Ambiente & Água - An Interdisciplinary Journal of Applied Science
ISSN 1980-993X – doi:10.4136/1980-993X
www.ambi-agua.net
E-mail: ambi.agua@gmail.com

Physicochemical, microbiological and parasitological characterization of the filter backwash water from a water treatment plant of Blumenau - SC and alternatives for treatment and reuse

ARTICLES doi:10.4136/ambi-agua.2372

Received: 05 Feb. 2019; Accepted: 12 Apr. 2019

Alinne Petris[1*]; Marcel Jefferson Gonçalves[2]; Paula Angélica Roratto[3]; Juliane Araujo Greinert Goulart[1,3]

[1]Universidade Regional de Blumenau (FURB), Blumenau, SC, Brasil
Programa de Pós-Graduação em Engenharia Ambiental (PPGEA).
E-mail: professoraalinne@gmail.com, julianeag@gmail.com
[2]Universidade Regional de Blumenau (FURB), Blumenau, SC, Brasil
Departamento de Engenharia Química (DEQ).
E-mail: marceljgoncalves@hotmail.com
[3]Universidade Regional de Blumenau (FURB), Blumenau, SC, Brasil
Centro de Ciências Exatas e Naturais (CCEN).
E-mail: p.angelica21@gmail.com, julianeag@gmail.com
[*]Corresponding author

ABSTRACT

Filter Backwash Water (FBW) from water treatment plants (WTP) is composed of raw water waste, chemicals and microorganisms. Inappropriate disposal of this residue impacts negatively in the environment and in the health of human populations. Aiming to characterize the FBW from one WTP of Blumenau-SC, physiochemical, microbiological and parasitological assessments and tests with different flocculants polymers were performed in order to propose strategies for treatment and reuse of this residue. Subsequently treated liquid is discharged into the Itajaí-Açu River (Class 2). Physicochemical and microbiological analyses showed results higher than those permitted by CONAMA Resolution n° 430/2011 and *Giardia duodenalis* (Assembly B) cysts and *Cryptosporidium* spp. oocyst positivity was observed, characterizing as polluted and contaminated residue that shouldn't be released in the hydric body. The anionic flocculant polymer showed satisfactory results in the turbidity sample reduction (99.49%), which may be a promising alternative in the treatment of this residue.

Keywords: *Cryptosporidium* spp., *Giardia* spp., wastes from WTP.

Caracterização físico-química, microbiológica e parasitológica da água de retrolavagem dos filtros de uma estação de tratamento de água de Blumenau – SC e alternativas para tratamento e reuso

RESUMO

A água de retrolavagem dos filtros (ARF) de estações de tratamento de água (ETA) é composta por resíduos da água bruta, produtos químicos e microrganismos. Seu descarte inadequado impacta negativamente o meio ambiente e a saúde da população humana. Objetivando caracterizar a ARF da ETA de Blumenau-SC, foram realizadas avaliações físico-químicas, microbiológicas e parasitológicas e testes com diferentes polímeros floculantes, afim de propor estratégias para tratamento e reuso deste resíduo para posteriormente, o líquido tratado, ser lançado no Rio Itajaí-Açu (Classe 2). Grande parte das análises físico-químicas e microbiológicas apresentaram resultados superiores aos determinados pela Resolução CONAMA n° 430/2011, além de positividade para cistos de *Giardia duodenalis* (Assembleia B) e oocistos de *Cryptosporidium* spp., caracterizando um resíduo poluído e contaminado que não deve ser lançado in natura no corpo hídrico. O polímero floculante aniônico apresentou resultados satisfatórios na redução da turbidez da amostra (99,49%), podendo ser uma alternativa promissora no tratamento deste resíduo.

Palavras-chave: *Cryptosporidium* spp., *Giardia* spp., resíduo de ETA.

1. INTRODUCTION

Water treatment Plants (WTP) are important for the human population, because from raw water, usually unsuitable for consumption, they produce drinking water, indispensable to the survival of any living being (Achon *et al.*, 2008). Traditionally, the WTP has a complete system, consisting of steps of raw gathering water, coagulation, flocculation, decanting, filtration and disinfection. During these steps, the majority of the WTP produce a large volume of residues, generated by sedimentation of the particles in the decanters and by the filter backwash water (FBW). These residues are called sludge (Richter, 2009).

Commonly, much of the sludge generated in the water treatment plants around the world was discharged directly into hydrous bodies causing serious environmental impacts. However, the interest in new technologies for the treatment of water and waste generated is aimed at studies that promote the reuse or recycling of these effluents, such as discarding them to exclusive or sanitary landfills, discarding them in sewage systems, applying them to soil, recovering of degraded areas and even incorporation of materials from civil engineering. This reduces to just 11% the number of water treatment plants that discharge their waste into water bodies in the United States (Cornwell *et al.*, 2000), 2% in the United Kingdom (Simpson *et al.*, 2002) and absence of disposal of these residues in water bodies in France (Adler *et al.*, 2002) and Germany (Gramel, 2002).

In Brazil, 2,098 towns produce sludge in the water treatment process and present various provisions such as landfill, incineration or reuse; however, a large part discharge untreated effluent directly into water bodies (IBGE, 2010), impacting negatively the environment because of their high concentrations of WTP and solids that form sediment and isolate the benthic layer, promoting imbalance in the aquatic environment and preventing the development of biota, in addition to causing risks to the health of the human population by presenting concentrated pathogenic microorganisms (Cordeiro and Campos, 1998).

In this scenario, alternatives are sought to minimize the negative impacts caused by inadequate disposal of these residues with various strategies. Among them the recirculation of filter backwash water at the beginning of the system (Menezes *et al.*, 2005; Braga *et al.*, 2007; Freitas *et al.*, 2010; Molina and Santos, 2010; Oliveira *et al.*, 2013; Silva-Junior *et al.*, 2014; Lustosa *et al.*, 2017) and the use of sludge generated in decanters as a component of materials for civil construction (Hoppen *et al.*, 2005; 2006) are those that have been gaining greater emphasis by providing savings in natural resources and recycling of these residues.

The system and operating particularities of each WTP must be considered before making decisions to mitigate the problem, such as the characterization of raw water, the sludge of decanters, the filter backwash water and the chemical products used in the processes. In addition, the difficulty in managing the WTP, the ancient architecture present in many of them, the area of occupation, financial conditions and lack of specialized human resources also hamper the solutions for the proper disposal of these wastes (Di Bernardo *et al.*, 2012; Richter, 2009; Januário and Ferreira-Filho, 2007).

Blumenau has four water treatment plants; among them is WTP II, which has been in operation since 1970 and supplies about 70% of the population. It's formed by two wings (North and South) composing a complete treatment system. It uses coagulant Polychloride Aluminum (PCA) and polymers as flocculation auxiliators when necessary. The filters are the fast descending type and, at the end, gaseous chlorine, fluosilicic acid and calcium hydroxide are added for disinfection, fluoridation and pH correction, respectively, before the water is distributed to the population (Samae, 2016).

As in the vast majority of Brazil's WTPs, WTP II generates residues during daily filtering using treated water from the cistern. An average of 130 m³ of water is spent in the washing of each filter, generating a monthly volume of 39,000 m³ of treated water. The wastewater is discharged directly into the Itajaí-Açu River (Class 2 according to CONAMA Resolution n° 357/2005) (Samae, 2016).

