" Contribution to the optimization of the purification of waste water from the Anaerobic Basins of WWTP Aïn taoujdate (Meknes-Morocco) by the application of Chrosopogon zizanioides.L and of Phragmites Australis."



Original Research Article

ISSN : 2456-1045 (Online) (ICV-ENVS/Impact Value): 63.78 (GIF) Impact Factor: 4.126 Publishing Copyright @ International Journal Foundation Journal Code: ARJMD/ENVS/V-21.0/I-1/C-5/JAN-2018 Category : ENVIRONMENTAL SCIENCE Volume : 21.0 / Chapter- V / Issue -1 (JAN-2018) Journal Website: www.journalresearchijf.com Paper Received: 30.12.2017 Paper Accepted: 11.01.2018 Date of Publication: 09-02-2018 Page: 17 -23

Name of the Author (s):

BOUHLAL .A ¹ * CHAHLAOUI .A ²

^{1,2}Management team and Valorization of Natural Resources, laboratory environment and health, Department of Biology, Faculty of Sciences, University Moulay Ismail. BP 11 20 Zitoune, Morocco.

Citation of the Article

Bouhlal A; Chahlaoui A. (2018) Contribution to the optimization of the purification of wastewater from the anaerobic basins of WWTP Ain taoujdate (Meknes-Morocco) by the application of Chrosopogon zizanioides.L and of Phragmites australis; Advance Research Journal of Multidisciplinary Discoveries.21.0,C-5 (2018) 17-23

ABSTRACT

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he present study is a contribution to the implementation of complementary treatment by the application of plants phytoremédiatrices; Chrosopogon zizanioides.L and Phragmites australis for the improvement of the purification of wastewater from anaerobic basins of the WWTP of Ain taoujdate (Morocco). So, the purified water leaking from the aquarium planted after 7 days of stays using the Phragmites australis: 66 mg O2/l BOD₅, 81 mg/l TSS and 110 mg O₂/l of COD. This assay had an abatement of 80% in BOD₅, 75% in TSS and 83% in COD, a low nitrogen assimilation of 3%, an abatement about 55% for phosphorus, 56% for orthophosphate, abatement of 37% Ba, 59% Al, 0% As, 0% Se, 15% Cr, 65% Fe²⁺ and 25% Mn^{2+} . While at the exit of the aquarium planted by Chrosopogon zizanioides, the measured TSS are of the order of 11mg / 1 with a reduction of 97%, of 32 mg / 1 for the BOD₅ with a yield of 90 % and 106 mg/l for COD with a yield of 84%, an improvement of nitrogen assimilation of 34%, a reduction of 46% for phosphorus, 44% for orthophosphate, an abatement of 92% Ba, 59% Al, 0% As, 67% Se, 31% Cr, 67% Fe^{2+} and 70% Mn^{2+} . Therefore, the two aforementioned plants generally show the possibilities of significant abatement of carbon pollution in terms of BOD₅, COD and TSS largely respecting the specific limit values of domestic discharge set by the decree n°1607-06 of July 25, 2006. Also, they have a great power of accumulation of trace elements and more particularly favorable for certain metals studied (Ba, Al and Cr) and trace elements (Fe $^{2+}$, Mn $^{2+}$).

Keywords :

Chrosopogon zizanioides, Phragmites australis, WWTP, wastewater

I. INTRODUCTION

The water resources available to Morocco are limited and subject to extreme cyclic variations. So, the annual volumes of wastewater discharges were estimated, in 1990 to 370 Mm3, in 1999 to 500 Mm3 and could reach 900 Mm3 the horizon by 2020[1-2]. This raw wastewater without any prior treatment would seriously pollute the environment and water resources [3]. That is why, throughout Morocco, universal awareness on the necessity of protecting the environment, makes wastewater treatment a field of investigation in full expansion. However, the natural lagoon treatment plants that should formerly treat domestic water answering an immediate need, must now face more problematic and especially the standards of direct discharges that have become very restrictive beyond the year 2016 and this; with a view to respecting the environment. In fact, non-compliant wastewater treatment plants should improve, review, correct and/or change the purification process in order to be more efficient. For that purpose, the Ain Taoujdate (Meknes Region) wastewater treatment plant natural lagoon type, this was built in July 2004, and is designed to purify a nominal flow of 1500 m^3/d to a secondary level. In fact the performances recorded during the years 2013 and 2014 showed average reductions at the out of the two optional basins of 59% in TSS, 68% in BOD5, 60% in COD, it is non-compliant since the revision of the standard of rejection decree N ° 1607-06 of 29 Joumada II 1427, July 25th, 2006.

