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The use of titaniferous sieved sand for the treatment of domestic wastewater in the percolation infiltration process

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Abstract

Regarding urban activities, the annual volumes of domestic wastewater discharges have increased. This problem is not limited to the amount of wastewater rejected but it also focuses on its quality. In fact its discharges cause some environmental problems related to chemical and biological pollution.

The objective of this work is to study the biological treatment process for culture fixed on thin substrates, percolation infiltration basins (PIB) and their effectiveness on the study of a number of physical and chemical parameters of wastewater before and after treatment (COD, BOD_5,...).

The massive used in this process is the titaniferous sieved sand also called black sand. The results show reduction of organic matter (COD: 95%; BOD_5: 97%) and some values that are included in Moroccan irrigation water norms for nutrients (NO^{-3} : 0.3mg/l ; NO^{-2} : 0.12mg/l ; $PO^{3-}{}_4$: 0.08mg/l).

Keywords: wastewater, titaniferous sand, infiltration-percolation, physico-chemical parameters.

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1. Introduction

The urbanization together with population growth has brought about an increase in water demand translating into excessive use of water resources and into the production and release of a large volume of wastewater into receiving environments [1]. As long as this water usually contains organic and inorganic matter, it becomes an important source of pollution to the receiving environment that receives it [2].

Infiltration percolation is a low-tech process used to treat primary and secondary effluents. The water percolates through aerobic biological processes through an unsaturated porous medium (massive, filtered titaniferous sand) until reaching a drainage system [3]. Infiltration percolation is a purification technique capable of completely oxidizing the wastewater. It is a vast treatment process that is set to remove organic pollution, ammonia oxidation and major ions [4].

The purpose of this work is to highlight the purification performance of massive (titaniferous sieved sand), by studying some major and global physico-chemical parameters of wastewater discharged from the anaerobic lagoon of BENSARGAO city purification plant (primary treatment), after trickling water to be treated on a semi-pilot system.

2. Materials and methods

2.1. Experimental device

The purification system's type is an infiltration percolation on a column filled with titaniferous sand (black sand) of the type (titaniferous sieved sand (TSS)). The titaniferous sieved sand is obtained by passing it through an 80µm sieve to remove particles of quartz sand. For the constituents of the filtered titaniferous sand we have 95% of titaniferous sand + 5% of quartz sand.

The experimental device consists of a PVC column that is 2 m in length and 20 centimeters in diameter, filled with titaniferous sieved sand of Agadir region (Installed in the Faculty of Sciences of Agadir). Purification is achieved by passing the settled wastewater, through the massive (titaniferous sieved sand). The various analyses covers the sand characteristics on the one hand and the purification performances of various parameters of wastewater on the other.

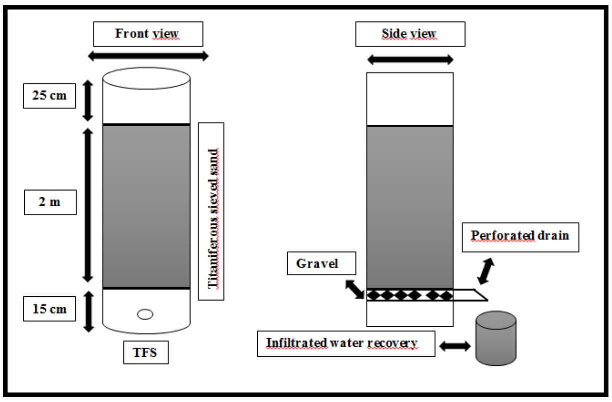

Figure 1: Experimental device used in this study

2.2. Frequency and feed mode

The hydraulic load of the column is tested weekly by 06 liters per square meter. The column is fed under the same conditions with the raw effluent. These waters of a domestic typology are composed of domestic wastewater from Bensargao station (Agadir, Morocco).

2.3. Parameters and analyzing methods of wastewater

All analyses and measures necessary to quantify organic pollutants are standardized according to the Moroccan standards, similar to the French AFNOR according to the techniques recommended by Rodier. The measured parameters include pH, temperature, conductivity, biological oxygen demand during 5 days (BOD_5), the chemical oxygen demand (COD), ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-), orthophosphate (PO_4^{3-}).

3. Results and discussions

3.1. Characterization of titaniferous sieved sand

The massive used in this study is the titaniferous sieved sand of Agadir region, the characteristics of this sand are shown in Table 1.

Table 1: Results of filtered titaniferous sand analyses

Parameter	Filtered titaniferous sand	Observation
D_{10}* (mm)	0.104	Tight particle size
D_{60}** (mm)	0.124	Tight particle size
$C_u = D_{60}/D_{10}$***	1.192	Pure sand
Water content %W	0.333	Damp sand
Relative density (g/cm^3)	3.846	Fairly heavy sand
Dry unit mass	2.555	Normal value
Porosity	0.335	33 % à 56 % of vacuum
Permeability (cm/s)	0.011	Pretty high permeability

(*)D_{10} (DE): corresponds to the mesh size of the sieve that allows 10% of the sample mass to go through
(**)D_{60}: corresponds to the mesh size of the sieve that allows 60% of the sample mass to go through
(***) $C_u = D_{60}/D_{10}$: The uniformity coefficient

3.2. Elemental analysis of titaniferous sieved sand

Elemental analysis (microanalysis) of sand was determined using scanning electron microscopy (SEM). It shows the presence with a significant amount of iron, titanium and silicon (Figure 2 and

Table 2). The main constituents of the titaniferous sieved sand are: Fe_3O_4, $FeTiO_3$, $ZrSiO_4$, SiO_2 and TiO_2.

