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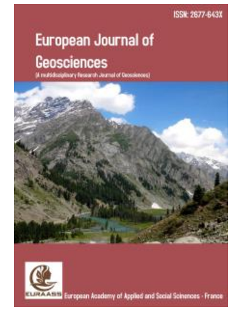

Research Article

Study of Sulfate removal using Nanofiltration compared to biological method to access sustainable water resources in urban areas, A case study of Najaf Abad in Iran

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Abstract

Population growth and the need for sustainable urban development as well as lack of water resources due to the position of Iran in the arid and semi-arid zone and the occurrence of recent drought has seriously raised the importance of water scarcity. Nowadays, unconventional water resources are considered as one of the possible solutions to provide water supplies. Among different resources of unconventional waters, the use of wastewater as a sustainable resource for water scarcity management is considered as a strategic strategy. The aim of this study was to compare biological treatment method and nanofiltration method to remove sulfate from industrial wastewater. Thus, industrial wastewater of Najaf Abad treatment plant was used for this purpose and the experiments were carried out for 11 weeks and 11 replications. The appropriate method was chosen by calculating the removal percentage of various parameters and SPSS software was used to analyze the significance of the difference between the results of the two methods. According to the results, the percentage of sulfate removal in all experiments in the nanofiltration system was higher than the biological system and nanofiltration method is more reliable to remove sulfate. So, nanofilter system would be a good alternative for the biological system to reduce and remove sulfate in industrial wastewater.

Keywords: Nano filtration, Sulfate Removal, biological treatment method, Sustainable Development.

1. Introduction

Due to population growth and industrial development, human life is now faced with a lot of problems such as producing large amounts of wastewater which were easily absorbed by the nature in the past. But, because of population increase and rising industrial and municipal wastewater volumes, a large amount of wastewater may not be able to absorb through the nature. Whereas Iran is located in arid and semi-arid region of the globe, so it would face severe resource constraints. Therefore it is necessary to identify a method for achieving sustainable water resources such as wastewater reuse. It should be noted that reuse of wastewater is one of the most sustainable sources of water that can even be counted on this source despite the occurrence of drought (Eslamian and Esfahani, 2009). Most infectious diseases in the world are transmitted through contaminated water and a large number of people get sick or even

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die every day because of the lack of proper water treatment and drinking contaminated water. So, these challenges show importance of water treatment (Mohamadi et al., 2014).

The importance of sulfate in agriculture is because of the fact that a small amount of sulfur compounds is beneficial for plant growth. Also, Sulfur is applied as a fungicide but if the sulfate concentration in irrigation water increases, it will lead to deposition and corrosion in irrigation facilities [6]. There are many ways to treat wastewater which have advantages and disadvantages and the appropriate method can be chosen according to the need. For example, chemical method is mainly used for the treatment of wastewater produced by the oil and gas industry while the biological method is more applicable for sanitary wastewater and food industry. Recently, there has been a great deal of interest in nanotechnology in all disciplines and water engineering discipline is no exception. Perhaps the reason for this is that nanotechnology is a great step to achieve sustainable development and a have created significant distance compared to the previous methods.

Nanofilters have many capabilities that make it easy to use in the treatment processes. The advantages of nanofiltration include less labor costs, ability to reduce organic chemicals, the possibility of reducing heavy metals, the possibility to make smart filters for removing specific compounds and applications, the ability to remove contamination according to need, the ability of water treatment to the distilled water and etc. (Ramaswamy et al 2013). The disadvantages of nanofilters also include the high initial cost and the need for skilled workers, need for spending a lot of energy to pass water through filters. In recent years, there has been a lot of research in these areas due to the great importance of industrial wastewater treatment as well as the efficiency of nanofiltration for wastewater treatment. These researches include the following:

Kohansal et al (2014) have investigated the removal of phosphate by nanofiltration. Their results indicated the high capacity of the nanofilter to remove phosphate. They also compared nanofiltration with biological method and indicated that nanofiltration can be much more effective than the biological method. Eslamian et al (2011) collected the wastewater of industrial factories in the north of Isfahan and after the advanced treatment of the wastewaters; these resources were used in firefighters, cooling towers and boilers (Eslamian and Esfahani, 2011).

Kheirkhah et al (2011) compared nanofiltration methods with other old methods and showed that nanotechnology treatment is more cost effective in addition to being more suitable for removal of harmful substances compared to old ones. Mondal and Ranil (2008) treated wastewater produced by the oil and gas industry with two nanofilters and an osmosis membrane. According to the results, they reported that treatment using nanofiltration has made significant progress in Non-conventional Water.