The filter backwash water is a residue described as a polluter and contaminate due to the fact that its composition presents the chemical substances used in the previous stages of water treatment, dirt from raw water and various structures infected by microorganisms, among them cysts of *Giardia* spp. and oocyst of *Cryptosporidium* spp., (Oliveira *et al.*, 2013; Braga *et al.*, 2007; Freitas *et al.*, 2010) that are pathogenic protozoa with recent records of outbreaks and worldwide epidemic caused by water transmission (Baldursson and Karanis, 2011; Efstratiou *et al.*, 2017).

Based on the above considerations, this study characterized the filter backwash water regarding the physicochemical, microbiological and parasitological aspects of the water treatment station of Blumenau – WTP II, identifying alternatives for treatment and reuse to suggest improvements in this process contributing to the quality of life of the population and preservation of this natural resource.

2. MATERIALS AND METHODS

The samples of the filter backwash water were collected monthly in the two wings (North and South), from November 2016 to October 2017. All the sample collections were carried out during the night near to midnight, due to the lower use of water by the population, when the water treatment at the station is interrupted to reverse the water from the cistern for cleaning of the filters (Figure 1).

Figure 1. Image of one of the filters during the backwash process.
Source: Samae (2016).

It was chosen to work with composite samples collected at the beginning, middle and end of the washing of the filters, according to the diminished visible turbidity of the water.

The samples were collected with the aid of a collector made available by the town’s autonomous water and sewage service (SAMAE) and stored in different vials, according to the requirement of each of the analyses subsequently performed. For the physicochemical characterization tests, the samples were stored in 3 L plastic containers, previously cleaned and for determination of chlorine, in glass containers with a grinding lid with a capacity of 250 mL. For microbiological analyses, 100 mL sterile bottles of were used and for the parasitological analysis, glass bottles with a capacity of 1 L previously washed with elution solution tween 80-0.01%.

The procedures for collection, preservation, preparation and physicochemical analyses of the samples followed the Standard Methods for the Examination of Water and Wastewater (Apha, 2012).

The physicochemical parameters analyzed were turbidity, pH, true color, total residual chlorine, nitrite, nitrate, phosphorus (P), chemical oxygen demand (COD), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), dissolved aluminum (Al), total solids, fixed and volatile, sedimentary solids, fixed and volatile total suspended solids and total dissolved solids.

Microbiological analyses were performed using Quanti-Tray® Cartelas and Colilert® reagent in the determination and quantification by most probable number (MPN) of total coliforms and *Escherichia coli*. In this method, the presence of total coliforms is verified when the wells have yellow coloration and for confirmation of *E. coli*, the color chart is subjected to ultraviolet light of 365 nm, and the wells with fluorescence indicate the presence of the bacterium. The result is obtained by combining the quantity of large and small positive wells in most probable number by 100 mL (100 mL^{-1}) determined by a table available along with the Quanti-Tray® Carscreen Kit.

In the parasitological analyses, the calcium carbonate flocculation technique described was used by Vesey *et al.* (1993) and Greinert *et al.* (2004). The technique of detection and quantification applied was direct immunofluorescence according to the instructions of the manufacturer of the diagnostic kit (Merifluor ®-Meridian Bioscience, Cincinnati, Ohio) employing monoclonal antibodies marked with fluorescent substances. It’s currently the most widely used method for detecting and quantifying *Giardia* spp. cysts and *Cryptosporidium* spp. oocysts in high turbidity environmental samples. The microorganisms of interest were observed and quantified under the Epifluorescence microscope (Olympus-CH30) with excitation filter from 450 to 490 nm and a barrier filter of 520 nm, followed by morphological confirmation by phase contrast.

The positive samples for the parasites were subjected to molecular genotyping. The environmental DNA was extracted using the DNeasy® Blood and Tissue kit (Qiagen INC), according to manufacturer's instructions. The triose phosphate isomerase (TPI) gene amplifications were performed following a two-step nested polymerase chain reaction (PCR) protocol for genotyping of *Giardia* spp., using the AL3543 [5′-AAATIATGCCTGCTCGTCG-3′] and AL3546 [5′-CAAACCTTITCCGCAAACC-3′] primers for the primary PCR (605 pb), and the AL3544 [5′-CCCTTCATCGGIGGTAACTT-3′] and AL3545 [5′-GTGGCCACCACICCCGTGCC-3′] primers for the secondary PCR (530 pb). Reagents and cycling conditions were the same for both steps, as described in Sulaiman *et al.* (2003), with some modifications. The PCR reaction comprised 3-5.0 μL of DNA, 250 μM each of deoxynucleoside triphosphate (dNTP), 1X PCR buffer (20 mM Tris-HCl, 50 mM KCl, 2.0 mM $MgCl_2$) 1.0 U of Taq polymerase (CELLCO Biotec – Brazil Ltda), 2.0 μL of bovine serum albumin (0.1 g/10 mL), and 1.5 μM of each primer in a total of 25 μL reaction. For the secondary PCR, 4.0 μL of the primary PCR product was used as template. The reactions were performed for 35 cycles (94°C for 45 s, 48°C for 45 s, and 72°C for 60 s), with an initial hot start (94°C for 5 min) and a final extension (72°C for 10 min).

For genotyping of *Cryptosporidium* spp., the 18s small subunit rRNA gene was amplified in a two-step nested PCR protocol according to Macarisin *et al.* (2010), with some modifications. The primary PCR amplify an 1325 bp fragment using 5.0 µL of DNA, 1X PCR buffer (10 mM Tris-HCl, 50 mM KCl), 1.5 mM $MgCl_2$, 250 µM each of deoxynucleoside triphosphate (dNTP), 2.5 U of Taq polymerase (LUDWIG Biotec – Brazil Ltda), 1.25 µL of bovine serum albumin (0.1 g/10 mL), and 1.0 µM concentrations of each Crypto-F [5’-TTCTAGAGCTAATACATGCG-3’] and Crypto-R [5’-CCCATTTCCTTCGAAACAGGA-3’] primers in a 25 µL reaction volume. The reactions were processed with an initial hot start at 94°C for 3 min, followed by 35 cycles of 94°C for 45 s, 59°C for 45 s, and 72°C for 1 min, and a final extension step at 72°C for 7 min. The secondary PCR used 5.0 µL of primary PCR product as template, in order to amplify an 830 bp fragment, and the same mixture conditions, except that the primers were AL1598 [5’-AAGGAGTAAGGAACAACCTCCA-3’] and AL3032 [5’-GGAAGGGTTGTATTTATTAGATAAAG-3’]. The processing program was an initial hot start at 94°C for 1 min, 40 cycles of 94°C for 30 s, 58°C for 90 s, and 72°C for 1 min, and a final extension at 72°C for 7 min. All PCRs were performed in a AXYGEN® Maxygene II PCR thermocycler. Positive genomic DNA controls from concentrated samples of *Giardia* spp. cysts and oocyst of *Cryptosporidium* spp., provided by the FURB Parasitology Laboratory, were included with each PCR run as positive control, as well as distilled water as negative control. PCR products were analyzed on 1% agarose gel and visualized after Gel Red ® (BioLabs) staining.

The amplified products were subjected to enzymatic purification with exonuclease I and alkaline phosphatase (CELLCO Biotec – Brazil Ltda), according to the manufacturer's recommendations, and both stands were sequenced directly at Myleus Biotecnologia (MG-Brazil). The Chromas program (http://technelysium.com.au/wp/chromas/) was used to analyze the quality of the sequences. The reliable sequences were compared to those of the other assemblages using the local alignment tool BLASTN of the National Center for Biotechnology information (NCBI) database (https://blast.ncbi.nlm.nih.gov/Blast.cgi).