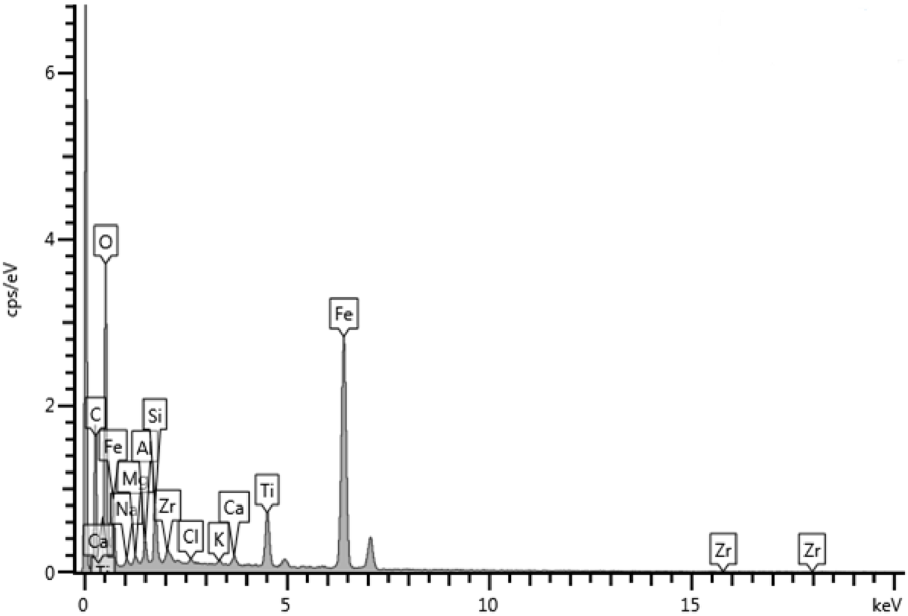

Figure 2: Spectrum of elementary analysis of titaniferous sieved sand

Table 2: Mass and atomic percentages of some elements of the TSS

Element	% Mass	% Atomic
Na	1.45	3.12
Mg	1.11	2.26
Al	2.35	4.31
Si	5.74	10.10
Cl	0.40	0.56
K	0.41	0.51
Ca	1.03	1.28
Ti	8.77	9.05
Fe	76.09	67.37
Zr	2.65	1.44
Total	100	100

Pictures of (Figure 3) show the general appearance of the surface morphology of titaniferous sieved sand different magnifications, we see that it is clean and very porous sand.

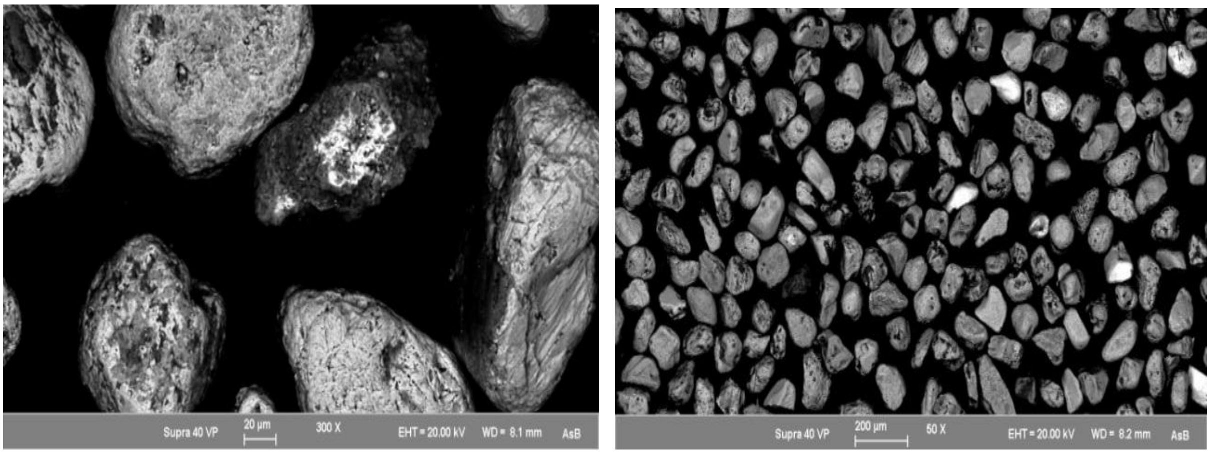

Figure 3: Electronic image of the surface morphology of the titaniferous sieved sand at different magnifications

3.3. Temperature

The temperature of the wastewater brought from the purification plant is measured before and after percolation in the massive.

According to the results found, we see that the temperature of the decanted wastewater (DW) is still high 22.8 °C (on average) compared to that of treated water (TW) 21.7 °C on average (Figure 4). This very small difference could be explained by the temperature gradient between the external and the internal environment of the column containing the massive. These recorded temperatures remain below 35 °C, considered as limit value referred by Moroccan standards of quality of waters used for irrigation [5].

