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# Urban Waste Water Treatment with Classical Coagulation and Sand Filtration

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**ABSTRACT**
Pollution has significant impact on surrounding. Industrial and domestic wastewaters are the main sources of water pollutants that are responsible for various diseases. A number of methods are available in literature but expensive, due to that not feasible. The aim of this research work is to treat the grey wastewater with economical coagulant and filtration treatment methods. The coagulation process carries out with Jar test apparatus and filtration with normal filter. The results shows that alum reduced pH 6.5, turbidity 1.42 mg/L, biological oxygen demand 85mg/L and chemical oxygen demand 215 mg/L as well ferric chloride reduced pH 8, turbidity 0.771 mg/L, biological oxygen demand 60mg/l and chemical oxygen demand 130mg/L was achieved. At last both treatment are convenient to operate and economical to the pollutant level from urban area. Treated water can be recycling for agricultural and gardening purpose. It protects from unwanted discharge to controlled files and misquotes breeding.



**Conflict of interest**: The authors declare that they have no conflicts of interest.

## Introduction

Water is vital needs of human being. Water is a clear thin liquid that has no color or taste when it is pure. It is a neutral substance, an effective solvent for many compounds. It's used as a standard for many physical properties and chemical formula of $H_2O$[1]. It covers two-third portion of Earth and essential for life[2]**.** Water scarcity is one of the most significant challenges to human health and environmental integrity in most parts of the world[3]. As the world's population grows and prosperity spreads, water demands increase and multiply without the possibility for an increase in supply[2]. When foreign material mixed and alters the quality of fresh water, that water is known to be Wastewater. In other words wastewater refers to all effluent from household, commercial establishments and institutions, hospitals, industries and so on[4]. It also includes storm water and urban runoff, agricultural, horticultural and aquaculture effluent. It contains various types of impurities that cannot be directly used for different purpose[5]**.**

The sources of wastewater, mainly classified in four categories domestic, industries, agriculture and power plants. Including this it also categories in terms of quality like domestic sewage and non-sewage[6]. Domestic sewage, this includes all wastewater generated by home dwellings, public restrooms, hotels, restaurants, motels, resorts, schools, places of worship, sports stadiums, hospitals and other health centers, apartments and the like. They all produce high volumes of wastewater[7]. Non-sewage these include water from floods (storm-water), runoff (rainwater running through cracks in the ground and into gutters), water from swimming pools, water from car garages and cleaning centers. They also include laundromats, beauty salons, commercial kitchens, energy generation plants and so on[8].

In most of urban area there is water scarcity because of high population growth and the water supply demand is insufficient[9]. Most of the quantity of water distributes to the society is convert to gray waste water comes from kitchen, bath and launders. The wastewater is disposed to open fields without any reuse because of there is no treatment plant or cell in town area[10]. The domestic waste water contains such characteristics of compensation with color, BOD, COD and several pollutants. If being directly discharged without treatment, it will bring serious problem to the ecological environment such as deficiency of dissolved oxygen, toxic effect, and biodiversity loss[11]. This study will use to assess the chemical, physical and biological characteristics of the waste water. The information is important to the society who wants to start the practice of waste water reuse by the application of coagulation and sand filter[12-14].

The main objective of the treatment process is to remove the impurities of wastewater and bring the quality of water to the required standard. The study focused on determines the physico-chemical characteristics of grey wastewater, treatment of wastewater with chemical coagulant (ferric chloride and alum), determine the settling and filtration rate of wastewater with best coagulant. To enhance safe and economical way of waste water treatment and then to reuse for agriculture, construction and fire fighting.

## Method

**2.1.1. Raw wastewater**: The sewage wastewater collected from local area of city. Initial concentration of raw grey water is mention on Table 1.

Table 1. Physicochemical Characteristic of grey water

| S.No | Characteristics | Unit | Range |
|---|---|---|---|
| 1 | pH | - | 8 |
| 2 | Total dissolved solid | mg/L | 1600 |
| 3 | Turbidity | mg/L | 711 |
| 4 | Color | mg/L/pt | 350 |
| 5 | Electrical Conductivity | Micro-simens | 2200 |
| 6 | Biological oxygen demand | mg/L | 200 |
| 7 | Chemical oxygen demand | mg/L | 650 |

**2.1.2: Chemicals**: All the lab grade chemical has been used for experiment, that is mention in Table 2

Table 2. Chemical used in grey water treatment

| S.No | Chemical | Molecular Formula | Remark |
|---|---|---|---|
| 1 | Alum | $Al_2(SO_4)32H_2O$ | As coagulant |
| 2 | Ferric Chloride | $FeCl_3$ | As coagulant |
| 3 | Sodium Hydroxide | NaOH | Reagent |
| 4 | Hydro chloric acid | HCl | Reagent |

**2.2: Methods:** The method used to conduct the study was laboratory scale determination of removal efficiency of domestic waste water using coagulant ferric chloride and alum at different dosage and pH value.

**2.2.1. Coagulation:** Coagulation method is carried out in Jar test apparatus 400ml of sewage wastewater was taken in a 500 mL glass beaker. The pH of the effluent was noted and the initial pH was adjusted by adding aqueous NaOH (1 M) or HCl (1 M) solution. A known amount of the coagulant was added to the effluent and flash-mixed for 5 min by a magnetic stirrer and, thereafter, slowly mixed for 30 min. The effluent sample was then taken in a glass cylinder and kept quiescent for 6 h[15]. The supernatant liquor was centrifuged and analysed for its total dissolved solid (TDS), Turbidity, Electrical Conductivity (EC) and color. These steps were repeated at different dosages of the coagulant. The experimental jar test apparatus is shown in Fig.1.