For the evaluation of the treatment and possible reuse of FBW, the company Projesan – environmental sanitation, located in Gaspar - SC, yielded three flocculant polymers for the development of the research: 1. PROFLOC A 100: Anionic Polymer, pH 6.0 – 8.0 and viscosity (sol 0.1% / cSt): 100 to 300; 2. PROFLOC C 209: Cationic polymer, pH 5,0 - 8,0 and viscosity (sol. 0.1% / cSt): 50.00 a 150.00; 3. PROFLOC A 110: Slightly anionic polymer, pH 6.0 - 8.0 and viscosity (sol. 0.1% / cSt): 70.0 to 130.0. All polymers presented solid granular appearance and white to slightly yellowish coloration. Preliminary tests were performed with the use of the Jar-Test and Turbidimeter aiming to determine which polymer would be more efficient for the removal of the solid particles from the filter backwash water, its ideal concentration to be added in the sample, agitation speed and effectiveness in decreasing turbidity.

Data were organized in descriptive tables containing absolute frequencies, relative averages, standard deviations and estimates in the form of range with 95% confidence. The data of the quantitative variables were tested using the normality Shapiro-Wilk Test. To compare the groups with respect to the quantitative variable, we used the Student’s t-Test (Parametric Test) and the Mann-Whitney Test (Non-Parametric Test) that compares the two independent groups. Pearson's Linear correlation and Spearman's correlation were used to correlate the quantitative. In the cases of association whose variables were categorical or qualitative, Fisher's exact test was used. In all cases, the statistical significance was considered if the P value < 0.05 and the data analysis performed by the Microsoft Excel 2016 software.

3. RESULTS AND DISCUSSION

3.1. Physicochemical analyses of the filter backwash water

Comparing the results of the physicochemical analyses of the North and South wings no significant differences were observed between them. So, the results of the two wings were combined to perform the subsequent statistical analyses.

The physicochemical characteristics of the filter backwash water of WTP II, carried out in this study in general, present agreement with the results obtained in other Brazilian WTPs (Freitas *et al.,* 2010; Molina and Santos, 2010). In relation to the dissolved aluminum content, the data of this study was much lower than those recorded by other researchers. This difference can be explained due to the different dosages of aluminium-based coagulants, as well as the flow volume of the stations, the operating conditions and the characteristics of the raw water. The contents of all groups of solids, and consequently the average of turbidity, showed much higher values. These variations are probably due to differences in the quality of raw water, disposal of wastewater from domestic and industrial exhaustion, erosion rates, agricultural activities, land occupation and influence of the biotic community of the environment (Campos, 2015; Canale, 2014; Freitas *et al.*, 2010; Molina and Santos, 2010; Chaves, 2012; Scalize, 1997).

The concentrations of iron and phosphorus are expressive as compared to the studies by Freitas *et al.* (2010), Molina and Santos (2010) and Scalize (1997). High concentrations of iron may be related to the composition of solids, since this is one of the main elements of soil formation (Carneiro *et al.*, 2013). The characteristics of the filter backwash water are closely related to those of the raw water from the catchment, so the phosphorus content found in the FBW suggests the origin of sanitary sewage, since only 42% of the population is served by the sewage collection network in the Blumenau (Brk Ambiental, 2018).

It's known that filter backwash water from water treatment plants is composed of chemical substances used during the processes to achieve water potability and is closely related to the characteristics of raw water. In a recent study, Piazza *et al.* (2017) evaluated the chemical parameters of the raw water of the four water treatment plants from Blumenau and a conservation unit. Among the evaluated parameters, the raw water captured by WTP II obtained the highest rates in chloride, sulfate, sodium and total organic carbon. The authors report that, due to the watershed of the spring being large, management is difficult, since the waters come from other cities; in addition, natural causes, the use of the soil, and several other mechanisms of action exert anthropic influence on the quality of the hydric body.

Grott *et al.* (2016) evaluated the turbidity value of the raw water catchment of the water treatment plant – WTP II of Blumenau and verified values between 18.3 and 934 UNT. The authors report that this high turbidity value occurs due to the geological formations characterized by Neossolos Fulvic, which have dark coloration and varying granulations. Also, the absence of basic sanitation in part of the city causes the discharge of domestic wastewater into the water body. The high incidence of industries in the region is also responsible for this increase in both the values of chemical parameters and the turbidity index.

The raw water capture of the WTP II of Blumenau is framed as Class 2, according to the CONAMA Resolution n° 430/201, which provides classifications of bodies of water and environmental guidelines for rating, as well as establishes the conditions and standards of effluent discharge.

The results of the physicochemical parameters of the washing water of the filters evaluated in this study were compared with the values established by CONAMA Resolution nº 430/2011 to dispose of effluent in a Class 2 water body (Table 1).

Table 1. Comparison between the physicochemical parameters of the washing water of the filters of WTP II with the limits set by CONAMA Resolution n° 430/2011 for the disposal of wastewater in Class 2 water bodies.

Variables	Average	CONAMA 430/2011	Meets the established standards
Turbidity (uT)	210,08	100 uT	NO
pH	6,69	5,0 to 9,0.	YES
True Color (uH)	4,96	75 mg Pt L^{-1}	YES
Iron (mg L^{-1})	16,81	15 mg L^{-1}	NO
Manganese (mg L^{-1})	0,2	1.0 mg L^{-1}	YES
Copper (mg L^{-1})	0,01	1.0 mg L^{-1}	YES
Zinc (mg L^{-1})	0,07	5.0 mg L^{-1}	YES
Aluminum (mg L^{-1})	0,05	0.1 mg L^{-1}	YES
Phosphor (mg L^{-1})	1,15	0.050 mg L^{-1}	NO
Nitrite (mg L^{-1})	0,02	1.0 mg L^{-1}	YES
Nitrate (mg L^{-1})	3,9	10.0 mg L^{-1}	YES
Total residual chlorine (mg L^{-1})	0,16	0.01 mg L^{-1}	NO
Total solids (mg L^{-1})	575,58	-	-
Fixed total solids (mg L^{-1})	356,17	-	-
Volatile total solids (mg L^{-1})	219,42	-	-
Sedimentary solids (mL L^{-1})	42,13	1 mL L^{-1}	NO
Total suspended solids (mg L^{-1})	394,67	-	-
Fixed suspended solids (mg L^{-1})	269,08	-	-
Volatile suspended solids (mg L^{-1})	125,58	-	-
Total dissolved solids (mg L^{-1})	180,92	500 mg L^{-1}	YES
COD (mg L^{-1})	63,35	-	-

According to the results, it's observed that some of the parameters are above the maximum standards established by CONAMA Resolution n° 430/2011, for the discharge of effluents in Class 2 Rivers, making it illegal to discharge this residue in the water body.

The high turbidity of raw water resulting from the high concentration of solids from the disposal of domestic and industrial effluents and by natural phenomena such as water speed and erosion are related to the composition of the filter backwash water as these particles remain in the WTP at this stage of treatment. Returning this water to the hydric body, besides contributing to the increase of the turbidity of the raw water at the point of discharge, promotes changes in the color of the river, siltation and influence in the regional biota.