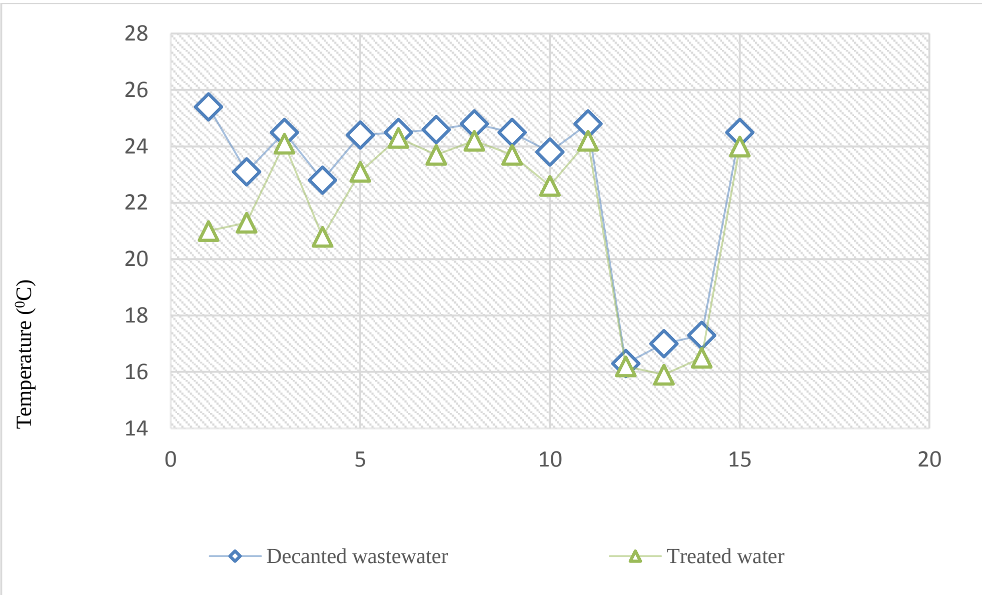

Figure 4: Study of temperature growth of decanted wastewater (D.W) and treated water (T.W)

3.4. Water potential of Hydrogen

The pH (potential of Hydrogen) measures the H^+ ion concentration of water. This parameter characterizes many physico-chemical balances and depends on many factors, including the origin of water The pH of the decanted wastewater (D.W) in the column entrance varies between 7.7 and 8.2 with an average value of 7.8. The pH of treated water with titaniferous sieved sand (T.W) varies between 8.8 and 7.7 with an average value of 8.4 (Figure 5).

The increase in pH of the treated water at the outlet of the process may be explained by both the decrease of aerobic decomposition of organic matter along the massive and the likely reactions among the H_3O^+ ions and sand components such as carbonates [6].

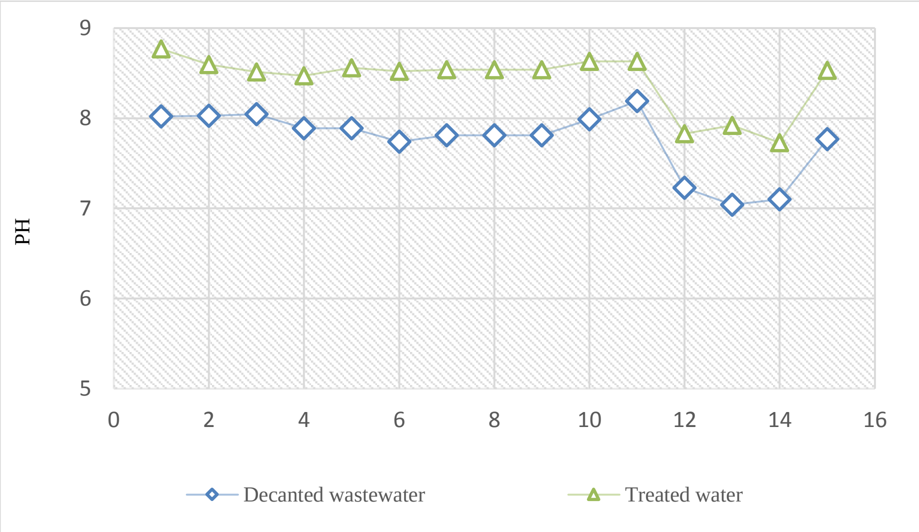

Figure 5: Study of pH growth of decanted wastewater (D.W) and treated water (T.W)

3.5. Turbidity

Solids in suspension give water a bad taste and a bad smell, and prevent penetration of light rays that are essential for good plant growth in water stream bottom. The majority of the suspended solids are removed after runoff of raw sewage on the massive by infiltration-percolation system [7]. This is primarily due to physical processes (filtration and sedimentation) and to the sifting in the massive [8]. The determination of the solid in suspension is made by measuring the turbidity, which corresponds to the reduction of the transparency of a liquid due to the presence of suspended particles. It is measured by passing a light beam through the test sample. The turbidity is determined by measuring the light scattered by the suspended particles.

We find from these results that much of the solids in suspension are removed during infiltration in the massive. In fact, the turbidity spends an average of 121 UNT at the entrance of massive to 2.8 UNT at its output (Figure 6).

