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# COMPARISON BETWEEN DIFFERENT TYPES OF CHEMICAL COAGULANTS USED IN WATER PURIFICATION

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**Abstract.** An experimental study was conducted to compare between different types of coagulants and select the most suitable type in Geziret Al-Dahab water treatment plant. Five types of coagulants were applied, the first one was ferrous sulfate $FeSO_4$ the second was ferric sulfate $Fe_2 (SO_4)_3$, the third was ammonium chloride, the fourth one was ferrous chloride $Fe Cl_2$ and the last one was aluminium sulfate (alum) $Al_2 (SO_4)_3$. It was found that, the highest removal efficiency of turbidity was achieved by using aluminuim sulfate (alum). The highest removal efficiency was 77.32% at dose = 45 mg/l of initial concentration 1%. On the other hand, the lowest removal efficiency of turbidity was obtained when using ammonium chloride as coagulant. The maximum removal efficiency of ammonium chloride was 42.45% at dose = 25 mg/l. There was no significant effect on the values of total dissolved salts and conductivity of raw water when using the above coagulants.

**Keywords**: Water Purification; Drinking water; Coagulants; Chemical Coagulation; Chemical Precipitation.

## 1. INTRODUCTION

Coagulation and flocculation processes are considered the most important stages of water purification because they represent important barriers to different contaminants. They are key processes for reducing turbidity, which can seriously affect the efficiency of disinfection. Lilian de Souza Fermino, et al [1] compared between two types of coagulants the first was, aluminum sulphate coagulant and the second was the seed extract of Moringa oleífera (MO). It was found that, MO proved to be more efficient, with removals of 94.9% of turbidity and 92.5% of color, when using a dosage of 20 mg/l. Xu, jie,zhao, et al [2] investigated the coagulation performance of titanium tetra chloride ($TiCl_4$) for microcystis aeruginosa synthetic water treatment. It was found that, complete removal of algal cell. It was stated that, 60 mg/l $TiCl_4$ was effective in removing the microcystins up to 85%. To facilitate water recycling without secondary contamination, the algae – containing sludge after $TiCl_4$. Coagulation ought to be disposed within 12 days at 20ºC and 8 days at 35ºC. Removal of dissolved organic nitrogen (DON) was checked by Zhu, Guocheng, et al [3] using hybridized coagulant of polyacrylamide with iron based coagulant. It was discovered that, a higher flock growth rate (119.82 µm/ min) and recovery factors (26.96) were found in the hybrid coagulant. It was observed that, removal was affected by the ingredient and the species composition of the hybrid coagulant. It was reported that, the enhance efficiency of DON removal was attributed to the increased adsorption – bridging and sweep – flock in the presence of cationic polymers (CPAM).

Lohr, et al [4] stated that, the input of ferrous iron together with Pinus dissolved organic matter to surface waters may reduce precipitation of hydrous ferric oxides (ferrihydrite) and increase the flux of dissolved Fe out of the catchment. Post, et al [5] reported that, deviations from the equation of state were found to be due to the changes in electrical conductivity and the density caused by geochemical reactions, such as the dissolution of carbonates, degradation of organic carbon, cation exchange, and sulfate loss. Peter Gebbie [6] studied different factors affecting the removal efficiency of coagulants, the first one was "basicity". It was stated that, the higher the basicity of a coagulant, the lower the impact it will have on dosed water pH. For example, ACH ($Al_2(OH)5Cl$) has a basicity of 83.3%. It was found that, commercially produced ACH will have a basicity of 83-85%, indicating that it will have less impact on dosed water pH than poly-aluminium chloride . Alum has no OH ions in its structure and hence has zero basicity. Klaus Töpfer [7] stated that, The base is aluminium or iron, two of the most common elements in the earth's crust, with a share of 8.1% and 5.1% respectively. It was reported that, coagulants are produced either directly from ores taken from the crust or via side streams from other production processes in which iron or aluminium ores are raw materials.

## 2. MATERIALS AND METHODS

### 2.1 Material

Five types of coagulants were applied, the first one was ferrous sulfate $FeSO_{4.}7\ H_2O$ of purity 98%. The second one was ferric sulfate $Fe_2\ (SO_4)_3.\ x\ H_2O$ of purity 98%, the third one was ammonium chloride. The fourth one was ferrous chloride $Fe\ Cl_2.\ 4H_2O$ of molecular weight = 198.81- Assay: min 99%– Cat number 02281. The last one was aluminium sulfate (alum) $Al_2\ (SO_4)_3.\ 16H_2O$ of molecular weight = 630.38- Min assay: 97%. All these chemicals are Egyptian products but the only Indian one was ferrous chloride. The weight of the whole used package was 500 gm per each package.

