



Purification Performance of Wastewater on the Sand - A Case Study Tamanrasset Region

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Abstract

This work aims to test the performance of sand slow filtration to treat urban wastewater from the city of Tamanrasset, Algeria. The objective is to carry out a comparative study between two types of sand (Tamanrasset and In Salah) in order to show the influence of the type of aggregate on the biological filtration performance of wastewater. The analyses carried out in the laboratory showed that the filtrate pH values are between 7 and 8 (neutral medium), the values of electrical conductivity (3.6-4.2 mS/cm) are higher than that of salt water, and the purification yields of suspended solids, chemical oxygen demand (COD), and biochemical oxygen demand exceed 60%, 55%, and 70%, respectively. Our results show that slow sand filtration has a positive impact on the removal of suspended contaminants and biological parameters, and its purification performance is mainly dependent on the types of aggregates and raw water properties.

Keywords: Tamanrasset, Waste Water, Sand Filter, Performance Purification

1 Introduction

Population growth has a direct effect on the disruption of natural and climatic resources, especially in developing countries with highly intensive economic, industrial, and agricultural activities (1). One of the goals of the global sustainable development strategy is to improve food security in the face of population growth (2), with the supply of drinking water being a major challenge for policymakers.

The issue of water scarcity in arid and semi-arid areas is currently the subject of much scientific research in the literature (3, 4, 5). The scarcity of water has led to the search for and development of alternative resources, notably the reuse of wastewater. This water has to be treated to comply with and adapt to different possible uses, whether agricultural, industrial or hydrogeological, such as groundwater recharge and more generally the preservation of wetlands and natural resources.

The processes of wastewater treatment or purification differ from country to country or from region to region within the same country and depend on climatic, economic, and social conditions (6, 7, 8). The objective of the treatment is to eliminate all materials or objects that can degrade the quality of the water on the one hand and to reduce the pollution load on the other hand (9, 10). Indeed, several methods and procedures are available for wastewater treatment; the best technique is one that can be adapted to the local resources of water, people, and materials available in the study area (11). Unfortunately, in the South of Algeria, in Tamanrasset, and given the poor means and the absence of urban wastewater treatment technology, the creation

and development of a simple and efficient wastewater treatment system, compatible with the available resources and materials, is an urgent and certain need (12, 13). Slow sand filtration (SSF) is generally considered among the most effective and simultaneously very favorable technologies for the reduction of pollutant load, including particulate organic substances, mineral matter, turbidity, and suspended solids (7, 14). It is a treatment based on a technology of low energy intensity, low dependence on chemical products, and simple manipulation, which does not require skilled labor. This mode of treatment is profitable from an economic point of view (9, 15).

The technique has been widely used for tertiary wastewater treatment, integrating physical, chemical, and biological processes to modify wastewater characteristics including temperature, hydrogen potential, hydraulic head, turbidity, chemical oxygen demand, and biochemical oxygen demand, etc (15, 16). From a morphological point of view, the sand material is considered the most available element in the Algerian Sahara figure 1. The objective of this study is to use it to treat urban wastewater discharged by the population of the Tamanrasset region. This work aims to verify the purification performance of two types of sand, sampled in the Tabrakat wadi which crosses Tamanrasset, and In Salah, to monitor the evolution of the physico-chemical parameters of the purified water.

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2 Materials and Methods

2.1 Study Area

The Tamanrasset region is located in the extreme south of Algeria, and covers an area of 556,100 km², i.e. ¼ of Algeria's total surface area, making it the largest region in Algeria (17).

It lies between 18°43' and 29°03' North latitude and 0°45' and 10°15' East longitude. The Tropic of Cancer crosses it 80 km north of the town of Tamanrasset. It is bordered to the north by Ghardaia, to the north-east by Ouargla province, to the east by Illizi province, to the west by the province of Adrar, to the south and south-east by the Republic of Niger, and to the south-west by the Republic of Mali. Its population in 2020 with more than 150,000 inhabitants(18).

