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Residential Graywater Treatment Through Phytoremediation

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Abstract— *In a globalized world with information on environmental issues, it is observed an increasing number of researches focusing on issues related to soil and water pollution. In this context, the reuse of domestic waters (gray waters) for reuse in agriculture with ecological technology, appears as one of the alternatives to equate water demand and supply, especially in the caatinga biome of the semiarid northeast, characterized by low rainfall. Several techniques are being studied and phytoremediation among the other techniques has had a differentiated attention due to its efficiency and low cost. This study is based on the literature review of several works developed in Brazil and in the world, all related exclusively to the theme. This Review was developed through the analysis of the available material on the in the international databases SciELO, Science Direct, Springer Journal, Embase and PubMed, as well as dissertations and theses that were developed in the area of the use of phytoremediation for effluent treatment.*

I. INTRODUCTION

The development of Brazil has strong characteristics that contributed to the existence and repetition of a huge regional inequality with an enormous poverty concentration on north and northeast regions. On northeast especially on the semiarid region. (Fig.1).

From the housings' point of view, João Pinheiro Foundation, through its statistics and information directory (2018), stated that "in 2015, Brazil had 942.000 precarious houses, more the half, 517.000 on rural areas. Most of them are located on north and northeast, which concentrates 655.000 units.

Corroborating the above data, the 2010 Demographic Census reaffirms this precariousness by demonstrating that 29.07% of rural households in the country do not have bathrooms and that only 16.36% of these households have a general sewage network or septic tank.

The National Water Resources Policy (Law 9.433/97) gave greater scope to the Water Code from 1934, which centralized the decisions about the water resource management in the electricity sector. Establishing as a foundation the respect for multiple uses and as a priority the human supply and animal desedation in cases of scarcity. According to the National Water Agency (Agência Nacional de Águas – ANA) (2019), "Any human activity that changes the natural conditions of water is considered a type of use. Each type of use can be classified as consuntive or non-consuntive use.

A survey made by the United Nations (UN) predicts that by 2030 the planet will need 40% more water. In addition, there is another worrying fact: in some cities the water waste exceeds 50%. Considered as a renewable natural resource, the water for industrial and domestic use only can recover its qualities if it is correctly treated.

According to the IBGE (2017), "Brazilian semiarid region has an average annual rainfall of 800 mm or less; the Thornthwaite Aridity Index equal to or less than 0.50 and the daily percentage of water deficit equal to or greater than 60%, considering all days of the year". So, the development of techniques to minimize this deficit is extremely urgent. The reuse of domestic water (greywater) appears as one of the alternatives to balance the demand and supply of water. Gray water comes from washbasins, showers, laundry tubs, etc. (water from toilets is not considered as such).

Nowadays, the use of water is carefully monitored by civil society. Thus, applying effluent treatment methods aimed at reusing them is essential for the conscious use of this precious asset. In this regard, some Sewage Treatment Plants (in Portuguese Estação de Tratamento de Esgotos - ETE) have been using unconventional treatment systems. These ETE's do not use chemical products in their processes, it is used aquatic plants, which carry out the treatment process in an ecological and economic way called Phytoremediation.

The Phytoremediation uses plant systems to recover water and soil contaminated by organic or inorganic pollutants. Although this area of study is not new, it had an impulse at the last ten years, when it was verified that the root zone of plants is able to biotransform exogenous organic molecules. (DINARDI *et al.*, 2003).

The rhizosphere, as this zone is called, has been studied for its important function of using polluting molecules as a source of nutrients for the various microorganisms that cohabit in this region (DINARDI *et al.*, 2003).

Thus, the main objective of this study is to present phytoremediation as one of the alternatives for the treatment of effluents, contributing to the preservation of the environment.

II. METHODS

This study is a bibliographic review with an analytical character regarding the treatment practices for the reuse of residential gray water through Phytoremediation.

The bibliographic review was developed from the scientific production indexed in the following electronic databases: SciELO, Science Direct, Springer Journal, Embase e PubMed, in addition to dissertations and theses that were developed in phytoremediation of polluted waters area.

The time delimitation covered the period from January 2003 to October 2019. It was also sought to use textbooks that present a theoretical basis for understanding the concept and its application. It should be noticed that this is a conceptual approach since this theme only gained momentum in the 1990s.

Other criteria used for analysis were the selection of papers by the analysis of abstracts, including only those that were directly related to the proposed approach, and the use of keywords: depollution, phytoremediation, reuse of gray waters and wetlands.

After the selection of the papers and texts according to the previously defined inclusion criteria, it was followed the following steps: exploratory/interpretive reading, material choice which relates to the objectives and theme of this study, and finally the writing of the base text.

III. RESULTS AND DISCUSSION

From the 38 papers and texts that were found initially, 15 were selected for reading and filing. All selected papers/texts are related to the topic Phytoremediation in the context of graywater treatment. The publications in Portuguese totalized eight publications, five in English, one in French and one in Spanish.