So, the existing Aïn Taoujdate WWTP can only satisfy this performance by providing adjustments to reduce this pollutant load as much as possible according to the expected performances. On the other hand, for a possible reuse of the treated water because the application of raw or poorly treated water in agricultural land irrigation can cause contamination of different compartments of ecosystems (soil, water and plants) by heavy metals, organic trace compounds, as well as pathogenic micro-organisms[4-5-6]. In addition, the transfer of these elements at trophic level will present a danger for humans. While the irrigation of the soil with treated water makes it possible to benefit from their fertilizing value because they constitute a nonnegligible source of Nitrogen (N), phosphorus (P), potassium (K), organic matter and micronutrient

These characteristics make them more and more of great agronomic interest. They also allow the improvement of the physic-chemical properties and the increase of the enzymatic and microbial activities of the soil ensuring good condition necessary for the good development of the plant.

However, the problem lies in the choice of a better process for the purification of domestic wastewater, because Morocco has several intensive and extensive purification techniques such as natural lagoon, infiltration and percolation, aerated lagoon, oxylag, activated sludge,.. But, for the standing filters until now, are not applied in Morocco even if they are among the biological rustic processes,, constituting of the proven technologies, treatment of small and medium communities whose performances have been successfully tested for several years in developed countries such as Germany, France and Belgium [7-8-9-10].

That is why, the problem thus posed, justified the choice to experiment at the laboratory scale in the field of green biological purification of Moroccan domestic wastewater recovered from the anaerobic basins of the Ain taoujdate WWTP under controlled conditions, involving two types of phytoremedial aquatic plants (Chrosopogon zizanioides L and Phragmites australis). This system could be an appropriate solution that adapts to the climatic and socio-economic context of Morocco; since they have several advantages residing in their purification capacity, their simplicity of implementation, management and cost and are added to this is the potential for

valorizing of poaceas plants used in various areas of livestock farming as fodder plants, erosion control and to restore soil fertility [11-12].

Finally, the economic interest by deriving substantial revenue through the making, crafting and selling of utility tools.

II. MATERIALS AND METHODS

The principle of this study is to carry out experimental tests at the laboratory level, by preparing two aquariums. One of which is planted by vetiver grass (Chrosopogon zizanioides L) and the reed (Phragmites australis) plants the second aquarium. To test the effect of the purifying power of both plants, the aim is to verify the output of the two aquariums the conformity of the purified water with the standards of direct discharge (120 mg / 1 of DB05, 250 mg / 1 of COD and 150 mg / 1 of TSS).

In fact, the injection of wastewater is done according to the principle of the tarpaulin system which consists in evacuating a volume of wastewater recovering anaerobic basins. After 3 days, we calculate its purification performance, also we extend until 4 days (Figure 1) and we will calculate the global parameters of pollution and their purification yields.



FIG. 1: Aquarium or planted filter with vertical flow

According to Figure (1), the wastewater $\{1\}$ enters discontinuously and is distributed over the entire surface of the aquarium $\{2\}$ and then infiltrates through a thin layer of sand $\{3\}$ before percolating on fine gravel $\{4\}$ and being collected by drains $\{6\}$ implanted in coarse gravel $\{5\}$.

In general, a fine and medium gravel recovered by a sand with a specific grain size in order to slow down the percolation [13]. The influent of the outlet of the anaerobic basins are distributed directly, after preliminary decantation which flows through the filtering mass undergoing a physical treatment by filtration, chemical adsorption, complexion and biological biomass fixed on fine support.