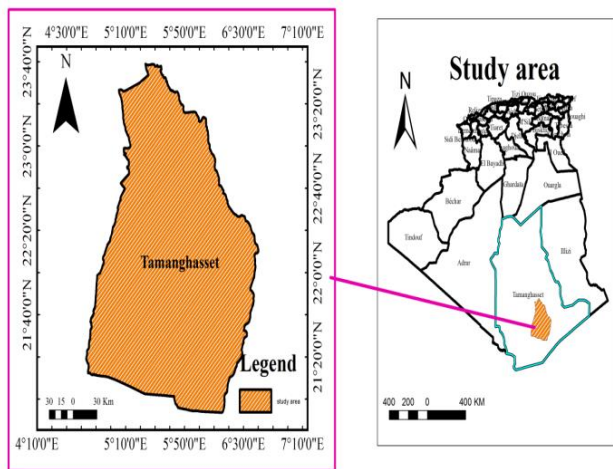


Figure.1: Study area

2.2 Sampling and Collection

The two sand samples were taken from the Tamanrasset and In Salah regions. All the granulometric analyses were carried out within the Laboratory of the Public works of the South unit of Tamanrasset, these analyses will give the power to determine certain characteristic indices of the sand used.



Figure 2: Sand dunes Tamanrasset province, Algeria (19)

The urban wastewater samples were collected in a 250 ml plastic bottle that was filled at different points for 7 weeks. Daily samples of the two 1000 ml filters were taken separately for each filter at the end of every 3 hours during filter operation and stored

in a closed plastic container, the feed wastewater sample was analyzed for total solids suspended solids (TSS), chemical oxygen demand (COD) and biochemical oxygen demand (BOD) (20).

These analyses of the chemical elements were carried out in the laboratory of the National Office of Sanitation (ONA) unit of Tamanrasset. Analyses are made on the five physicochemical parameters according to standard methods of analysis. pH and conductivity were measured in situ, using a pH meter coupled with a thermometer and a WTW 315i SET type conductivity meter. TSS, BOD, and COD were measured using standard method spectrophotometers HACH (DR 3900), AFNOR (XPT 90-319), and DCO AFNOR (NF T90-101), respectively (21).

2.3 Analytical Procedures and Calculations

The experimental pilot consists of a sand column, the column consists of a PVC tube with a height of 1 m and an internal diameter of 110 mm (see Fig. 2 and 3), i.e. a free area of about 95 cm² (5). The raw water is fed into the filters intermittently, a total of 5L of the sample was used for each filter, the time of passage through the filter was measured using a stopwatch (table 2) (13), and the flow rate of the sample passed through the filter was determined using the equation (1) following

$$Q\left(\frac{L}{min}\right) = \frac{5L}{T} \quad (1)$$

Table 1: Times for the sample passed through the filter

Samples	T ₁	T ₂	T ₃	T ₄	T _{avrege}	Q
Tamanrasset	90	98	102	107	99.25	14.51
In Salah	45	50	42	53	47.5	28.80

T (min), Q (L/day).

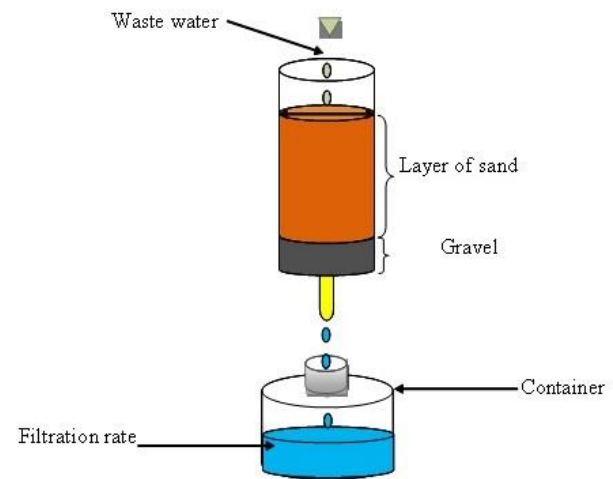


Figure.3: Layout diagram of sand filter pilot

2.4 Granular Media

The sand properties shown in the table, namely the uniformity coefficient Cu (4.70 and 4.00), the grading coefficient Cc (0.84 and 1.02), and the porosity n (39 and 41%) for the samples from Tamanrasset and In Salah, respectively, showed their potential to

be used as filtration media. The granulometry shows that the sand size can be characterised as medium.