Phytoremediation is the use of plants in soils, waters and sediments contaminated with organic or inorganic substances in order to sanitize them. The word phytoremediation etymologically consists of the prefix "phyto", which indicates plants and "remedium" which means to restore, phytoremediation consists of removing through the use of plants a variety of residential, industrial and commercial compounds, such as: metals, metalloids, solvents, petroleum hydrocarbons, excess salts, etc. (Cuuningham & Ow, 1996, apud TCHANG, 2018).

Phytoremediation is a biological process and is carried out *in situ*, which means, directly in the type of

environment to be treated, where there is insertion of decontaminating plants, or *ex situ*, in greenhouses or in pots. (SUSARLA et al., 2002, apud TCHANG, 2018).

Phytoremediation of polluted areas is extremely useful for the environment, in order to appease or clean it up completely. It is necessary to use plants that have some characteristics like for example a great absorption capacity, deep root system, accelerated growth rate, easy harvesting, and a great resistance to pollutant (COUTINHO e BARBOSA, 2007).

Generally, native plants are preferred in phytoremediation techniques, as an example of native plants researched: Capim Elefante Roxo (*Pennisetum purpureum Schum)*, Common water hyacinth (*Eichhornia crassipes), Common Duckweed (Lemna minor),* Alface-d'água (*Pistiastratiotes*), Orelha-de-onça (*Salvinia auriculata*), Taboa (*Typha domingensis*), etc. These species have many ecological and technical advantages due to the low maintenance cost, but also because of their local compatibility. In fact, they provide the best conditions for other organisms in the ecosystem. Besides, they adapt very well to the environmental conditions such as climate.

In accordance with Campos e Teixeira Filho, (2019), "Incorrect waste disposal, even after treatment, may cause negative impacts to riverbeds. Substances like nitrogen and phosphor, especially, because of its concentration might became toxic for the aquatic organisms. These substances also can produce favourable conditions for the proliferation of vegetation, which can initiate eutrophication processes", This process makes a body of water acquires high levels of nutrients.

In other circumstances, it is possible, in the environment to be treated. The use of exotic species is possible when the plant is previously introduced into the environment, and it is considered part of the landscape and no longer poses a risk to the ecosystem.

Based on the world literature of 2016's on Web de Science and Scopus, Brazil participated of only 4% of the scientific papers related to bioremediation, biosorption and phytoremediation on the last 20 years. However, there was 190 research groups including state-owned enterprises, private enterprises and academic institutes related to these words. (TCHANG, 2018).

Regarding plants, Mota & Von Speling (2009) state that "phosphorus is an essential nutrient for the growth of microorganisms responsible for stabilizing organic matter, and phosphorus does not have health implications for water quality. The quantity of total phosphorus is due to the use of detergents and saponaceous in the washing of phytovolatilization clothes."

According to Van de Moortel *et al*. (2009), the release of oxygen by plant roots can increase the adsorption capacity of phosphorus through substrates. This may influence the item that plant treatment systems have a higher removal efficiency than plantless systems.

The ability of a plant to be phytoremediator will depend on the pollutant. So, several plants must be tested in order to define which plants have a greater resistance to the pollutant.

Due to the wide variety of pollutants, various specific surveys will be required. Thus, the characterization of the pollutant is essential for the recognition of the effectiveness of phytoremediation.

Phytoremediation can be classified depending on the technique to be used, the chemical nature or the pollutant property. There are five types of phytoremediation based on plant physiological processes: phytostabilization, phytovolatilization, phytodegradation, phytostimulation and phytoextraction (VIEIRA, G. E. G, et al., 2011). (Fig.2).

The basics characteristics of each process are:

a) Phytostabilization: the pollutant is immobilized through its lignification or humification.

b) Phytovolatilization: the pollutant is absorbed and converted into a volatile form, which is released into the atmosphere.

c) Phytodegradation: the pollutant undergoes bioconversion inside the plant or on its surface

d) phytostimulation: the presence of plants stimulates microbial biodegradation through exudates and/or supply of plant tissues.

e) Phytoextraction: the plant absorbs the pollutant from the environment, and it is stored in the plant tissue, facilitating its later disposal.

The phytoremediation of this study is the one that uses floating macrophyte plants as wastewater treatment systems. The floating macrophyte plants comprise a wide and varied group of plants, among which Common water (*Eichhornia crassips)* and some varieties of grasses might be used as biomass or animal feed stand out. (Fig.3).

According to Borrero and Martelo (2012) "at the photosynthesis, floating macrophytes use oxygen and carbon dioxide available in the atmosphere. The nutrients are taken from water through the roots, which is an excellent way of filtration/absorption of suspended solids. The root development happens because of the nutrient's availability in the water and the demand for nutrients by the plant".

In accordance with Bolaños (2008, p 39-48), "the first explorations with floating macrophytes in wastewater treatment were carried out in the 70s at the space Centre of the National Aeronautical and Space Administration - NASA, as a Potential system for wastewater treatment in space travel" (apud BORRERO e MARTELO, 2012, p. 227).

