Water Lake Remediation using physical and chemical treatments methods.

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ABSTRACT

The contamination of natural water bodies with nutrients is a global environmental issue. Generally, the particles in water bodies are organic matter, microalgae, silica and some adsorbed ions. The main propose of the present work was the achievement of a technological process to remove particles, that embody nutrients, and improve water lakes quality. The technologies involved include retention processes and ultrafiltration membranes. Different materials, such as sand, anthracite and calcite, were studied as granular media filters for particulate matter. A comparing study about up-flow and down-flow processes was carried on in fixed bed columns and it was conclude that up-flow process was more suitable for this water treatment process. It was also concluded that an integrated process: fixed bed column with mixed sand media followed by ultrafiltration with membranes, was the most reliable process.

Keywords:

Fixed bed columns, ultrafiltration, nutrients, eutrophication, water treatment

1. Introduction

The contamination of water bodies with nutrients is a global environmental issue. Through the years, several methods have been applied to remove these nutrients from water bodies. The treatment technologies of particles removal could be gathered in physical and chemical categories [1-3].

In the physical category the most common technology is deep bed filtration, mostly applied to remove particles. The packed bed of filters is usually made up of sand, gravel, anthracite or other packing having a particle size with a distribution between 0.4 and 5 mm [4]. The fixed bed columns can operate in upper or down flow mode. In a segregated bed the finer particles which have a greater particle capture efficiently will be at the upper bed surface. If the filter operate in the classical down flow mode the filter can be clogged at the top layers leaving the lower layers with low solid concentration and serviceable. If the filter is used in an up flow mode the particle deposition is spread much more evenly throughout the bed, leading to longer bed service times, however the range of allowed flow rate of filtration, and allowable pressure drops in an up flow filter is more restricted since the bed cannot be fluidized during the filtration operation. For cleaning the flow of a down flow filter is reversed to fluidize the bed and to wash off the particles (back flushing). It is usual practice to inject compressed air for increasing the turbulence of the fluidized bed. The backwash volume for deep bed filters correspond to 2 to 5% of the filtrate volume [5].

The membrane technologies have been growing of interest for the particulate removal. The ultrafiltration, using dead end hollow fibre units, has been applied to water treatment, due to the compactness of the membrane modules and smaller backwash volume, required to clean the hollow fibres [6]. However ultrafiltration requires higher working pressure (1.5 -2.5 bar) and may have fouling problems when the water has particles with diameter < 1 micro. Uncontrolled operation can lead to irreversible membrane fouling, high costs for cleaning, and low water recoveries [7] [8].

In the chemical treatments the most common technology is chemical precipitation using calcium hydroxide and some coagulants and flocculants.

Coagulants such as aluminium salts, polyaluminumchloride, ferric chloride and cationic flocculants can be applied prior to deep bed filtration (direct filtration or contact flocculation) or ultrafiltration in order to increase the particle size and facilitate the filtration process. These reagents also remove the soluble ions since aluminium precipitates are insoluble and the particles of ferric hydroxide or hydroxide aluminium are known adsorbents of anionic elements. However soluble aluminium is toxic to the aquatic ecosystem and the ferric chloride deliver a characteristic brown colour to the treated water body. One of the most studied alternatives to the addition of coagulants and flocculants for removal of soluble matter is to use adsorbents immobilized in a multilayer bed of a deep bed filter [9-12]. The removal of mechanism is a mixed process of a complex ion exchange and chemical precipitation [9]. The affinity as well as the total capacity of the adsorbent materials to adsorb soluble matter is depend of the pH, of the ionic strength and most importantly of the soluble organic matter.

2. Materials and Methods

2.1 Materials

The water lake used in the experiments was a water form an eutrophic lake, which has a frequent algal bloom and an average of nutrients concentration of 85 ppb and chlorophyll a of 37 ppb.

2.2 Analytical Methods

Total Solids Analysis

Total Solids were analysed by the standard method 2540 B [13].