At the filtering mass, the purified water is drained. The aquarium is supplied with wastewater by sheeting but in order to alternate the phases of operation and the phases of rest [14].

The purification principle is based on the development of an aerobic biomass fixed on the grains of reconstituted sand. Oxygen is brought by convection, diffusion and by the movement of water in the aquarium [15].

2.1. Packing material

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The packing material of the first stage consists of a layer of gravel. The active layer is gravel having a granulometry of 8 to 20 mm, for a thickness of about 40 cm (Figure 1). The whole is surmounted by a layer of homogeneous sand with a height of at least 30 cm of the same type as that used in the undrained sand filters which refines the purification which represents the same principle of the second stage of the filter vertical planted to ensure the retention of suspended solids and nitrification. FOUNDATION

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The composition of the sand is mainly siliceous and its alluvial origin. They are recovered from the filter of the drinking water treatment plant of BITIT at the Bouderbala center (Fes-Meknes Region) to avoid the risks of clogging induced by the use of crushed sands, even without their fines $[D < 80 \ \mu\text{m}]$, do not advocate for their use. Mostly siliceous sands are preferable because a priori less attackable during the acidification of water that naturally results from nitrification.

We will therefore ensure that the characteristic of the sand layer is as follows:

- $0.25 \text{ mm} < d_{10} < 0.40 \text{ mm} [16];$
- 3 <CU <5 [16];
- fines content <3% by mass ;
- thickness 40 cm minimum and depending on the target of treatment to be achieved ;
- 5 cm of water slide over the entire surface of the fed filter bed;
- Minimum feed rate per sheet = 0.5 m3/m2/h;
- Stays of 3 days and lengthened to 7 days.

2.2. Choice of plants

Much work has been done on the chemical composition of aquatic plants [17], the conditions of assimilation and transport, and the purification of wastewater [18-19-20]. In effect, plants Chrosopogon zizanioides and Phragmites australis are selected according to their own qualities; such as, purifying power, hardiness and the possibility of repeated harvests [21]. So, the aforementioned plants are emergent plants phytoremédiatrices whose base is normally in the water and the development of the reproductive parts is in contact with the atmosphere indirectly contributing to the degradation of the organic matters of the raw effluent. The roots which support the different microorganisms acting as the purifier by absorbing pollutants [22].

However, the root development extends the surface of fixing for the development of microorganisms and for precipitation reactions. In this increase, the surface in active area, there is certainly a factor that stimulates the activity and even the diversity and density of the micro-organisms involved in various ways in the purification processes. It is a well-known concept in agronomy and can be summed up in the trivial form "a planted soil is biologically richer and active than a bare soil", sometimes referred to as a rhizosphere effect [23]. The root tissues and their exudates are likely be more inviting niches to microorganisms than inert mineral substrates [24-25]. The quantity and composition of root exudates also condition the nature of bacterial activities [26]. These activities result from the synthesis of metabolites such as siderophores, antibiotics, growth substances, hydrogen cyanide, lipopolysaccharides [27-28-29-30-31]. The metabolism of the plants ensuring the assimilation of nutrients influences the treatment depending on the surfaces involved. The beneficial effects of the rhizobacteria are linked to their strategic position at the root-soil interface. Indeed, the rhizoplan and the rhizosphere are the seat of intense exchanges between the plant and the surrounding environment [32].

