Redução bacteriológica de efluentes de ETAR através de leitos de macrófitas

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ABSTRACT

Wastewater treatment (WWT) is mandatory in order to maintain the quality of water resources. The input of high loads of organic matter and nutrients, such as nitrogen and phosphorus, overloads the surrounding environment due to the intense activity triggered by its break down. The break down capacity of an aquatic environment is exceeded once its oxygen input is not enough to sustain its biological activity. The input of high concentrations of pathogens is a hazard for public health, as the contact with this highly infectious microorganisms is responsible for thousands of deaths worldwide.

Conventional WWT systems apply an efficient treatment. However, its high construction, operation and maintenance costs turn this solution unsuitable for many contexts, where WWT cannot be ignored. Constructed wetlands (CW) have then appeared as a low cost, and easy to operate and maintain solution.

In the presente work, the pathogen removal by CW was studied. In order to do so 4 microcosms were monitored at the WWT plant (WWTP) of Frielas. There was an unplanted unit (control), and the remaining units were planted with *Carex pendula*, *Typha latifolia* and *Phragmites australis*. The units were supplied with effluent from the WWTP before disinfection, having been analyzed the influent and effluent concentration of Total coliforms, Enterococci and E.coli.

From the units tested, the planted with *Carex pendula* registered the highest logarithmic reductions. Considering the standards imposed by the current legislation the discharge of the effluents from the referred unit and the one planted with *Typha latifolia* was suitable in bathing water.

The control unit performed worse than the planted ones, which supports the positive influence of the presence of plants. The performance of the unit planted with *Phragmites australis* was worse than the remaining planted units, due to its troubled adaptation.

Key-words: removal efficiency of pathogens, constructed wetlands.

EXTENDED ABSTRACT

INTRODUCTION

Wastewater treatment (WWT) is mandatory in order to preserve the quality of water resources. Wastewater (WW) represents a threat to the preservation of the aquatic environment where it is discharged because of its organic matter and nutrient loads.

The input of high volumes of organic matter in an aquatic environment is rapidly broken down by microorganisms in the water, causing their explosive growth. This phenomenon, known as eutrophication, causes a dramatic fall in oxygen levels, suffocating other living organisms.

Also, the input of high volumes of nutrients, such as nitrogen and phosphorus, has a similar effect, as it stimulates an excessive proliferation of algae and cianobacteria. The death of these organisms leads to its decomposition and increases the oxygen demand of the environment.

The discharge of untreated WW can also represent a hazard to public health because of its concentration in pathogens. These highly infectious microorganisms are responsible for thousands of deaths each year, especially in areas with poor sanitation.

Conventional WWT solutions, carried out in WWT plants (WWTP), are compact and effective solutions to treat great volumes of WW. Although this treatment includes natural reactions, its occurrence and performance depends on aeration mechanisms and mechanical mixing, as well as the addition of chemicals.

The compact treatment offered by these solutions depends on fossil energy, which influences its operational cost. Furthermore, conventional WWTP are centralized solutions, where WW is transported far from its generation, requiring consequently the investment in WW collection systems.

These solutions are not suitable for several contexts where WWT cannot be ignored. Among them developing countries and small rural or isolated settlements stand out.

The absence of specialized workers and machinery, as well as the difficult access to chemicals compromise the application of such systems in developing countries. In addition, the investment in sanitary infrastructures is not considered as a priority in these countries, due to financial inability, or ignorance.

In small rural and isolated settlements, this solution is not applied mainly because of the high cost of its associated collection infrastructures. Also, the application of such solutions locally is not suitable due to financial factors, and/or the low volume of WW produced.

Considering the above, and the growing need to preserve the existing water resources, which future is compromised because of other reasons than the contamination with untreated WW, it is necessary to seek cheap and effective solutions that offer an alternative to the present treatment technologies. Constructed wetlands (CW) are a suitable solution to developing countries, small rural and isolated settlements, and other contexts where conventional WWTP are less appropriate.

