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MICROALGAE: THE USE OF NANOTECHNOLOGY IN BIORREMEDIATION[1]

MICROALGAS: O USO DA NANOTECNOLOGIA NA BIORREMEDIAÇÃO

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ABSTRACT

Over the past two decades, great attention has been paid to managing environmental pollution caused by hazardous materials, such as: metals (lead, cadmium), pesticide residues, leakage of rights, among others. Many methods have been developed for the removal of such substances as precipitation, evaporation, ion exchange. However, these methods have several disadvantages such as: high cost of implantation, need for a large quantity of chemical products and interference of the process due to the presence of oils. It is known that there is a need to awaken more and more human and collective consciousness for the development and application of new technologies in favor of the environment. This review highlights the alternative biological agent abundantly present in nature, that is, microalgae as a possible sink for the removal of these toxic substances from the environment. Microalgae biomass has also been used to remove heavy metals, and in wastewater treatment facilities, they can be used to reduce the amount of toxic chemicals needed to clean and purify water, reaffirming its bio-absorption capacity toxic.

Keywords: Nanoscience, Environment, Contamination, Nanofilters.

RESUMO

Durante as últimas duas décadas, foi dada grande atenção ao gerenciamento da poluição ambiental causada por materiais perigosos, como: metais (chumbo, cadmio), resíduos de pesticidas, vazamento de combustíveis, entre outros. Neste sentido, um grande número de métodos foi desenvolvido para remoção de tais substâncias como precipitação, evaporação e troca iônica. No entanto, esses métodos têm várias desvantagens como: alto custo de implantação, necessidade de grande quantidade de produtos químicos e interferencia do processo pela presença de óleos. Sabe-se da necessidade de se despertar cada vez mais a consciência humana e coletiva para o desenvolvimento e aplicação de novas tecnologias em prol do meio ambiente.Esta revisão destaca o agente biológico alternativo abundantemente presente na natureza, ou seja, microalgas como um possível sumidouro para a remoção dessas substâncias tóxicas do ambiente. A biomassa de microalgas tem sido usada

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para remover metais pesados, e em instalações de tratamento de águas residuais, as mesmas podem ser utilizadas para reduzir a quantidade de produtos químicos tóxicos necessários para limpar e purificar a água, reafirmando a sua capacidade de bioabsorção de tóxicos.

Palavras-chave: *Nanociências, Meio Ambiente, Contaminação, Nanofiltros.*

INTRODUCTION

Water pollution is global issue that has been affecting many people worldwide and, as a vital asset, very important that measures are implemented to solve this problem efficiently and quickly. Population growth and the disordered advance of urban occupation in coastal regions, oupled with the intensification of industrial activities, represent an increase in human influence in these ecosystems. Due to the high generation of waste, which is normally discarded in rivers, lagoons, estuaries, bays and reaches the ocean, water pollution has become an issue of increasing concern worldwide.

The growing demand for services and products has increased industrial activity, sometimes generating more and more waste and increasing the use of natural resources, which are becoming scarce and are often polluted and degraded (DAL MAGRO *et al*., 2011).

Based on this, biological processes have become an increasingly interesting alternative in combating pollution and in generating new products, as these processes use microbial metabolism to degrade and remove pollutants (GADD, 2009), as well as to transform raw materials generating products that are less harmful to the environment.

With regard to the specific removal of contaminants from wastewater, traditional removal technologies, such as ion exchange, chemical precipitation and adsorption by activated carbon, are inefficient or quite expensive for situations where the concentration of contaminants (METCALF and EDDY, 2014).With this, a major emphasis has been given to the microalgae of different species, which has been used in waste water treatment and retention studies of toxic metals (DAL SLIM *et al*., 2011).

New technologies are necessary, the possibilities of applying microalgae in the treatment of wastewater are fundamentally three: removal of nutrients, disinfection, and removal of contaminants. More recently, some studies have also been carried out on the use of microalgae in the removal of toxic organic compounds, such as phenols and chlorophenols (HIROOKA *et al*., 2003; LIMA *et al*., 2004).

In addition, microalgae provide oxygen to bacteria, making their biological degradation activity more efficient, removing nutrients, such as nitrogen and phosphorus, responsible for the eutrophication processes of water media, in addition to removing some heavy metals and pathogenic microorganisms (MAYO and NOIKE, 1994).They have advantages over higher plants, as they are traditional sources of bioactive compounds, such as rapid growth or short cultivation time, high biomass productivity, high carbon dioxide fixation and oxygen production and low water consumption.

Microalgae produce more oxygen than all plants combined in the world, being responsible for at least 60% of the Earth's primary production (CHISTI, 2004).

Currently, the focus of research on microalgae in Brazil revolves around the investigation of potential species for bioremediation in relation to the treatment of wastewater, reducing costs in crops, production and obtaining biomass. Given this scenario, we seek to combine economic development with environmental protection, developing new products through nanotechnology, new process alternatives and efficient techniques in combating and remedying pollution, thus making industrial activity less impacting on the environment.

Through nanotechnologies and their changes in the behavior of materials, it is possible to find solutions or even alleviate this problem, dealing with the neglect with water treatment. Several companies around the world and in Brazil have been looking for a way to purify water and properly treat sewage, developing innovative, affordable and sustainable water purification systems (Seldom Technologies, access 03.11.2019).