### 2.2 Methods

All works were done in the Extension of Gezerit Al-Dahab water treatment plant. This plant is located southern of Cairo at El-Giza –governorate the capacity of the extension of this plant was = 204000 $m^3$/day. Jar test in the main laboratory was used in bench-scale simulating processes of coagulation and flocculation for water to determine the different values of turbidity. It consists of six flasks of total volume one liter per each flask as revealed clearly in Figs. 1, 2. All samples of the experiments were collected by the staff of the water plant and taken from the raw water intake of Geziret Al-Dahab water treatment plant. The concentration of the coagulant was 1% for the whole types of coagulants. Pre chlorination were added by the same values applied in the water plant = 5.50mg/l. The flash mixing stage were run at mixing speed = 130 r.p.m for two minutes. Then, the gentle mixing stage was started at speed = 30 r.p.m for 20 minutes. The last step was the sedimentation stage. Then, the turbidity and conductivity of the whole samples were measured before and after finishing the jar test. The initial value of turbidity was varied for each run because each experiment was run in different days not in the same day. It was noticed that, in case of using ferrous sulfate the flocks were heavy and settled down easily. But, in case of using ferric sulfate the formed flocks were light and part of these flocks did not settle down. The applied dosages of the whole types of coagulants were 20, 25, 30, 35, 40 and 45 ppm respectively.

The assessment of the concerned parameters was carried out according to the methods of water quality described in "Standard methods for the examination of water and wastewater American Public Health Association".

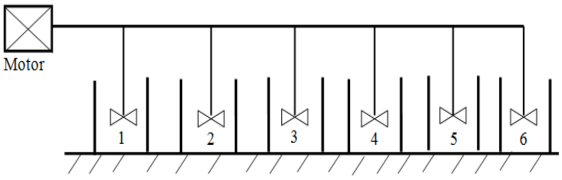


Fig.1. Schematic diagram for Jar Test

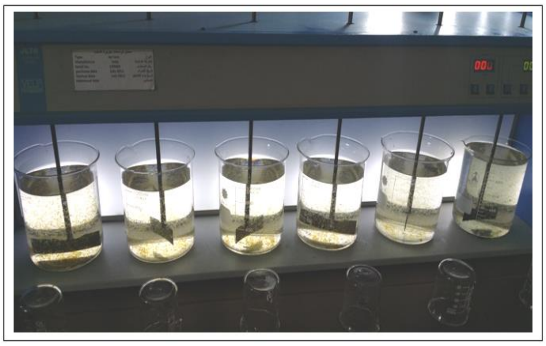

Fig.2. Photo for Jar Test

## 3. RESULTS AND DISCUSSION

The obtained results were listed in the following tables and illustrated clearly in the following figures.

### 3.1 Results of Ferrous Sulfate

Turbidity of raw water = 5.60 NTU and conductivity = 379 μS/Cm. Concentration of coagulant = 1% and pre chlorination = 5.5 ppm. Table 1 and Fig. 3 illustrate the removal efficiencies of ferrous sulfate at different doses and the maximum removal efficiency = 61.96% was obtained at dose = 30 mg/l.

Table.1 Ferrous Sulfate Removal Efficiencies

| Dose (mg/l) | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|
| Turbidity value NTU | 2.80 | 2.64 | 2.13 | 2.25 | 2.20 | 2.68 |
| Removal percentage % | 50 | 52.86 | 61.96 | 59.82 | 60.71 | 52.14 |
| TDS values (ppm) | 260 | 260 | 261 | 262 | 260 | 263 |
| Conductivity µS/Cm | 390 | 390 | 391 | 393 | 390 | 395 |

The removal percentages of turbidity when using ferrous sulfate are plotted in Fig. 3.

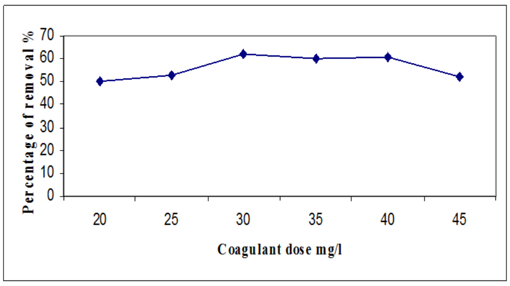


Fig.3. Removal Efficiency of Turbidity Using Ferrous Sulfate

### 3.2 Results of Ferric Sulfate

Turbidity of raw water = 9.20 NTU and conductivity = 382 µS/Cm**.** Concentration of coagulant = 1% and pre chlorination = 5.5 ppm**.** Table 2 and Fig. 4 reveal the removal efficiencies of ferric sulfate at different doses and the maximum the efficiency of turbidity = 59.78 % at dose = 25 mg/l.