These exchanges are reciprocal. If the plant releases the organic compounds, conversely, it takes wastewater from the mineral elements essential to its metabolism and playing indirectly to its purification. This taking away is also associated besides with proton extrusion, which contributes to lower the value of the pH of the rhizosphère [33]. The roots are also able to absorb certain organic molecules, produced by the microbes present in the rhizosphere [34]. If for aquariums vertical flows the assimilation of nutrients is unimportant for the phosphor of at least 1 % of the entrant load [35-36-37]. In the horizontal standing filters, surfaces are more important and can lead to the assimilation of very reasonable nutriments which be situated around 5 % for the nitrogen [38-39 and appreciably less for the phosphor [40-41]. So, the foliar cover protects the surface of

Generally, in the filtering massif, the diversity of species (bacteria, protozoa, invertebrates) of which their presence depends closely on the organic load and the conditions of renewal of the oxygen. They also participate, as predators, in the decrease of the populations of fecal bacteria, but the abatements are also under the dependence of the residence time. Several types of plants can be used for the treatment of wastewater, but commonly reeds (Phragmites australis) by their resistance to the conditions encountered for long periods submerged filters, dry periods, high organic matter content and their rapid growth. Roots and rhizomes, are the most commonly used (Figure 2). These plants have a particular tissue, the aerenchyma that allows the transfer of oxygen from the upper parts to the rhizomes and roots, allowing the plant to grow in permanently saturated water environments. They withstand alternating periods of immersion and periods "dry" and adapt very easily to different altitudes and climates. The second plant chosen is vetiver grass, its scientific name Vetiveria zizanoides from the Graminae family (Figure 3). The vegetative apparatus is perennial herb up to 2m tall; narrow, rough leaves with sharp edges; floral spike of brown color clearly visible; thick tuft formed of numerous tillers; roots up to 6m deep. It has a greater ability to adapt to wastewater treatment such as a settling filter. Also, thanks to its extraordinary morphological and physiological characteristics, this plant has significant a peculiarity assimilates large amounts of nitrogen and large quantities of heavy metals.



FIG. 2 : Phragmites australis



FIG. 3 : Chrosopogon zizanioides L.

III. **RESULTS AND DISCUSSION**

In our study, the analytical parameters measured at the entrance of the WWTP, at the exit of the anaerobic basins, at the exit of the aquarium planted by the reed, at the exits of the aquarium planted by the vetiver grass are ranked in 4 categories:

- Physico-chemical parameters (water temperature, pH and conductivity).
- Global pollution parameters (TSS, BOD₅ and COD);
- Nutrients (Total Nitrogen, Total Phosphorus and Orthophosphates);
- Toxic elements (Pb, Cd, Se, Cr, As, Zn and Br); Trace elements (Fe^{2+} and Mn^{2+}).

Parameters analyzed on site

Temperature : The temperature has a direct impact on the activity of the bacteria and according to the figure 4, we notice that there is not a big variation of the temperature which can cause problems on our biological process of purification. Indeed, the values of the temperature at the entry of the WWTP is of the order of 24 °C, at the exit of the anaerobic basins is of the order of 20,3 °C and at the exit of the two aquariums them oscillate between 20.8 and 21.8 °C. It remains below the limit value of direct rejection in the receiving medium which is 30 °C.



FIG. 4 : Evolution of the temperature according to the time of stays of the water

Hydrogen potential: Ph : PH is an important parameter in the control of water quality at the entrance of a WWTP, important pH variations are almost always the consequence of industrial discharges, so pH influences both the level of process activity. Biology bacterial growth and solubility of the compounds and from Figure 5, the pH values at the inlet of the WWTP are basic and after treatment in anaerobic basins, the values recorded show a slight decrease in pH, it is of the order of 7,70 and at the exit of the aquarium the pH varies between 7,06 and 7,88.

It remains within the range recommended by Order No. 2942-13 of 7 October 2013.



FIG. 5: Evolution of the pH as a function of the residence time of the waste water

Conductivity : The conductivity of a water will be all the more important as its mineralization will be high. According to Figure 6, at the inlet of the WWTP and at the time of sampling, the measured values are of the order of 1725 µm/cm, after water treatment at the level of anaerobic basins, we measured 1671 µm/cm and at the exit of the two aquariums planted independently by the reed and the vetiver grass, we note a decrease of the mineralization that is to say it is used by the two plants and the contents of the conductivity oscillate between 1548 and 1600 µm/cm, they are lower than the limit value of direct rejection which is 2700 µm/cm.