Figure 4: Experimental pilot of sand filtration

Table 2: Granular media

Samples	D ₁₀ (mm)	D ₃₀ (mm)	D ₆₀ (mm)	Cc	Cu	n (%)
Tamanrasset	0.226	0.451	1.06 4	0.84	4.7 0	39
In Salah	0.679	1.373	2.72 0	1.02	4.0 0	41

The various analytical results that were obtained after the experimental operation of each filter are presented in figures 4 to 8. These analytical values will allow us to examine the performance of the filter by determining the average percentage removal of various pollutants. The formula used to calculate the percentage removal is as in equation (2) (6).

$$R_a = \left[\left(\frac{c_i - c_e}{c_i} \right) \right] 100 \quad (2)$$

where R_a percentage removal efficiency of chemical parameters; C_i initial concentration of analyzed chemical parameters of raw water;

C_e final concentration of the analyzed parameters of the filtrate (22).

3 Results and Discussion

In the following figures, a, b, and c represent wastewater, filtrate for Tamanrasset, and In Salah filtrate respectively.

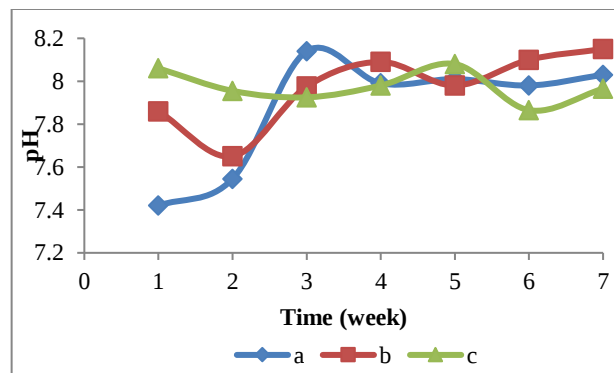


Figure 5: pH values before and after filtration

The pH values presented in Figure 5 showed that the raw water values varied between 7.4 and 8.14. This variation in pH values can be explained by the quality of the wastewater tested and the variation in ambient temperature. The pH values of the filtrate are generally higher than those of the raw water; they ranged between 7.9 and 8.2 for both sand filters. The filtrate medium tends to become basic. This increase in pH is due to the trapping of organic acids caused by the disappearance of protons.

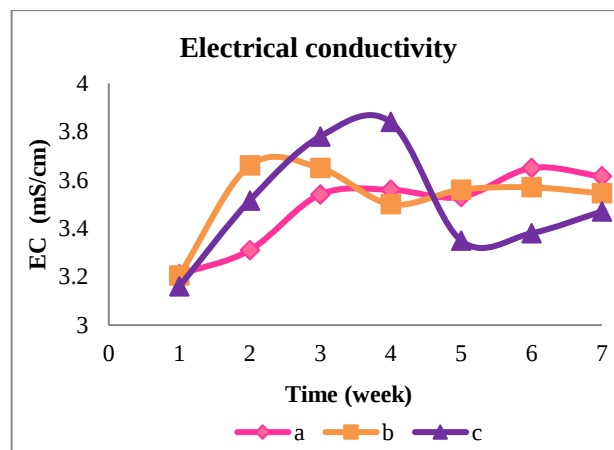


Figure 6: Electrical conductivity before and after filtration

The EC values in the first four weeks record high values. The increase in the concentrations of the electrical conductivity values presented in figure 6 is mainly due to (1) the salinity of the pilot sands, on the one hand. The values of the salinities of the sands measured from the samples of Tamanrasset and In Salah have values of 3.67 and 4.2 ms/cm respectively. (2) The transformation of organic matter into dissolved salt and the properties of the treated effluent. The values of the filtrates obtained after the passage of the effluent through the sand pilots record values higher than the values of the saline water (1.2 ms/cm), which can be justified by the sources of very soluble salts due to the effect of common ions linked to the composition of the treated effluent or the microbial activity (16).