Table.2 Ferric Sulfate Removal Efficiencies

| Coagulant Dose mg/l | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|
| Turbidity value NTU | 5.40 | 3.70 | 3.96 | 3.87 | 3.91 | 3.90 |
| Removal percentage % | 41.30 | 59.78 | 56.96 | 57.93 | 57.50 | 57.61 |
| TDS values (ppm) | 256 | 256 | 257 | 257 | 257 | 258 |
| Conductivity µS/Cm | 384 | 384 | 385 | 385 | 386 | 387 |

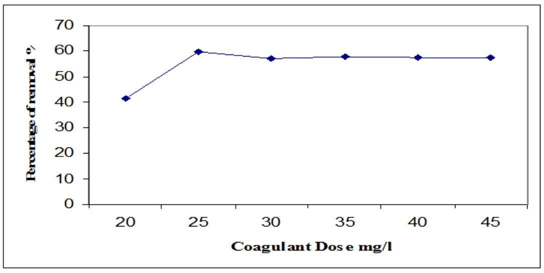


Fig.4. Removal Efficiency of Turbidity Using Ferric Sulfate

### 3.3 Results of Ammonium Chloride

Turbidity of raw water = 7.10 NTU and conductivity = 351 µS/Cm. Concentration of coagulant= 1% and pre chlorination = 5.5 ppm. Table 3 and Fig. 5 show the removal efficiencies of ammonium chloride at different doses. The maximum removal efficiency of turbidity = 42.25 % at coagulant dose = 20mg/l and it is a weak efficiency. From the concerned figure it was noticed that, increasing the dose of ammonium chloride gives negative effect on the removal efficiency of turbidity.

Table.3 Ammonium Chloride Removal Efficiencies

| Dose mg/l | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|
| Turbidity value NTU | 4.10 | 4.70 | 5.0 | 4.99 | 4.70 | 4.70 |
| Removal percentage % | 42.25 | 33.80 | 29.58 | 29.72 | 33.80 | 33.80 |
| TDS values (ppm) | 265 | 275 | 283 | 291 | 299 | 307 |
| Conductivity µS/Cm | 398 | 412 | 424 | 436 | 448 | 461 |

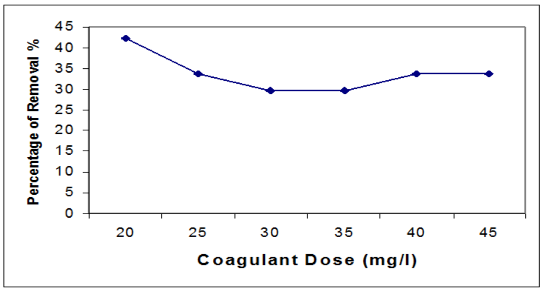


Fig.5. Removal Efficiency of Turbidity Using Ammonium Chloride

### 3.4 Results of Ferrous Chloride

Turbidity of raw water = 6.50 NTU and conductivity = 361 µS/Cm. Concentration of coagulant = 1% and initial chlorination = 5.5 ppm. Noting that, this type of coagulant dissolved with great difficult in raw water. It was observed that, the obtained maximum removal efficiency of turbidity = 72.31% at dose = 35 mg/l as illustrated clearly in Table 4 and Fig. 6. On the other hand, the values of total dissolved salts did not affected by the coagulation by ferrous chloride.

Table.4 Ferrous Chloride Removal Efficiencies

| Dose mg/l | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|
| Turbidity value NTU | 2.4 | 2.09 | 2.2 | 1.80 | 1.90 | 2.10 |
| Removal percentage % | 63.08 | 67.85 | 66.15 | 72.31 | 70.77 | 67.69 |
| TDS values (ppm) | 245 | 246 | 247 | 247 | 249 | 249 |
| Conductivity µS/Cm | 368 | 369 | 370 | 371 | 373 | 374 |