FIG. 6: Evolution of the conductivity as a function of the dwell time of the waste water

Global parameters of carbon pollution (BOD₅, COD) and TSS

The abundance of suspended solids in the water favors the decrease of the luminosity and lowers the biological production, in particular because of the reduction of the photosynthesis and consequently the fall of the dissolved oxygen which is used by the bacteria for the degradation organic matter. Therefore, sedimentation of SS is essential at the level of anaerobic basins. Indeed, at the entrance of the WWTP, we record a value of the order of 667 mg / l, at the exit of the anaerobic basins is of the order of 322 mg/l with a yield of 52% and at the out of the aquarium planted with reed, we note a reduction of MES of the order of 109 mg / 1 during the 3 days of rest and 81 mg/l during 7 days of rest. Therefore, these values remain well below the direct release standards of 150 mg/l.

At the outlet of the aquarium planted with vetiver grass, the measured TSS is of the order of 171 mg/l after 3 days of rest and a large sedimentation of TSS which of the order of 11mg/l with a reduction of 97% at the level of the aquarium planted with vetiver and after a rest of 7 days.

Also, the importance of the pollution in the effluent at the entrance of the WWTP is evaluated by the chemical oxygen demand (COD) and the biochemical oxygen demand which makes it possible to determine the polluting load of a wastewater. By the organic materials before and after purification by appreciating the concentration of organic or mineral matter, dissolved or suspended in water through the amount of oxygen necessary for their total chemical oxidation or biochemical. Thus, the traced results of COD and BOD5 from the entrance of the WWTP to the exit of the aquarium have a strong decrease with abatement at the outlet of the anaerobic tanks of 43% in BOD5 and 50% in COD.

Also, during a rest period of 3 days at the aquarium planted by the reed we find a reduction of 63% in BOD5 and 55% in COD, then we extended rest time up to a maximum of 7 days and the results are conclusive in terms of 80% BOD5 and 83% COD reduction. Thus, the BOD5 and COD values of the outlet of the aquarium are respectively of the order of 66 mg O2/l and 110 mg O2 / l. These values remain well below the direct discharge standards of 120 mg O2/l in BOD5 and 250 mg O2/l in COD.

At the outlet of the aquarium planted with vetiver grass and after 3 days of rest, the values of BOD5 and COD respectively are of the order of 140 mg/l and 32 mg/l with an abatement of 58% and 44% respectively. By extending the water rest until 7 days and after measuring the pollution parameters, we see a very important decrease of 32 mg/l for the BOD5 with a yield of 90% and 106 mg/l for the COD with a yield 84% (Figure 7).

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FIG. 7: Evolution of the carbon pollution BOD5, COD and MES according to the stay time of the wastewater

Nutrient (Total Nitrogen, Total Phosphorus and Orthophosphates) : Given results (Figure 8), we find that there is a low assimilation of nitrogen by the reed plant (Phragmites australis) and this has been proven by a low rate of abatement at the exit of the aquarium. After 3 days of rest which is 3% and after 7 days of rest. While, for the aquarium planted with vetiver, we note improvement of the nitrogen assimilation by the vetiver plant which went from 26% during the 3 days of rest to 34% during the 7 days of rest. This is due, on the one hand, to the pH, which plays an important role in the assimilation of nitrogen in the form of ammonium, which increases strongly at high pH [44] and, on the other hand, by the physiological behavior of the plants which were totally different in natural conditions and in polluted environment because the plants object of our study were transplanted from unpolluted natural environment towards a very polluted environment by waste water of STEP Aïn Taoujdate. On the other hand, the plants need some adaptation time, for example, it is estimated to be one year for the reed [45].