The authors also stated that the efficiency of floating macrophytes in the treatment of wastewater with organic matter content and nutrients was already studied by several authors and that during 1973 at the University of Florida. Harvey e Fox tested *Lemna minor* for nutrient removal and had reductions of 89% and 67% for nitrogen and phosphorus respectively".

In this same line of results, Tomoaki et al. (2006), mentioned that "we usually use some kind of detergent in the kitchen and thus it is necessary to remove this compound. Phytoremediation is efficient in this removal process, however, the removal efficiency in summer is 60% higher than in winter". These studies are the result of experiments of several years carried out on Shikoku Island in Japan.

Baracuhy et al. (2015), state that "The treatment of gray water with phytoremediation is efficient, reducing total coliforms and very effectively in minimising the presence of faecal coliforms E. coli.

IV. FIGURES AND TABLES

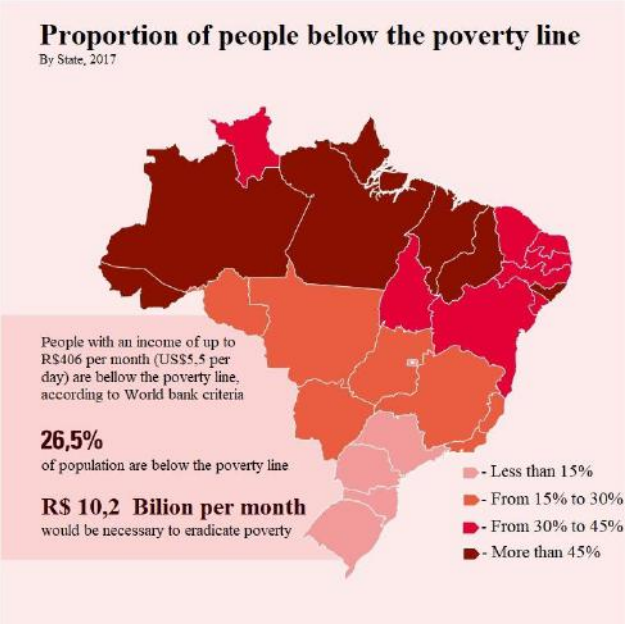

Fig.1 – Proportion of people below the poverty line

Source: IBGE

Adapted from - https://agenciadenoticias. ibge.gov.br/ agencia-noticias /2012-agencia-de-noticias/noticias /23299-pobreza-aumenta-e-atinge-54-8-milhoes-de-pessoas-em-2017 - Accessed on: September 2019.

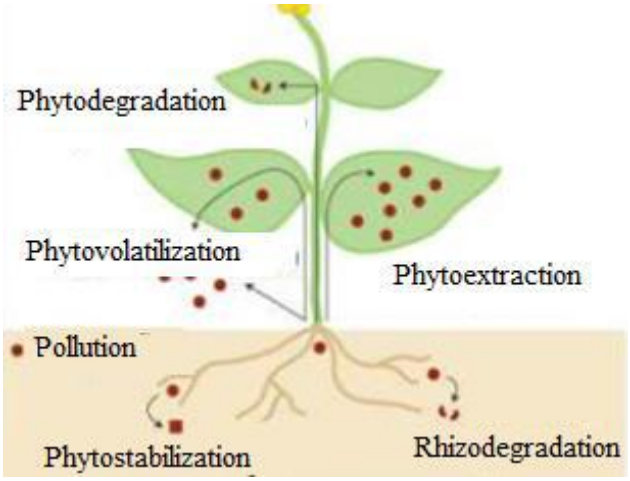

Fig.2 – Mechanisms involved in phytoremediation

Source: TCHANG, Valérie, (2018)

Adapted from – https://savoirs.usherbrooke.ca/bitstream/ handle/11143/14079/Tchang_Valerie_MEI_2018.pdf?seq uence=1- Accessed on: October 2019.

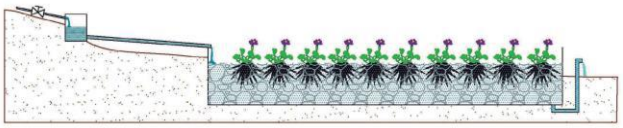

Fig.3 – Longitudinal cutting of a cultivated subsurface flow bed with Eichhornia crassipes

Source: CAMPOS and TEIXEIRA FILHO, (2019)

Available on – http://dx.doi.org/10.1590/s1413-41522019133600 - Accessed on: October 2019.

V. CONCLUSION

Greywater treatment with phytoremediation is efficient in removing nutrients, pathogenic microorganisms and non-biodegradable compounds. Phytoremediation is a viable alternative that allows the reuse of gray water for the cultivation and food production.

Studies about phytoremediation are being developed aiming at many benefits for the environment and future generations. There are several pollutants and every day something new appears, bringing damage to the entire habitat.

This research reports some of the works that have been developed in environmental pollutant remediation area, as well as other techniques aimed at

decontaminating polluted areas. The necessary mechanisms are various, but organisms, especially plants, have specific ways to remove, immobilise or transform specific pollutants.

Therefore, it is necessary that more studies in this area be carried out to better understand the phytoremediating capacity of plants and their possible use in combatting pollution.

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