3.6. Conductivity

The electric conductivity measures the importance of dissolved salts in water, it depends on some factors such as pH, temperature and the ions in water. The measurement of this parameter is a good assessment of the degree of mineralization of water where each ion acts by its concentration and by its specific conductivity [9]. The average value recorded in the entry of the column is 1759 µS/cm. In contrast, the conductivity of recovered waters is defined of an average value of 1485 µS/cm, a slight decrease of the electric conductivity of treated waters in comparison to that of decanted wastewater (Figure 7). This is explained by the reactions among the ions in the decanted water and that of titaniferous sieved sand (massive).

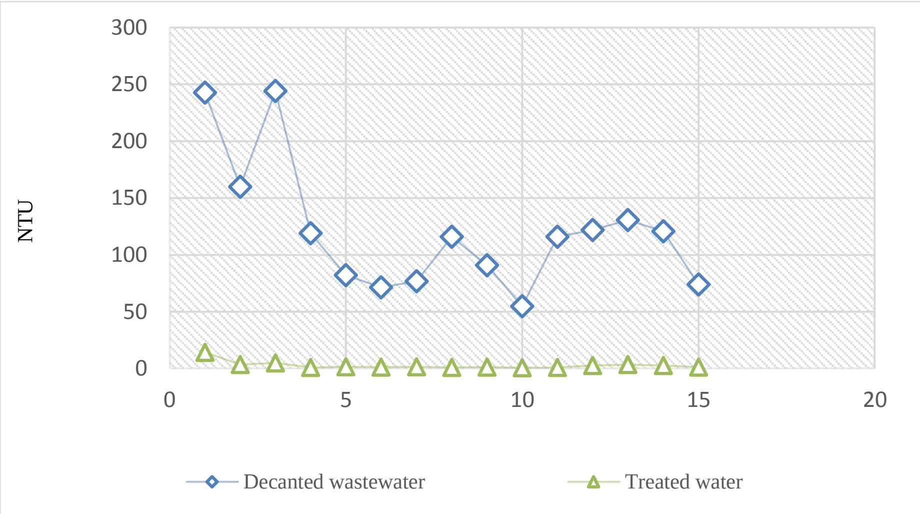

Figure 6: Study of solid in suspension growth of decanted wastewater (D.W) and treated water (T.W)

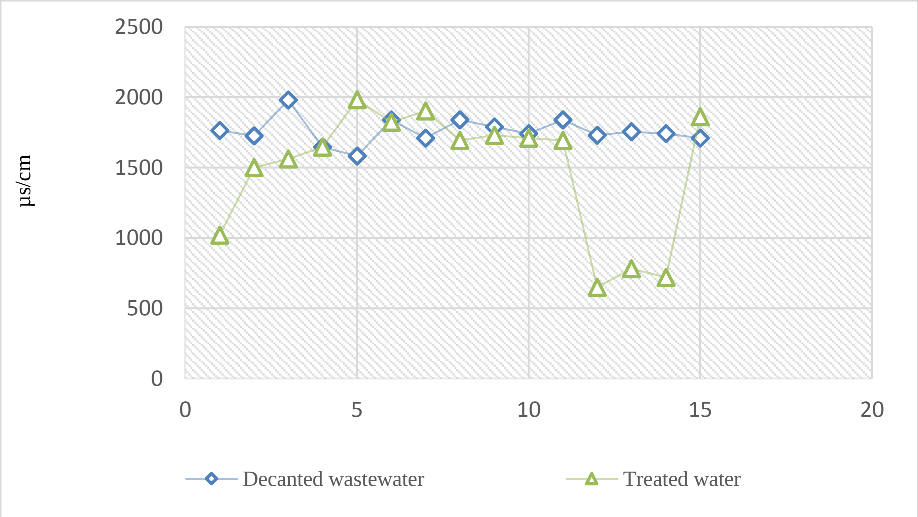

Figure 7: Study of conductivity growth of decanted wastewater (D.W) and treated water (T.W)

3.7. Chemical oxygen demand

The COD is the content of all organic materials that have a biodegradable or doesn't [10]. COD concentration for the decanted wastewater used at the entrance of the pilot system fluctuates between 202 mg/l and 644 mg/l with an average value 384.5 mg/l. Concentrations in COD measured at the outlet of the massive vary from 8 mg/l to 30 mg/l with an average concentration of 17 mg /l.

The elimination rate of this pollutant by this system shows a significant retention of oxidizable materials. The reduction percentage in COD fluctuates between 92% and 98% with an average reduction of 95.5% (Figure 8). This is likely due to the physical retention of the organic matter of the wastewater in the massive and the oxidation thereof by biological processes related to bacterial flora.

