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RESEARCH ARTICLE

Methylene Blue Reduction by Using Multistage Filtration

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Abstract

Slow sand filtration (SSF) is established and workable equipment for drinking water handling in small societies. However, this technology is sensible to depressed water temperatures which can result in reduced biological treatment, and excessive water turbidity quantities which can result in early plugging of the filters and repeated cleanup necessities, leading to raised danger of-pathogen development. Multistage filtration (MSF), comprising of roughing filtration (RF) tracked by slow sand filtration, can cope these treatment restrictions and give a strong treatment option for surface water resources of changeable water characteristics in northern climates, that normally water temperatures ranging below 2^{o}C. The main objective of this study was to reveal the accuracy of MSF to remove methylene blue (MB) dye from water. In this research, testing was achieved by pilot multistage filtration system and fed with synthetic water polluted with MB dye. A system consisted from roughing filters filled with limestone media with different sizes and slow filter filled with glass media (SGF). The removal of MB of pilot plant was tested at hydraulic loading rates (0.5 and 1) m/h and initial concentration of (10 and 30) mg/L. The percentage reduction of MB dye reduced with increasing the influent MB dye concentration and increasing filtration rate. Limestone roughing filter (LRF) and slow glass filter gave good MB removal with average removal efficiency of 99.20% and 99.85% at least influent MB concentration of 10 mg/L and least velocity of 0.5 m/hr.

Keywords: *Slow sand filtration, Multistage-filtration (MSF), Roughing-filtration, Methylene Blue, Glass, Limestone.*

Introduction

The treatment of raw water to potable quality is a worldwide problem. Traditional water handling including many methods (coagulation, rapid mixing, flocculation, sedimentation, slow or rapid sand filtration, disinfection) and need to large amounts of chemical such as chlorine, flocculants, hydrogen peroxide, lime, ozone, therefore these processes include high capital and operating costs, complex operation and maintenance and the need for specialist expert supervision [1].

These setbacks have rendered conventional processes inappropriate in most developing countries, especially for small water supply systems [2, 3]. In most developing countries, equipment, spare parts, and chemicals have to be imported and small water supply systems are usually unable to attract skilled manpower and adequate funding. So the need to simple, inexpensive and efficient technology is required to improve the water source for people are living in developing regions [4, 5, 6, 7].Slow sand filtration is the only robust option that can meet those requirements because it is an effective, cheap, and easy to operate without chemicals usage [8, 9]. Slow sand filters because of their simplicity, efficiency and economy are appropriate means of water treatment, particularly for community water supply in developing countries [2, 10].

SSF is recognized as a well-established water treatment technology capable of removing viruses, cysts, turbidity and bacteria and reducing levels of BOM found in natural waters [11, 12, 7].However the technology associated with slow sand filtration is relatively simple, requiring no chemicals or sophisticated instrumentation. SSF has two important limitations. Firstly, is sensitive to high turbidity and color in the natural water where high turbidity values can result in premature blockage, reduced filter run length, and possible pathogen development by disrupting the biological balance of the filter media [13]. It was recommended that slow sand filters can be used to treat waters that have turbidity less than 10 NTU and color less than 15 true color units (TCU) capacity, so SSF should not be used in tandem with poor-quality surface waters [14].

Secondly, the biological character of SSF handling needs a permanent flow of the water to provide a continuous feeding of oxygen and nutrients. Handling with SSF is negatively influenced by depressed temperature (<5^{o}C), little nutrient concentration or little levels of dissolved oxygen [15, 13, 16]. To overcome these troubles related with these restrictions, study was originated into the improvement of pretreatment systems to enhance water characteristics prior it deliver the SSF [13].

Riverbank filtration, riverbed filtration, modular sub-sand abstraction system, plain sedimentation, and roughing filtration are the appropriate pretreatment processes that used before SSF. Roughing filtration is the most suitable option among these because of effectiveness, simplicity, reliability, and adaptability [15, 17].