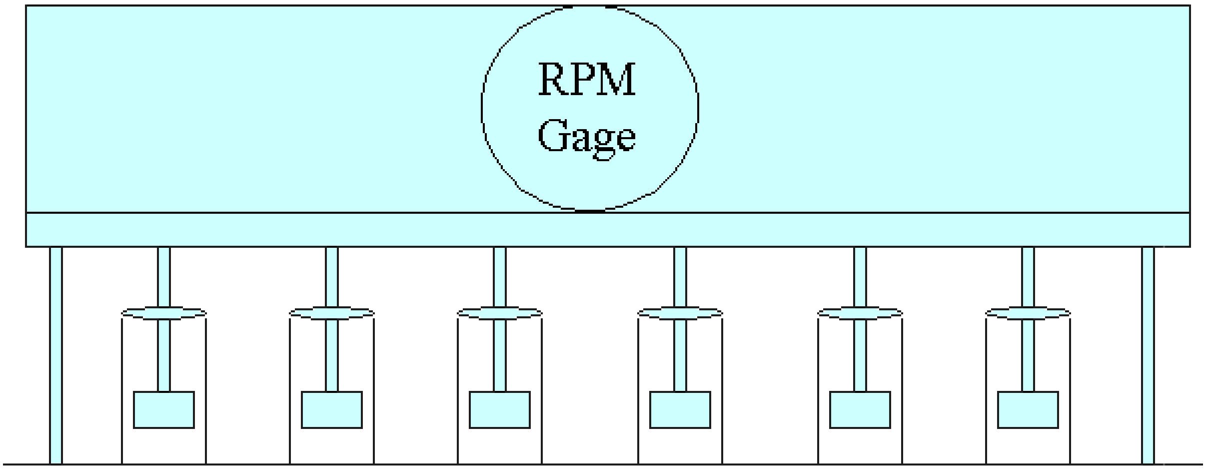



Fig 1. Jar Test Apparatus

**2.2.2: Settling**: The sample that we treated by using coagulation is carried out for settling in order to give it further treatment. Settling study was carried out with 500 mL measuring cylinder and stop watch. The solid and liquid interface was noted with respect to different time. In this phase the flocs are allowed to settle by gravity. The clarified water that remains on the top represents the effluent and the bottom depth represents sludge[16]. The experimental setup for settling is shown Fig.2.

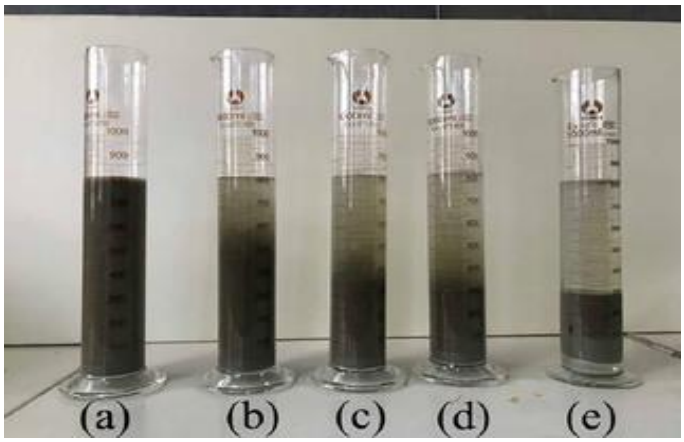



Fig 2. Settling process of grey water

**2.2.3: Filtration**: after the sample was settled, we collect the supernatant for additional treatment or filtration In order to remove the reaming impurities or wastewater characteristics found in the swage. Filtration was carried out with different size of sand (2.5, 1.5 and 0.5 mm) in measuring cylinder[17]. The filtrate volume was collected with respect to different time. The filtrates were further analysis for turbidity and TDS. The treated sample or effluent of sand filter is taken for measurement of BOD, COD and DO. The filtration study of grey water is shown in Fig.3.

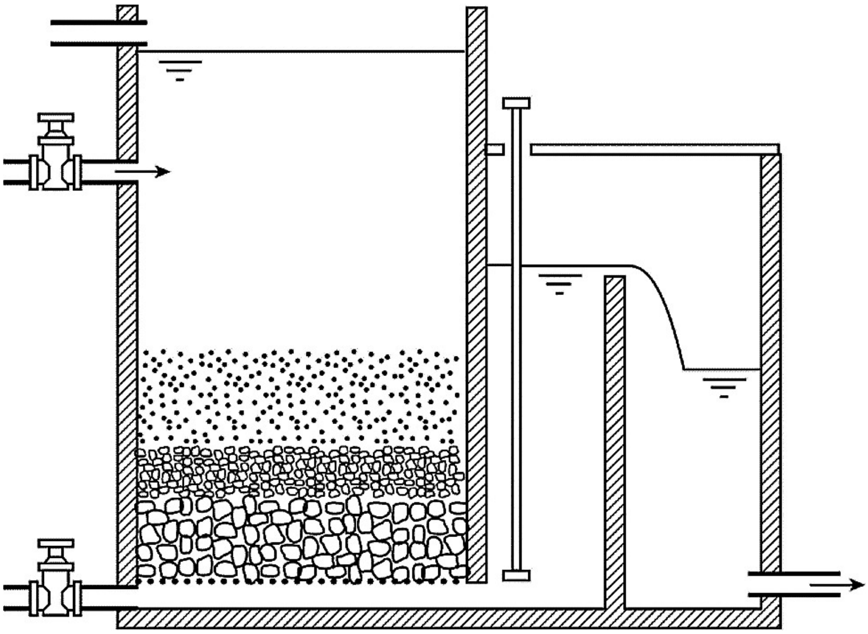


Fig 3. Sand filtration method

**2.3: Analytical method**: The sample collected were analyzed for color, pH, Total Solids (TS), Total Dissolved Solids (TDS), color, dissolved oxygen (DO), BOD and COD the techniques and methods followed for collection, preservation, analysis and interpretation. All the physicochemical characteristics (TDS, Turbidity, color and EC) are determine with photometer. The pH was measure with pH meter[18,19].

$$Percentage\ removal\ of\ pollutant\ = \frac{(Ci - Cf) \times 100}{Ci}$$

Ci = Initial concentration
Cf = Finial concentration

## Results and Discussion

**3.1. Coagulation process:** The coagulation process was carried at initial grey water concentration by using alum and ferric chloride.

**3.1.1. Optimization of pH:** The optimization of pH for sewage wastewater was carried out by initial concentration of TDS 1600 mg/L; turbidity 711 NTU; EC 2200 micro semen's and color 350 mg/lPt 5 gm/L coagulant dose and different pH 6, 7 and 8 respectively.

The optimization of pH was carried out with different pH 6, 7 and 8 for both alum and ferric chloride at fixed mass loading 5 mg/L. The result represent in Fig. 4 for alum. It has been observed that maximum 73.5% TDS, 47% color, 99.3% turbidity and 99.6% EC at pH 6. Further increase in pH 7 and pH 8 the removal efficiency was decreased. Similarly for ferric chloride optimization of pH is shown in Fig.5. From Fig.5 it can be clearly seen that maximum 37.56% TDS, 72.83% color, 99.3% turbidity and 99.01% EC was found at pH 8. At lower pH 7 and pH 6 removal efficiency was decreased. The lower removal efficiency at pH 6 and pH 7 for ferric chloride may be due to the metal ions hydrate and hydrolyze to form monomeric and polymeric species[20].