A well-mixed sample is evaporated in a weighed dish and dried to constant weight in an oven at 103 to 105ºC. The increase in weight over that of the empty dish represents the total solids. Choose a sample volume that yield a residue between 2.5 to 200 mg. After that, pipet a measured volume of well-mixed sample, during mixing, to a preweighed dish. Evaporate to dryness in a drying oven. Stir sample with a magnetic stirrer during transfer. If necessary, add successive sample portions to the same dish after evaporation. When evaporating in a drying oven, lower temperature to approximately 2ºC below boiling point to preventing splattering. Dry evaporated sample for at least 1 hour in an oven at 103 to 105ºC, cool dish in a desiccator to balance temperature, and weigh. Repeat cycle of drying, cooling, desiccating and weighing until a constant weight is obtained or until weight change is less than 4% of previous weight.

Dissolve Solids Analysis

To analyse dissolved solids a well-mixed sample is filtered through a standard glass fiber filter and the filtrate is evaporated to dryness in a weighed dish and dried to constant weight a 180ºC. The increase in dish weight represents the total dissolved solids. Choose sample volume to yield between 2.5 and 200 mg dried residue. If more than 10 minutes are required to complete filtration, increase filter size or decrease sample volume. Stir sample with a magnetic stirrer and pipet a measure volume onto a glass fiber filter with applied vacuum. Wash with three successive 10 mL volumes of reagent grade water, allowing to complete drainage between washings, and continue suction for about 3 min after filtration is complete. Transfer total filtrate to a weighed evaporating dish and evaporate to dryness in a drying oven. If necessary add successive portions to the same dish after evaporation. Dry evaporated sample for at least 1 hour in an oven at 180ºC, cool in a desiccator and weigh. Repeat cycle until a constant weight is obtained or until weight change is less than 4% of previous weight.

Turbidity Analysis

Turbidity was measure with turbidimeter *Turbiquant 3000 IR*.

2.3 Equipment

In fixed bed columns experiments it was used two columns. The first column was a glass column with .2.5 cm diameter (figure 1).

Figure 1 - Fixed bed column with 2,5 cm of diameter

The second column was an acrylic column with 5.2 cm of diameter (figure 2).

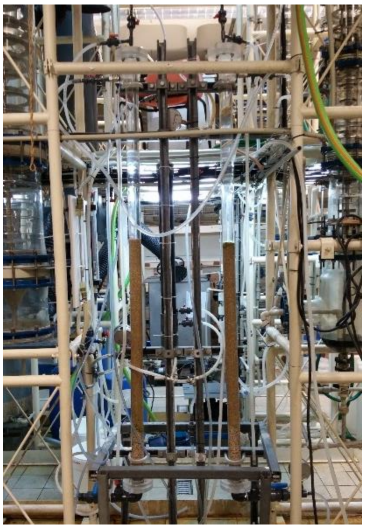

Figure 2 - Fixed bed column with 5.2 cm of diameter

Ultrafiltration experiments were taken in an ultrafiltration membrane with hollow fibres (figure 3).

Figure 3 - Ultrafiltration membrane

3. Results and discussion

This section presents the results of different assays using fixed bed columns and ultrafiltration membranes.

3.1 Fixed bed columns with 2.5 cm of diameter.

The purpose of these assays was to select the most efficient media to remove particles and soluble matter from water. The parameters considered in this study were: the volume of effluent that passes through the granular media before clogging, the superficial velocity of filtration and the turbidity of the effluent.

The materials studied and their particle size distribution, porosity and density are in table 1.

Table 1 - Particle size distribution, porosity and density of studied materials

Granular Media	Particles Size (mm)	d (g/cm^3)	ε
Sand	0.45 – 0.9	1,53	0,33
	1.7 - 2	1,84	0,45
Anthracite	0.6 – 1.6	1,5	0,43
	2.36 – 4.6	-	0,47
Calcite	0.6 – 1.6	1,28	0,49
	1.6 – 2.36	1,97	0,63

Sand Media

The results of particle removal by sand media, for both particle size distribution, are present in table 2.