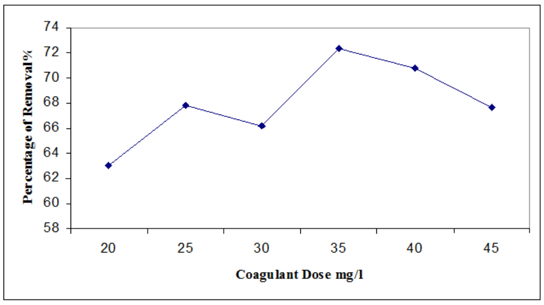


Fig.6. Removal Efficiency of Turbidity Using Ferrous Chloride

### 3.5 Results of Aluminium Sulfate

Turbidity of raw water = 5.60 NTU and conductivity = 344 µS/Cm. Concentration of coagulant = 1% and initial chlorination = 5.5 ppm. Table 5 and Fig.7 reveal that, the obtained maximum removal efficiency of turbidity = 77.32% at dose = 45 mg/l. This efficiency is considered the highest removal efficiency for the whole applied coagulants. It was noticed that, there is no significant effect of the used coagulant in the values of total dissolved salts (TDS).

Table.5 Aluminium Sulfate Removal Efficiencies

| Dose mg/l | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|
| Turbidity value NTU | 1.85 | 1.55 | 1.78 | 1.46 | 1.30 | 1.27 |
| Removal percentage % | 66.96 | 72.32 | 68.21 | 73.93 | 76.79 | 77.32 |
| TDS values (ppm) | 233 | 233 | 234 | 235 | 235 | 235 |
| Conductivity µS/Cm | 349 | 350 | 351 | 352 | 353 | 353 |

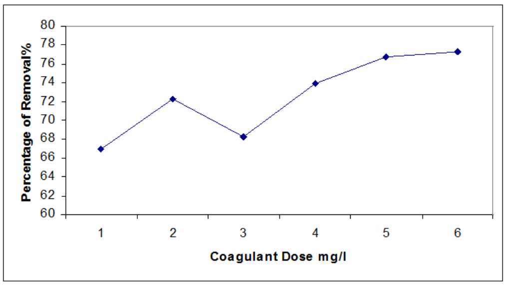


Fig.7. Removal Efficiency of Turbidity Using Aluminium Sulfate

### 3.6 Comparison between the Different Types of Coagulants

Comparison between different types of coagulants was illustrated in Fig. 8. It was noticed that, alum is the most efficient type and the second choice is ferrous chloride and the third one was ferrous sulfate.

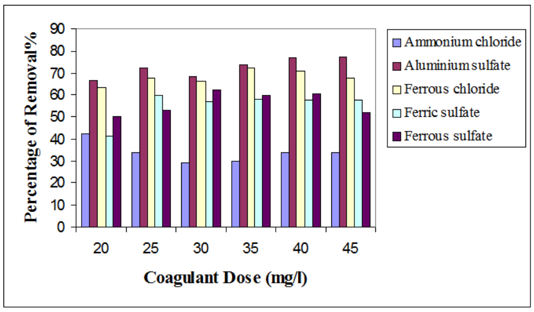


Fig.8. Comparison between Removal Efficiencies of Coagulants

Based on the above experimental results, it was found that, Aluminium Sulfate (alum) has a suitable chemical structure for forming flocks consequently, the obtained removal efficiency of turbidity was more efficient than the other chemicals used in this research. The recommended dose of alum = 45 mg/l which leads to removal efficiency of turbidity = 77.32%. Comparing the obtained results of Ferrous Chloride with the results of Ferrous and Ferric Sulfates it was noticed that, Ferrous Chloride is more efficient than both of Ferric Sulfate and Ferrous Sulfate. On the other hand, in case of using ammonium chloride the higher dose used the lower removal efficiencies were obtained because the chemical structure is not suitable for forming good flocks. There was no significant effect on the values of total dissolved salts and conductivity of raw water when using the above coagulants.

## 4. CONCLUSION

Research findings may be concluded as follows:

1-The best type of coagulant is aluminium sulfate because the highest removal efficiency = 77.32% was obtained at dose =45 mg/l.

2-The second type is ferrous chloride because the maximum removal efficiency of this type was achieved= 72.31% at dose = 35 mg/l.

3-The third preferable type is ferrous sulfate the removal efficiency of turbidity = 60.71% at 40 mg/l coagulant dose.

4-The fourth preferable type, according to the obtained results is ferric sulfate, the maximum removal efficiency of turbidity = 59.78% was gained at dose= 25 mg/l.

5-The weakest type is the ammonium chloride, the maximum removal efficiency was = 42.25% at 20 mg/l.

6-There is no significant effect on the values of conductivity and total dissolved salts after before and after coagulation process.

Generally, aluminium sulfate (alum) is the most preferable choice because of its lower cost and its widespread availability.

## 5. Acknowledgements

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