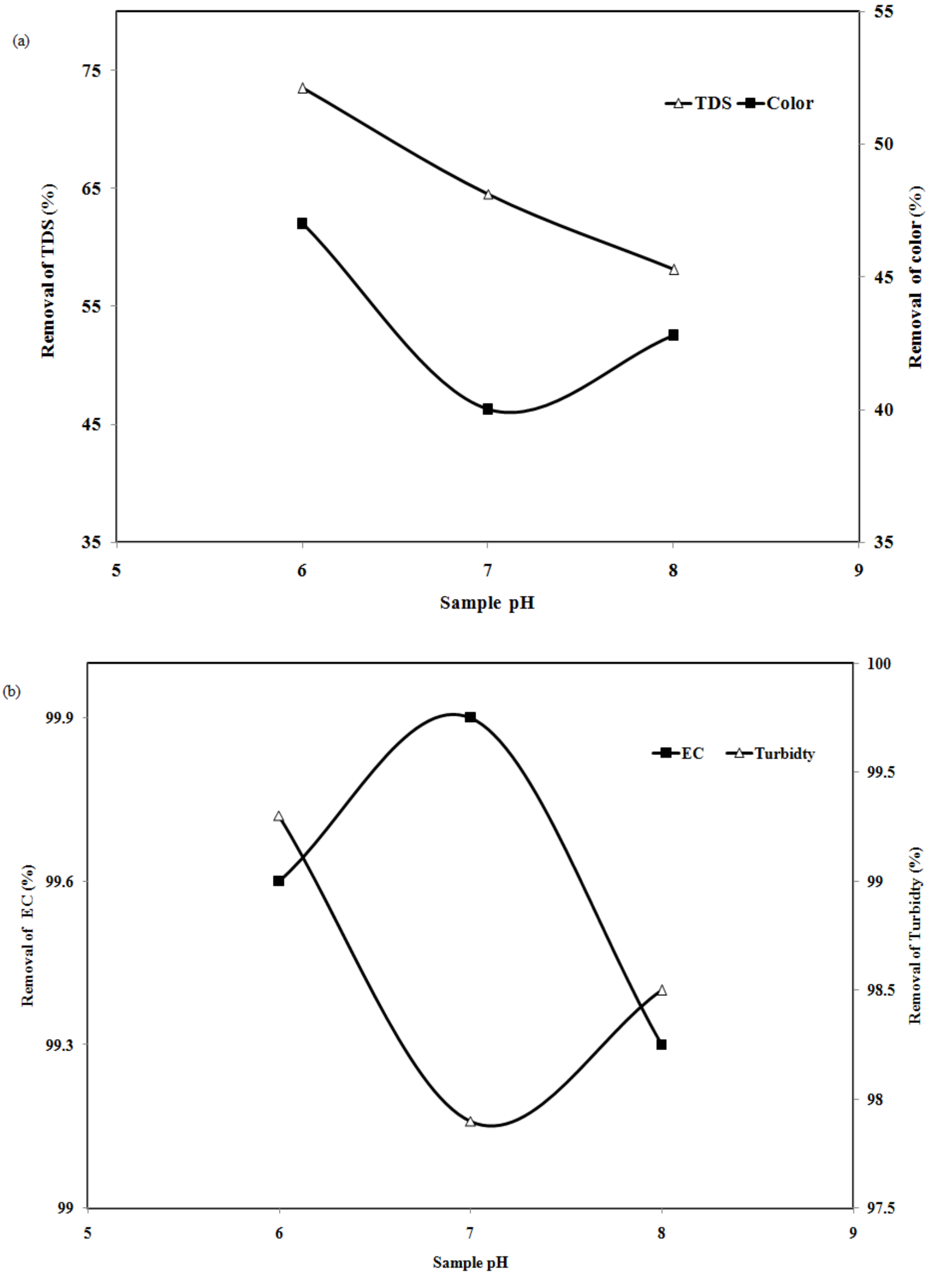



Fig 4. Optimization of pH with alum (a) TDS and Color and (b) EC and Turbidity

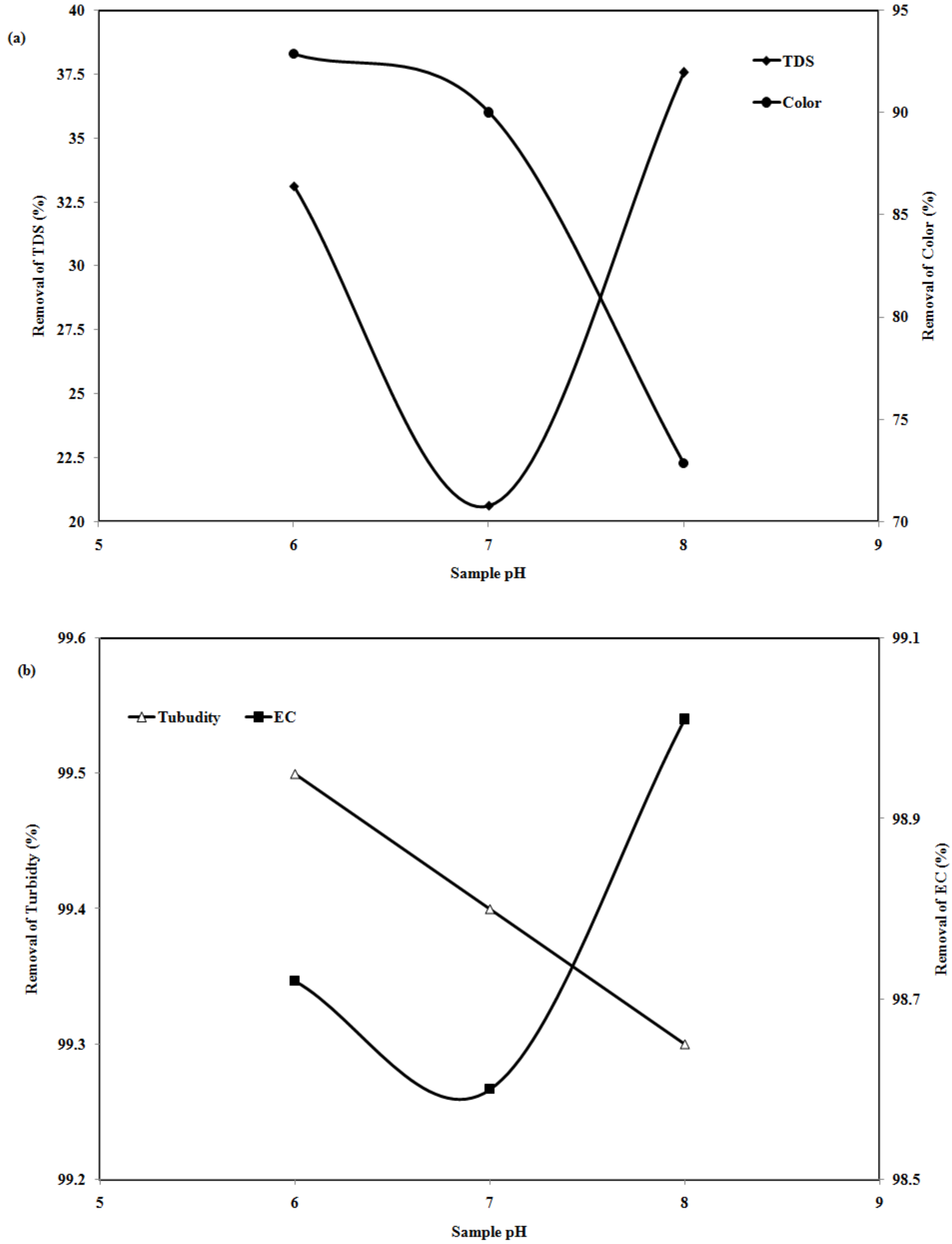



Fig 5. Optimization of pH with ferric chloride (a) TDS and color and (b) EC and Turbidity

**4.1.2. Optimization of dose:** The optimization of dose was carried at different mass of alum and ferric chloride (2.5, 7.5 and 10 g/L) at optimum pH 6 (alum) and pH 8 (ferric chloride) respectively. The result represent in Fig.6 for alum. Coagulant dosage is one of the most important factors in determining coagulation performance. With the best coagulation performance, the