The bioremediation process consists of removing contaminating compounds from the environment from living organisms such as microorganisms, plants, fungi, and algae, which can use these elements present in the water for their development. Algae have in their cellular structure a large area called vacuole, a type of cavity limited by a membrane, where it can store large amounts of substances.

This aims to optimize the culture medium in order to obtain a higher cell concentration, to obtain a greater amount of biomass in order to produce nanofibers to compose a filter for bioremediation.Therefore, this paper aims to produce nanofibers based on microalgae for application in the bioremediation process of pollutants/effluent contaminants.

MICROALGAE

The growing demand for services and products has increasingly increased industrial activity, sometimes generating more and more waste and increasing the use of natural resources, which are becoming scarce and are often polluted and degraded (DAL MAGRO *et al.*, 2011).The greatest emphasis has been given to microalgae of several species, which have been used in studies of effluent treatment and toxic metal biosorption (DAL MAGRO *et al.*, 2011), Carbon dioxide (CO_2)biofixation (MORAIS and COSTA, 2007) and production biofuels (XU and MI, 2011).The culture media are very important for the cultivation of microalgae. Some other aspects such as concentration and composition of nutrients, light intensity, carbon dioxide concentration, salinity, temperature, among other aspects, can significantly influence the final composition of the biomass obtained, more than the choice of a species for cultivation (FÁBREGAS *et al.*, 1996).

Microalgal biomass has about 50% carbon in its composition, as well as a source of this nutrient in crops, it represents an important component of production costs, whether gaseous in the form of carbon dioxide or solid, mainly in the form of bicarbonate (VONSAHK, 1997). Given this scenario, its sought to combine economic development with environmental protection, developing new products, new process alternatives and efficient techniques in combating and remedying pollution, thus making industrial activity less impacting on the environment.

Intensive cultivation of microalgae today represents one of the most modern processes in biotechnology. From these crops it is possible to obtain food and various products of nutritional, pharmacological and industrial interest, at much lower costs than those employed by traditional agriculture, and at a much faster production speed (CHISTI, 2007).

Spirulina has been found in many different environments such as brackish waters, the sea, saline lagoons, sub-arctic waters, tropical lagoons, and hot springs. Thus, these organisms may be able to adapt to extreme environmental conditions (CIFERRI and TIBONI, 1985). To obtain an efficient cultivation of these microalgae, one must think about the culture medium used, which has an important role, providing the nutrients for its growth (REITAN *et al.*, 1997).

The first research on cultivating microalgae was marked by the discovery of the relationship between algae and the physical and chemical environment (LOURENÇO, 2006). It can be emphasized that different species also have different nutrient needs, so it is essential to improve the culture medium according to the species to be cultivated and according to the desired biochemical composition at the end.

Such composition of microalgae varies with different concentrations of certain nutrients (FÁBREGAS *et al.*, 1996), therefore they are directly related, the culture medium and the biochemical composition, favoring a greater production of biomass and oil from microalgae on a large scale.

POPULATION GROWTH AND WATER CONTAMINATION

The rapid growth of the population leads to the establishment of high population density conglomerates, which contributes significantly to the phenomenon of environmental contamination, due to the increase in the amount of waste produced. In turn, the industrial activity that grows alarmingly satisfying the consumerism that characterizes our society, contributes with large volumes of waste of different nature, which, generally, carry toxic chemical species (BRITO *et al.*, 2004).

For decades, industrial activity has produced gaseous, liquid and solid waste that is harmful to the environment. Xenobiotic chemicals (man-made) have significantly altered the quality of ecosystems. Likewise, industrial processes that use large volumes of water contribute significantly to the contamination of water bodies, mainly due to the absence of treatment systems for the large volumes of liquid effluents produced (FREIRE *et al.*, 2000).

Contamination of natural waters has been a major problem in modern society. The saving of water in production processes has been gaining special attention due to the added value that has been attributed to this good, through principles, as a paying consumer and paying polluter, recently incorporated into our legislation (KUNZ; ZAMORA, 2002).

The release of organic matter in water bodies produces a series of effects, such as the consumption of Oxygen (O_2) and eutrophication of the springs, in addition to taste and odor in the water supply sources. The heavy metals that are adsorbed to this organic matter, can bioaccumulate along the food chain and reach human health. The change in color and turbidity and the presence of oils and floating materials cause a series of inconveniences for the water treatment plant (ETA) and alter the aesthetics of the source. The sedimentable materials can cause the silting up of rivers and dams and the drop in speed of water courses (Secretaria do Meio Ambiente do Estado de São Paulo).

Pollutants can reach surface and groundwater in a punctual or diffuse manner. Point sources include the discharge of effluents from industries and sewage treatment plants, among others. These sources are easy to identify and therefore can be easily monitored. Diffuse sources, on the other hand, are spread over numerous locations and are difficult to determine due to the intermittent characteristics of their discharges and the coverage over extensive areas. Diffuse sources include urban runoff, runoff from agricultural areas and atmospheric deposition (BUNCE, 1994).

Many of these substances still do not have an adequate method of treatment established and, thus, effluents not efficiently treated, still containing a high polluting load, have been discarded in the environment, which can cause a series of environmental disturbances (DELLAMATRICE, 2005).In recent years, Brazilian legislation has become restrictive regarding the treatment of effluents discharged into aquatic bodies, and according to Resolution No. 357 of the National Environment Council (CONAMA), effluents from any polluting source may only be released, directly or indirectly, into bodies of water, after due treatment and provided they comply with conditions, standards and proposed requirements.

