with low dosages of PACl, like 20 or 30 mg/L, it is possible to obtain values of turbidity under 3.0. Al species of PACl possesses high positive charge and it has the great capacity for charge neutralization [24]. However, as the PACl dosage increases, the turbidity increases indicating disruption on the phenomenon of destabilization of charges in the solution [30]. It is not possible to establish a direct relationship between the initial turbidity value and the best PACl concentrations.

Failure to adjust the coagulant concentration may lead to too high residual metal content as well as reduced filtrate quality levels. Increasing the coagulation dose may lead to increasing the operating cost, increasing the amount of sludge produced, short filter runs and reduced alkalinity [29].

Aluminium or iron based coagulants that do not form flocs are not soluble and will form preflocs which attach to any surface to neutralise its charge. This includes multi-media filters, cartridge filters and ultimately the membrane surfaces as well [31].

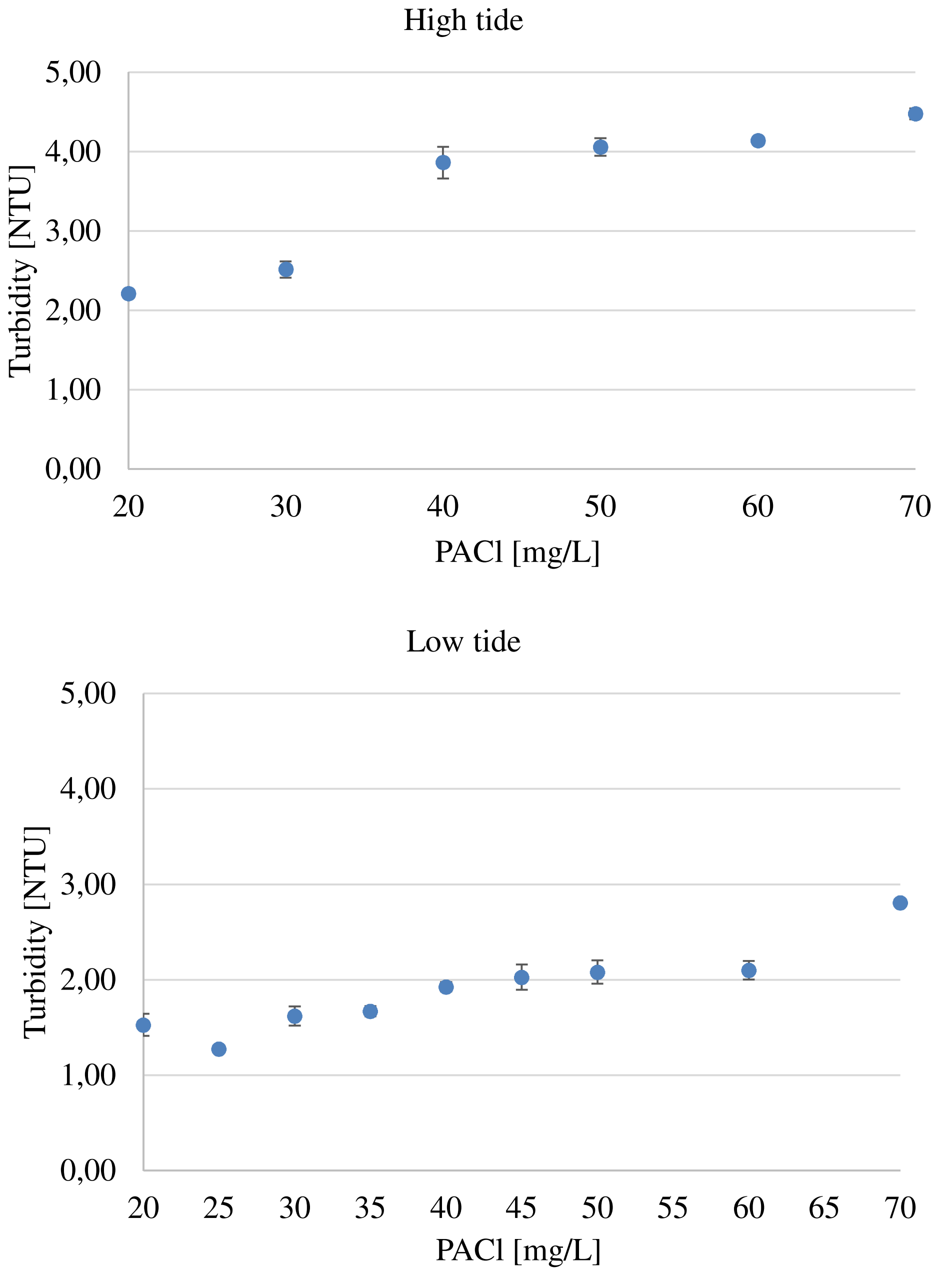
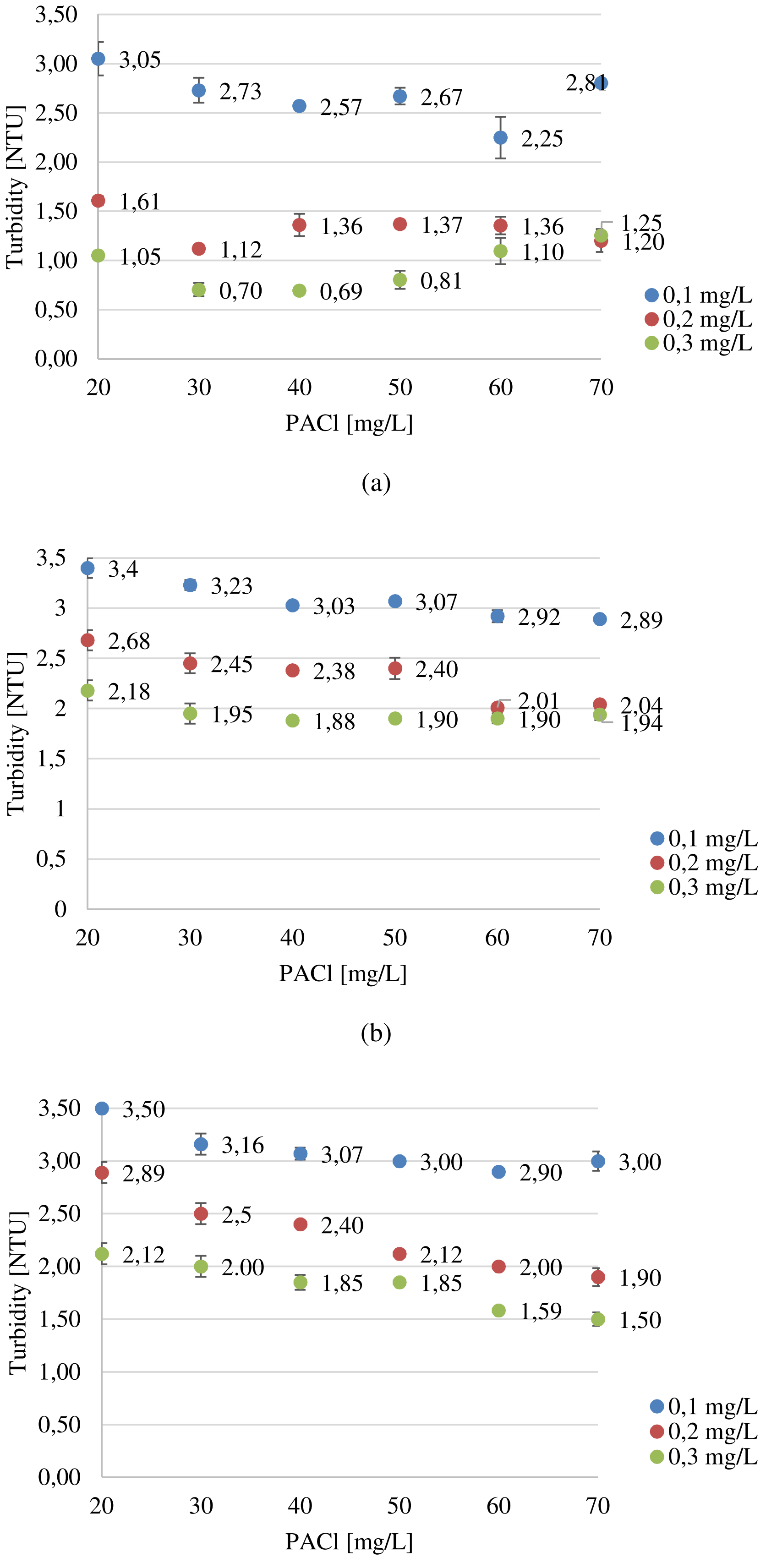


Figure 5. Jar test: evaluation of PACl concentration [mg/L]

The results presenting the effect of flocculent aids along with PACl on the turbidity of the samples are shown in Figures 6 and 7. It is observed that during high tide, the course of turbidity decay was more clear than compared to low tide. This phenomenon could be due to the charges present in the solution. The use of anionic polymers could balance the positive charges of the coagulant based on Al, resulting in low turbidity at certain moments [24].