The use of natural or synthetic flocculant polymers to reduce turbidity of the filter backwash water has been studied and is proving an efficient alternative (Braga *et al.*, 2007; Freitas *et al.*, 2010). However, in addition to water clarification, it's important to characterize the clarified water in order to verify the removal of other chemical or biological compounds that can negatively impact the environment and the surrounding population.

Iron is one of the main elements of soil formation, along with oxygen, silicon and aluminum. It presents two stages of oxidation, being Fe^{+3} predominant in aerated soils, and in soils with low O_2 content, the reduction of Fe^{+3} for Fe^{+2} is highly observed, being also the form available for plants and animals, since the Fe^{+3} precipitates more easily. The high concentration of this element in the filter backwash water may be related to the soil composition of the region, and also intensified by the coagulant, since the Aluminium Polychloride (PCA) can contain concentrations of up to 0.03% of Fe (Carneiro *et al.*, 2013).

High concentrations of iron may cause irritation when inhaled or by contact with the skin or eyes (Macedo, 2001). In addition, it causes some impacts to the public water supply by conferring color and flavor to the treated water. Biological contamination can occur in the distribution network itself with the deposit of this element through plumbing and the development of iron bacteria (Oliveira *et al.*, 2013).

For the removal of iron in water, the techniques of oxidation with free chlorine, ozone or potassium permanganate followed by filtration are used (Rönnholm *et al.*, 2001; Moruzzi and Reali, 2012). Aeration processes also promote the reduction of these compounds (Di Bernardo *et al.*, 1993; Knocke, *et al.*, 1987).

Freitas *et al.* (2010), using ionic polymers to reduce the physicochemical parameters of the filter backwash water of water treatment plant filters in Minas Gerais, obtained satisfactory results in relation to iron, decreasing the values from 3.5 to 0.1 mg L^{-1}.

The removal of this compound in water is most often impossible in practice, mainly due to the high investment cost, since an increase in the number of steps of the WTP is required. Thus, studies aimed at the removal of these ions are important to promote more efficient strategies and mainly shorter execution time and cost.

The presence of phosphorus in water is usually related to the disposition of in natura domestic sewage in the hydric body, agricultural activity, industrial effluents, among other anthropic actions (Carneiro *et al.*, 2013). Phosphorus is one of the main elements responsible for eutrophication, which consists of the excessive growth of algae damaging the use of water; moreover, the excessive consumption of oxygen by the algae causes the death of fish and other organisms in the surroundings (Klein and Agne, 2012).

The measures of phosphorus control are related to the correct application of fertilization and effective practices in the prevention of soil erosion. In sanitary sewage, where the concentration of phosphorus is high, the main removal strategies are chemical precipitation by the use of iron or aluminum salts such as coagulant, biological processes of treatment, ion exchange and adsorption (Kaveeshwar *et al.*, 2018).

The use of chlorine (Cl) for disinfection in water treatment plants is very common, its main function being the inactivation of microorganisms such as bacteria. The chlorine found in the filter backwash water comes from the water treatment, since to perform the washing volumes of water from the cistern are used. The amount of free residual chlorine found in this study is much higher than that permitted by CONAMA Resolution n° 430/2011 for disposal in Class 2 water bodies.

The problem related to this high concentration of free residual chlorine is the capacity that this compound has in forming trihalomethanes (THM) from its reaction with organic compounds (Meyer, 1994). Raw water, due to the decomposition of biological material, promotes the development of fulvic and humic acids, which in turn form haloforals due to the presence of ketone radicals in their composition and the reaction with free chlorine. These acids are the precursors of the formation of trihalomethanes (Opas, 1987; Van-Bremem, 1984). Studies establish a certain relationship between trihalomethane compounds formed during the stages of water treatment and cancer (Santos, 1987).

The strategies for the control of the formation of the THM can occur with the reduction of the concentration of precursor acids in the treatment plant by clarification of the water using on coagulants, or in the spring, by aeration, oxidation or by adsorption in activated charcoal. The use of other alternatives for disinfection, such as ozone or ultraviolet light become interesting, or even the removal of THM already formed by activated granular carbon (Laubusch, 1971; Santos, 1987).

The alternatives quoted for the removal of components that were above the values allowed by CONAMA n° 430/2011 resolution require investments in the infrastructure of the water treatment plant, as well as specialized human resources. The deterioration of raw water influences the results of the characterization of effluent generated in the water treatment plant, so it’s possible to understand that public policies and more effective inspections in relation to the regulations of use and soil occupation would help to improve the quality of raw water and consequently lower generation of sludge and wastewater in the water treatment plant, being more profitable to conserve the city's water resources than to invest in the infrastructure of the water treatment station.

3.2. Microbiological analysis of filter backwash water

According to CONAMA Resolution n° 430/2011, for water bodies framed as Class 2, a limit of 1000 thermotolerant coliforms per 100 mL of water shouldn't be exceeded and *Escherichia coli* may be determined in substitution to the parameter of thermotolerant coliforms. Table 2 shows the values of total coliforms and *E. coli* found in this study in both wards and the significance between them.

Table 2. Total coliforms and *E. coli* found in the filter backwash water of the WTP II filter in the north and south wings.

Bacterias	**ALA**		**TOTAL**	**P**
	South (n = 12)	**North (n = 12)**		
Total coliforms (MPN 100 ml^{-1})				
≤ 1000	5 (41.7%)	2 (16.7%)	7 (29.2%)	0,2223
>1000	7 (58.3%)	9 (75%)	16 (66.7%)	
Missing Data	0 (0%)	1 (8.3%)	1 (4.2%)	
E. coli (MPN 100 ml^{-1})				
≤ 1000	4 (33.,3%)	4 (36.4%)	8 (34.8%)	0,6084
>1000	7 (58.3%)	6 (54.5%)	13 (56.5%)	
Missing Data	1 (8.3%)	1 (9.1%)	2 (8.7%)	

I - P: P-value of the T-Test for correlation. If $P < 0.05$ then significant correlation.

According to the results, no significant difference was observed between the total coliform values and *E. coli* between the south and north wings. Regarding the values obtained the presence of quantities higher than 1000 MPN, 100 mL^{-1} was verified for both total coliforms and *E. coli* in most analyses. Thus, the microbiological parameters of the water to wash the water treatment station filters – WTP II of Blumenau, aren't in accordance with the values established by the current norm. It's in natura disposal is inappropriate, and can cause negative impacts both to the environment and to the health of the human population.

Grott *et al.* (2016) evaluated the presence of total coliforms and *E. coli* in the raw water of the water treatment station – WTP II of Blumenau. They obtained minimum and maximum values of 240 - 600 MPN 100 mL^{-1} sample of total coliforms and 33 – 240 MPN 100 mL^{-1} of *E. coli*. The values found in this study were 9.7- > 2419,6 MPN 100 mL^{-1} for total coliforms and 22.6 - > 2419,6 MPN 100 mL^{-1} for *E. coli*.

Filtration is the main barrier for microorganisms during water treatment (Arora *et al.*, 2001; Lechevallier and Norton, 1995). The accumulation of these bacteria in the filter bed suggests the reason for this high number of microorganisms in the filter backwash water, being important information for verifying the potential functioning of the filters.

It's noteworthy that the inadequate disposal of this wastewater causes an increase in the concentration of these microorganisms in the area of discharge, which can negatively impact the population that lives near the river and uses the water without adequate treatment.

Due to the fact that the washing of the filters of the water treatment station in question occurs with the water of the cistern, which include chlorine, it's possible that during the process part of these microorganisms are inactivated. However, as shown by the results, the treatment of this residue before its disposition in the hydric body should be carried out.