The establishment of international laws that regulate the issue of environmental management, combined with pressure from governments and public opinion, has meant that great efforts have been devoted to the development of cleaner technologies for the treatment of waste and the remediation of contaminated environments (BRITO *et al.*, 2004). Although there are several technologies that use physical and/or chemical processes for the decontamination of polluted environments, the biological bioremediation process is an ecologically more appropriate and effective alternative for the treatment of environments contaminated with organic molecules of difficult degradation and toxic metals (GAYLARD; BELLINASO; MANFIO, 2005).

USE OF NANOTECHNOLOGY AND MICROALGAE

Nanotechnology has developed rapidly in recent decades, being characterized as the fourth industrial revolution. In the current market, the use of products that incorporate nanotechnologies is increasing. (YUAN EXECUTIVO, 2015)

It comprises particles from the size of 1 to 100 nanometers (nm), that is, extremely small particles that have a large contact area per volume unit, capable of passing, for example, cell barriers more easily than other substances, causing a concern in relation to the potential risks to humans and the environment. Due to their size, nanoparticles are being extensively studied (GHANEM, 2006; AMORIM, 2007).

The challenges related to global climate change and the excessive dependence on traditional fossil energy sources increasingly encourage investments in innovative technologies with greater environmental sustainability (AMORIM, 2007).In Brazil, there are currently many investments in technological development and the beginning of commercial exploitation of microalgae, starting with the products with high added value obtained from them. (AGROENERGIA EM REVISTA, 2016).

Studies suggest that the use of Nanotechnologies can contribute to solutions for the probable lack of drinking water in the coming years, in addition to applications for medicine, energy and agriculture. With the use of Nanotechnologies, Nananofilters appear, as a main advantage in comparison with traditional systems, they require less pressure for the water to pass through the filter, they are more efficient, they have very large surface areas and can be easily cleaned through retro unload AGROENERGIA EM REVISTA, 2016).

NANOTECHNOLOGY AND THE ENVIRONMENT

Although there is no clear definition about the use and regulation of nanotechnology in the environment and the influence of that on it is still recent, some benefits can be observed (SIQUEIRA-BATISTA *et al.*, 2010):

a) Pollution detection and monitoring, through the preparation of nanosensors, which are more sensitive and more specific, for the identification and environmental monitoring of pollutants;

b) Treatment of pollution, due to the important absorption property of various substances, such as metals, by the large surface area of the nanoparticles; it has also been reported the use of magnetic nanoparticles and carbon nanotubes for water desalination;

c) Prophylaxis of pollution hazards, with emphasis on the use of catalytic nanomaterials, thus competing for a greater use of raw materials, with little energy expenditure and less production of undesirable residues.

BIORREMEDIATION WITH USE OF MICROALGAE

Bioremediation is a process in which living organisms, usually plants, microorganisms, or their enzymes, are used technologically to remove (remedy) or reduce pollutants in the environment. The metabolic process that has been shown to be more apt to biodegrade xenobiotic molecules

(molecules foreign to the natural environment) recalcitrant (molecules of difficult degradation) in the bioremediation processes, is the microbial one, since the microorganisms participating in the main biogeochemical cycles and therefore representing , life maintenance support on Earth (GAYLARD; BELLINASO; MANFIO, 2015).

According to Yakubu (2007), the biotechnological process of bioremediation uses the metabolism of microorganisms for the rapid elimination of pollutants, in order to reduce its concentration to acceptable levels, transforming them into compounds of low toxicity.The presence of heavy metals in the environment is a major concern because of its toxicity to flora and fauna. In addition, the recovery of heavy metals from industrial waste streams is becoming increasingly important, as society realizes the need for recycling and conservation of essential metals. Industrial waste, geochemical structure and metal mining create a potential source of metal pollution in the aquatic environment (GUMGUM *et al.* 1994).

Heavy metals are the main pollutants in marine, ground, industrial and even treated wastewater. Rapid urbanization, industrialization, the use of fertilizers and pesticides resulted in pollution by heavy metals, land and water resources. The presence of heavy metals in the environment is a major concern because of its toxicity to flora and fauna. In addition, the recovery of heavy metals from industrial waste streams is becoming increasingly important, as society realizes the need for recycling and conservation of essential metals. Industrial waste, geochemical structure and metal mining create a potential source of metal pollution in the aquatic environment (GUMGUM *et al.*, 1994).

Heavy metals are not biodegradable and tend to accumulate in living organisms. To reduce heavy metal pollution problems, many processes have been developed for treating wastewater containing metals. Heavy metals have been shown to affect a wide range of cellular microalgae activities, including viability and membrane structure and properties. Many contaminating chemicals, including organochlorine compounds, herbicides, household and municipal waste, petroleum products and metals are now recognized to have adverse effects on ocean environments, even when released at low levels (HAYNES; JOHNSON, 2000).

Among the species used for the removal of excess nutrients from effluents, as well as for the production of biomass for bioenergy purposes such as biodiesel, ethanol and hydrogen, or for commercial extraction, such as pigments and lipids, there are chlorophytes (*Chlorella* sp. , *Scenedesmus dimorphus*, *Dunaliella salina*, *Haematococcus pluvialis*) and some cyanobacteria (*Spirulina sp.* , *Arthrosira* sp.) (BOROWITZKA, 1999). Large-scale cultivation of algae can contribute significantly to reducing eutrophication resulting from anthropic action. (TWIST *et al.*, 1998).