Wu et al (2012) have done a pilot study to determine the effect of nanofiltration to control COD, ammonium, color, concentration, pH, temperature, etc. Their experiments showed that the color has dropped to 99% and did not depend on other factors. Other item such as control and removal of ammonium has varied from 83% to 90% in proportion to other factors and indicated most of the organic compounds in the industrial wastewater were removed by the NF membrane using GC-MS analysis.

2. Materials and Methods

2.1 Nanofiltration and industrial wastewater treatment

Wastewater need to be modified for reuse or even returning to the environment. Wastewater collected from either the population centers or the factories should eventually be returned to water or soil resources. The entry of wastewater into water and soil resources without treatment will cause environmental problems. Also, industrial wastewater requires to be treated in order to reuse or return to the environment. Generally, wastewater treatment methods can be divided into three main categories including physical, chemical and biological. It rarely happens that one of the methods can meet all demands of the treatment system. Therefore, it is necessary to use a combination of the above methods (Eslamian and Esfahani, 2011).

Nanofiltration method has flourished in the past decades. In this method, nanosized Physical filters can capture 100% of bacteria, viruses and even small protein units. Also, salt and heavy materials can also be separated from water using electric separators that absorb ions through super-capacitor. In nanofiltration, separation is based on the size of the molecule and is a compression process. In principle, this method has the ability to remove organic components such as micro-contaminants and multiplicity ions.

Other uses of nanofiltration include removing chemicals that are added to water in order to kill harmful organisms, removal of heavy metals, treatment of water, decolorization and removal of contaminants and nitrates. Nanofiltration can produce clean water from almost every water source and remove all bacteria in the water and also makes it easy to use treatment methods. By using nanofilters, the minerals required for human health remain in the water and toxic and harmful substances are removed from it.

Scientists and researchers have achieved a simple method to produce filters using carbon nanotubes In addition to the effective removal of pollutants in Nano and Micro Scales, heavy hydrocarbons can be separated from crude oil. The use of carbon nanotubes for filter manufacturing makes it easy to clean, increase strength, reuse and resistance to heat. These filters are very precise and can remove viruses (25 nm in size) and larger pathogens, including E. coli bacteria very well.

2.2 The Study Area

This study has been performed in industrial treatment plant in Industrial Zone 1 in Najaf Abad. It should be noted that inlet wastewater of this Treatment Plant is industrial and sanitary wastewater. Also, the quantity of sanitary wastewater in the inlet of the treatment plant is less than industrial wastewater and industrial wastewater include the main part of inlet wastewater.

Meanwhile, the designed pilot plant is still in the treatment plant and further experiments will be carried out.

2.3 Characteristics of Filters and Pilot

A Metal Screen Filter with pore diameter of 50 micrometers is considered (behind the pump) for treatment. The first filter behind the pump has a pore diameter of 10-20 microns. Magnetic filter is used inside this filter to absorb iron compounds as shown in Figure 1.

Figure 1: Magnetic filter.

Figure 2: Nanofilter made of carbon-neon.

The third filter that is located behind the main Nanofilter has pore diameter of 1-10 µm and is made of asbestos. The last filter is the same Nanofilter. Alternative filter can be replacing the main Nanofilter if necessary. The system and designed pilot is shown in Figure 3. The main filter is the type of nano tube filter with small holes at the Nano-Scale and the combination of carbon and neon. The water enters from the sides and its exit is from the middle of filters toward down. Nanofilter is shown in Figure 2. The filter has diameter of 3 cm, a thickness of 5 mm, a height of 30 cm and pore diameter of 50-80 nm. The design of the filter is such that it can also filter and treat microorganisms and bacteria. The optimal operating pressure of the filter is 10 times, although it works 6 times. It should be noted that the replacement filter is also considered which can be replacing the main Nanofilter (if needed). The system and designed pilot is shown in Figure 3.

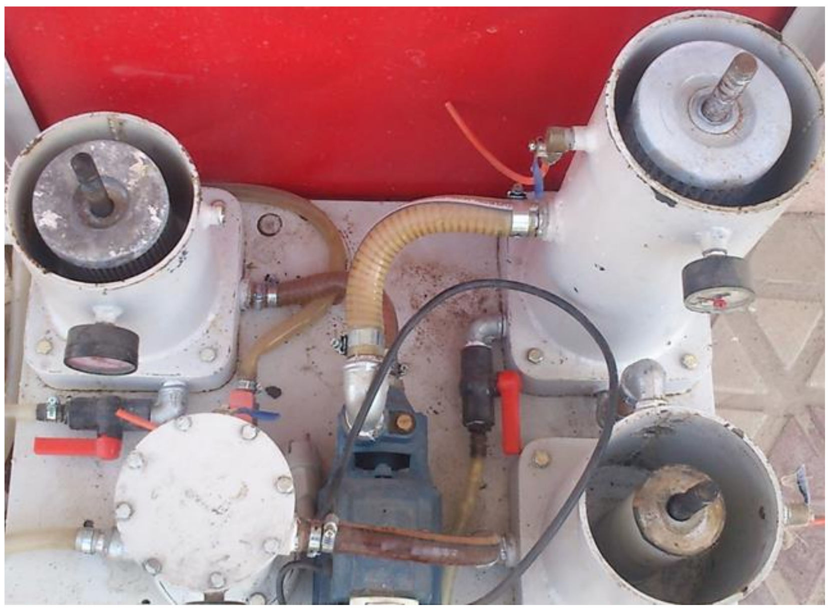

Figure 3: The designed pilot.