Multistage filtration is defined as a filtration process that uses pre-oxidation and roughing filtration ahead of standard filtration methods [18]. A roughing filter is a standard filtration column filled with coarse media (such as broken rocks cracked burnt bricks, gravel, plastic material, burnt charcoal and etc.) that provides robustness to the system by reducing turbidity, solids loading and alga, increasing filter run time, decreasing maintenance requirements and increasing hydraulic retention time [19, 20]. Roughing and slow sand filters are of equal technical level, and their operation is characterized by a high process stability which permits treating raw water of fluctuating quality and they make full use of natural purification, without any use of chemicals [21, 15].

Material and Method

The constructions of the RF& SF were completed with locally available PVC pipe as shown in figure 1. The pilot unit consists of up-flow roughing filter column with 4in (10.16 cm) diameter and length of 2m and down-flow slow filter with 6in (15.24 cm) diameter and also length of 2m. RF is filled with limestone gravel media at depth of (70, 50 and 30) cm with gradation size of (9.51 - 12.7), (4.74 - 9.5) and (2 - 4.74) mm respectively, while the slow filter filled with glass media with effective size of 0.21 mm at depth of 80 cm. In roughing filter (RF), the water flowed upward throughout a series of media layers with different sizes. After the RF, water came in the upper of slow glass filter (SGF) and run downward throughout an 80 cm depth of glass media bed.

The exit pipe of the slow glass filter lifted to an altitude of 5 cm over the media bed to avoid negative pressures in the media bed, which lead to the creation of air bubbles [22, 16]. At this altitude, the water was exposed to the air with air release piping to avoid siphon of the filter bed. This too stopped the water level from falling under the upper of the media bed and drying the biological skin in the state of a stoppage.