coagulation at the optimal coagulant dosage reduces the amount of coagulant used in wastewater treatment[21]. From Fig.6, it was found that maximum 73.5% TDS, 71.42 color, 99.3% turbidity and 99.6% EC for alum at 5 g/L mass loading. Similarly for ferric chloride, shown in Fig.7, maximum reduction 65.8% TDS, 85.7% color, 99.6% turbidity and 99.9% EC at 2.5 g/L was respectively. So in this research work optimum dose for alum is 5 g/L and for ferric chloride 2.5 g/L is sufficient to neutralize the impurities[22].

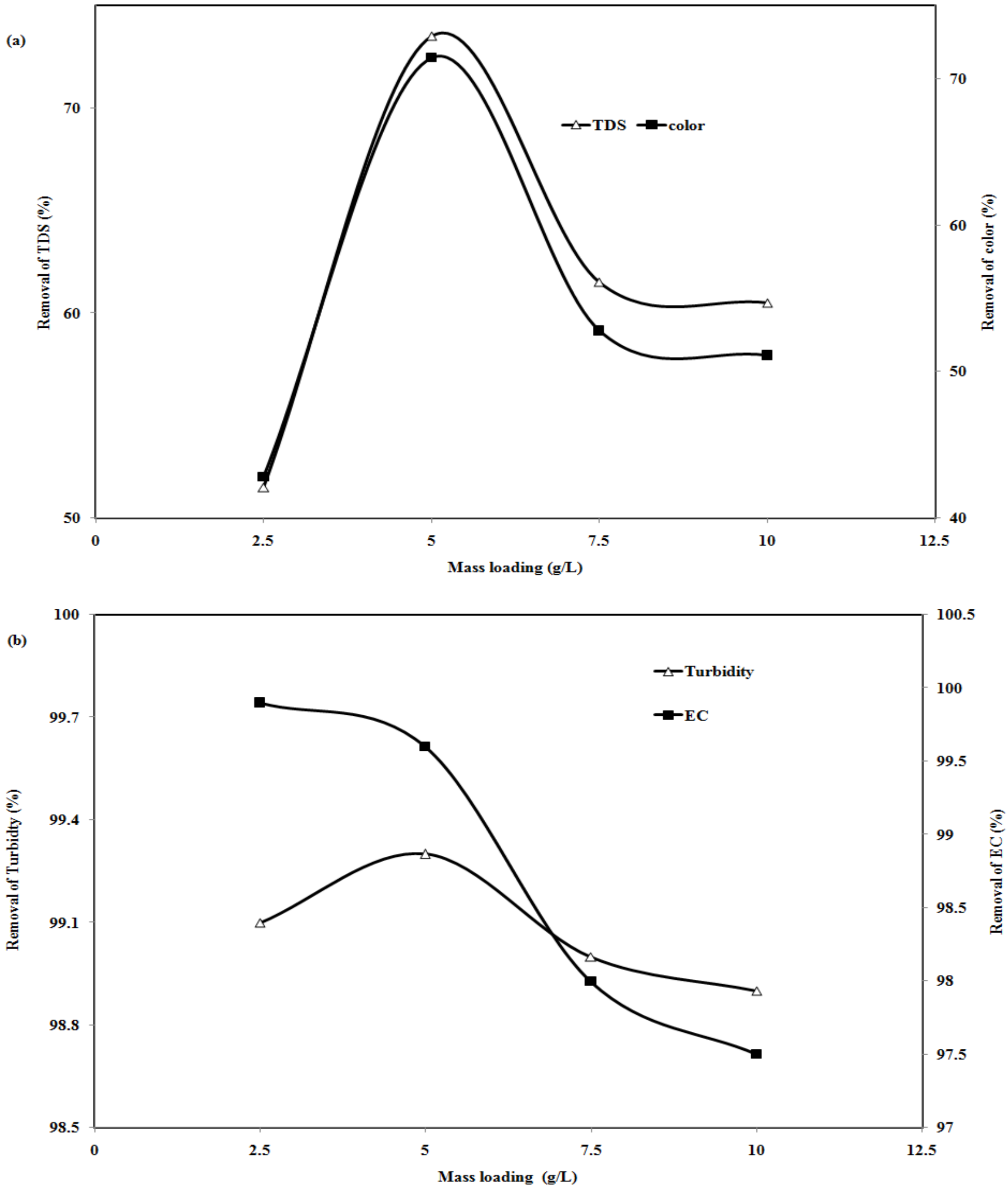



Fig 6. Optimization of dosing with alum (a) TDS and Color and (b) EC and Turbidity