2.4 Treatments and control

This research was carried out on 2 treatments and 1 control with 11 replications. Treatments in this study include treated wastewater by biological method and treated wastewater by designed nanofilter method. Control is including untreated (raw) wastewater. Treatments and control are shown in figure 4 which the color difference of the samples is quite obvious.

The experiments were carried out 11 weeks and 11 replicates. Samples were harvested on a weekly basis, on Tuesday and from control and two treatments. At the same time, the experiments were performed to reduce the error rate. In order to avoid excessive rise of pressure in nanofilter pilot, the filters were washed (in case of excessive rise of pressure). The input of the nanofilter and the treatment plant was the same to avoid additional testing. After obtaining the results, the percentage of removal of sulfate in each experiment was calculated. Finally, the results were analyzed statistically and the comparison was done between the two tested methods in terms of removal rate and percentage.

2.5 The used software

In this study, the data are entered in the Excel 2010 software and the removal percentage of various parameters has been calculated. Also, the required graphs are drawn by this software. Then, SPSS software was used to determine meaningfulness of percentage difference. Due to the existence of two independent data sets for each parameter, including the amount of wastewater by nanofiltration and biological methods, The T-Method was used for two independent samples. The average of two methods for each parameter is calculated by this software. Then, a significant amount is considered for each parameter. If the value is greater than 0.05, the significant level written in the upper row, and if it is less than 0.05, the level written in the lower row is considered. If the level of significance is less than 0.05, then there is a significant difference at the level of 5% but if there is more (than 0.05), there will be no significant difference.

Figure 4: Treatments and control.

2.6 Sampling

Experiments were performed weekly during 11 consecutive weeks. For this reason, inlet of treatment plant and outlet of biological system in treatment plant and pilot output was sampled during 11 consecutive weeks. The output of the biological is important to compare the results obtained from the nanofiltration and the treatment plant method. It should be noted that sampling was done on Tuesday.

3. Results

Experiments were carried out on raw wastewater, outlet wastewater by nanofiltration and biological methods during 11 weeks and the results of the experiments were determined as the parameter value and the removal percentage in the form of a table and the figure was drawn, so that the percentage of removal was above 98 in most of the experiments and only one test had the removal percentage of less than 98. According to this table, the biological system has an acceptable percentage removal and efficiency on this parameter and reduces it to an acceptable level. But this does not mean that the biological system has a better efficiency than the nanofilter system to remove and reduce sulfate.

Looking at Figure 5 clearly shows that the percentage of sulfate removal in all experiments in the nanofiltration system was higher than the biological system. This diagram shows that the percentage of sulfate removal by nanofilter system was almost equal in all experiments. So, this point makes it possible to look at this system as a safe system while this does not happen in the biological system. Another noteworthy point is that the amount of sulfate in the wastewater effluent by nanofiltration has been located in the close proximity to each other, which also makes it more reliable.

Table 1: The results obtained from the experiments of sulfate on wastewater and raw wastewater.

Test Number	Sulfate (mg / L)			Percentage Sulfate Reduction	
	Raw Wastewater	Wastewater by nanofiltration	Biological wastewater	Wastewater by nanofiltration	Biological wastewater
1	1160	20	280	98.28	75.86
2	1320	22	499	98.33	62.20
3	1280	22	487	98.28	61.95
4	1120	18	273	98.39	75.63
5	1190	22	281	98.15	76.39
6	1300	23	500	98.23	61.54
7	1040	17	224	98.37	78.46
8	930	20	180	97.85	80.65
9	1090	18	238	98.35	78.18
10	1010	20	212	98.02	79.01
11	980	18	210	98.16	78.57