Table 2 - Results of sand media on particle removal from water

	Inlet Water lake			Outlet Water Lake					% Removal	
Media	Cycle	Turbidity (NTU)	pH	Height (cm)	Velocity (m/h)	Volume (L)	Turbidity (NTU)	pH	Particle Removal (%)	Soluble matter Removal (%)
Fine Sand	1	20,2	7,5	6	4	4,4	1,0	7,2	67	30
	2	14,6	7,5	6	4	10,5	1,2	6,9	76	33
Coarse Sand	1	11,8	7,5	9	4	22,2	1,2	7,4	70	18,8
	2	11,8	7,5	9	8	15,7	1,5	7,2	66	5,2

Regarding the results above, sand was an effective media in removal particles from Water Lake, independently of media size distribution. Finer sand media was able to remove a higher percentage of soluble matter than coarser sand media.

As to volume of effluent before bed clogging, coarser sand media has treated a higher volume of water than the finer one. The turbidity of effluent had shown satisfactory results since the values approach 1 NTU with both media size distributions.

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Anthracite Media

Table 3 – Results of anthracite media on particle removal from Water Lake.

	Inlet Water Lake			Outlet Water Lake					(%) Removal	
Media	Cycle	Turbidity (NTU)	pH	Height (cm)	velocity (m/h)	Volume (L)	Turbidity (NTU)	pH	Particle Removal (%)	Soluble matter removal(%)
Fine Anthracite	1	20,3	7,5	16	4	47,2	4,5	7,3	78	48
	2	20,3	7,5	16	10	27,4	3,2	7,5	64	57
Coarse Anthracite	1	6,9	7,3	14,7	4	19,8	2	7,1	57	-
	2	6,9	7,3	14,7	10	5,8	1,9	7,4	54	-

Table 3 shows the results obtained with a fixed bed of anthracite granular media. This media could remove a high percentage of particles present in water, regardless the grain size distribution. However the soluble matter was only removed by finer anthracite media. The two size distribution of anthracite had drop the values of turbidity above 2 NTU. In this case, sand studies were more effective. As to processed volume, finer anthracite had shown better results than coarser one.

In anthracite studies the superficial velocity was change between work cycles. The cycles where were used higher velocities were the ones with less effluent volume.

Calcite Media

Table 4 - Results with calcite media on particle removal form water

	Inlet Water Lake			Outlet Water Lake					Removal	
Media	Cycle	Turbidity (NTU)	pH	Height (cm)	velocity (m/h)	Volume (L)	Turbidity (NTU)	pH	Particle Removal (%)	Soluble Matter Removal (%)
Fine Calcite	1	14,6	7,5	10	4	28,3	1,7	7,9	74	46
	2	20,3	7,5	10	4	29	1,7	7,1	74	41
Coarse Calcite	1	14,6	7,5	6	4	20,5	1,8	7,6	63	-
	2	14,6	7,5	6	8	12	1,9	7,4	58	-

Calcite media was an effective material on particle removal from water, independently of the grain size distribution of the media, with the finer particles were more effective than the coarser ones. Regarding soluble matter, like what happened with anthracite, only the finer calcite media was able to remove 41-46% of soluble matter. The turbidity of water had drop to values approaching 2 NTU, has shown in table 4.

Regarding all the studies above mentioned and taking account the results obtained with different materials, it was concluded that all media were effective in particle removal. The soluble matter was only removed by the finer grain size distributions of media.

The chosen media to study fixed bed columns with a larger diameter was a mixed granular sand bed.

3.2 Fixed Bed Columns with 5,2 cm of diameter

The purpose of these assays were verified which flow was more suitable for particle removal from water lake. The results are shown in table 5.