The idea of using microalgae in bioremediation processes was initially proposed by Oswald and Gotaas (1957), but it gained momentum in the 1980s (PROULX & DE LA NÖUE, 1988; OSWALD, 1988). Microorganism systems are able to efficiently eliminate nitrogen and phosphorus compounds responsible for eutrophication problems (LALIBERTÉ *et al.*, 1992). The use of microalgae for bioremediation has several advantages (TALBOT & DE LA NÖUE, 1988) such as:

a) use of cheap and abundant energy (sunlight).

b) production of biomass for animal feed.

c) obtaining high value-added products and fine chemicals.

To reduce heavy metal pollution problems, many processes have been developed for treating wastewater containing metals. Heavy metals have been shown to affect a wide range of cellular microalgae activities, including viability and membrane structure and properties. Many contaminating chemicals, including organochlorine compounds, herbicides, household and municipal waste, petroleum products and metals are now recognized to have adverse effects on ocean environments, even when released at low levels (HAYNES and JOHNSON 2000). The need for economical, effective and safe methods of removing heavy metals from wastewater has resulted in the search for unconventional materials that can be useful in reducing the levels of heavy metals in the environment.

Microalgae are superior in the remediation of a wide variety of toxic waste. Knowing that the risks of accidental release of pollutants into the atmosphere causing safety to health and the environment are problems that are avoided when microalgae are used in remediation. The bioremediation process can occur by methods such as flocculation, which is one of the stages of water treatment in which chemical coagulants are added to form flakes that carry dirt. (CPRH, Companhia Pernambucana do Meio Ambiente, 2001).

FLOCULATION

For basic definitions contained in Metcalf & Eddy, 2014, the term chemical coagulation is used whenever there are reactions and mechanisms involved in chemical destabilization of particles and in the formation of larger particles through perokinetic flocculation (aggregation of particles in sizes between 0.001 to 1 μm).

The term flocculation is used to describe the process by which the particle size increases through the result of particle collision.The main techniques used in the recovery of microalgae biomass are centrifugation, flocculation, filtration, gravitational sedimentation, flotation and electrophoresis techniques, and each of these has advantages and disadvantages (UDUMAN, QI AND DANQUAH, 2010; SELESU, 2012).

Centrifugation and electroflotation are efficient processes, but very expensive due to the high energy consumption while filtration demands constant work to change filters and takes a long time. Flocculation, on the other hand, is a low energy cost process if a low cost flocculant is chosen that does not make the process more expensive (UDUMAN, QI AND DANQUAH, 2010; SELESU, 2012).

Flocculation has been identified as an alternative because it is a low-cost technology that in combination with sedimentation using biofloculants can reduce the demand for centrifugation energy after flocculation (SALIM, VERMUË E WIJFFELS, 2012).

The use of organic flocculants of animal and vegetable origin becomes a promising alternative to inorganic flocculants, being biodegradable, natural and non-toxic (HANSEL, RIEFLER AND STUART, 2014).

INORGANIC FLOCCULANTS

Iron (III) Sulfate: It is stable in a pH range of 4 to 11 and is one of the most well-known coagulants. It produces large, dense flakes that decant quickly, so it is indicated in preliminary precipitation and in the co-precipitation of urban and industrial wastewater (AGUILAR, 2002).

Iron (III) Chloride: When dissolved in water, iron chloride III undergoes hydrolysis and releases heat through an exothermic reaction. The result is an acidic and corrosive solution that is used as a coagulant in the treatment of wastewater (DEL CINCA, 2016).

Aluminum Sulphate: Aluminum sulphate is used extensively as a flocculant in the treatment of wastewater, drinking water and swimming pools. It allows organic and inorganic matter in suspension to associate in flakes. (DEL CINCA, 2016).

Iron (II) Sulfate: Ferrous sulfate or iron sulfate II is an inorganic salt used in medicine, a percussion agent for dye synthesis, a catalyst in reactions for grading organic contaminants, flocculant for water treatment, etc. (RIBEIRO, BORGES E LUPIANHES, 2010).

NATURAL FLOCCULANTS

Chitosan: Chitosan, being a compound of animal origin and biodegradable, has been widely used, the search for potential flocculating agents is still necessary in order to reduce the cost of biomass globally (SELESU, 2012).

Tanfloc SG: An alternative to using chitosan is tanfloc, a compound of vegetable origin based on tannins with a high potential for flocculation. However, its use in the flocculation process is little studied in the literature, although in water treatments it has shown to be quite promising. Tanfloc is a trademark of the company TANAC (Brazil) (TANAC, 2014) and is a tannin-based product modified by a physical-chemical process with a high flocculating power.

Tannins are defined as biodegradable phenolic molecules capable of forming complexes with proteins and other macromolecules and minerals. They are extracted from the peel of vegetables, such as Wild Acacia mearnsi (black wattle), which has high concentrations of tannin and is easily found in Brazil (BELTRÁN-HEREDIA *et al.*, 2011).