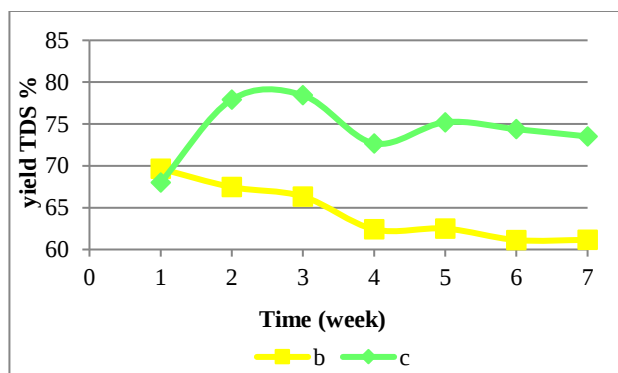


Figure.7: Total suspended solids of the sample after filtration

Figure 7 shows the efficiency of total suspended solids removal, in the first three weeks, all values were above 65% for the two samples used. The vertical downward flow of the effluent favors the removal of suspended solids and consequently the accumulation of dense mineral matter between the sand particles during the maturation phase of the filters. From 4 weeks onwards, the yields of the filters start to decrease due to the properties of the raw effluent, the purification performance of the filter in the In Salah sample being more efficient than in Tamanrasset.

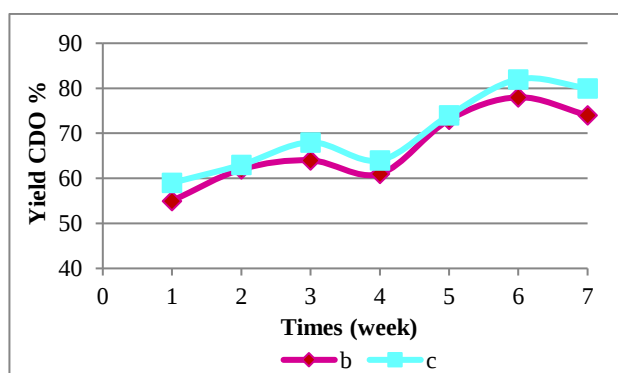


Figure.8: Yield of COD after filtration

Figure 8 shows the COD removal efficiency during the operation of the sand filtration pilots. The COD removal efficiency for both filters (a, b) is above 50%, which can be explained by the efficiency of the bacterial activity and the adsorption of organic matter on the filter material. These significant yields can be justified by the formation of biofilm on the surface layer of the pilots, which can favor the decantation of the organic matter. This phenomenon appears clearly between the 4th and the 6th week, where the evolution of the COD yield is remarkable (61-78% sample of Tamanrasset) and (68-82% sample of In salah). The BOD₅ treatment efficiency curves of the two pilots studied are presented in figure 9, they have the same trend as the. All the yields are higher than 69% or the maximum value is 86% recorded in the 6th week (the ideal phase of filter operation). The accumulation of organic and mineral particles between the sand grains leads to biological life and consequently to the formation of a biofilm that allows for excellent purification. From the 7th week onwards the BOD₅ yields start to decrease, accompanied by the fragility of the filters, this is the phase fatigue of the filter. The COD/BOD₅ ratio of the effluent used is between

3 and 4, which implies that the effluent is more or less difficult to biodegrade (23, 24).