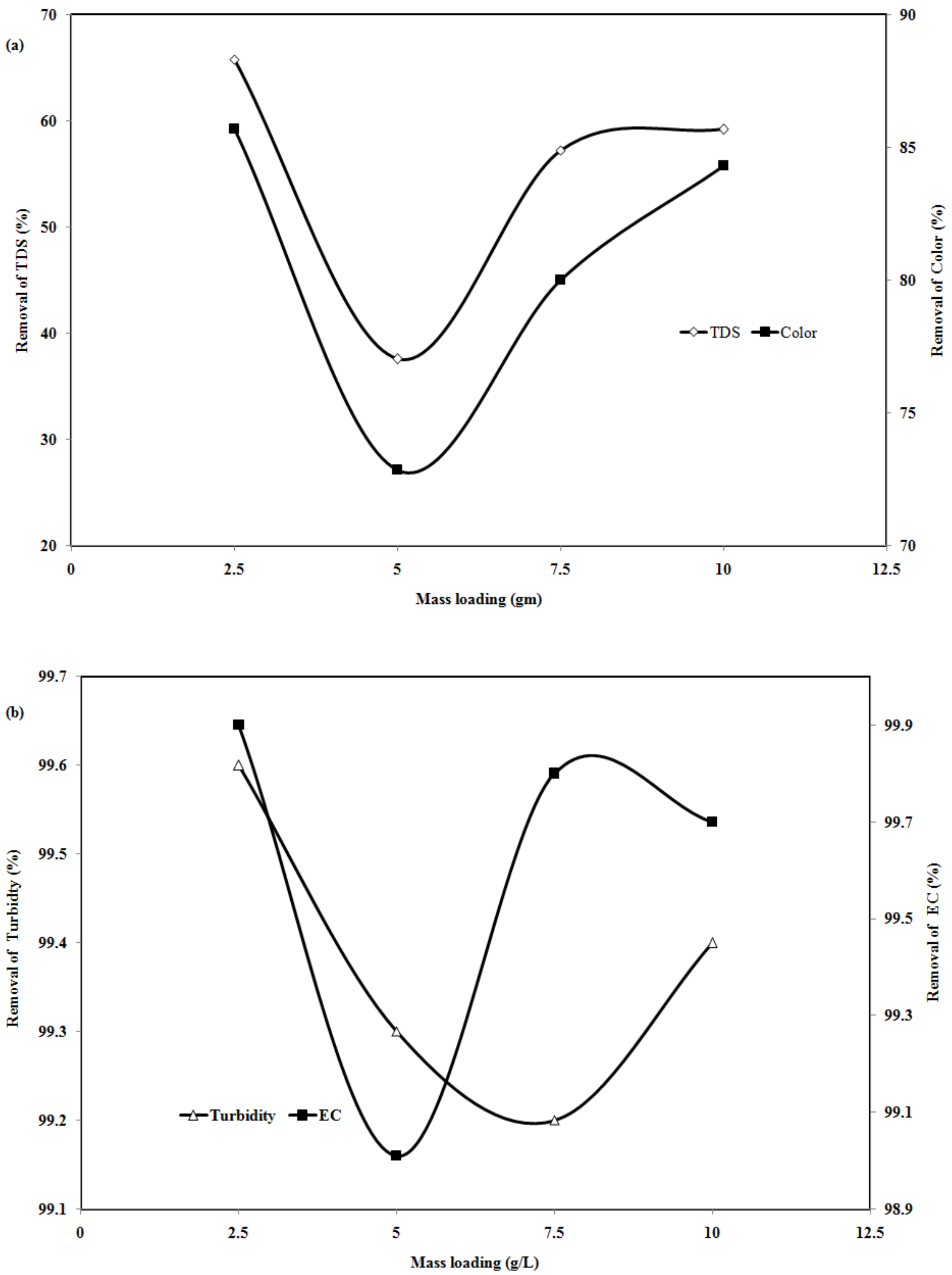
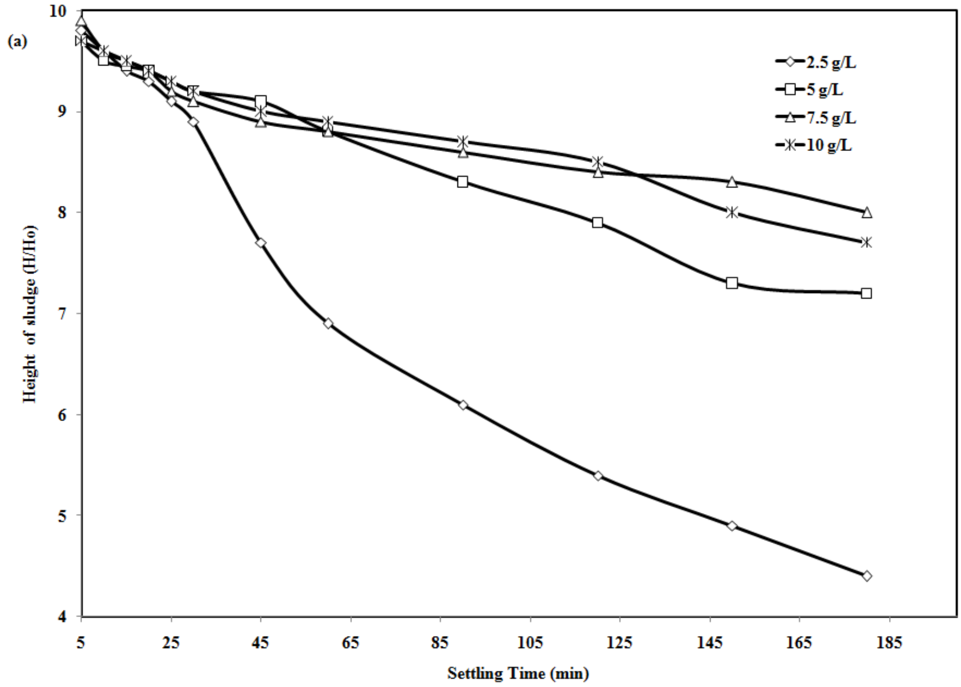