Tannins are present in hydrolyzed and condensed form, the condensed form being responsible for more than 90% of world tannin production (PIZZI, 2008). According to Da Silva (1999), tannins are molecules with coagulating properties, which destabilize colloids with elimination of the solvation layer, reducing the zeta potential during the coagulation process and, thus, allowing formation of flakes. In this way, they can be used in wastewater treatment and supply in the coagulation and flocculation process. Commercially, tannin is used as a basis for coagulant production, from the reaction between condensed tannin and iminium chloride (formed by the reaction of ammonium chloride, for example, and formic aldehyde), forming a cationic organic polymer (MANGRICH *et al*., 2014).

Studies by Corbit *et al.* (1989) show that coagulation/flocculation is an effective technique capable of reducing the strength of pollutants in effluents and colloidal particles, it is a process widely used in the treatment of effluents in which compounds such as aluminum and iron salts are added to the effluents in order to destabilize the colloidal material and form small particles, agglomerating into larger, sedimentable flakes.

The effectiveness of this process will depend on the coagulation agent, dosage, pH, concentration, and nature of the organic compounds present in the effluent. Studies by Verma *et al.* (2008) show that this is also an effective and low-cost technology that presents excellent color removal for a wide variety of dyes, reaching removal percentages of 86%, making it a promising technology for discoloration of effluents. Sludge production can be minimized by optimizing process parameters and appropriately selecting coagulants and flocculants. The removed substances, which cause water turbidity, usually consist mostly of clay minerals and important proteins of varying sizes.

Lamb *et al.* (2003) presented in his work the division of tannins into two groups: condensed and hydrolyzable:Condensed tannins precipitate in the presence of strong mineral acids consisting of a flavonoid structure, with difficulty in breaking the C-C bonds, keeping the molecule intact, while hydrolyzables hydrolyze easily when subjected to strong acids and are composed of a structure formed by the esterification of phenolic acids with polyols. (LAMB *et al*., 2003).

The modified tannins can be applied to effluents from different segments such as: oil refineries, municipal sewage, petrochemical industries, food industries, slaughterhouses, effluents containing oil / water emulsions, metal-mechanical industries, mining effluents, in addition to being used as primary coagulant and coagulation aid in supply waters. (LAMB *et al*., 2003).

Studies by Beltrán-Heredia *et al.* (2010), point out that environmental aspects are the first reasons seen in research with tannins, while economic and availability criteria are generally not taken into account when a technical solution is proposed for remediation in water treatment.

Some research focuses on water treatment motivated by a new coagulation process that is more economical than others, based on a natural product, so that its biodegradability is superior to other coagulants, and using a coagulant that does not needs pH adjustment, making its use more practical than others. New coagulants can be studied to facilitate water treatment and reduce the price of reagents. (BELTRÁN-HEREDIA *et al*., 2010).

In 23 laboratory-scale experiments, cationic tannin syntheses were verified and showed the possibility of synthesizing tannin coagulants derived by different ways of Acacia mearnsii, Schinopsis balansae and Pinus pinaster using very simple processes. The tests performed with these products, synthesized in the laboratory by Beltrán-Heredia *et al.* (2010) were successful in removing surfactants, eliminating pigments, remedying wastewater and clarifying surface waters.

Based on Graham *et al.* (2008), there is great commercial interest and research in the use of cationic polyelectrolytes in the field of water and effluent treatment, as there is an increase in the number of new plants worldwide, increasing the need for greater performance in coagulation / flocculation.

Several studies by Sanchez *et al.* (2011), Ferrari-Lima *et al.* (2013) and Sanchez *et al.* (2010) prove that there is a reduction in all parameters of removal of organic and colloidal matter in the effluents of oil stations in physical-chemical treatments, highly effective for the treatment of water, textile and laundry effluents, as they demonstrated great affinity of tannins for removing pigments and surfactants and is efficient over a wide range of working conditions. Tests showed a significant improvement in water quality with the application of tannins, especially considering the removal of contaminants and turbidity, presenting the same efficiency as the use of aluminum sulfate, but with a dosage up to 40% lower.

Despite the use of this coagulant present many advantages in compared to traditional aluminum and iron salts, Beltrán-Heredia *et al.* (2010) presents a serious disadvantage related to the increase in residual organic carbon such as the increase in dissolved organic carbon (COD) and total organic carbon (COT), which prevents its use in large-scale installations.

Authors presented results of studies in which using tannins as coagulation aids, together with aluminum sulfate, the sludge formed can be filtered more easily and, as a consequence, the filtration process would be carried out more easily and economically than with aluminum sulfate. It was verified that the specific resistance of the formed sludge was decreasing while the turbidity value was falling considerably. Thus, the permeability of the formed aluminum-tannate sludge is better and the specific strength is lower. Therefore, the lower the specific resistance, the more easily the liquid passes through the mass during filtration and the better the results.

Sanchez *et al.* (2010) showed that the application of tannins for water purification is remarkable, verifying the removal of turbidity in surface waters and municipal wastewater, as well as the removal of 95% of dye in textile industry effluent and 80% of water removal. surfactant substances in laundry effluent.

Ying (2010) and Muthuraman *et al.* (2014) mention that natural coagulants, when applied to water treatment with turbidity between 50 and 500 NTU, resulted in removal efficiencies close to the chemical coagulants used for the same function.