CONSTRUCTED WETLANDS

CW are artificial systems designed to simulate the function of natural wetlands for water quality improvement. Wetland is a land area saturated with water, either permanently or seasonally, such it takes the characteristics of a distinct ecosystem, where a wide range of plants and microorganisms coexist.

The constant submersion of sediments reduces the gaseous exchanges between sediments and the atmosphere, turning them anoxic or anaerobic. These conditions slow down the break down and mineralization rate of organic matter, which accumulates on the surface of sediments. The layers of settled organic matter on the substrate and root surface, if the wetland is planted, allow microbial establishment and development.

These ecosystems have the ability to convert many common pollutants present in conventional WW in harmless by-products, or nutrients which can be consumed by the surrounding ecosystem.

The circulation of WW through these artificial systems, when appropriately designed, guarantees their survival and development, as it provides three essential resources: water, nutrients and organic matter. However, as these systems are biological, they are sensitive to the WW composition, which can compromise their integrity due to the presence of chemicals, such as pesticides.

These structures offer a decentralized WWT solution. The investment in collection systems, which can reach long extension, is not necessary as the WW is treated and discharged near its generation. In addition, CW do not depend of fossil fuel, lowering its operational cost.

On the whole, CW offer lower construction and maintenance costs, and have low energy and maintenance requirements, as their operation is similar to an agricultural zone.

There are different types of CW, classified according to the type of flow, plants and arrangements.

PATHOGEN REMOVAL BY CONSTRUCTED WETLANDS

The purpose of the present study is to evaluate the removal capacity of pathogens by subsurface horizontal flow CW.

In conventional WWT systems the removal of this group of microorganisms can be achieved by the addition of chlorine, ozonation or UV radiation. The referred mechanisms apply adequate treatment, but have negative environmental impacts, or high investments and operational costs.

The addition of chlorine is a cheap and efficient process, and has been adopted for many years. However, its secondary effects are turning this mechanism a less suitable solution.

The residual chlorine is toxic to the species of fish and other aquatic microorganisms. Its contact with naturally occurring organic compounds found in water produce disinfection by-products potentially carcinogenic. The most common are trihalomethanes and organochloride compounds.

Considering the above, the ozonation and UV radiation disinfection mechanisms have been adopted rather than the addition of chlorine, even though they are more expensive. Once again, the overall higher cost of conventional WWT systems is highlighted.

Regarding pathogen inactivation by CW, this is the result of a combination of physical, chemical and biological processes.

- Physical processes: mechanical filtration and sedimentation;
- Chemical processes: adsorption, oxidation, exposure to biocides excreted by some plants and other microorganisms;
- Biological processes: predation, attack by lytic bacteria and viruses, natural die-off.

UV radiation also represents a removal mechanism, however, as the CW studied have subsurface flow, its contribution is negligible.

The treatment achieved by these structures depends on factors such as hydraulic retention time (HRT), presence of plants, substrate and inlet concentration.

HRT is inversely proportional to the hydraulic loading rate (HLR), which consists in the volume of effluent introduced by surface of wetland in a strict period of time. These hydraulic variables affect the duration of contact between pollutants and the microbial population within the wetland system.

Generally higher HRT leads to better pathogen removal. However, even though some authors have agreed with the positive influence of longer HRT, they concluded that these systems reach a saturation value, in general at an HRT of 3 to 4 days.

The presence of plants also enhances pathogenic inactivation, because of their ability to modify soil microenvironment and substance release. The situations where presence of plants did not have a positive influence are unusual. As the effectiveness of treatment by these structures is influenced by a great number of factors, one cannot discredit the importance of vegetation.

The substrate also influences the pathogenic removal because its characteristics (granulometry and porosity) affect the hydraulic conductivity and consequently the HRT. Finer mediums have a greater capability to filtrate effluent. However, it may lead to an apparent removal, where pathogens are retained in the wetlands, and are not broken down. Also, bacteria are better protected from bacterivory in small pores than in larger pores since many predators are too large to exploit smaller pores.