As Nalco 8110 is a cationic polymer with low positive charge, it obtained good results with turbidity close to 2.0 NTU on samples of high tide sea water. At samples of low tide, all polymers obtained growth of turbidity on the concentration of 0.1 mg/L, that could be originated from the imbalance of charges from coagulant and polymers or unstable flocs formed [24].

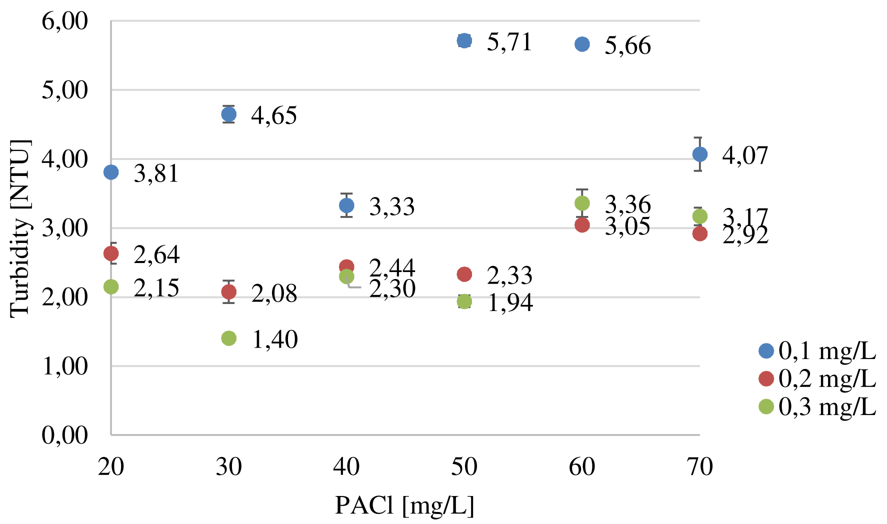


(a)

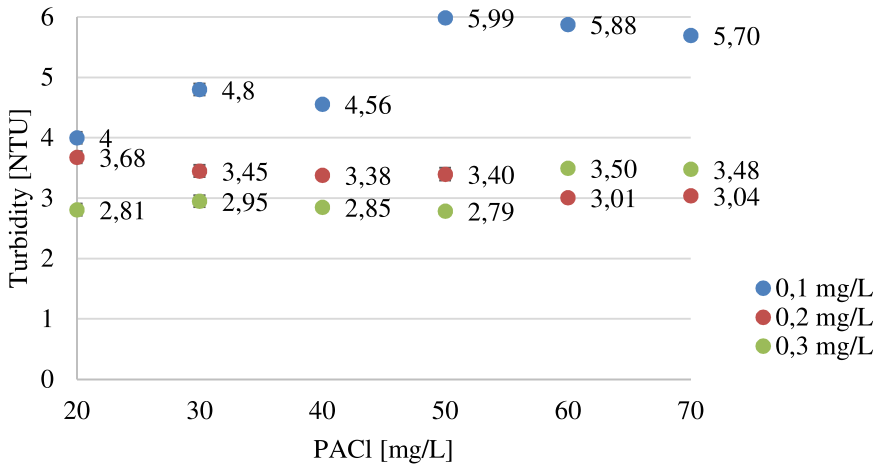
(b)

(c)

Figure 6. High tide samples of sea water: evaluation of PACl concentration [mg/L] and polymers Nalclear 8173 (anionic) (a); Magnafloc LT27 (anionic) (b) and Nalco 8110 (cationic) (c) at natural pH



(a)



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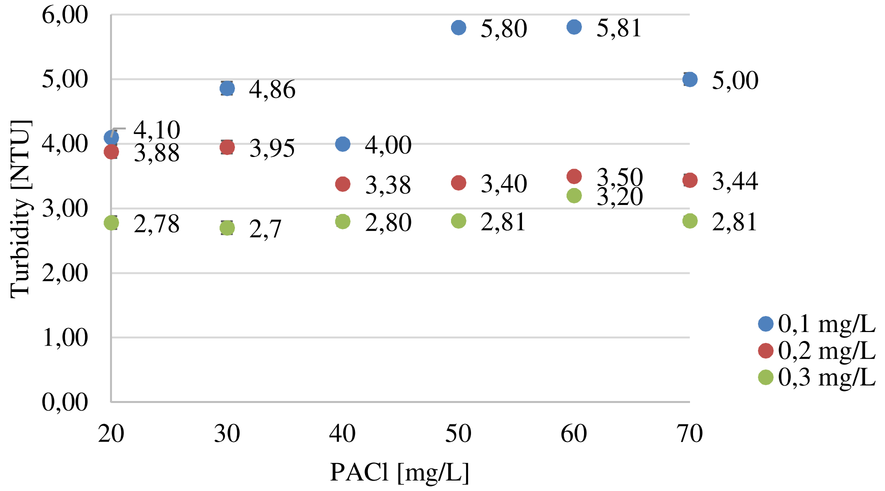