Fig 7. Optimization of dosing with ferric chloride (a) TDS and Color and (b) EC and Turbidity

**4.2. Settling:** Settling process is one of the convenient methods to separate the suspended present in the wastewater. The settling study were carried out for both chemical coagulatant (alum and ferric chloride) at different mass loading (2.5, 5, 7.5 and 10 g/L) and optimum pH ( pH 6 for alum and pH 8 for ferric chloride) for 180 mins of retention time. The separation of solid and liquid for alum is shown in Fig. 8. From Fig. 8 (a) it can be seen that at the lower dose

2.5 g/L of alum at optimum pH show good settling in 180 min of detention time. Almost 66% of clear liquid and 44% of settle sludge were has been achieved. When dosing was increase beyond 2.5 g/L of alum, 5 g/L, 7.5 g/L and 10 g/L the performance were decreased. At 5g/L, 7.5 g/L and 10g/L the solid liquid ratio was 28:72, 20:80 and 23:77 respectively. In the same way the settling study were carried for ferric chloride, shown in Fig.8 (b). The result shows that at minimum dose 2.5 g/L and optimum pH 8 ferric chloride show 70:30 solid liquid separation as best performance. Further increase in mass loading 5 g/L, 7.5 g/L and 10 g/L of ferric chloride 60:40, 52:48 and 63:37 of solid and liquid ratio was observed. The settling behaviour of particles strongly depends on physico-chemical properties[23-25].