Table 5 - Results from fixed bed columns with 5.2 cm of diameter

	Inlet Water Lake			Outlet Water Lake			Removal	
Flow	Turbidity (NTU)	pH	velocity (m/h)	V (L)	Turbidity (NTU)	pH	Particle Removal (%)	Soluble Matter Removal (%)
Down Flow	4,6	7,5	4-20	786	1,1	7,3	41,3	25,1
Up Flow	4,4	7,5	4-20	746	1,1	7,4	45	34

Both flows were effective in particles removal from water. Up flow studies shown a higher removal percentage of particles and soluble matter than down flow studies. Both flows drop water turbidity to values near 1 NTU. The processed volumes were above of 700 L. However, it is important that neither one of flows reached the point of bed clogging. The velocities changes didn’t had a significant effect on particles removal, so a set-up of a high velocity that doesn’t drop the particle removal and doesn’t allow a fluidized bed (in case of up flow), it is adequate to this treatment.

3.3 Ultrafiltration studies

The ultrafiltration studies were made with two different inlet waters: water lake and water that was pre-treated with fixed bed columns with granular sand media. The experiments tested were at constant flow and constant work pressure. The results obtained are present in tables 6 and 7.

Table 6 - Results from Ultrafiltration of pre-treated water

	Inlet Water	Outlet Water		Removal		Experiments
Runs	Turbidity (NTU)	Turbidity (NTU)	Volume (L)	Particles Removal (%)	Soluble Matter (%)	
1	1,0	0,1	814	38	0	Constant Flow (300 L/h)
2	2,2	0,08	708	52	9	Constant Pressure (Pe=1 bar)

Table 7 - Results from Ultrafiltration of water lake

	Inlet Water	Outlet Water		Removal		Experiments
Runs	Turbidity (NTU)	Turbidity (NTU)	Volume (L)	Particles Removal (%)	Soluble Matter (%)	
1	4,4	0,1	450	58	17	Constant Flow (225 L/h)
2	9,4	0,09	415,4	57	17	Constant Flow (277 L/h)
3	9,4	0,2	180	65	31	Constant Flow (360L/h)
4	7,6	0,1	450	69	26	Constant Pressure (Pe=1 bar)
5	7,6	0,08	336	70	22	Constant Pressure (Pe=2 bar)

In the experiments with pre-treated water (table 6) it was concluded that ultrafiltration process was capable of remove some solid particles that was still on water, after fixed bed columns treatment. Regarding soluble matter this technology was not effective since percentages removal were pending to zero. Ultrafiltration process was the most effective process concerning turbidity since the final values were less than 0.2 NTU. The effluent volumes were 708 L and 814 L.

The experiments proceeded with water lake concluded that ultrafiltration as single treatment is an effective treatment. The particles removal reached 70% and some soluble matter was removed by this process (less than 30%).The effluent volumes obtained were between 180 L e 450 L, less than the experiments mentioned before. The final turbidity had values less than 0,2 NTU.

4. Conclusions

Different materials were studied as granular media for fixed bed columns in order to remove particles and some soluble matter from Water Lake to prevent or revert eutrophication phenomena. All materials were effective on particles removal but only the finer grain size media was capable of remove soluble matter.

Ultrafiltration processes had the most effective results on turbidity with a treated water with less than 0.2 NTU.

It is important mention that all solid particles with less than 0.45 µm of diameters were considered soluble matter.

It was concluded that an integrated process was the most suitable for the water lake treatment. Fixed bed columns with a granular size distribution sand as media would remove particles and some organic matter while ultrafiltration would remove the smaller particles and resolve turbidity problems.

An important aspect frequently neglected is the management and treatment of the aqueous phase resulting from the backflush operation developed dehydration process for agro industries residues based in a filter press with membrane plates and thermal drying capabilities using hot water as heat source. A future work that involves this innovative process should be developed for the treatment of the backflush residue producing a filter cake of biomass with less than 10% of moisture and rich in nutrients that could be used as a fertilizer.

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