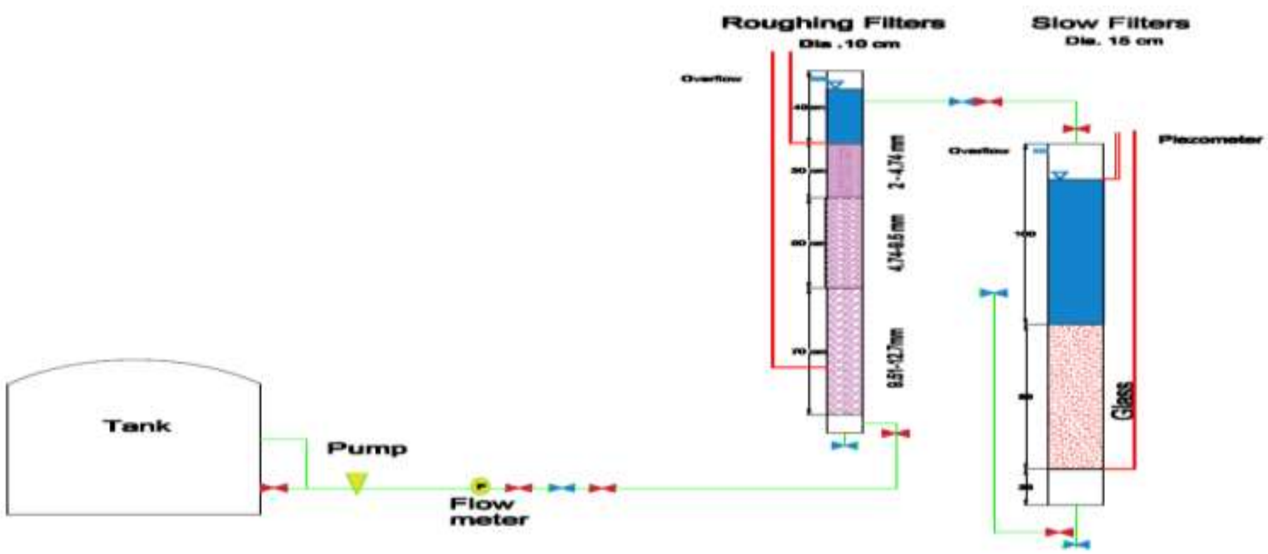

Figure 1: MSF Pilot Plant

Results and Discussions

Two filtration rates of (0.5 and 1) m/hr with two input MB dye concentrations of (10 and 30) mg/L were investigated in this study. At filtration rate of 0.5 m/hr and input MB concentration of 10 mg/L, it was noticed that average removal efficiencies of limestone roughing filter and slow glass filter were 99.20 and 99.85 respectively but when the input MB concentration increased to 30 mg/L the average removal efficiencies also decreased to 88.42 and 98.07 for LRF and SGF respectively. At filtration rate of 1 m/hr and input MB concentration of 10 mg/L, it was observed that average removal efficiencies of LRF and SGF were 93.09 and 98.7 respectively, but these removal efficiencies decreased to 63.37 and 94.49 respectively for LRF and SGF when the input MB concentration increased to 30 mg/L.

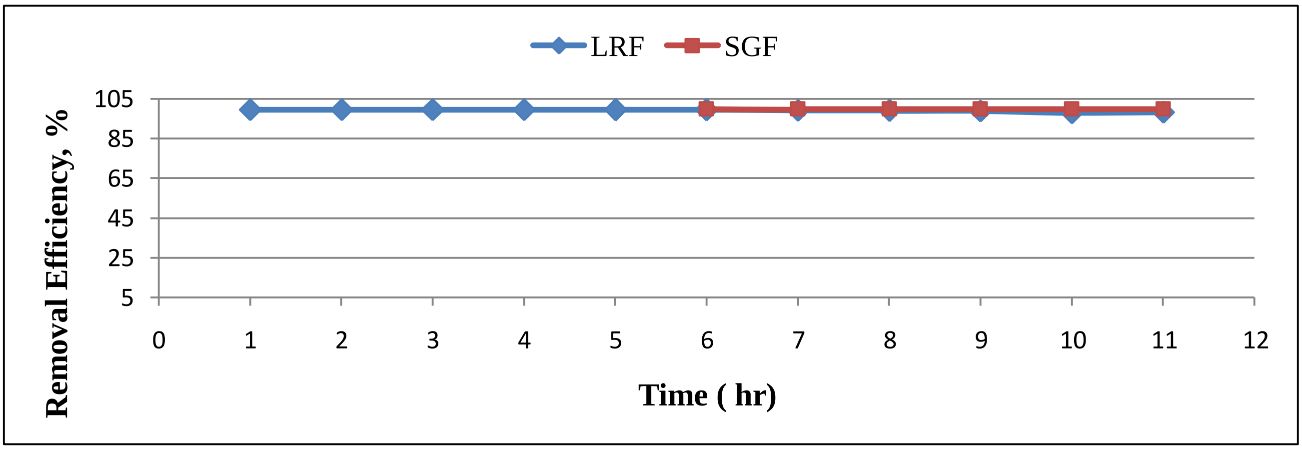

Figure 2: The Variant of the Reduction Efficacy of MB Dye with Time of Limestone Roughing Filter and Slow Glass Filter, Influent MB dye = 10 mg/L, Filtration Rate= 0.5 m/hr