There are numerous disinfection mechanisms for water, among them, disinfection by chemical agents, which is commonly performed with liquid or gaseous chlorine, or derivatives such as sodium or calcium hypochlorite and chlorine dioxide because they are easy to apply and low cost. However, these mechanisms are not efficient against cysts and oocysts of *Giardia* spp. and *Cryptosporidium* spp., since they are highly resistant (Cheung, 2017). Other disinfection mechanisms are the use of ozone and ultraviolet (UV) radiation. The use of ozone in water treatment plants in the United States obtained satisfactory results in the inactivation of *Giardia* spp. (Thompson and Drago, 2015). Cantusio-Neto *et al.* (2006) obtained a 98.9% reduction of *Giardia* spp. cysts and 99.7% of *Cryptosporidium* spp. oocysts using activated sludge UV disinfection at a sewage treatment plant. However, the action of UV was not completely efficient in relation to the inactivation of *Giardia* spp. cysts. Trophozoites were found in a rat intestine scraping of the UV-treated group. However, the combination of the three techniques - use of chlorine, ozone and UV can play an important role in the inactivation of these protozoa (Thompson and Draco, 2015).

When a correlation analysis between turbidity and *E. coli* values was performed, it was possible to verify a moderate correlation between these parameters (P = 0,0420).

Souza and Gastaldini (2014) found no correlation between the parameters of *E. coli* and turbidity in their study carried out in hydrographic basins that suffer anthropic action. The turbidity ratio was evident with the parameters of suspended solids and flow, and *E. coli* was strongly related to the values of DBO.

Roberto *et al.* (2017) in the study on the evaluation of pH, turbidity and parasitological analysis of the water of the Guará Velho Stream, in the city of Guaraí/TO, verified a strong relationship between the results of turbidity and MPN of *E. coli* in two of the five points evaluated in the study.

The concentration of solids in water is closely related to the turbidity value, as well as the dumping of sanitary sewage. The bacterium *E. coli* is of fecal origin both of humans and other animals; thus, the absence of sewage collection networks in more than 50% of the population of the municipality of Blumenau, suggests the relationship between the turbidity and MPN parameters of *E. coli* in this study.

Due to the presence of *E. coli*, most often associated with contamination of fecal origin, another important relationship is that of these bacteria with the possible presence of pathogenic enteric protozoa, such as *Giardia* spp. and *Cryptosporidium* spp.

3.3. Parasitological analyses of the filter backwash water

The parasitological analyses for *Giardia* spp. and *Cryptosporidium* spp. in the period of one year performed in the north and south wings didn’t present significant differences for *Giardia* spp., with the value of P = 0.9110 using the Mann-Whitney test after normality was determined by the Shapiro-Wilk test. Regarding the research of *Cryptosporidium* spp., it wasn’t possible to perform the statistical tests since the presence of this parasite wasn’t determined in one of the wings during the entire study period.

Of the 24 analyzed samples, in 11 were verified the presence of *Giardia* spp. and in only three of *Cryptosporidium* spp. The greater detection of *Giardia* spp. indicates greater circulation of this protozoan in the region. Similar results were observed by Grott *et al.* (2016) analyzing raw water from the Itajaí-Açu River in Blumenau (SC), Miglioli *et al.* (2017) in Sewage Treatment Plant sludge, also in Blumenau (SC), Greinert *et al.* (2004) in pool water in the city of Florianópolis (SC), Franco *et al.* (2001) in Campinas (SP), Cantusio-Neto *et al.* (2006) in Sewage Treatment Plant sludge also in Campinas (SP), Sato *et al.* (2013) in several springs of the state of São Paulo.

Grott *et al.* (2016), evaluated the parasitological profile of the raw water uptake of the water treatment station – WTP II of Blumenau, and the results were compared with this research (Table 3).

Table 3. Comparison between the results of the survey of *Giardia* spp. and *Cryptosporidium* spp. in the raw water and in the filter backwash water of the water treatment station of Blumenau – WTP II.

	Filter backwash water		**Raw Water (Grott *et al.*, 2016)**	
	***Giardia* spp.**	***Cryptosporidium* spp.**	***Giardia* spp.**	***Cryptosporidium* spp.**
Total Analyses	24	24	14	14
Positive	11	3	8	2
Range	200 - 600	200 - 400	40 - 70	118 - 454
Average	133.33	33.33	141.10	286
Frequency	45.83%	12.50%	57.14%	14.28%

The positivity frequency of both protozoa was similar in the analyses of raw water and in the filter backwash water. Regarding the detection of *Giardia* spp. cysts, the maximum and minimum values in the filter backwash water are much higher than those found in the raw water. This variation is probably related to the higher concentration of these organisms during the filtration stage consequently the filter backwash water also presents a greater abundance of these protozoa.

Regarding the detection of oocyst of *Cryptosporidium* spp., the amplitude found in both studies was similar. The smallest amount of positive results for the analysis of *Cryptosporidium* spp. may be related to the epidemiology of cryptosporidiosis in the area of Blumenau. In addition to the lower frequency of infection in the population, the high turbidity of the sample may interfere with the efficiency of the technique in the detection of oocyst.

No positive sample for *Cryptosporidium* spp. presented the expected two-step PCR amplification pattern, even with several attempts to optimize the protocol.

Only two of the FBW positive samples for *Giardia* spp. presented the approximately 530 pb expected amplification by two-step PCR. The sequences obtained (NCBI accession numbers MK208823 and MK208824) presented 99% homology with sequences of *G. duodenalis* - Assemblage B.

With the presented results, it was found that the filter backwash water of the WTP II presents high levels of turbidity, iron, manganese, copper, phosphorus, free residual chlorine, total coliforms and *E. coli*, being above that allowed by CONAMA Resolution nº 430/2011, in addition to the presence of *Giardia duodenalis* cysts genotype B, which is zoonotic, and *Cryptosporidium* spp. oocysts.

Karanis *et al.* (1996) detected *Giardia* spp. and *Cryptosporidium* spp. or both in 92% of the filter backwash water from a WTP in Germany. The detection rate in raw water samples was 91.7%. Karanis *et al.* (1998) observed that good elimination results were obtained by optimizing relevant water treatment processes, but a low flocculant dose following sudden variation in the raw water quality causes a breakthrough of these protozoan into the treated water.

The use of polymer flocculant to clarify the filter backwash water was evaluated, and, after preliminary tests, higher efficiency was found in the polymer Profloc A 100, with anionic character, in the concentration of 0.01% with rapid agitation of one minute, followed by slow agitation for another minute in a jar-test. The sedimentation time was 30 minutes and its efficiency in reducing turbidity reached 99.49%.

One of the main alternatives studied and applied by water treatment plants in relation to the waters of filter backwash, is its recirculation to the beginning of the system. However, the high rates of turbidity of this residue can cause losses in the treatment process. In this way, several studies aimed at the quality of reuse of this effluent propose pre-treatment with application of different polymers in order to clarify the filter backwash water before it's forwarded to the beginning of the treatment.

Freitas *et al.* (2010) also evaluated the clarification of the waters of filter backwash without and with different polymers in order to determine which is the most efficient in decreasing the physicochemical values before this water is recirculated to the system. The values of DQO, Fe, Al, Mn, pH, turbidity, solids in total suspension and sedimentary solids were significantly reduced when cationic polymer was used; turbidity was decreased from 33.5 UNT to 1.5 UNT

Braga *et al.* (2007) determined the reduction of turbidity from 33.5 UNT to 5.32 UNT and total suspended solids from 75 mg L^{-1} to 13.5 mg L^{-1} also when the cationic polymer was used in the clarification of FBW.