(c)

Figure 7. Low tide sample of sea water: evaluation of PACl concentration [mg/L] and polymers Nalclear 8173 (anionic) (a); Magnafloc LT27 (anionic) (b) and Nalco 8110 (cationic) (c) at natural pH

The anionic polymer Nalclear 8173 obtained the best results. It is observed that with the addition of the polymer it can obtain turbidity of 0.70 ±0.07 NTU for water sample of high tide and obtain turbidity of 1.40 ±0.02 NTU for water sample of low tide, both using 30 mg/L of PACl and 0.3 mg/L of Nalclear 8173, and these were the experimental conditions used on the next sequence of experiments. It could be explained by the combination of high charge anionic polymers that could balance the positive charges of the coagulant based on Al [24], resulting in low turbidity and more stable flocs formed considering the conditions of jar test used.

Pretreatments (sand filter or Microfiltration) applied to Reverse Osmosis

The samples treated with 30 mg/L PACl and 0.3 mg/L Nalclear 8173 were tested through the sand columns and MF individually prior to RO. The SDI of the samples was measured according to ASTM method D4189 using a 15 min assay time. All assays were performed in triplicate. The characterization results of the clarified and subsequently treatments of high tide and low tide samples are shown in Table 2 and Table 3, respectively.

Table 2. Characterization of sea water from high tide [Coagulation-Flocculation (C-F), Sand Filter (SF), Microfiltration (MF), Reverse Osmosis (RO)]

High tide							
Parameters	Unit	Raw water	C-F	C-F + SF	C-F + MF	C-F + SF + RO	C-F + MF + RO
Turbidity	[NTU]	123.7 ±2	0.70 ±0.07	0.40 ±0.04	0.33 ±0	< 0.1	< 0.1
Aluminum	[mg/L]	0.023 ±0.001	0.027 ±0	0.027 ±0	0.025 ±0	0	0
Freechlorine	[mg/L]	0.12 ±0	0	0	0	0	0
Total chlorine	[mg/L]	0.13 ±0.03	0.1 ±0	0.1 ±0	0.1 ±0	0	0
Conductivity	[mS/cm]	45.72 ±0.13	43.68 ±0.05	43.65 ±0	41.98 ±0	13.91 ±0.1	12.88 ±0
Chloride	[mg/L]	19,430 ±314	18,916 ±80	18,346 ±39	17,056 ±19	5,513 ±498	2,097 ±8.1
Sulphate	[mg/L]	1,883 ±40	1,863 ±20	1,800 ±10	1,612 ±10	301 ±20	180 ±1
pH	[-]	7.42 ±0.03	7.12 ±0.02	7 ±0.1	6.8 ±0.1	3 ±0.02	2.78 ±0.1
TS	[mg/L]	33,008 ±1,163	31,695 ±321	31,670 ±230	26,580 ±200	8,500 ±100	7,100 ±180
TSS	[mg/L]	317 ±28	6 ±0	2 ±0	0	0	0
SDI	---	---	5 ±0.1	4.8 ±0.1	3.1 ±0.1	---	---
DOC	[mg/L]	6.1 ±0.3	2.4 ±0	2.38 ±0	2.1 ±0.1	1.01 ±0	0.88 ±0