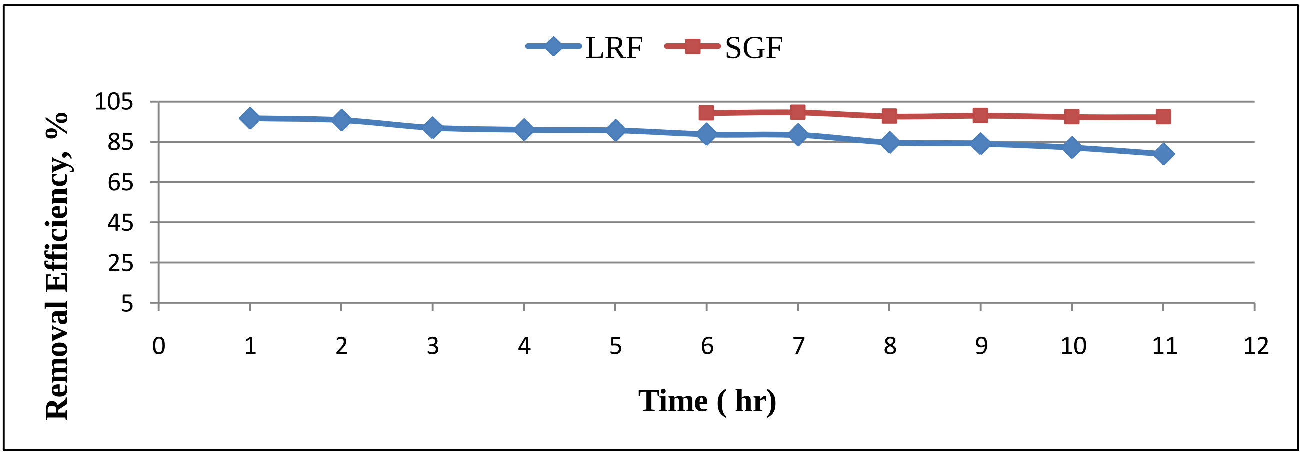

Figure 3: The Variation of the Removal Efficiency of MB Dye with Time for of Limestone Roughing Filter and Slow Glass Filter, Influent MB = 30 mg/L, Filtration Rate= 0.5 m/h

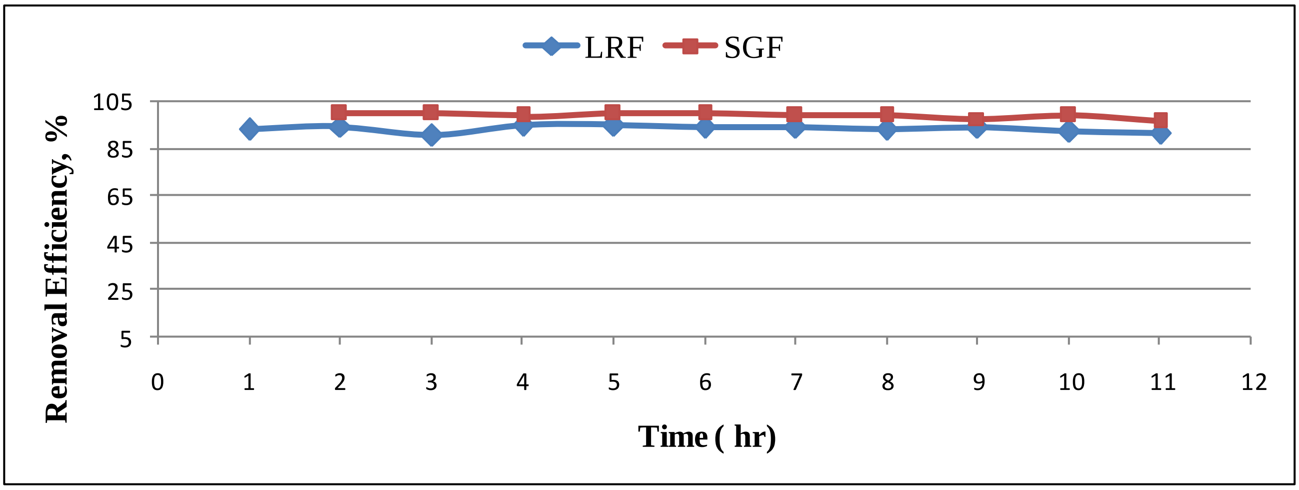

Figure 4: The Variation of the Removal Efficiency of MB Dye with Time for of Limestone Roughing Filter and Slow Glass Filter, Influent MB = 10 mg/L, Filtration Rate= 1 m/h.