PRODUCTION OF NANOFILTERS / NANOFIBERS THROUGH ELECTROPHYING OR *ELECTROSPINNING*

Some of the main aliphatic polyesters of interest for the development of micro to nano-structured systems are the homopolymers of lactic acid (PLA) and glycolic (PGA) and their copolymers (PLGA), poly-and-caprolactone (PCL) and polyhydroxyalkanoates (PHA)) (DURÁN *et al*., 2006). Polymeric nanofibers or nanofilters can be produced by various techniques, such as drawing, template synthesis, phase separation, self-assembly and electrospinning.

Electrospinning is one of the most used techniques to produce nanofibers, it presents increased potential for scale, repeatability, and easy control of fiber sizing, in addition to being low cost. It produces long nanofibers and its process is used continuously. The disadvantage is the jet instability (RAMAKRISHNA *et al*., 2005).

Electrospinning is a technique patented by Formhals, in 1974, but which is only now being explored in a more consistent manner, due to the advances of the textile industry in the development of fabrics and nonwovens with special properties. (RAMAKRISHNA *et al*., 2005).

In the electrospinning process, the polymer is injected through the tip of the pipette forming nanofibers due to the high tension. The jet is electrically charged, forming the fibers, where they are deposited in the collector (RAMAKRISHNA *et al*., 2005).

Generally, polymeric nanofibers can reach different diameters, presenting different functionalities regarding mechanical, electrical, and thermal properties. Fibers can be an ideal material to produce tissues, medical prostheses, protective clothing, and electrical devices. This technological process can have applications within the food industry to produce new materials or improve the properties of existing products (WEISS *et al*., 2006).

Meng *et al*. (2011) used an electrospinning process to produce nanofibers from chitosan and PLGA (lactic acid-co-glycolic acid). PE (polyethylene) nanofibers with incorporation of microalgal biomass were produced from the electrospinning process, obtaining nanofibers with a diameter of 107 ± 12 nm (MORAIS, 2008).

CONCLUSION

Microalgae have proven to have a high-performance potential in the Bioremediation of several compounds. This remedial capacity can be seen in several studies, being a more efficient way when compared to traditional methods of remediation. The fact that there are numerous species of microalgae serves as a stimulus for further research in this area to be carried out.

Increasingly, the improvement of new technologies is necessary, in such a way Nanotechnology contributes to the improvement from large scale water purification systems to water filters.

REFERENCES

AGROENERGIA EM REVISTA, Microalgas. Ano IV, nº 10, dezembro de 2016.

AMORIM, Tade-Ane. **Quão seguro é seguro o suficiente?** Controvérsias científicas e a construção da idéia da segurança dos nanomedicamentos. UFSC - Universidade Federal de Santa Catarina, 2007.

BELTRÁN-HEREDIA, J.; SÁNCHEZ-MARTÍN, J.; GÓMEZ-MUÑOZ, M.C. New coagulant agents from tannin extracts: Preliminary optimisation studies. **Chemical Engineering Journal**, v. 162, p. 1019-1025, 2010.

BELTRÁN-HEREDIA, J.; SÁNCHEZ-MARTÍN, J.; MARTÍN- SÁNCHEZ, C. Remediation of dye-polluted solutions by a new tannin-based coagulant. **Industrial & Engineering Chemistry Research,** v. 50, p. 686-693, 2011.

BOROWITZKA, M.A. Commercial production of microalgae: ponds, tanks, tubes and fermenters. **Journal of Biotechnology**, v. 70, p. 313-321, 1999.

BRITO, N. N. *et al.* Utilização de fungos na remediação de efluentes industriais. In: FÓRUM DE ESTUDOS CONTÁBEIS, 4., 2004, Rio Claro. **Anais...** Rio Claro: Faculdades Integradas Claretianas, 2004.

BUNCE, N. J. **Environmental chemistry**. Canadá: Wuerz, 1994.

CHISTI, Y. Biodiesel from microalgae. **Biotechnology Advances**. v. 25. p. 294-306, 2007.

CHISTI, Y. Microalgae: our marine forests. Book reviews. IN: RICHMOND, A. (Ed). **Handbook of microalgal culture:** biotechnology and applied phycology. Oxford: Blackwell Science, 2004. 566p.

CIFERRI, O.; TIBONI, O. The biochemistry and industrial potential of Spirulina. **Annual Review of Microbiology**, v. 39, p. 503-26, 1985.

CORBITT, R. A. (1998) **Standard handbook of environmental engineering**. 2. ed. New York, McGraw-Hill.

CPRH, **Companhia Pernambucana do Meio Ambiente, Roteiro Complementar de Licenciamento e Fiscalização:** Tipologia Galvanoplastia. Recife - PE (2001).

DA SILVA, T. S. S. **Estudo de tratabilidade físico-química com uso de taninos vegetais em água de abastecimento e de esgoto.** Dissertação (Mestrado) - Fundação Oswaldo Cruz, Rio de Janeiro, 1999.

DAL MAGRO, C.; HEMKEMEIER, M.; COLLA, L.M. Remoção de cromo VI e DQO de meio de cultivo adicionado de efluente com elevada concentração de cromo a partir da microalga Spirulina platensis. In: XVIII SIMPÓSIO NACIONAL DE BIOPROCESSOS, 2011, Caxias do Sul. **Anais...** Caxias do Sul: Editora da UCS, 2011. 1 CD-ROM.

DEL CINCA. **Coagulantes Del Cinca**. 2016.

DELLAMATRICE, P. M. Biodegradação e toxicidade de corantes têxteis e efluentes da Estação de Tratamento de Águas Residuárias de Americana. 137 f. 2005. **Tese** (Doutorado em Ecologia de Agroecossistemas) - Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba.