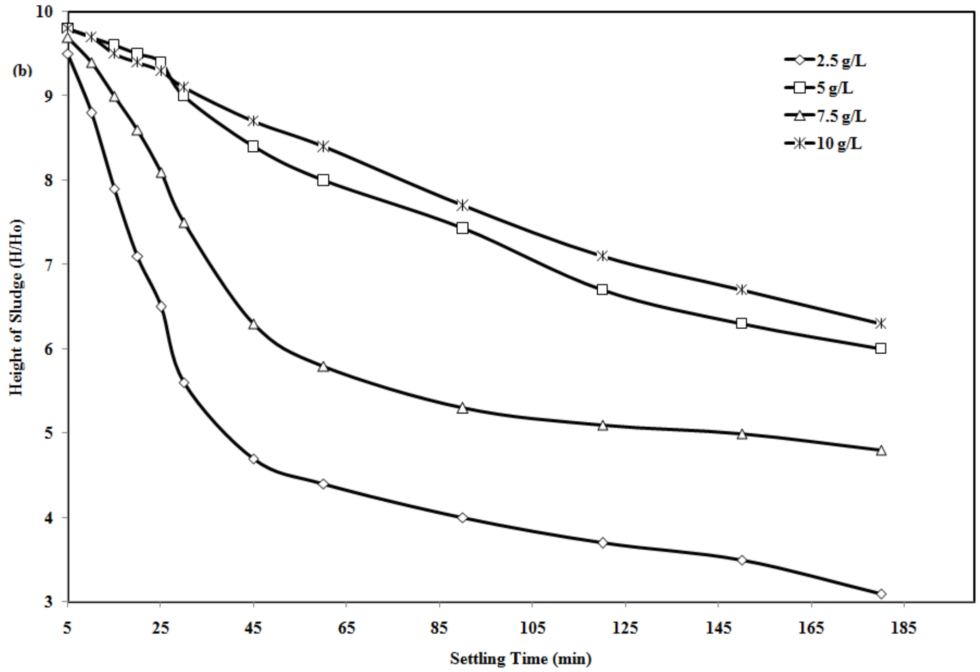




Fig 8. Settling of chemical coagulant (a) alum and (b) ferric chloride

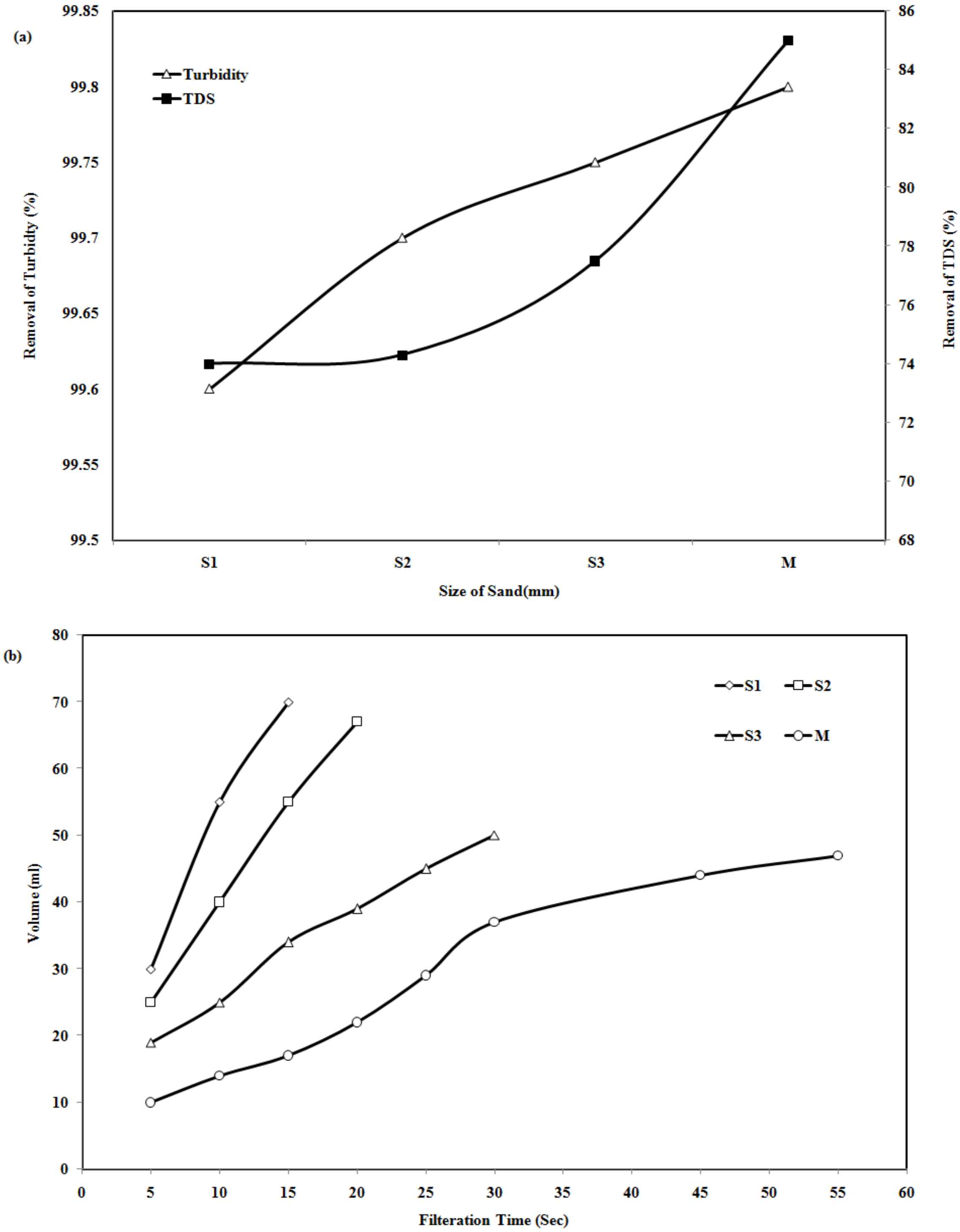



Fig 9. Filtration of alum treated grey water (a) turbidity and TDS removal and (b) filtration rate

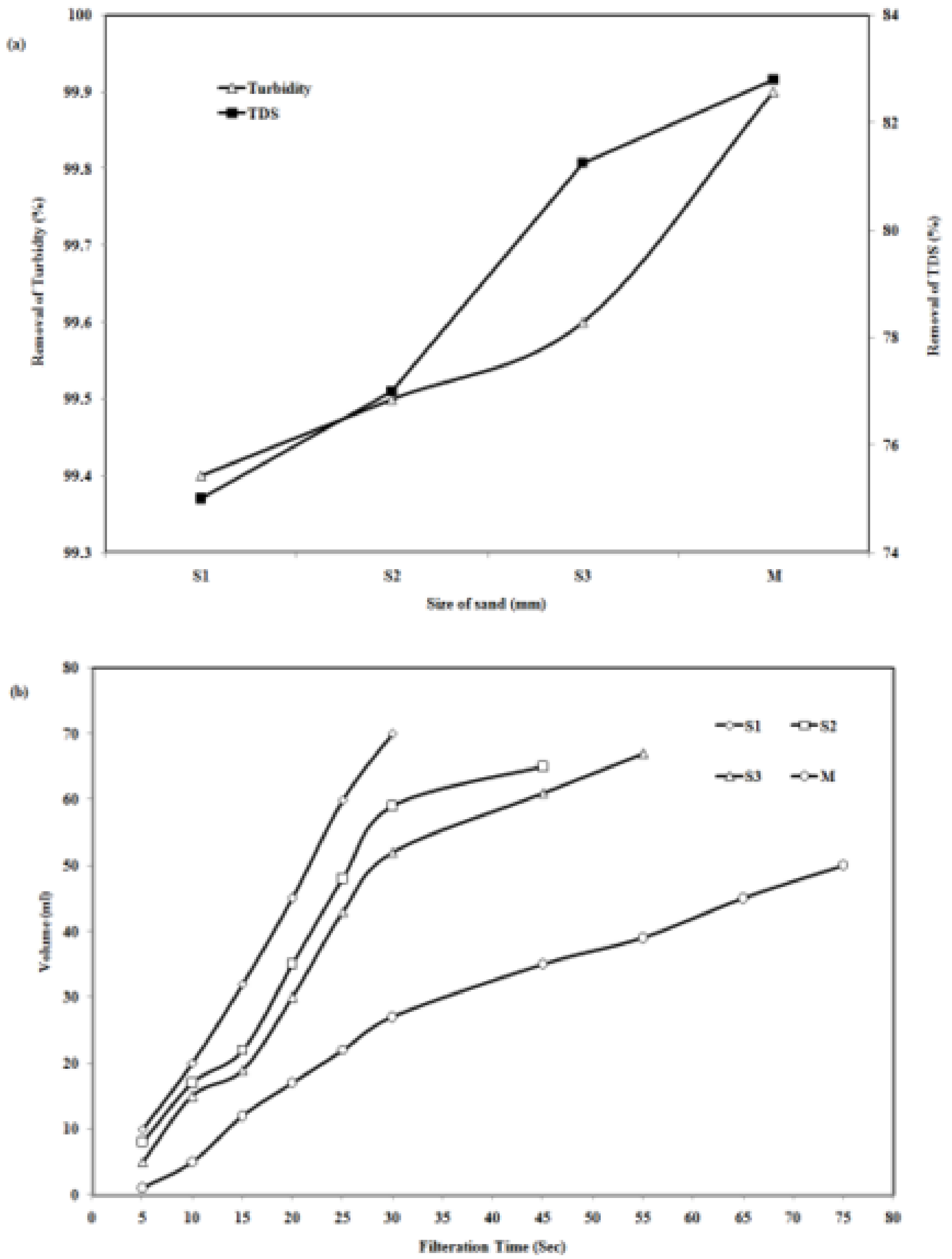



Fig 10. Filtration of ferric treated grey water (a) turbidity and TDS removal and (b) filtration rate

**3.3. Filtration study:** Filtration is used in both water treatment and wastewater treatment as a separation process, which removes fine inorganic and organic particles from the water[26]. Sand filters are often used in treatment of water to remove fine particles, which cannot be economically removed by sedimentation. Sand filtration is a form of granular medium filtration, in which the filtering medium consists of granular material such as sand, anthracite, activated carbon or other grains[27]. Gravity filtration study were carried out for both chemical coagulant treated grey water at different range of sand form 1.5 mm (S1), 1 mm (S2) and 0.5 mm (S3), including mixed of all this size (M) at 4cm bed depth. The removal efficiency of turbidity and total dissolved solid with respect to all sizes sand at optimum condition for alum treated wastewater is shown Fig.9 (a) and (b). The result indicates that maximum 99.8% turbidity and 85% TDS was achieved with mixed sand filtration, and it was decreases 99.75%, 99.7%, 99.6% turbidity and 77.5%, 74.3%, 74% TDS with increase in size of sand 0.5 mm, 1 m and 1.5 mm (S1<S2<S3). Filtration rate were also studied at 75 ml/min of flow rate, which shown in Fig. 4.6(b). From the plot it can be observed that 70 ml were collected in 15 second of filtration for sand (S1). With increase in size S2 and S3, the filtration rate was decrease 67 m/20sec and 50 ml/30sec. For mixed sand study the bed depth was maintained with 1.5 cm (S1), 1.5 (S2) and 2 cm (S3). The result shows minimum 47ml volume of filtration in 65 second. Similar experiment was also carried out for ferric chloride treated grey water, which shown in Fig.10 (a) and (b). The result show highest 99.9% turbidity and 82.8% TDS removal with mixed sand filtration. The removal efficiency were decrease (99.6%, 99.5%, 99.4% turbidity and 81.25%, 77%, 75% TDS) with increases in sand size (0.5 mm, 1 mm and 1.5 mm). Additionally only 50 ml of filtrate volume were collected in 75 second for mixed sand filtration. The filtrate volume increases 67 ml, 65 ml and 70 ml at 55 sec, 45 sec and 30 sec with increase in size 05 mm, 1 mm and 1.5 mm. The decrease in filtrate volume with respect to size may attributes to porosity of sand filter. Bigger size sand make large pore as compared to smaller size, due to that with small filtering time more volume was collected. This study was also confirmed that ferric chloride makes large floc as compared to alum. Due to large floc filter volume collected more for alum as compared to ferric chloride in short filtering time[28-30].