Molina and Santos (2010) verified the efficiency in the clarification of FBW using light and medium anionic polymer and potato starch. The three components presented similarity in results, achieving great efficiency in the removal of the flakes. The use of potato starch stands out because it's natural, inexpensive and easy to acquire.

The process of sedimentation of the filter backwash water, with or without the use of polymer generates a more concentrated sludge that, depending on its characteristics, can be incorporated into ceramic material or civil construction or then be destined to a landfill appropriate to its classification (Vitorino *et al.*, 2009).

The filter backwash water of the WTP II of Blumenau presents characteristics similar to those found in these studies that aimed to recirculate of this type of sample to the beginning of the system. However, the importance of a pre-treatment of this residue before its reuse is evident. The use of polymer is a promising alternative, since the quantity to be used and the time for the removal of solids are low, which promotes the reuse of the filter backwash water and the reduction of operating costs (Lustosa *et al.*, 2017).

4. CONCLUSIONS

The filter backwash water of the water treatment plant of Blumenau – WTP II presents some physicochemical and microbiological indices higher than the maximum limit allowed by CONAMA Resolution N° 430/2011 for in natura disposal in Class 2 water bodies, highlighting turbidity, some solids, Fe, P and Cl, Coliformes Total and *E. coli*. Therefore, it shouldn't be discarded without prior treatment.

The high concentrations observed in the microbiological and parasitological analyses can bring negative impacts both to the environment and to the health of the human population, emphasizing the importance of a pre-treatment of this residue before it's disposed of in water bodies.

The use of flocculant polymers is an interesting alternative to clarify the filter backwash water, since they have properties that reduce the physicochemical, microbiological and parasitological loads of the effluent, and through this process allow the recirculation of FBWat the beginning of treatment, being an option for the reuse of this residue.

The high concentrations of phosphorus and turbidity, which suggest a relation with the discharge of sanitary sewage, anthropic actions and erosion episodes, can be solved with investments in the basic sanitation of the city and public policies in the supervision of occupation and land use.

Investments in the conservation of the Itajaí-Açu River and maintenance of surface water quality can be more profitable than the application of new methodologies in the water treatment plants of Blumenau, since with the preservation of raw water, the physicochemical, microbiological and parasitological parameters of the effluent of the WTP tend to conform with CONAMA Resolution n° 430/2011.

5. ACKNOWLEDGEMENTS

To the Coordination of Improvement of Personnel in Superior (CAPES) Level for the concession of the master's degree to the first author. To the University Regional of Blumenau (FURB) through the Program of Master’s Degree in Environmental Engineering for the orientation and use of laboratories and equipment. To the Municipal Autonomous Service of Water and Sewer (SAMAE) for authorizations and pertinent information from the water treatment system of the municipal district of Blumenau. To the company PROJESAN for providing the polymer used in the research.

6. REFERENCES

ACHON, C. L.; BARROSO, M. M.; CORDEIRO, J. S. Leito de drenagem: sistema natural para redução de volume de lodo de estação de tratamento de água. **Revista Engenharia Sanitária e Ambiental**, v. 13, n. 1, p. 54-62, 2008. http://dx.doi.org/10.1590/s1413-41522008000100008

ADLER, E. Management of wastes from drinking water treatment in Norway. *In*: CIWEM (Org.). **Management of Wastes from Drinking Water Treatment.** London, 2002.

APHA. **Standard methods for the examination of water and wastewater.** 22nd ed. Washington DC, 2012.

ARORA, H.; DI GIOVANNI, G.; LECHEVALLIER, M. Spent filter backwash water contaminants and treatment strategies. **Journal American Water Works Association**, v. 93, n. 5, p. 100-112, 2001. http://dx.doi.org/10.1002/j.1551-8833.2001.tb09211.x

BALDURSSON, S.; KARANIS, P. Waterborne transmission of protozoan parasites: review of worldwide outbreaks–an update 2004–2010. **Water research**, v. 45, n. 20, p. 6603-6614, 2011. https://dx.doi.org/10.1016/j.watres.2011.10.013

BRAGA, M. D.; BEVILACQUA, P. D.; BASTOS, R. K. X.; FREITAS, A. G.; FERREIRA, G. M. Microbiological characterization of filter washing water and evaluation of different recirculation scenarios. **Revista AIDIS de Ingeniería y Ciencias Ambientales: Investigación, Desarrollo y Práctica,** v. 1, n. 3, 2007.

BRK AMBIENTAL. **Seu esgoto.** 2018. Available in: https://www.brkambiental.com.br/blumenau/agua-e-esgoto/seu-esgoto/. Access: 24 Dec. 2018.

CAMPOS, H. L. **Caracterização das águas de lavagem de filtros em estações de tratamento de água de filtração direta.** 2015. Dissertação (Mestrado em Engenharia Sanitária) – Universidade Regional do Rio Grande do Norte, Natal, 2015.

CANALE, I. **Caracterização microbiológica, parasitológica e físico-química da água de lavagem de filtros recirculada em ETA de ciclo completo.** 2014. Dissertação (Mestrado em Tecnologia) - Universidade Estadual de Campinas, Campinas - SP, 2014.

CANTUSIO-NETO, R.; SANTOS, J. U.; FRANCO, R. M. B. Evaluation of activated sludge treatment and the efficiency of the disinfection of *Giardia* species cysts and *Cryptosporidium* oocysts by UV at a sludge treatment plant in Campinas, south-east Brazil. **Water Science and Technology**, v. 54, n. 3, p. 89-94, 2006. https://dx.doi.org/10.2166/wst.2006.453

CARNEIRO, C.; WEBER, P. S.; ROSS, B. Z. L. Caracterização do Lodo de ETA gerado no Estado do Paraná. *In*: CARNEIRO, C.; ANDREOLI, C. V. (Eds.). **Lodo de Estações de Tratamento de Água:** Gestão e Perspectivas Tecnológicas. Curitiba: Sanepar, 2013. Cap. 3. p. 132-178.

CHAVES, K. O. **Desenvolvimento e Aplicação de sistema de floco-flotação por ar dissolvido para tratamento da água de lavagem do filtro da WTP Gavião.** 2012. Dissertação (Mestrado em Engenharia Sanitária) – Universidade Federal do Ceará, Fortaleza, 2012.

CHEUNG, P. C. W. A historical review of the benefits and hypothetical risks of disinfecting drinking water by chlorination. **Journal of Environment and Ecology**, v. 8, n. 1, p. 73-151, 2017. https://dx.doi.org/10.5296/jee.v8i1.11338

CONAMA. Settlement n. 357 from March 17th 2005. It deals with the classification of water bodies and environmental guidelines for its classification, as well as establishes the conditions and standards for the discharge of effluents, and provides other measures. **Diário Oficial [da] União,** Brasília, DF, 18 Mar. 2005. Available: http://www2.mma.gov.br/port/conama/legiabre.cfm?codlegi=459. Access date: 11 May 2016.

CONAMA. Settlement n. 430 from May 13th 2011. It has on conditions and standards for the release of effluent, complements and alters the resolution No 357, of March 17, 2005. **Diário Oficial [da] União**, Brasília, DF, 16 May 2011. Available in: http://www2.mma.gov.br/port/CONAMA/legiabre.cfm?codlegi=646. Access date: 11 May 2016.