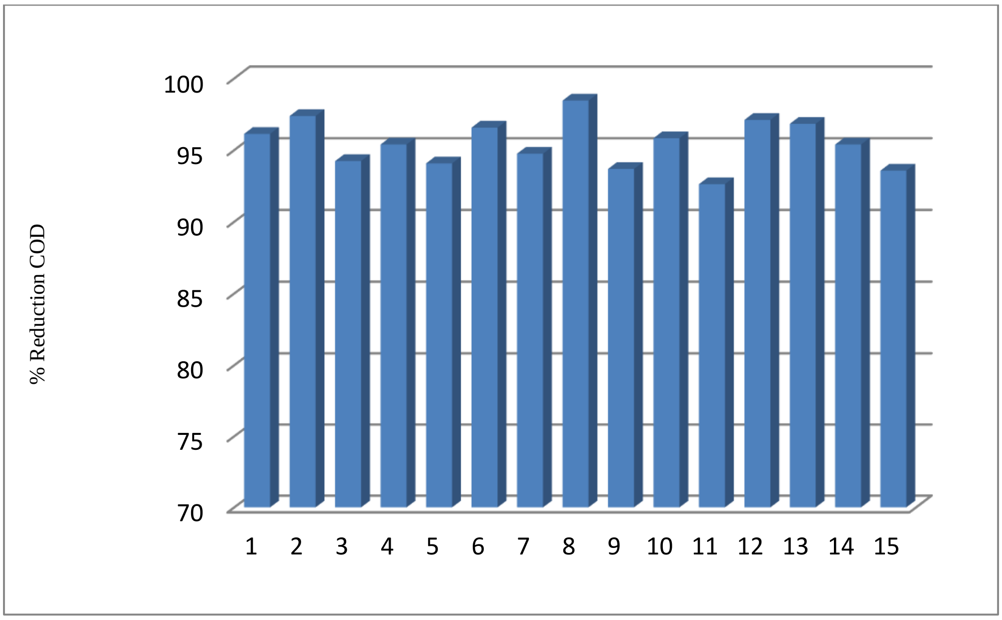

Figure 8: Study of abatement growth in COD for this process

3.8. Biochemical oxygen demand

BOD_5 is an expression that indicates the amount of oxygen that is used for the destruction of decomposable organic matter by biochemical processes [11]. BOD_5 concentration for the decanted wastewater used at the entrance of the pilot system fluctuates between 123 mg/l and 200 mg/l with an average value 175.5 mg/l (Figure 9).

3.9. Ammonium

Ammoniacal nitrogen constitutes one of the links of the complex cycle of nitrogen in its original state. It is a gas soluble in water. There is a small proportion, less than 0.1mg/l of ammoniacal nitrogen in natural waters. It is a good indicator of water stream pollution by urban effluents [12]. Nitrogen, mainly in ammoniacal form, is rapidly oxidized by bacteria in nitrates and nitrites.

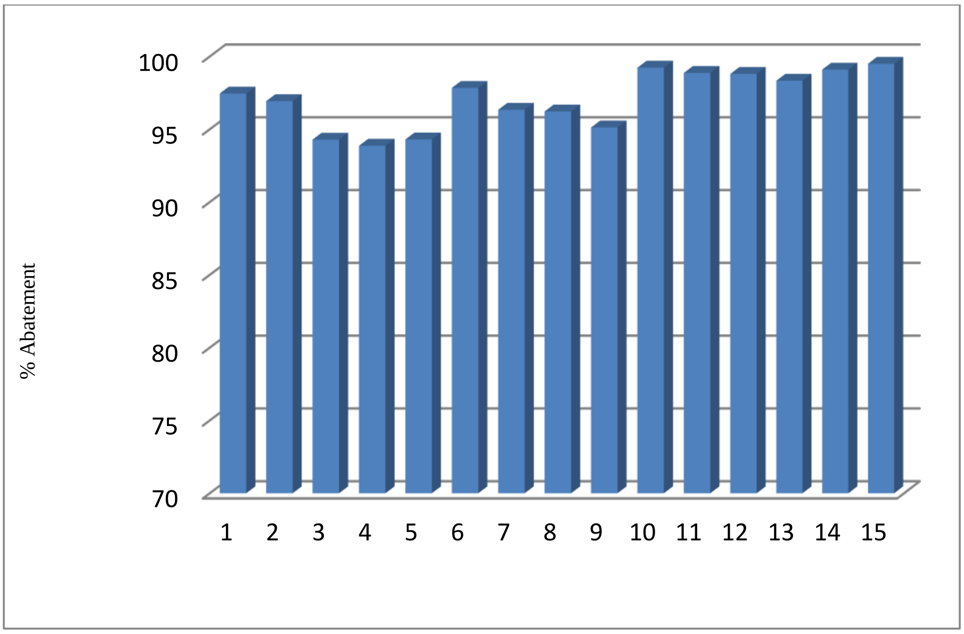

Figure 9: Study of abatement growth in BOD_5 for this process

The results of Ammonium contents in the decanted wastewater used at the entrance of the pilot system fluctuates between 0.5 mg/l and 4.8 mg/l with an average value 1.7 mg/l (Figure 10). The concentrations in Ammonium measured at the outlet of the massive vary from 0 mg/l to 0.09 mg/l with an average concentration of 0.02 mg/l. This indicates that the average retention was 99%.