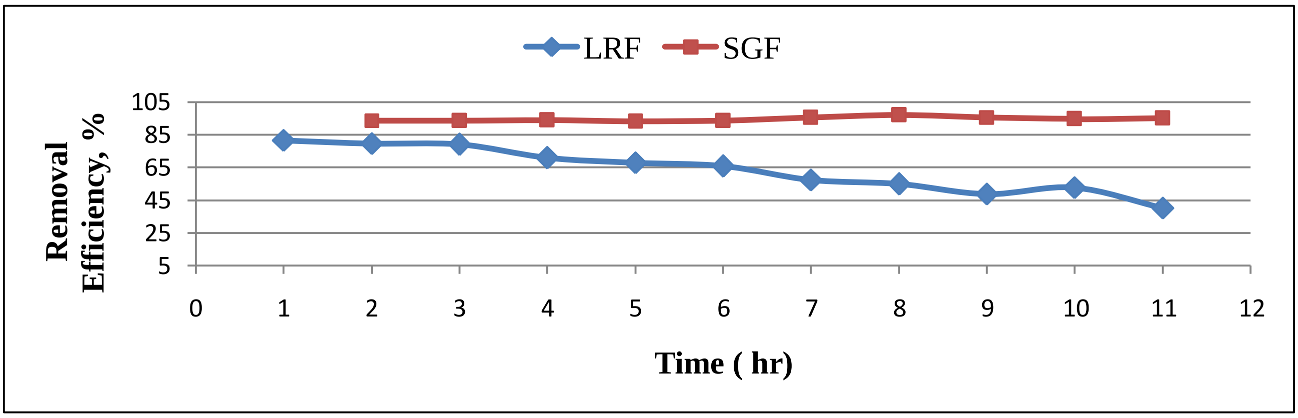

Figure 5: The Variation of the Removal Efficiency of MB Dye with Time for of Limestone Roughing Filter and Slow Glass Filter, Influent MB = 30 mg/L, Filtration Rate= 1 m/h

Conclusions

In the present study, it was noticed that the low filtration velocity of (0.5 m/h) generated lower average effluent and high reduction efficiency. Also, It can be noted that the reduction efficacy of roughing filters is significantly affected by filtration rate, where the removal efficiency decreased with increasing filtration rate. Whereas the slow glass is slightly affected by filtration rate. It was observed from figure (9) that the MB dye reduction efficacies for LRF and SGF have the best performance at a filtering rate of 0.5 m/hr than that at a filtering rate of 1 m/hr. The reduction efficacies of LRF and SGF were 99.2 % and 99.85 %, respectively, with filtering rate of 0.5 m/hr and inlet MB concentration of 10 mg/L, these reduction efficacies were reduced to a values of 93.09% and 98.7 % respectively, with filtering rate of 1 m/hr with the same inlet MB concentration.

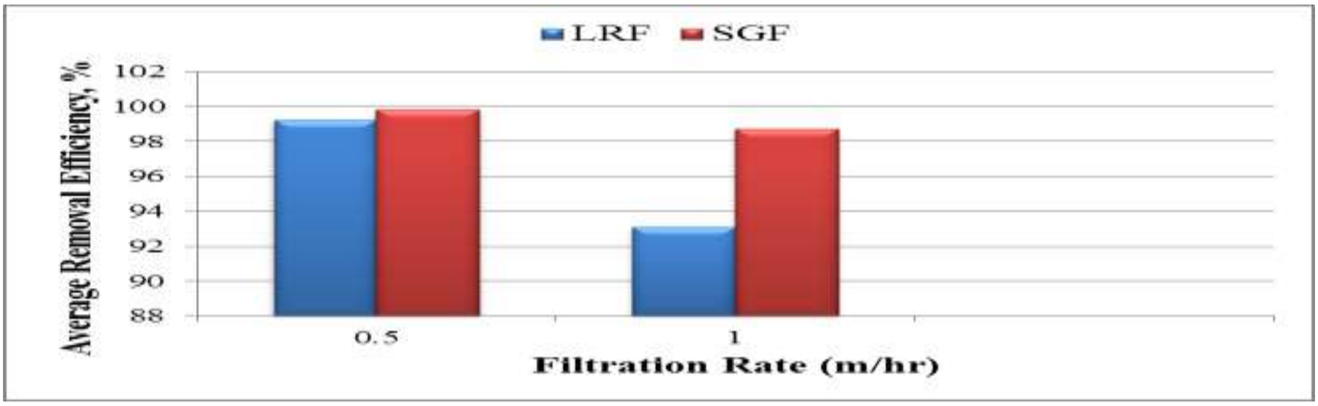

Figure 6: The Removal Efficiency of MB Dye vs. Filtration Rate for LRF and SGF at Influent MB Dye of = 10 mg/L

While figure (10) shows the effect of filtration rate on the performance of LRF and SGF at influent MB concentration of 30 mg/L where the average reduction efficacies of LRF and SGF at filtering rate of 0.5 m/hr were 88.42 % and 98.07 % respectively, these reduction efficacies were lessened to a values of 63.37% and 94.49 % respectively, with filtering rate of 1 m/hr with the same inlet MB concentration.