CORDEIRO, J. S.; CAMPOS, J. R. O impacto ambiental provocado pela indústria da água de abastecimento. *In:* APIS. **Gestión ambiental en el siglo XXI**. Lima, 1998. p. 1-12.

CORNWELL, D. A.; MUTTER, R. N.; VANDERMEYDEN, C. **Commercial Application and Marketing of Water Plant Residuals.** Denver: AWWA, 2000.

DI BERDARDO, L.; DANTAS, A. D.; VOLTAN, P. N. **Métodos e técnicas de tratamento e disposição dos resíduos gerados em estações de tratamento de água.** São Carlos: LDiBe, 2012.

DI BERNARDO, L.; DANTAS, DI BERNARDO, A. **Métodos e técnicas de tratamento de água.** Rio de Janeiro: ABES, 1993.

EFSTRATIOU, A.; ONGERTH, J. E.; KARANIS, P. Waterborne transmission of protozoan parasites: review of worldwide outbreaks-an update 2011-2016. **Water research**, v. 114, n. 20, p. 14-22, 2017. https://dx.doi.org/10.1016/j.watres.2017.01.036

FRANCO, R. M. B.; ROCHA-EBERHARDT, R.; CANTUSIO-NETO, R. Occurrence of *Cryptosporidium* oocysts and *Giardia* cysts in raw water from the Atibaia river, Campinas, Brazil. **Revista do Instituto de Medicina Tropical de São Paulo**, v. 43, n. 2, p. 109-111, 2001. http://dx.doi.org/10.1590/S0036-46652001000200011

FREITAS, A. G.; BASTOS, R. K. X.; BEVILACQUA, P. D.; PÁDUA, V. L.; PIMENTA, J. F. P.; ANDRADE, R. C. de. Recirculation of water to wash filters and hazards associated with protozoa. **Revista Engenharia Sanitária e Ambiental**, v. 15, n. 1, p. 37-46, 2010. http://dx.doi.org/10.1590/S1413-41522010000100005

GRAMEL, S. **Results of the Case Study on the Water Supply in the Region of Frankfurt/Germany.** In: Achieving Sustainable and Innovative Policies through Participatory Governance in a Multi-Level Context. Final Report of a Research Project funded by the European Community. Darmstadt, 2002.

GREINERT, J. A.; FURTADO, D. N.; SMITH, J. J.; BARARDI, C. R. M.; SIMÕES, C. M. O. Detection of *Cryptosporidium* oocysts and *Giardia* cysts in swimming pool filter backwash water concentrates by flocculation and immunomagnetic separation. **International Journal of Environmental Health Research**, v. 14, n. 6, p. 395-404, 2004. https://dx.doi.org/10.1080/09603120400012892

GROTT, S. C.; HARTMANN, B.; SILVA FILHO, H. H.; FRANCO, R. M. B.; GOULART, J. A. G. Detecção de cistos de *Giardia* spp. e oocistos de *Cryptosporidium* spp. na água bruta das estações de tratamento no município de Blumenau, SC, Brasil. **Revista do Instituto de Medicina Tropical de São Paulo**, v. 11, n. 3, p. 689-701, 2016. http://dx.doi.org/10.4136/ambi-agua.1853

HOPPEN, C.; PORTELLA, K. F.; JOUKOSKI, A.; BARON, O.; FRANCK, R.; SALES, A.; ANDREOLI, C. V.; PAULON, V. A. Co-disposição de lodo centrifugado de Estação de Tratamento de Água (WTP) em matriz de concreto: método alternativo de preservação ambiental. **Water research**, v. 51, n. 20, p. 85-95, 2005. http://dx.doi.org/10.1590/s0366-69132005000200003

HOPPEN, C.; PORTELLA, K. F.; JOUKOSKI, A.; TRINDADE, E. M.; ANDREÓLI, C. V. Uso de lodo de estação de tratamento de água centrifugado em matriz de concreto de cimento portland para reduzir o impacto ambiental. **Revista do Instituto de Medicina Tropical de São Paulo**, v. 29, n. 1, p. 79-84, 2006. http://dx.doi.org/10.1590/s0100-40422006000100016

IBGE. **Pesquisa Nacional de Saneamento Básico 2008.** Rio de Janeiro, 2010. Available in: http://biblioteca.ibge.gov.br/visualizacao/livros/liv45351.pdf Access: 11 Feb. 2018.

JANUÁRIO, G. F.; FERREIRA FILHO, S. S. Planejamento e aspectos ambientais envolvidos na disposição final de lodos das estações de tratamento de água da Região Metropolitana de São Paulo. **Engenharia Sanitária e Ambiental**, v. 12, n. 2, p. 117-126, 2007. http://dx.doi.org/10.1590/s1413-41522007000200002

KARANIS, P.; SCHOENEN, D.; SEITZ, H. M. Distribution and removal of *Giardia* and *Cryptosporidium* in water supplies in Germany. **Water science and technology**, v. 37, n. 2, p. 9-18, 1998. http://dx.doi.org/10.2166/wst.1998.0091

KARANIS, P.; SCHOENEN, D.; SEITZ, H. M. *Giardia* and *Cryptosporidium* in backwash water from rapid sand filters used for drinking water production. **Zentralblatt für Bakteriologie**, v. 284, n. 1, p. 107-114, 1996. http://dx.doi.org/10.1016/s0934-8840(96)80159-9

KAVEESHWAR, A. R.; PONNUSAMY, S. K.; REVELLAME, E. D.; GANG, D. D.; ZAPPI, M. E.; SUBRAMANIAM, R. Pecan shell based activated carbon for removal of iron (II) from fracking wastewater: Adsorption kinetics, isotherm and thermodynamic studies. **Process Safety and Environmental Protection**, v. 114, p. 107-122, 2018. https://dx.doi.org/10.1016/j.psep.2017.12.007

KLEIN, C.; AGNE, S. A. A. Fósforo: de nutriente à poluente. **Engenharia Sanitária e Ambiental**, v. 8, n. 8, p. 1713-1721, 2012. http://dx.doi.org/10.5902/223611706430

KNOCKE, W. R.; HOEHN, R. C.; SINSABAUGH, R. L. Using alternative oxidants to remove dissolved manganese from waters laden with organics. **Journal American Water Works Association**, v. 79, n. 3, p. 75-79, 1987. http://dx.doi.org/10.1002/j.1551-8833.1987.tb02818.x

LAUBUSCH, E. J. Chlorination and other disinfection processes. *In*: APHA. **Water quality and treatment**: a handbook of public water supplies. New York, 1971. p. 158-224.

LECHEVALLIER, M. W.; NORTON, W. D. *Giardia* and *Cryptosporidium* in raw and finished water. **Journal American Water Works Association**, v. 87, n. 9, p. 54-68, 1995. http://dx.doi.org/10.1002/j.1551-8833.1995.tb06422

LUSTOSA, J. B.; BRACARENSE, D. C.; CASTRO, F. B. S.; QUEIROZ, S. C. B.; SILVA, G. G. Tratamento e aproveitamento de água de lavagem de filtro em estação de tratamento de água. **Revista DAE**, v. 65, n. 206, p. 44-61, 2017. http://dx.doi.org/10.4322/dae.2016.027

MACARISIN, D.; SANTÍN, M.; BAUCHAN, G.; FAYER, R. Infectivity of *Cryptosporidium parvum* oocysts after storage of experimentally contaminated apples. **Journal of Food Protection**, v. 73, n. 10, p. 1824-1829, 2010. http://dx.doi.org/10.4315/0362-028x-73.10.1824

MACEDO, J. A. B. **Águas & Águas.** São Paulo: Livraria Varela, 2001.