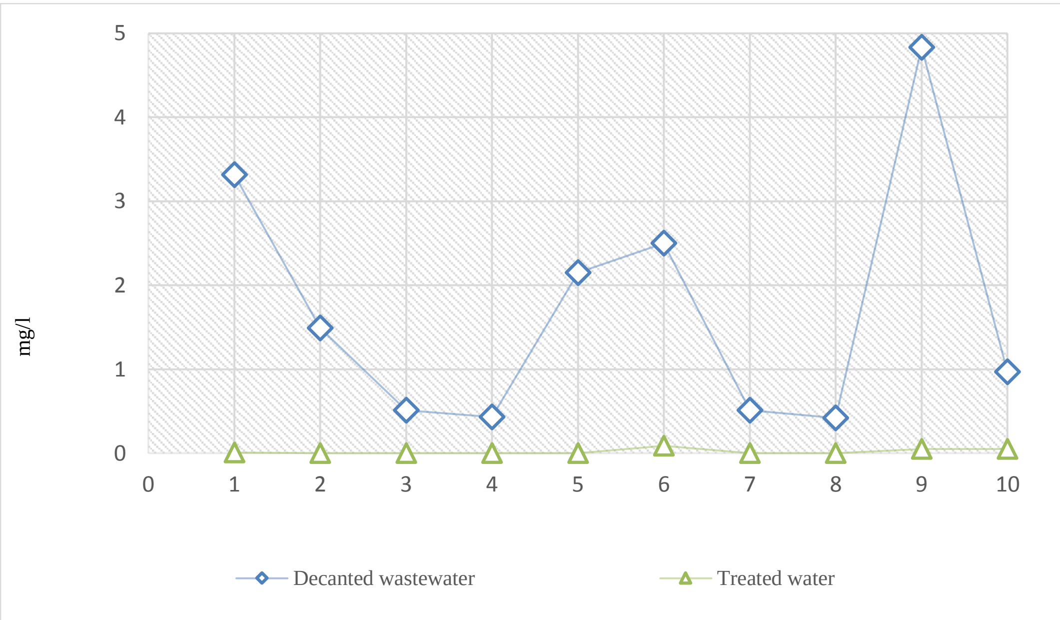

Figure 10: Study of Ammonium growth of decanted wastewater (D.W) and treated water (T.W)

3.10. Nitrates

Nitrates are listed among the main categories of chemical pollutants found in water, they are chemical compounds consisting of nitrogen and oxygen, and are necessary for plant growth (Figure 11). However, their excessive presence in water raises concerns for the health of humans and animals. In fact, nitrates are easy leachable pollutants reach the aquifer without undergoing changes [13].

The results of nitrate contents in the treated waters show a slight increase in these contents that range from 0.2 mg/l and 0.6 mg/L with an average value of 0.3 mg/l (Figure 11), and regarding the settled waters, they have a low content with an average value of 0 mg/l. This increase is due to the nitration and nitrification which convert (NH_4^+, NH_3) into NO_2^-(nitrites) and NO_3^- (nitrates). These are oxidation reactions that are a result of enzymatic catalysis linked to bacteria in the sand and water.

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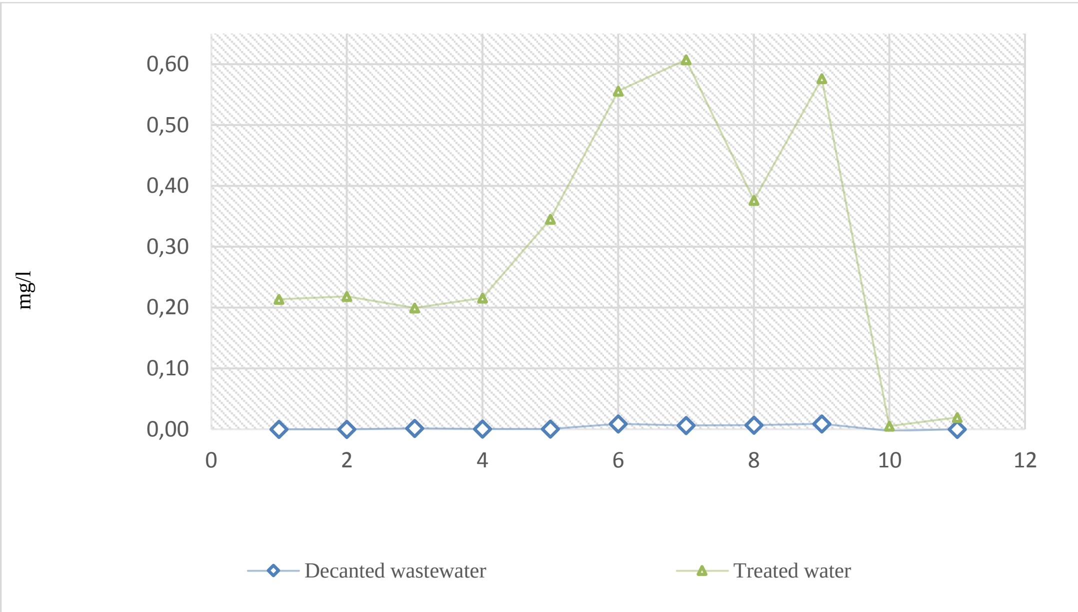

Figure 11: Study of nitrates growth of decanted wastewater (D.W) and treated water (T.W)

The results show that there is no need to couple other techniques to the first so as to solve the problem of nitrates in treated water, like all the processes used in infiltration percolation by sand. We can conclude that contents in nitrates recorded in the treated water by the titaniferous sieved sand are lower than the content suggested by Moroccan and international standards (50 mg/l). This indicates that the studied waters are not subject to pollution risk of nitrates.

3.11. Nitrites

The existence of the nitrite ions in the treated water is due to incomplete oxidation of ammonium ions or to a nitrate reduction defined as denitrification phenomenon [14].