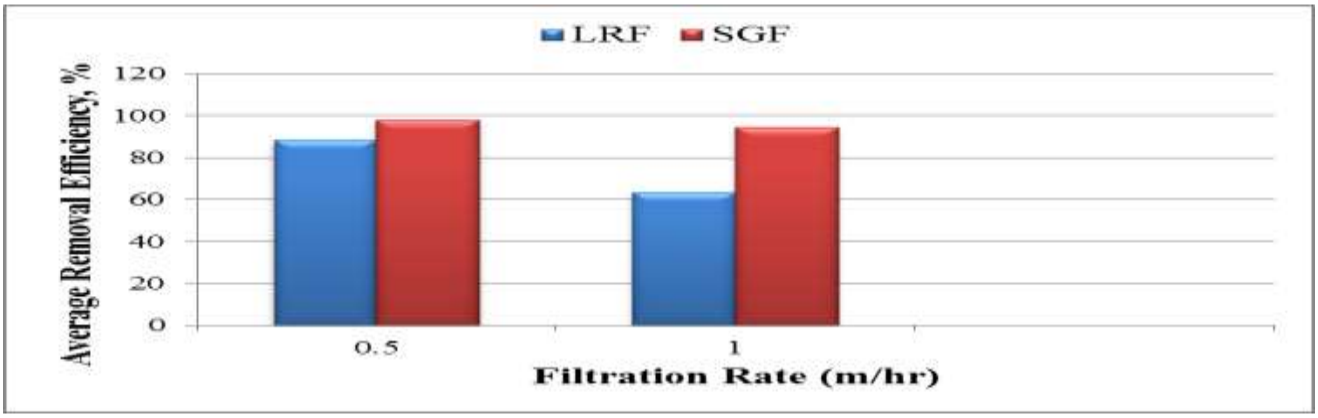

Figure 7: The Average Removal Efficiency of MB dye Vs. Filtration rate for LRF and SGF at Influent MB = 30 mg/L

It was observed that the average removal efficiency of MB dye reduced with the increasing of influent MB dye concentration for all filters because the binding sites became more quickly saturated in the column hence all MB molecules may interact with the media and be removed from the solution. Figure (7) shows that removal efficiency of LRF at influent MB dye concentration of 10 mg/L was higher than that of 30 mg/L. The removal efficiency of LRF at influent MB dye of 10 mg/L was 99.2%, but it reduced to 88.42% at influent MB dye of 30 mg/L with filtration rate of 0.5 m/hr.