The inlet concentration is approached in the present study as pathogenic concentration, and organic load. Empirical data show that higher inlet pathogenic concentrations lead to higher removal rates. Also, higher organic loads support a higher microbial development, which increases its contribution in pathogen removal.

However, Puigagut *et al.* (2007) did not found the above relation so clear. For the author, higher organic loads lead to a reduction in the abundance of the population of ciliated protozoa and micro flagellates. The most likely explanation for the verified is that higher organic loads lower the dissolved oxygen concentration in the system, affecting its microfauna.

The research conducted on this subject did not reach consensus. On the one hand high organic loads promote the development of predatory communities. On the other hand it triggers a biological activity so intense that it affects the survival of its microfauna.

Moreover, it is vital to consider the outlet pathogenic concentration, as this parameter defines the quality of the treated effluent, and its possibility of being discharged safely.

ASSESSMENT ON THE PATHOGEN REMOVAL BY EXPERIMENTAL CONSTRUCTED WETLANDS IN FRIELAS

In order to achieve the purpose of this study, the removal of Total coliforms, Enterococci and E.coli was assessed in four experimental horizontal subsurface flow wetlands in the WWTP of Frielas, Portugal.

The conduction of this experiment in the WWTP of Frielas allowed its operation conditions to be close to a real WWT scheme. The climatic and environmental conditions were the same experienced in the WWTP, as well as the composition of the effluent, which was pumped right before the disinfection by UV radiation.

The wetlands were boxes of polyvinyl chloride (555 x 361 x 400 mm). The substrate was gravel with a granulometry varying between 4 and 8 mm, and with a porosity of 30%.

The substrate depth was of 40 cm, and the surface of the effluent would be 5 cm below the substrate's surface. The flow level was regulated by an elbow pipe. The effluent, pumped from the WWTP scheme, would remain in a tank before being gravitically fed to the four units.

The parameters presented above were previously settled. Many studies have been conducted in order to assess the capability of these structures in removing nutrients, chemicals and microorganisms. However, not much has been developed considering the removal of viruses and aquatic parasites.

The choice of the species of plants and the HLR applied had the purpose of achieving the best treatment, and considered the available data on this subject.

Three of the four units were planted (units 2, 3 and 4). The unplanted unit (unit 1) was the control and allowed the assessment of the contribution of plants in the disinfection process. Initially it would be planted a common specie in this kind of study (*Phragmites australis*), and two local species in order to evaluate the disinfection capability of the surrounding environment of Frielas. However, the complexity of its identification and the impossibility of collecting them from the wild compelled a further consideration.

There is data on the suitability of some species when conducting specific WWT. However, the main feature which allows a good performance of the planted species is their adaptability to the local conditions.

Considering the above *Carex pendula* (unit 2) and *Typha latifolia* (unit 3) were chosen. These are native to Europe and develop in swamps and river margins, being consequently suitable to the local weather and saturation conditions. Other factor that influenced this choice was the market availability of the species.

Phargmites australis (unit 4) was collected from an artificial wetland of the IST Environment laboratory.

The determination of the HLR considered the information available on studies with the same purpose as the present one, the capability of CW as a disinfection structure.

After the conducted research the HLR was established at 2.5 cm/day, which represented a HRT of 4.2 days. As the interior surface area of the PVC boxes was of 2072 cm^2 the daily flow to each wetland would be of 5.18 L.

The supply valves initially installed were not accurate enough, unabling the establishment of such low flow. Thus, the installation of more accurate valves was necessary in order to meet the operation conditions.

Once the monitoring period started, 5th of May, it was verified that a high treatment was being held in the tank between the structure from which the effluent was pumped, and the four units. The inlet concentrations of pathogens was very low, which interfered with the purpose of the present study, assess the disinfection capability of CW.

The high treatment verified could be due to three factors:

- The long HRT in the tank;
- The biological activity of microalgae and protozoa which came from the structure of the WWTP and consequently grew in the tank;
- The solar exposure of the tank.