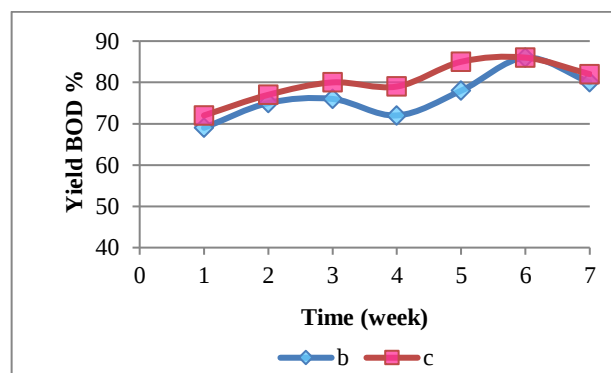


Figure.6: Yield of BOD after filtration

4 Conclusion

The experimental results obtained in this work made it possible to make a comparison of the purification performance of the wastewater of the city of Tamanrasset with sand, the evolution of the physicochemical parameters analyses of the filtrates such as the TSS, electrical conductivity, the DBO, and the DCO shows that the granulometric analysis has a considerable influence on the effectiveness of filtration on the sand, the structure of the samples of In salah and Tamanrasset used is of fine sand with 80% and 50% respectively. The removal efficiencies of TSS, COD, and BOD exceed 60%, 55%, and 68% respectively over seven weeks. The filtrates obtained are saline with a conductivity generally exceeding 3 ms/cm, this concentration is found to depend on the properties of the effluent and the accumulation of salts in the filters. The best purification yield leads us to select the best sand, and that is the sand of In Salah compared to the one coming from the city of Tamanrasset.

Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing.

References

1. Nedjraoui D, Bédraoui S. La désertification dans les steppes algériennes: causes, impacts et actions de lutte. Vertigo. 2008;8(1):15. <https://doi.org/10.4000/vertigo.5375>