After summarizing the results of the evolution of nitrites in this process we find that the nitrite content is lower than that of nitrate, which explains that the nitration is faster than the formation of nitrites or the latter are less stable and disappear fairly quickly from the natural environment (disproportionation). The contents of treated waters by titaniferous sieved sand vary from 0.04 mg/l to 0.2 mg/l with an average value of 0.12 mg/l (Figure 12).

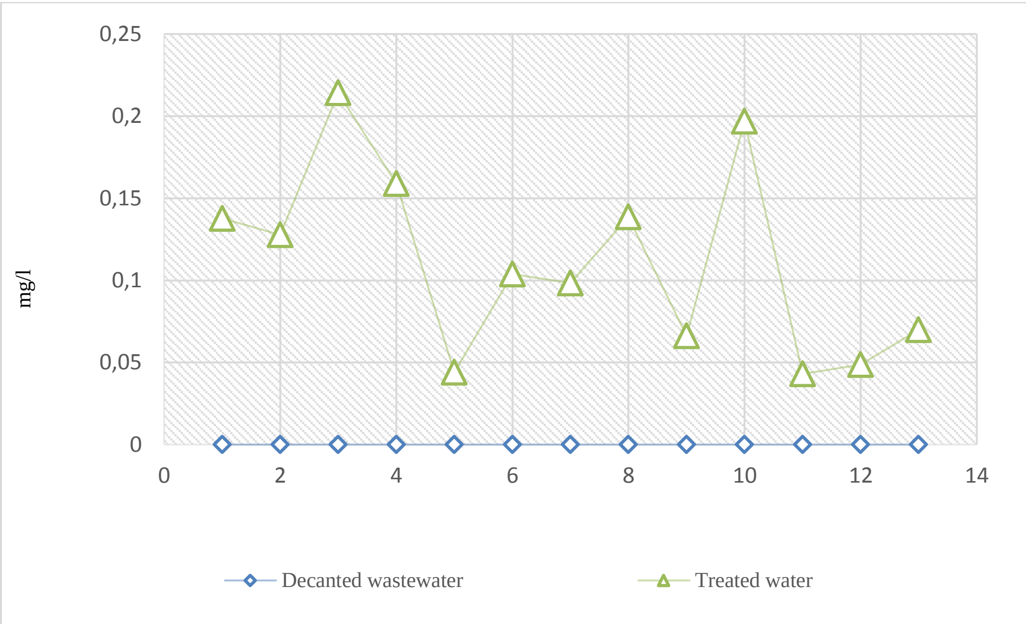

Figure 12: Study of nitrites growth of decanted wastewater (D.W) and treated water (T.W)

3.12. Orthophosphates

The monitoring of the phosphorus content in the treated wastewater is necessary because an excess of phosphorus can cause undesirable results, such as the proliferation of plants in aquatic environments. Similarly phosphates in some detergents cause fertilization of rivers and lakes, and superabundance can cause eutrophication of the receiving environment [15].

The joining of phosphate to titaniferous sieved sand is quite important, the concentration of orthophosphates in decanted wastewater has an average value of 6 mg/l and 0.08 mg/l in the treated water (Figure 13). We note that the concentration of this element in the output is very low compared to the standards (<2 mg / L).

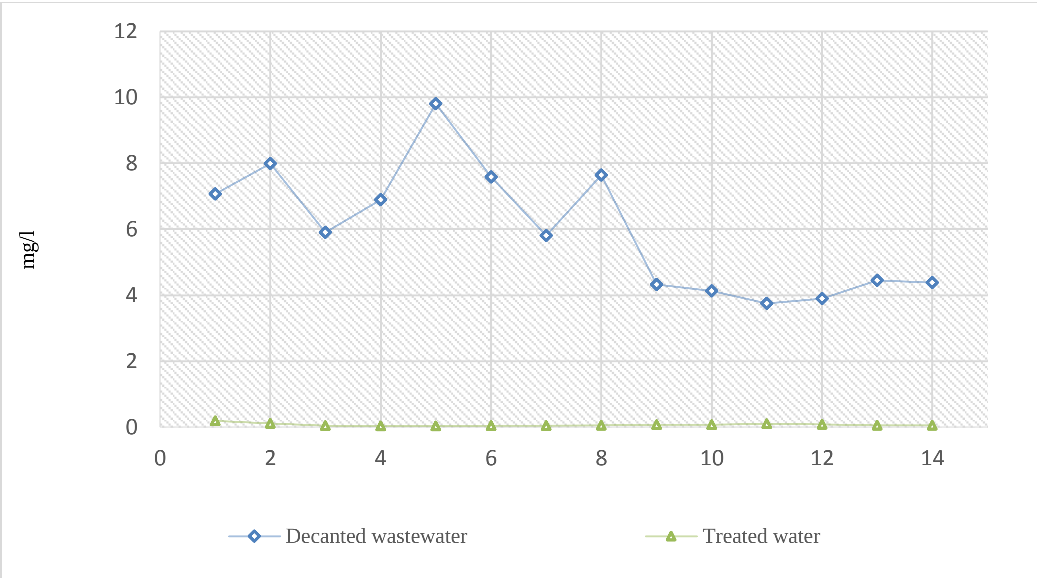

Figure 13: Study of the orthophosphate growth of decanted wastewater (D.W) and treated water (T.W)

Conclusion

This study aims to test the treatment performance of urban wastewater on the black sand (titaniferous sieved sand), by the process of infiltration-percolation.