In order to reduce the HRT in the tank, and mitigate the verified treatment, a T section was installed, which allowed the periodic renewal of the volume of water retained.

Even though controlling the growth of microalgae and protozoa in the tank is difficult, the renewal of its content and consequent HRT reduction resulted in the more feasible solution in order to mitigate their development. Other measure adopted was pumping the effluent closer to the surface, rather than the bottom of the structure of the WWTP, where the pump settled, and is expected to have a higher organic load because of the gravitical deposition of sediments.

To avoid a potential treatment due to the tank's solar exposition, it was covered with a membrane against UV radiation.

Because of the transmittance of solids to the tank, the unit's supply valves clogged easily. Even though a bigger flow had been adopted (23.6 L/day unit) and the valves have been calibrated regularly, a constant flow was not fed during the monitoring period, varying a parameter that was supposed to be constant (HRT).

The disappearance of unit's 4 *Phargmites australis* between the 1st and the 4th of July caused a break in the performance of this unit. In addition to its disappearance, this specie's adaptation, when planted as the others, also resulted more difficult, probably due to its different origin (Laboratory transplant vs. greenhouse).

Results and discussion

On the whole, the performances of the units had a random evolution through the monitored period, and no satisfactory correlation was established between the logarithmic reduction of pathogens and the physical-chemical and operation parameters.

Considering the performance of the units, the one of unit 4 was clearly more troubled. The evolution of its performance was very variable, and worse than the control unit most of the time monitored.

Units 2 and 3 had a similar behavior, and their treatment capacity was superior to the control unit. From this observation it is evident that the presence of plants has a positive influence on the removal of the pathogens monitored.

The average logarithmic reductions for each unit are shown in Table 1.

Table 1 – Average logarithmic reduction for each unit during the sampling period

	Average logarithmic reduction (log-units)		
	Enterococci	E.coli	TC
Unit 1	2.85	3.24	2.41
Unit 2	3.36	3.79	2.86
Unit 3	3.11	4.10	2.63
Unit 4	2.53	3.22	2.15

Relating the pathogen concentration of the effluent with the required by the current law, this technology is a viable solution for the production of an effluent with pathogenic quality for discharge (Figures 1 and 2).