**3.4. Biological and Chemical Oxygen Demand Removal:** The organic and inorganic removal of treated grey water was also determined, which shown in Fig. 11. Biological oxygen demand is a measure of the quantity of oxygen used by microorganisms in the oxidation of organic matter. BOD of the untreated gray water was 200 mg/l. After treatment it reduced to 60 mg/l (70%) with ferric chloride and 85 mg/l (57.5%) for aluminum sulfate. Chemical oxygen demand values conveyed the amount of dissolved oxidize able organic matter including non-biodegradable matter present polluted water. The COD of untreated gray water was found to be 650 mg/l. After the treatment it reduced to 130 mg/L (80%) with ferric chloride and 215 mg/L (66.9%) with aluminium sulphate[31].

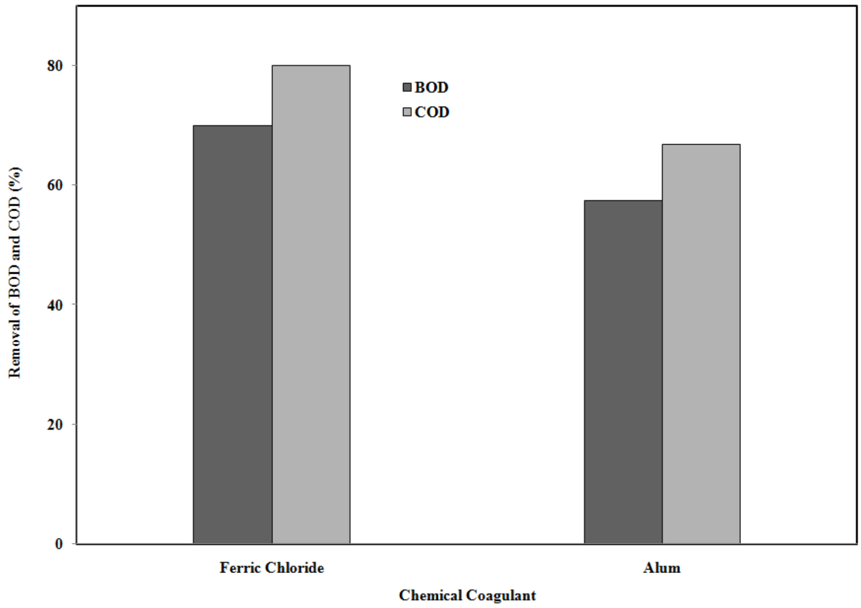



Fig 11. BOD and COD removal of grey water with chemical coagulant

**3.5: Comparatively study of treated water:** The initial grey water quality, limitations, treatment of alum and ferric chloride is mention in Table 3.

Based on the Table 3, it can see that all the physicochemical parameter of grey water are beyond the discharge limit fixed by Ethiopian Pollution Authority. After treatment with aluminium sulphate salt the physico chemical characteristic reduced to pH is 6, TDS 240 mg/L, turbidity 1.42 mg/LBOD 85 mg/L and COD 215 mg/L. Treatment with ferric chloride brings pH 8, TDS 275.2 mg/L, turbidity 0.711 mg/L, BOD 60 mg/L and COD 130 mg/L. All the parameters were under the limitation norm except TDS. As compared to alum salt, ferric chloride shows better removal efficiency[32].

Table 3. Physicochemical characteristic of untreated and treated grey water

| **S.No** | **Parameters** | **Grey water** | **Limitation** | **After treatment** | |
|---|---|---|---|---|---|
| | | | | **Alum** | **Ferric chloride** |
| 1 | pH | 8 | 6 - 8.5 | 6 | 8 |
| 2 | Color (mg/L-Pt) | 350 | Transparent | ND | ND |
| 3 | Total dissolved solid (mg/L) | 1600 | 100 mg/L | 240 | 275.2 |
| 4 | Turbidity (NTU) | 711 mg/L | 30 mg/L | 1.42 | 0.771 |
| 5 | Electrical conductivity (mg/L) | 2200 | 100 | ND | ND |
| 6 | Biological oxygen demand (mg/L) | 200 | 250 mg/l | 85 | 60 |
| 7 | Chemical oxygen demand (mg/L) | 650 | 250 mg/L | 215 | 130 |

## Conclusion

Treatment of grey water with coagulation and sand filtration have been shown good efficiency to remove the pollutants. It was found that maximum 73.5% TDS, 71.42 color, 99.3% turbidity and 99.6% EC for alum at 5g/L mass loading. Similarly for ferric chloride, maximum reduction 65.8% TDS, 85.7% color, 99.6% turbidity and 99.9% EC at 2.5g/L was respectively. The BOD level reduced to 60 mg/l (70%) with ferric chloride and 85mg/l (57.5%) for aluminium sulfate and and chemical oxygen demand values reduced to 130mg/L (80%) with ferric chloride and 215 mg/L (66.9%) with aluminium sulphate after treatment. The outcome of this research finding is to inform that wastewater from urban area can be recycle and used for different purpose. It protect unpleasant odor to surrounding area as well as ground water contamination.

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## Author contributions

All authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by [**Magi Mercy**], [**Astibha Brhane**] and [**Omprakash Sahu**]. The first draft of the manuscript was written by [**Omprakash Sahu**] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.