DURÁN, N., MATTOSO, L. H. C., MORAIS, P. C. **Nanotecnologia:** Introdução, preparação e caracterização de nanomateriais e exemplos de aplicação. 1. ed. São Paulo: Artliber Editora Ltda, 2006, p. 208.

FÁBREGAS, J.; PATINO, J.; MORALES E. D.; CORDERO, B.; OTERO, A. Optimal renewal rate and nutrient concentration for the production of the marine microalgae Phaeodactylum tricornutum in semicontinuous cultures. **Applied and Environmental Microbiology**, v. 62, p. 266-268, 1996.

FERRARI-LIMA, A. M.; MARQUES, R. G.; FERNANDES-MACHADO, N. R. C.; GIMENES, M. L. Photodegradation of petrol station wastewater after coagulation/flocculation with tannin-based coagulante. **Catalysis Today**, v. 209, p. 79- 83, 2013.

FREIRE, R. S. *et al.* Novas tendências para o tratamento de resíduos industriais contendo espécies organocloradas. **Química Nova**, São Paulo, v. 23, n. 4, p. 504-511, 2000.

GADD, G.M. Biosorption: critical review of scientific rationale, environmental importance and significance for pollution treatment. **Journal of Chemical Technology & Biotechnology**, v. 84, p. 13- 28, 2009.

GAYLARD, C. C.; BELLINASO, M. L.; MANFIO, G. P. Aspectos biológicos e técnicas da biorremediação de xenobióticos. **Biotecnologia, Ciência e Desenvolvimento**, Brasília, v. 8, n. 34, jan./jun. 2005.

GAYLARDE, C. C.; BELLINASO, M. L.; MANFIO, G. P. Biorremediação. **Biotecnologia Ciência & Desenvolvimento**, n. 34, p. 36-43, 2005. Disponível em: Acesso em: 3 ago. 2015.

GHANEM, Hussein & Mohamed. **Possíveis aplicações dos nanorobôs na medicina sexual:** um artigo de revisão. v. 03, n. 1 - Setembro / Outubro - 2006.

GRAHAM, N.; GANGA, F.; FOWLER, A.G.; WATTS, M. Characterisation and coagulation performance of a tannin-based cationic polymer: A preliminary assessment. Colloids and Surfaces A: **Physicochem. Eng. Aspects**, v. 327, p. 9-16, 2008.

HANSEL, P. A.; RIEFLER, R. G.; STUART, B. J. Efficient flocculation of microalgae for biomass production usingcationic starch. **Algal Research**. 2014 133-139.

HIROOKA, T.; AKIYAMA, Y.; NAKAMURA, T.; NAGASE, H.; MIYAMOTO, K. (2003). Removal of Hasardous Phenols by Microalgae under Photoautothophic Conditions. *In:* **J. Bioscience and Bioeng**. 2, p. 200-203.

KUNZ, A.; ZAMORA, P. P. Novas tendências no tratamento de efluentes têxteis. **Quimica Nova**, São Paulo, v. 25, n. 1, p. 78-82, 2002.

LALIBERTE, G.; PROULX, D.; DE PAUW. N.; DE LA NÖUE, J. **Phycological Perspectives in Water Pollution**. New York. Springer-Verlag, 1992.

LAMB, L.H.; DINIZ, E.R.; CRUZ, J.G.H.; HASS. Aplicação de Tanino Catiônico em Tratamento de Efluentes de Curtume. M.E.A. XVI Encontro Nacional dos Químicos e Técnicos da Indústria do Couro. **Anais...** Foz do Iguaçu, 2003.

LIMA, S.A.C.; RAPOSO, M.F.J.; CASTRO, P. M.L.; MORAIS, R.M. (2004). Biodegradation of p-Chlorophenol by a Microalgae Consortium. *In:* **Water Research**, 38, p. 97-102.

LOURENÇO, S. O. **Cultivo de Microalgas Marinhas Princípios e Aplicações**. São Carlos. São Paulo: Ed. RiMa, p. 47-51, 2006.

MANGRICH, A. S.; DOUMER, M. E.; MALLMANN, A. S.; WOLF, C. R. Química verde no tratamento de águas: uso de coagulante derivado de tanino de *Acacia mearnsii.* **Revista Virtual de Química,** v. 6, p. 2-15, 2014.

MAYO, A.W.; NOIKE, T. (1994). Effect of Glucose Loading on the Growth Behavior of *Chlorella Vulgaris* and Heterotrophic Bacteria in Mixed Culture. *In:* **Water Research**, 28, p. 1001-1008.

MENG, Z. X.; XU, X. X.; ZHENG, W.; ZHOU, H. M. LI, L.; ZHENG, Y. F.; LOU, X. Preparation and characterization of electrospun PLGA/gelatin nanofibers as a potential drug delivery system. Colloids and Surfaces B: **Biointerfaces**, v. 84, p. 97-102, 2011.

METCALF & EDDY, I AECOM et al (Org.). **Wastewater Engineering:** Treatment and Resource Recovery. 5. ed. Ásia: Mcgraw-hill Edication, v. 2, 2014.

METCALF & EDDY, I AECOM et al (Org.). **Wastewater Engineering:** Treatment and Resource Recovery. 5. ed. Ásia: Mcgraw-hill Edication, v. 2, 2014.