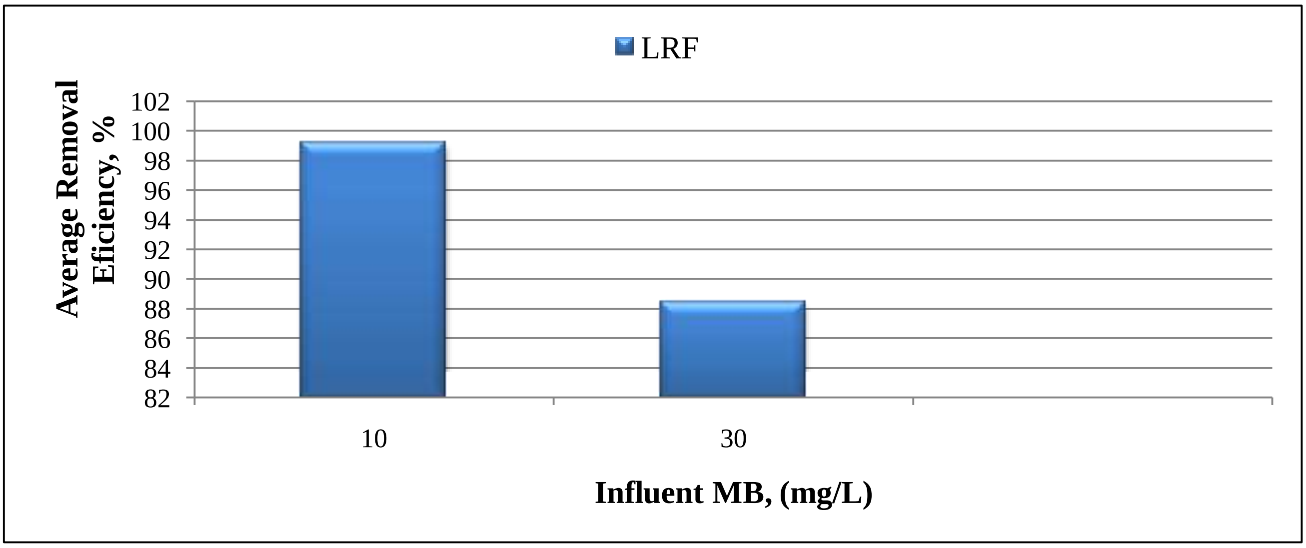

Figure 8: Effect of Influent MB dye on the Removal Efficiency for LRF with Rate of Filtering = 0.5 m/h

Figure (8) shows that removal efficiency of LRF at influent MB dye of 10 mg/L was higher than that of 30 mg/L with filtration rate of 1 m/hr. The removal efficiency of LRF at influent MB dye of 10 mg/L was 93.09% but it reduced to 63.37% at influent MB dye of 30 mg/L.

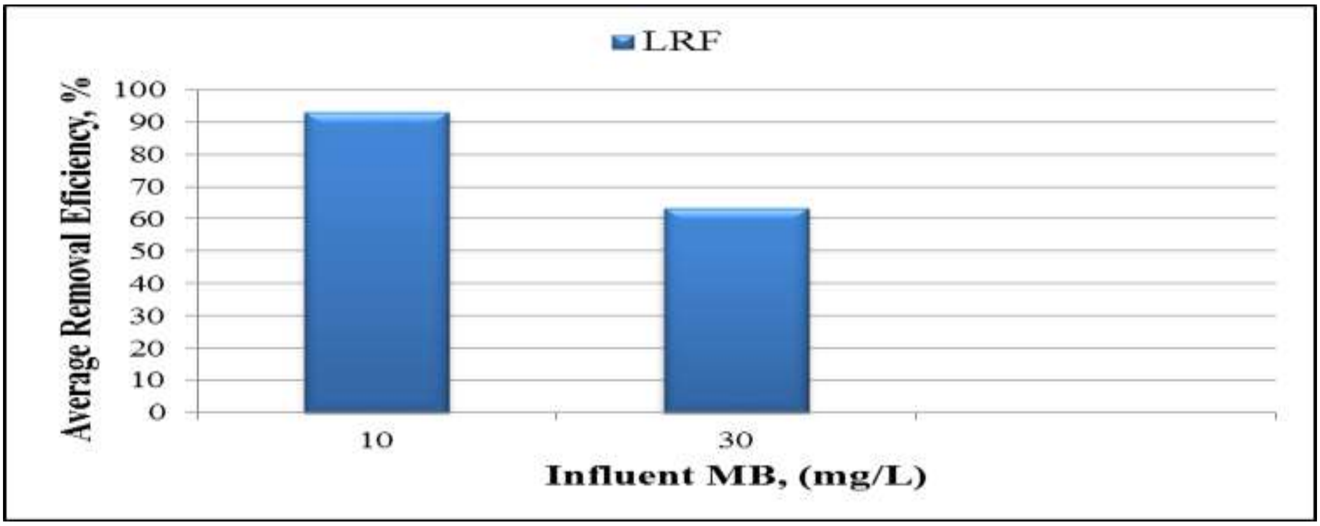

Figure 9: Effect of Influent MB Dye on the Removal Efficiency for LRF with Rate of Filtering = 1 m/h

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