Table 3. Characterization of sea water from low tide

Low tide							
Parameters	Unit	Raw water	C-F	C-F + SF	C-F + MF	C-F + SF + RO	C-F + MF + RO
Turbidity	[NTU]	135 ±1	1.41 ±0.02	0.82 ±0.02	0.44 ±0	< 0.1	< 0.1
Aluminum	[mg/L]	0.020 ±0.002	0.028 ±0	0.028 ±0	0.027 ±0	0	0
Freechlorine	[mg/L]	0.13 ±0.04	0	0	0	0	0
Total chlorine	[mg/L]	0.26 ±0.03	0.1 ±0	0.1 ±0	0.1 ±0	0	0
Conductivity	[mS/cm]	46.04 ±0.1	43 ±0	43 ±0	41 ±0	13.98 ±0.1	12.70 ±0
Chloride	[mg/L]	19,297 ±498	18,980 ±20	18,500 ±12	17,100 ±32	5,590 ±4	2,088 ±3
Sulphate	[mg/L]	2,402 ±20	2,300 ±18	2,258 ±20	2,009 ±20	327 ±5	171 ±2
pH	[-]	7.32 ±0.02	7.20 ±0.01	7.09 ±0.05	6.88 ±0.05	2.80 ±0.02	2.7 ±0
TS	[mg/L]	35,556 ±1,251	32,698 ±300	32,680 ±290	25,200 ±140	8,870 ±63	7,230 ±84
TSS	[mg/L]	328 ±38	4 ±0	2 ±0	1 ±0	0	0
SDI	---	---	4.58 ±0.05	4.27 ±0.03	2.98 ±0.1	---	---
DOC	[mg/L]	4.3 ±0.2	2.1 ±0.1	2.1 ±0.1	1.98 ±0	0.99 ±0	0.80 ±0

The results of coagulation-flocculation (Tables 2 and 3) obtained close to 99% reduction of turbidity, 50% reduction of DOC and 98% reduction of TSS, values cited by [6]. TS were not significantly influenced because the major fraction of solids is in dissolved form [9]. The MF treatment promoted the greatest remotion on turbidity, ensuring values below 0.45 NTU. Decreasing the turbidity to the lowest possible limit can help improve the quality of the water introduced to the membrane [29]. Guidelines for acceptable RO feed water recommend turbidity below 0.5 NTU [17, 20].

According to the results on Tables 2 and 3, it can be observed that aluminum in the filtered samples is less than the maximum acceptable value of 0.05 mg/L. The excess of PACl could result in an increase of aluminum in the water.

Any soluble iron or aluminium in the feed water present naturally or due to excess coagulant or flocculant dosing will oxidize to form iron and aluminium hydroxides and oxides on the membrane surface [31].

It is important to control the concentration of residual aluminum to avoid fouling on the RO membrane and the formation of aluminum silicates, as related to the thermoelectric plant. The study of conditions for coagulation could help the improvement of this treatment in the thermoelectric plant, avoiding the excess use of coagulant [31].

A gradual reduction of the other parameters js observed throughout each process used. The parameters conductivity, chloride and sulphate showed significant reduction only after RO because they are influenced by the rejection of reverse RO to dissolved solids [10].

In many desalination plants, SDI is used for in-situ monitoring of pretreatment performance. Despite its limitations in predicting membrane fouling, it is extensively used due to its simplicity. This measures only particulate fouling and is used as an indicator of produced water quality. For example, deteriorating quality of the pretreated water (SDI > 5) at the plant usually requires a higher coagulant dose to enhance treated water quality by reducing the colloidal fouling materials [17]. It can be observed that the control of coagulation process could give SDI above or equal to five units and avoid excess use of coagulant.

The values of SDI, obtained after clarification and filtration through sand bed are above three units (Tables 2 and 3). The recommended value established by many manufacturers is up to the five units [10]. Guidelines for acceptable RO feed water recommend SDI_{15} below 3 [17, 20]. The MF obtained better values of SDI (close to 3.0) than sand filtration (higher than 4), which is cited by [17].

CONCLUSIONS

The Itaqui project contemplates a chemically assisted clarification step, which is necessary due to a large amount of TSS and turbidity due to the large tidal variation in the coast of Maranhão, state of Brazil. In this case, the replacement of the first clarification step by membranes is not justified. When comparing the characteristics of Itaqui uptake water with that of other seawater desalination plants, it can be observed that in Itaqui the turbidity of the raw water can reach values about 100 NTU, while in most seawaters of desalination plants it is below 20 NTU.

From the presented results, it can be concluded that the coagulation-flocculation could achieve > 99% of turbidity removal, 50% of dissolved organic carbon removal and 98% of total suspension solids at 30 mg/L polyaluminum chloride and 0.3 mg/L anionic polymer. The final turbidity obtained was < 1.5 NTU.

It was concluded that after the coagulation-flocculation system, the use of MF ensured a permeate with turbidity lower than 0.45 NTU on low and high tide samples analysed, and lower SDI (close to 3), when compared to the sand filtration process. Guidelines for acceptable RO feed water recommend SDI below 3 which is obtained with this configuration. Field tests need to be performed to obtain more information about fouling.

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