2. Abada Z, Bouharkat M. Study of management strategy of energy resources in Algeria. *Energy Reports*. 2018;4:1-7. <https://doi.org/10.1016/j.egypr.2017.09.004>
3. Alikhani S, Nummi P, Ojala A. Urban wetlands: A review on ecological and cultural values. *Water*. 2021;13(22):3301. <https://doi.org/10.3390/w13223301>
4. Slimani S, Benziada S, Boutaoutaou D, Kettab A. Study of the reliability of "Chekfa" in water distribution in the "foggara" system: a case of Adrar region, Algeria. *Algerian Journal of Environmental Science and Technology*. 2020;6(3).
5. Khengaoui K, Mohammed MH, Touil Y, Amrane A. Influence of secondary salinity wastewater on the efficiency of biological treatment of sand filter. *Energy Procedia*. 2015;74:398-403. <https://doi.org/10.1016/j.egypro.2015.07.636>
6. Khan ZU, Naz I, Rehman A, Rafiq M, Ali N, Ahmed S. Performance efficiency of an integrated stone media fixed biofilm reactor and sand filter for sewage treatment. *Desalination and Water Treatment*. 2015;54(10):2638-47. <https://doi.org/10.1080/19443994.2014.903521>
7. .Latrach L, Ouazzani N, Masunaga T, Hejjaj A, Bouhoum K, Mahi M, et al. Domestic wastewater disinfection by combined treatment using multi-soil-layering system and sand filters (MSL-SF): A laboratory pilot study. *Ecological Engineering*. 2016;91:294-301. <https://doi.org/10.1016/j.ecoleng.2016.02.036>
8. Freitas BLS, Terin UC, Fava NdMN, Sabogal-Paz LP. Filter media depth and its effect on the efficiency of household slow sand filter in continuous flow. *Journal of Environmental Management*. 2021;288:112412. DOI: 10.1016/j.jenvman.2021.112412
9. Rolland L, Molle P, Liénard A, Bouteldja F, Grasmick A. Influence of the physical and mechanical characteristics of sands on the hydraulic and biological behaviors of sand filters. *Desalination*. 2009;248(1-3):998-1007.
10. Kramer OJ, de Moel PJ, Padding JT, Baars ET, Rutten SB, Elarbab AH, et al. New hydraulic insights into rapid sand filter bed backwashing using the Carman-Kozeny model. *Water Research*. 2021;197:117085. <https://doi.org/10.1016/j.watres.2021.117085>
11. Bayo J, López-Castellanos J, Olmos S. Membrane bioreactor and rapid sand filtration for the removal of microplastics in an urban wastewater treatment plant. *Marine Pollution Bulletin*. 2020;156:111211. <https://doi.org/10.1016/j.marpolbul.2020.111211>
12. Kaetzl K, Lübken M, Nettmann E, Krimmler S, Wichern M. Slow sand filtration of raw wastewater using biochar as an alternative filtration media. *Scientific reports*. 2020;10(1):1-11. <https://doi.org/10.1038/s41598-020-57981-0>
13. Sze YS, Aris A, Zaidi NS, Bahrodin MB. Performance of Sand Filtration System with Different Sand Bed Depth for Polishing Wastewater Treatment. *Journal of Environmental Treatment Techniques*. 2021;9(2):452-7.
14. .Hamoda M, Al-Ghusain I, Al-Jasem D. Application of granular media filtration in wastewater reclamation and reuse. *Journal of Environmental Science and Health, Part A*. 2004;39(2):385-95. DOI: 10.1081/ESE-120027530
15. Verma S, Daverey A, Sharma A. Slow sand filtration for water and wastewater treatment—a review. *Environmental Technology Reviews*. 2017;6(1):47-58. <https://doi.org/10.1080/21622515.2016.1278278>
16. Bendida A, Tidjani AE-B, Badri A, Kendouci MA, Nabou M. Treatment of domestic wastewater from the town of Bechar by a sand filter (sand of Beni Abbes Bechar Algeria). *Energy Procedia*. 2013;36:825-33.
17. Gastineau R, Hamed C, Hamed MBB, Abi-Ayad S-ME-A, Bak M, Lemieux C, et al. Morphological and molecular identification reveals that waters from an isolated oasis in Tamanrasset (extreme South of Algerian Sahara) are colonized by opportunistic and pollution-tolerant diatom species. *Ecological Indicators*. 2021;121:107104. <https://doi.org/10.1016/j.ecolind.2020.107104>
18. Benhadji Serradj DE, Sebitosi A, Fadlallah S. Design and performance analysis of a parabolic trough power plant under the climatological conditions of Tamanrasset, Algeria. *International Journal of Environmental Science and Technology*. 2022;19(4):3359-76. DOI: 10.1007/s13762-021-03350-x
19. Brahimi A, Meghachou M, Abbad H, Rahmouni A, Belbachir M. Valorization of Raw Materials Based on Fly Ash of Eggshells and Algerian Sand Dune (Southern West of Algeria) for Synthesis of Environmentally Cementitious Materials: Synthesis and Characterization. *Geotechnical and Geological Engineering*. 2020:1-16.
20. Dahou MEA, HADJ KOUIDER M, Dehmani S, Habchi A, Slimani S. Experimental Study of Increase of Biogas Production from Lagoon Station's Sludge by Alkaline Pretreatment. *Energy & Environment*. 2022:0958305X221088569. <https://doi.org/10.1177/0958305X221088>
21. Rodier J, Legube B, Merlet N. L'analyse de l'eau-10e éd: Dunod; 2016.
22. Gherairi F, Hamdi-Aissa B, Touil Y, Hadj-Mahammed M, Messrouk H, Amrane A. Comparative Study between two Granular Materials and their Influence on the Effectiveness of biological Filtration. *Energy Procedia*. 2015;74:799-806.
23. Teixeira CA, Ghisi E. Comparative analysis of granular and membrane filters for rainwater treatment. *Water*. 2019;11(5):1004. <https://doi.org/10.3390/w11051004>
24. .Katrivesis FK, Sygouni V, Paraskeva CA, Papadakis VG. A Performance Comparison of Pilot-Scale Sand Filtration and Membrane Filtration of Glafkos River Water. *Journal of Marine Science and Engineering*. 2021;9(2):203. <https://doi.org/10.3390/jmse9020203>

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