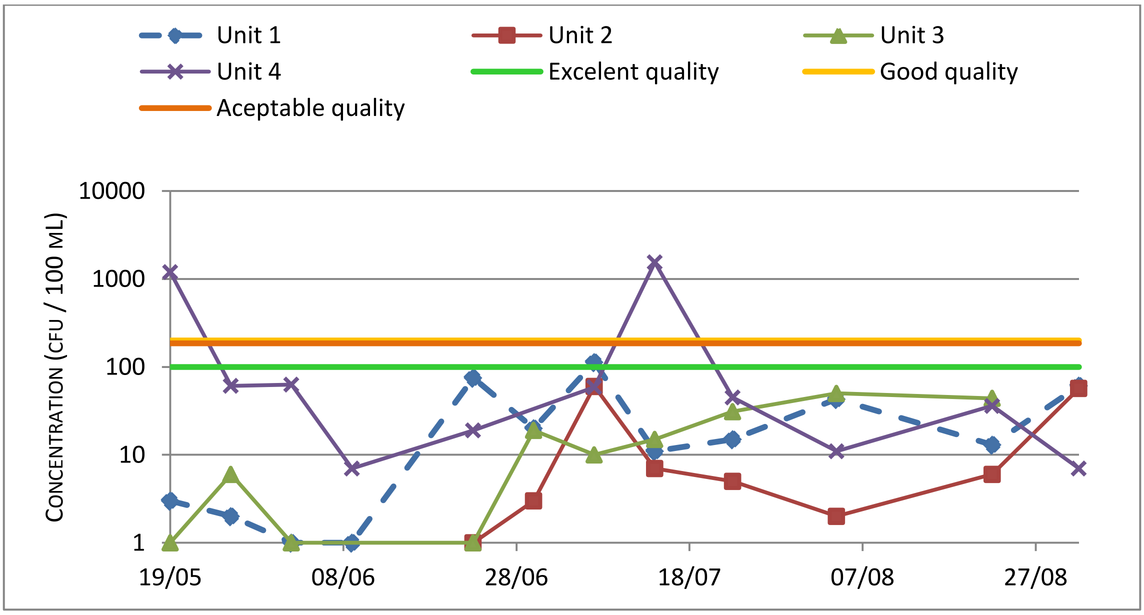

Figure 1 – Comparison between the outlet concentration in Enterococci and the standards imposed by the current legislation

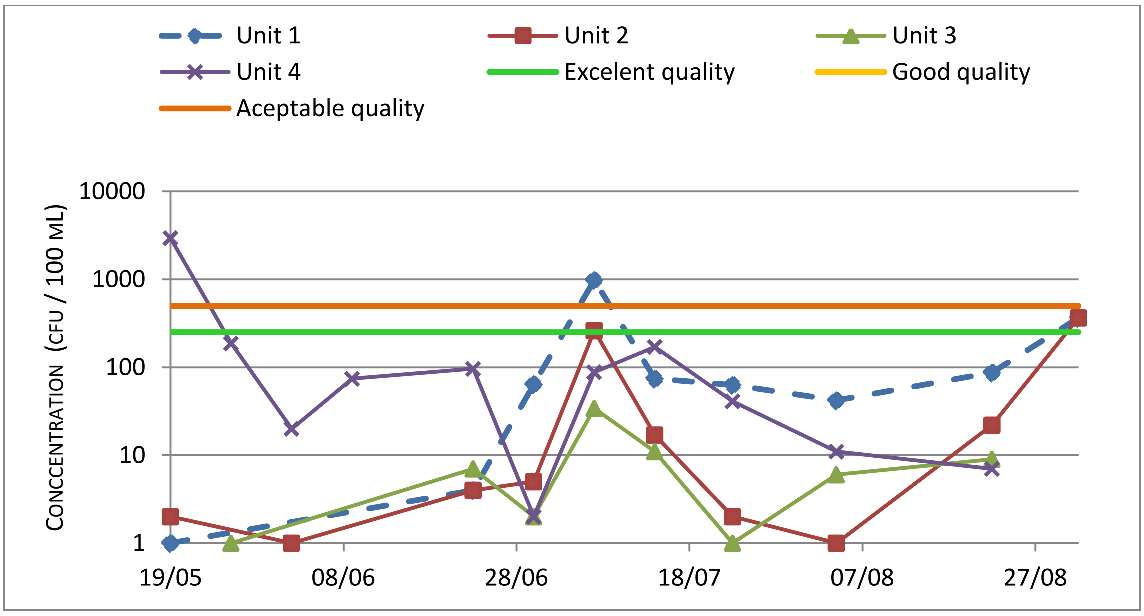

Figure 2 – Comparison between the outlet concentration in E.coli and the standards imposed by the current legislation

Only the units 1 and 4 produced an unsuitable effluent for discharge in bathing waters. This may be due to the absence of plants of unit 1, and to the troubled performance of unit 4.

CONCLUSIONS

Generally unit 2 presented a better performance than unit 3, which can indicate that *Carex pendula* is a more suitable specie for this type of treatment. Considering the suitability of *Phragmites australis*, little can be concluded by this study because of the irregularities of this unit's operation conditions.

The irregular performance of the units is related to the fact that these natural structures require a few months for the adaptation of vegetation and establishment of biofilm, so better performance is expected for more established structures.

Even though these structures produced an effluent with enough quality to be discharged, the variability of their performance cannot be ignored. As in a real context, discharges that represent a hazard to public health are not tolerated.

Considering the above, it would be interesting to continue the monitoring of the units, in order to assess if a stationary or better performance can be achieved. Also, having more data would allow a better appreciation on the viability of this technology.