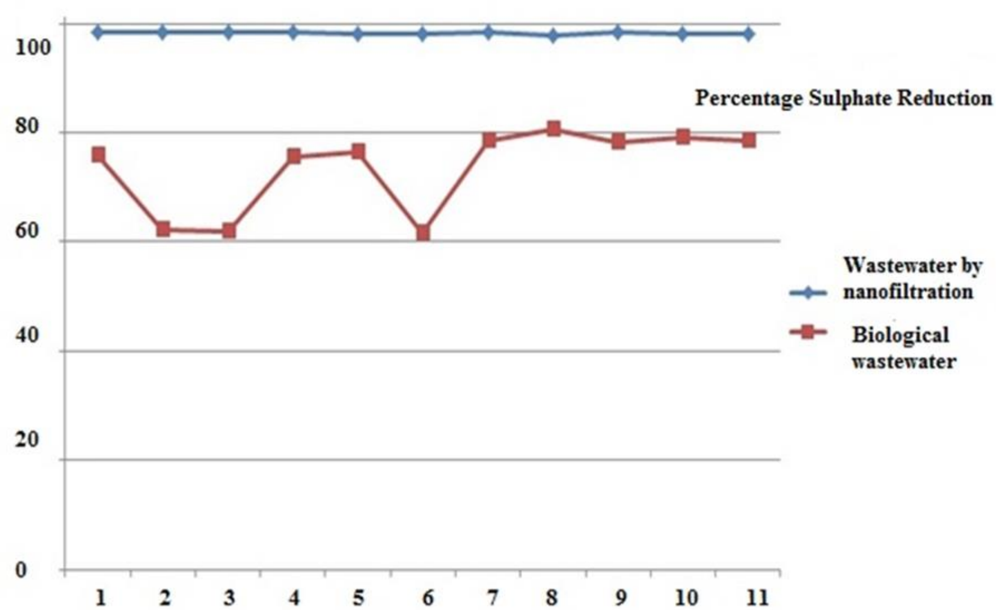

Figure 5: Comparison of sulfate reduction percentage of wastewater samples.

It should be noted that this is not due to complete inefficiency of the biological system and the removal of sulfate and as seen, nanofilter has more efficiency to remove this parameter compared to the biological system. In SPSS software, T-test was significantly less than 0.05 for comparison of the results between two methods and the results show that there is a significant difference in the results obtained from two methods for reducing sulfate in wastewater. According to the average of 20 for the nanofiltration system and 307.64 for the biological system, a significant difference was confirmed in the nanofiltration system.

4. Conclusions and Recommendations

The massive growth in the population, significant decrease in water resources, climate change and continuous droughts increase the importance of using non-conventional water resources. Among these non-conventional water resources, wastewater treatment and reuse of wastewaters are so important that has come to the fore during recent years. Today, finding a more suitable method with higher efficiency and lower costs is one of the current concerns of mankind to reuse the wastewater.

Therefore, different methods for treatment of wastewater are annually tested and analyzed, and perhaps any country that can achieve greater success in this field will attract more attention in the world. According to the results of this study, it can be concluded that the nanofiltration method has a high efficiency for removing and reducing sulfate and the pilot-scale wastewater effluent by nanofiltration has been at a level that is acceptable for all use in terms of the amount of sulfate.

Not only did the nanofilter system compete with the biological system well, it showed better efficiency in all experiments. The removal percentage was higher than the biological system which should be due to the very small diameter of the nanofilter and being antibacterial. This suggests that a nanofilter system can be a good alternative for the biological system in reducing and removing sulfate. The uniformity of output values in the nanofiltration method makes it possible to trust this method as a reliable method for wastewater treatment. This can be understood from table 1 and figure. The advantages of nanofiltration include the lack of need for time *durability*, rapid treatment, high efficiency for sulfate removal, low dependence on the amount of sulfate in raw wastewater and other items. Also, the disadvantages of using a nanofilter method consist the need for high energy to *pass wastewater* from the main filter and high initial cost compared to the *output volume of wastewater*.

In general, it can be concluded that *pilot-scale nanofiltration* used is better in terms of efficiency in removing and reducing the sulfate from the conventional biological system. Although this research has obtained good results and demonstrated the high efficiency of nanofiltration in reducing sulfate, in order to further carry on this research theme, suggestions are given that nanoscience and wastewater treatment enthusiasts can investigate in these areas such as a review of the efficiency of the nanofilter to reduce and remove other *polluting* parameters of water, especially BOD5 that biological systems have usually a high efficiency in reducing it and is considered as a very important parameter ; comparison of nanofilters with other wastewater treatment methods to determine superiority or lack of superior of this method compared to other methods; the treatment and experiments should be performed on other types of wastewaters including wastewater generated from other industries and even agricultural wastewater and efficiency of nanofiltration is investigated on different types of wastewaters; studying wastewater with *higher* and lower *pollution intensity* wastewater to provide a more appropriate and optimal range for using a nanofilter system; the use of combined methods is highly recommended; the economic analysis of the methods is an important subject to consider, and using other nanofilters and comparing them with the used filter will also have interesting results.

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