MENEZES, A. C. L. S. M.; GADELHA, C. L. M.; SILVA-JUNIOR, W. R.; MACHADO, T. T. V.; ALMEIDA, T. M. V. Caracterização de água de lavagem de uma estação de tratamento de água, com vistas ao reuso. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 9, p. 191-196, 2005.

MEYER, S. T. O uso de cloro na desinfecção de águas, a formação de trihalometanos e os riscos potenciais à saúde pública. **Cadernos de Saúde Pública**, v. 10, n. 1, p. 99-110, 1994. http://dx.doi.org/10.1590/S0102-311X1994000100011

MIGLIOLI, M. G.; ZUANAZZI, J. G.; SILVA, J. D.; FRANCO, R. M. B.; GREINERT-GOULART, J. A. Removal of *Cryptosporidium* spp. oocysts and *Giardia* spp. cysts at a Wastewater Treatment Plant Garcia, in Blumenau, SC, Brazil. **Revista Ambiente & Água**, v. 12, n. 6, p. 1001-1016, 2017. http://dx.doi.org/10.4136/ambi-agua.2028

MOLINA, T.; SANTOS, H. R. dos. Caracterização e tratamento de água de lavagem de filtros de ETA, com o uso de polímeros sintéticos e amido de batata. **Revista Engenharia e Tecnologia,** v. 2, n. 3, p. 28-44, 2010.

MORUZZI, R. B.; REALI, M. A. P. Oxidação e remoção de ferro e manganês em águas para fins de abastecimento público ou industrial: uma abordagem geral. **Revista de Engenharia e Tecnologia**, p. 29-43, 2012.

OLIVEIRA, C. A. de; BARCELO, W. F.; COLARES, C. J. G. Estudo das características físico-químicas da água de lavagem de filtro em uma estação de tratamento de água para fins de reaproveitamento. **Periódico Eletrônico Fórum Ambiental da Alta Paulista,** v. 9, n. 11, p. 113-130, 2013. http://dx.doi.org/10.17271/198008279112013665

OPAS. **Guias para la Calidad del Agua Potable.** Volume I, II e III. Genebra, 1987.

PIAZZA, G. A.; GROTT, S. C.; GREINERT-GOULART, J. A.; KAUFMANN, V. Caracterização espaço-temporal da qualidade das águas superficiais dos mananciais de abastecimento de Blumenau/SC. **Rega**, v. 14, n. 8, p. 1-13, 2017. http://dx.doi.org/10.21168/rega.v14e8

RICHTER, C. A. **Água:** métodos e tecnologia de tratamento. São Paulo: Blucher, 2009. 340p.

ROBERTO, M. C.; GUIMARÃES, A. P. M.; RIBEIRO, J. L.; CARVALHO, A. V.; NERES, J. C. I.; CERQUEIRA, F. B. Avaliação do pH, turbidez e análise microbiológica da água do córrego guará velho em Guaraí, estado do Tocantins. **Desafios**, v. 4, n. 4, p. 3-14, 2017. https://dx.doi.org/10.20873/uft.2359-3652.2017v4n4p3

RÖNNHOLM, M. R.; WÄRNA, J.; VALRAKARI, D.; SALMI, T.; LAINE, E. Kinetics and mass transfer effects in the oxidation of ferrous sulfate over doped active carbono. **Catalysis Today**, v. 66, p. 447-452, 2001.

SAMAE. **Revisão do Plano Municipal de Saneamento Básico de Blumenau (SC).** Volume 02/07 – Abastecimento de Água Potável - Versão Preliminar. September 2016. Available in: https://pmsbblumenau.wordpress.com/consulta-publica/ Access: Sep. 23rd 2016.

SANTOS, C. L. Trihalometanos: Resumo Atual. **Engenharia Sanitária**, v. 26, p. 190-194, 1987.

SATO, M. I. Z.; GALVANI, A. T.; PADULA, J. A.; NARDOCCI, A. C.; LAURETTO, M. S.; RAZZOLINI, M. T. P.; HACHICH, E. M. Assessing the infection risk of *Giardia* and *Cryptosporidium* in public drinking water delivered by surface water systems in São Paulo State, Brazil. **Science of The Total Environment**, v. 442, p. 389-396, 2013. http://dx.doi.org/10.1016/j.scitotenv.2012.09.077

SCALIZE, P. S. **Caracterização e clarificação por sedimentação da água de lavagem de filtros rápidos de estações de tratamento de água que utilizam sulfato de alumínio como coagulante primário**. 1997. Tese (Doutorado em Hidráulica e Saneamento) - Universidade de São Paulo, São Paulo, 1997.

SILVA-JUNIOR, I. C. S.; HARAGUCHI, M. T.; UCKER, F. E.; BORBA, W. F.; KEMERICH, P. D. C. Avaliação dos sistemas de reutilização da água de lavagem dos filtros de uma estação de tratamento de água: estudo de caso. **Revista Monografias Ambientais**, v. 13, n. 5, p. 3713-3717, 2014. http://dx.doi.org/10.5902/2236130814057

SIMPSON, A.; BURGESS, P.; COLEMAN, S. J. The Management of Potable Water Treatment Sludge: Present Situation in the UK. *In*:: CIWEM (Org.). **Management of Wastes from Drinking Water Treatment**. London, 2002. p. 29-36.

SOUZA, M. M.; GASTALDINI, M. C. C. Avaliação da qualidade da água em bacias hidrográficas com diferentes impactos antrópicos. **Engenharia Sanitária e Ambiental**, v. 19, n. 3, 2014. http://dx.doi.org/10.1590/s1413-41522014019000001097

SULAIMAN, I. M.; FAYER, R.; BERN, C.; GILMAN, R. H.; TROUT, J. M.; SCHANTZ, P. M.; DAS, P.; LAL, A. A.; XIAO, L. Triosephosphate isomerase gene characterization and potential zoonotic transmission of *Giardia duodenalis.* **Emerging infectious diseases**, v. 9, p. 1444–1452, 2003. http://dx.doi.org/10.3201/eid0911.030084

THOMPSON, C. M.; DRAGO, J. North American Installed Water Treatment Ozone Systems. **Journal-American Water Works Association**, v. 107, n. 10, p. 45-55, 2015. http://dx.doi.org/10.5942/jawwa.2015.107.0157

VAN-BREMEM, J. W. Q. **International Course in Sanitary Engineering**. Delft: IHE, 1984.

VESEY, G.; SLADE, J. S.; BYRBE, M. SHEPHERD, K.; FRICKER, C. R. A new method for the concentration of *Cryptosporidium* oocysts from water. **Journal Of Applied Bacteriology**, v. 75, p. 82-86, 1993. http://dx.doi.org/10.1111/j.1365-2672.1993.tb03412.x

VITORINO, J. P. D.; MONTEIRO, S. N.; VIEIRA, C. M. F. Caracterização e incorporação de resíduos provenientes de Estação de Tratamento de Água em cerâmica argilosa. **Revista Cerâmica**, v. 55, p. 385-392, 2009. http://dx.doi.org/10.1590/s0366-69132009000400008