Also, for the assimilation of phosphorus without taking into account the direct effect of certain factors such as intensity and duration of lighting or humidity that are not taken into account, as well as, the height of free water can modify the quantity of assimilated chemical elements and this is proved by the observations on several vegetative cycles in Phragmites australis show that during the immersion period, the accumulation of phosphorus, orthophosphate and biomass of the plant are proportional to the height of water. However, too long a period can cause a critical situation as a result of overuse of phosphorus rhizome. Indeed, we observe a growth of the reed plant which coincides with abatement of the order of 29% for phosphorus and 23% for orthophosphate during a rest of 3 days and about 55% for phosphorus and 56% for orthophosphate for 7 days of rest. Thus, there is a linear relationship between nutrient concentration in wastewater and plant growth [46]. While the aquarium planted with vetiver, we note a yield of 29% for the phosphorus and 28% for the orthophosphate during the 3 days of rest and of the order of 46% for the phosphorus and 44% for the orthophosphate for 7 days of rest. Therefore, we notice the two plants behave in the same way for the assimilation of phosphate and orthophosphate and a very clear difference for the assimilation of nitrogemn which is very weak for the Phragmites australis plant.



FIG. 8: Evolution of nutrients (Total Nitrogen, Total Phosphorus and Orthophosphates) as a function of the dwell time of the wastewater

Toxic elements (Ba, As, Al, Cr, and Se) : The analysis of heavy metals at the entrance of the WWTP and at the exit of the two aquaria planted with reed and vetiver aims to determine the direct impact of the use of both macrophyte plants as integrators or micronutrient traps to evaluate the level of pollution and the abatement rate of the above-mentioned metals at the outlet of the two aquariums [47-48-49-50-51]. In fact and in a general way, the main results (figure 9) show a very sharp decrease between the entry of the STEP and the exit of the aquariums planted after 7 days of stays, thus proving, that there is a the assimilation capacity of certain heavy metals (Ba, Al and Cr) for the reed planted aquarium while it is neutral for Arsenic (Se) which remains inexplicable and deserves to be continued. Also, we note and very importantly a great power of assimilation for all the metals studied (Ba, Al, Se and Cr) for the aquarium planted with vetiver grass.



FIG. 9: Evolution of toxic element levels at the entrance to the WWTP and at the outlet of two aquariums planted with Roseau and vetiver grass

Trace elements (Fe²⁺, **Mn**²⁺) : For the two plants phragmites australis and vetiver grass, the needs in these elements are very important, which makes them classify among the macroelements and according to the figure, we note an assimilation by the aquarium planted with reed with a reduction of 65% for iron and 25% for manganese whereas for aquarium planted with vetiver, we find that there is a significant yield of 67% for iron and 70% for manganese. So the mobility of manganese is lower than that of iron for the reed plant and greater for the vetiver plant. While she almost the same for iron. These findings are consistent with those of other authors [52].



FIG. 11: Evolution of trace element contents (Fe 2+ and Mn 2+)

IV. CONCLUSION

The analysis of the results relating to the physicochemical composition of domestic wastewater at the entrance of the Ain taoujdate WWTP, at the outlet of anaerobic basins and the testing of the possibility of purification by complementary treatments through the aquarium planted with reed (Phragmites australis) and the aquarium planted with vetiver grass (Chrosopogon zizanioides L.) object of our study shows that although these waters are highly polluted and undergoing primary treatment in anaerobic basins, two generally emerging macrophytic plants have the potential for significant abatement of carbon pollution in terms of BOD5, COD and TSS largely in accordance with the specific limit values for domestic discharge set by Order No. 1607-06 of 25 July 2006. Also, a great power of accumulation of trace elements and more particularly favorable for certain metals studied (Ba, Al and Cr) and trace elements (Fe Mn²⁺). While it seems conceivable to use the plants Chrosopogon zizanioides L and Phragmites australis in the small and medium-sized plants for the small and medium-sized centers in the purification of domestic wastewater, they have given spectacular results.

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Corresponding Author :

BOUHLAL .A *

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Management team and Valorization of Natural Resources, laboratory environment and health, Department of Biology, Faculty of Sciences, University Moulay Ismail. BP 11 201 Zitoune Morocco.

E-mail : bouhlal[dot]abdelaziz[dot]gie[at]gmail[dot]com

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