At the end of this study, the results obtained in terms of physico-chemical analyses of treated wastewater show good reduction of organic load (COD: 95%; BOD_5: 97%) . For nutrients (NO_3^-: 0.3mg/l; NO_2^-: 0.12mg/l; PO_4^{3-}: 0.08mg/l), their values are in Moroccan standards of water used for irrigation.

In view of the results obtained, the treatment of wastewater by titaniferous sieved sand during the infiltration-percolation process has allowed an effective abatement of organic and inorganic pollution, and especially nitrates and nitrites.

References

[1]. S. Fouad, K. Hajjami, N. Cohen and M. Chlaida, Qualité physico-chimique et contamination métallique des eaux de l'Oued Hassar : impacts des eaux usées de la localité de Mediouna (Périurbain de Casablanca, Maroc), *Afr. Sci.*, 10(1), 91-102 (2014).

[2]. D. Belghiti, Y. El Guamri, G. Ztit, M. L. Ouahidi, M. B. Joti, A Harchrass, H. Amghar, O. Bouchouata, K. El Kharrim and H. Bounouira, Caractérisation physico-chimique des eaux usées d'abattoir en vue de la mise en oeuvre d'un traitement adéquat : cas de Kénitra au Maroc, *Afr. Sci.*, 05(2), 199-216 (2009).

[3]. V. Mottier, F. Brissaud, P. Nieto and Z. Alamy, Wastewater treatment by infiltration percolation: a case study, *Water Sc. Techno,* 41(1), 77-84 (2000).

[4]. A. Bancole, F. Brissaud and T. Gnagne, Oxidation processes and clogging in intermittent unsaturated Infiltration, 5th Specialized Conference on Small Water and Wastewater Treatment Systems, Istanbul, 235-242 (2002).

[5]. NMEDI Normes marocaines de qualité des eaux destinées à l'irrigation, Portant fixation des normes de qualité des eaux destinées à l'irrigation (2002).

[6]. R. El haouti, R. Aba-aaki, K. Agga, S. Et-taleb, M. Abbaz, M. Ez-zahery, S. Lhanafi and N. El alem, Utilisation du sable noir comme massif filtrant dans le procédé d'infiltration percolation pour le traitement des eaux usées, *J. Mater. Environ. Sci*., 5 (S2), 2385-2390 (2014).

[7]. S. Et-taleb, R. El haouti, M. Abbaz, S. Lhanafi, M. Ez-zahery, R. Aba-aaki and N. El alem, Comparaison du phénomène de colmatage des eaux usées à travers deux types de sables : l'un vierge et l'autre utilisé lors de traitement par infiltration, *J. Mater. Environ. Sci.*, 5 (6), 1906-1912 (2014).

[8]. M. Achak, N. Ouazzani and L. Mandi, Elimination des polluants organiques des effluents de l'industrie oléicole par combinaison d'un filtre à sable et un lit planté, *J. Water Sci.,* 24 (1), 35-51 (2011).

[9]. M. El morhit, M. Fekhaoui, A. Serghini, S. El blidi, A. El abidi, R. Bennaakam, A. Yahyaoui and M. Jbilou, Impact de l'aménagement hydraulique sur la qualité des eaux et des sédiments de l'estuaire du Loukkos (côte atlantique, Maroc), *Bulletin de l'Institut Scientifique*, Rabat, section Sciences de la Terre, (30), 39-47(2008).

[10]. Dj. Kerboub and Ch. Fehdi, Impact des rejets urbains et industriels sur la qualité des eaux souterraines: cas de la région d'El Kantar, Sud-Est Algérien, *Afr. Sci.*, 10 (1), 127-138 (2014).

[11]. C. Hamid, L. Elwatik, Y. Ramchoun, R. Fath-allah, A. Ayyach, Z. Fathallah, A. El midaoui and EL M. Hbaiz, Etude des performances épuratoires de la technique du lagunage aéré appliquée à la station d'épuration de la ville d'Errachidia – Maroc, *Afr. Sci.*, 10 (2), 173-183 (2014).

[12]. M. Makhoukh, M. Sbaa, A. Berrahou and M. Van. Clooster, Contribution à l'etude physico-chimique des eaux superficielles de l'oued Moulouya (Maroc Oriental), *Larhyss Journal,* (09), 149-169 (2011).

[13]. I. I. Alami, M. Zeraouli, M. Addou, AB. Mokhtari and AB. Soulaymani Évaluation de la pollution nitrique de la nappe phréatique de la zone côtière du Gharb (M'nasra) au Maroc entre 1993 et 2003. *Afr. Sci*., 03(3), 378-390 (2007).

[14]. M. Ez-Zahery, Etude de l’influence des caractéristiques du sable sur le pouvoir de rétention du massif filtrant et sur les performances épuratoires dans le procédé d’infiltration percolation. *Thèse de doctorat*, Maroc (2009).

[15]. P.A. Chambers, M. Guy, E.S. Roberts, M.N. Charlton, R. Kent, C. Gagnon, G. Grove and N. Foster. Les éléments nutritifs et leurs effets sur l'environnement au Canada. Agriculture et Agroalimentaire Canada, Environnement Canada, Pêches et Océans Canada, *Santé Canada et Ressources naturelles Canada*, 241 (2001).

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