MORAIS, M. G. Bioengenharia microalgal na utilização de gás de combustão e extração de biopolímeros para desenvolvimento de nanofibras. **Tese** (Doutorado em Engenharia e Ciência de Alimentos) - Universidade Federal do Rio Grande - FURG, Rio Grande - RS, 2008.

MORAIS, M.G.; COSTA, J.A.V. Biofixation of carbon dioxide by Spirulina sp. and Scenedesmus obliquus cultivated in a three-stage serial tubular photobioreactor. **Journal of Biotechnology**, v. 129, p. 439-445, 2007.

MUTHURAMAN, G.; SASIKALA, S. Removal of turbidity from drinking water using natural coagulants. **Journal of Industrial and Engineering Chemistry**, v. 20, p. 1727- 1731, 2014.

OSWALD, W.J.; GOTAAS, H.B. Photosynthesis in sewage treatment. **Trans. Am. Sot. Civ. Eng**. v. 122, p. 73-105. 1957.

PIZZI, A. Tannins: major sources, properties and applications. In: BELGACEM; GANDINI (Eds). **Monomers, polymers and composites from renewable resources.** Elsevier: Amsterdam, 2008. p. 179-199.

PROULX, D.; DE LA NÖUE, J. Removal of macronutrients from wastewater by immobilized algae. Bioreactor Immobilized Enzymes and Cells: Fundamentals and Applications. (Moo-Young, M., Ed.). **Elsevier Applied Science**, London, 301-310. 1988.

RAMAKHISHNA, S.; Fujihara, K.; TEO, W-E.; LIM, T-C. & Ma, Z. - **An Introduction to Electrospinning and Nanofibers**, World Scientific Publishing, Singapore (2005).

Reitan, K. I., Rainuzzo, J. R., ∅ie, G. and Olsen, Y. 1997. **A review of the nutritional effects of algae in marine fish larvae**. Aquacult., 155: 207-221.

RIBEIRO, M. M.; BORGES, L. F.; LUPIANHES, B. H. **Obtenção, purificação, e caracterização do sulfato ferroso**. Universidade Federal de Alfenas. 2010

SALIM, S.; VERMUË, M.H.; WIJFFELS, R.H. Ratio between autoflocculating and target microalgae affects the energy-efficient harvesting by bio-flocculation. **Bioresource Technology**. 2012. p. 49-55

SÁNCHEZ-MARTÍN, J. Optimum Coagulant from Acacia mearnsii de Wild for Wastewater Treatment. **Chemical engineering & technology**, v. 34, p. 2069-2076, 2011.

SÁNCHEZ-MARTÍN, J.; BELTRÁN-HEREDIA, J.; SOLERA-HERNÁNDEZ, C. Surface water and wastewater treatment using a new tannin-based coagulant. Pilot plant trials. **Journal of Environmental Management**, v. 91, p. 2051-2058, 2010.

Seldom Technologies, **Technology**, http://seldontech.com/.

SELESU, N. F. H. *et al.* **Processos de limpeza em fotobiorreator tubular para produção de microalgas**. Universidade Federal do Paraná. 2012

SIQUEIRA-BATISTA, Rodrigo *et al.* Nanociência e nanotecnologia como temáticas para discussão de ciência, tecnologia, sociedade e ambiente. **Ciência & Educação**. v. 16, n. 2, p. 479-490, 2010.

TALBOT, P. ; DE LA NÖUE. J. **Algal Biotechnology** (Staedler, T., Mollion. J., Verdus, M. C. Karamanos, Y. Morvan, H., and Christiaen, D., Eds.). Elsevier, London, 1988.

TANAC. 2014. **Tanfloc Safety**

TWIST, H.; EDWARDS, A. C.; COD, G. A. Algal Growth responses to waters of Contrasting Tributaries of the River Dee, North-East Scotland. In: **Water Research**, v. 32, p. 2471-2479. 1998.

UDUMAN, N.; QI, Y.; DANQUAH, M. K. **Marine microalgae flocculation and focused beam reflectance measurement**. v. 162, n. 3, p. 935-940, 1 September 2010

VERMA, Y. Acute toxicity assessment of textile dyes and textile and dye industrial effluents using Daphnia magna bioassay. **Toxicology and industrial health**, v. 24, n. 7, p. 491-500, 2008.

VONSHAK, A. **Spirulina platensis (Arthrospira) Physiology, cell-biology and biotechnology**. London: Taylor & Francis, 1997, 252 p.

WEISS, J.; TAKHISTOV, P. ; McCLEMENTS, D. J. Functional materials in food nanotechnology. **Journal of Food Science**, v. 71, n. 9, p. 107-116, 2006.

XU, R.; MI, Y. Simplifying the Process of Microalgal Biodiesel Production Through In Situ Transesterification Technology. **Journal of the American Oil Chemists' Society**, v. 88, n. 1, p. 91-99, 2011.

YAKUBU, M. B. Biological approach to oil spills remediation in the soil. **African Journal of Biotechnology**, Nigeria, v. 6, n. 24, p. 2735-2739, Dec. 2007.

YING, C. Emerging usage of plant-based coagulants for water and wastewater treatment: a review. **Process Biochemistry**, v. 45, p. 1437-1444, 2010.

Yuan Executivo - EY. (2015). **Iniciativa de produtividade 4.0 de Taiwan:** relatório. Taipei: Yuan Executivo.