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Comparison Between Different Types of Organic And Inorganic Coagulants Used in Water Purification

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Abstract

An experimental study was conducted with the aim of comparing different types of coagulants and choosing the most suitable type in (Geziret Al-Dahab) water treatment plant. Seven 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 $FeCl_2$ the five was aluminium sulfate (alum) $Al_2(SO_4)_3$, the sixth one was chitosan and the last one was alum with chitosan. the maximum removal efficiency of turbidity was realized by using alum with chitosan. The maximum removal efficiency was 82% at dose =**15**/**5**mg/l of initial concentration 1%. Furthermore, the minimum removal efficiency of turbidity was obtained when using chitosan as a coagulant. was 56% at dose = 8 mg/l. There was no important effect on the values of entire dissolved salts when using the above coagulants .There was an important effect on the conductivity of raw water when using chitosan.

Keywords

Alum, chitosan, coagulation, flocculation, ferrous sulfate $FeSO_4$, ferric sulfate $Fe_2(SO_4)_3$, water purification.

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 Fermion, et al [1] compared two types of coagulants the first was, aluminium sulphate coagulant and the second was 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 colour, 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 of 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 a 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 are built-in in the provided template. Some parts, such as multi-leveled equations, figures, and tables are not prespecified. However, the various styles of table text are reported. The formatter will need to create these components, incorporating the applicable criteria that follow.

Chitosan as a Coagulant

Chitosan-based materials have also been recommended in laboratory studies as potentially eco-friendly coagulants and flocculants for water and sewage water treatment (WT) because of their inorganic biological characteristics and biodegradability [14]. Chitosan has been reported to perform well as a coagulant by removing chlorella in algae turbid water, removing turbidity from seawater, and for harvesting microalgae [15], [16]. It has several industrial and commercial utilities, can be recycled, and is an excellent chelating agent for many metals such as arsenic, molybdenum, cadmium, chromium, lead, and cobalt [17].

2. MATERIALS AND METHODS

2.1.Material

Seven 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%, and 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%. The five one was aluminium sulfate (alum) $Al_2\ (SO_4)_3.\ 16H_2O$ of molecular weight = 630.38- Min assay: 97%. The sixth one was chitosan an Egyptian product the weight of the whole used package was 50 gm per package. 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 package.

2.2. Methods

All works were done in the Extension of Gezerit Al-Dahab water treatment plant. This plant is located in southern of Cairo at El-Giza –governorate the capacity of the extension of this plant was = 218000 m3/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 two liter per each flask as revealed clearly in Figs. 1 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 type of coagulant. Pre-chlorination was added by the same values applied in the water plant = 7.00 mg/l. The flash mixing stage was 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 on different days, not on the same day. It was noticed that, in the case of using ferrous sulfate the flocks were heavy and settled down easily. But, in the case of using ferric sulfate the formed flocks were light and part of these flocks did not settle down. The applied dosages of the ferrous sulfate $FeSO_4$, ferric sulfate $Fe_2\ (SO_4)_3$, ammonium chloride, and ferrous chloride $Fe\ Cl_2$ were 20, 25, 30, 35, 40, and 45 ppm respectively .The applied dosages of the chitosan were 2,4,6,8,10, and 12 mg/L. The applied dosages of the aluminium sulfate (alum) $Al_2\ (SO_4)_3$ were 19,21,23,25,27and 29 mg/Land, and the applied dosages of the mixture of alum and chitosan at doses of 10æ4, 20æ4, 10æ5,15æ5, 10æ6, and 5æ6 mg/L. 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. Jar tester

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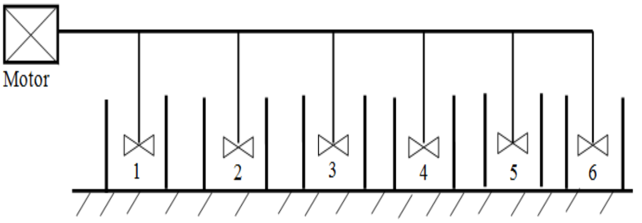

3. RESULTS AND DISCUSSION

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

3.1. ferrous sulfate FeSO4

Turbidity of raw water = 4.50 NTU, pH of raw water = 8 ppm, and conductivity = 379μS/Cm. Concentration of coagulant = 1% and pre-chlorination = 7.00 ppm. Table (1) and Fig. (2) illustrate the removal efficiencies of ferrous sulfate FeSO4 at different doses and the maximum removal efficiency = 61.96%, when pH = 7.31ppm, was obtained at dose = 30 mg/l.

Table (1) Water Turbidity with Various ferrous sulfate FeSO4.

Dose (mg/L)	Turbidity Removal NTU	Removal Percentage %	TDS Values (ppm)	Conductivity us/Cm
20	2.80	50	260	390
25	2.64	52	260	390
30	2.13	62	261	391
35	2.25	60	262	393
40	2.20	61	260	390
45	2.68	53	263	395

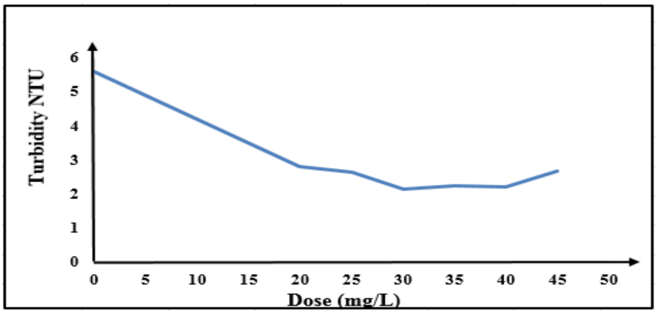

Figure (2) Turbidity and pH in water versus ferrous sulfate FeSO4 Doses

3.2. ferric sulfate Fe2 (SO4)3

Turbidity of raw water = 5.6 NTU, pH of raw water = 8 ppm, and conductivity = 382μS/Cm. Concentration of coagulant = 1% and pre chlorination = 7.00 ppm. Table (2) and Fig. (3) illustrate the removal efficiencies of ferric sulfate Fe2 (SO4 at different doses and the maximum removal efficiency = 60% ,was obtained at dose = 25 mg/l

Table (2) Water Turbidity with Various ferric sulfate Fe2 (SO4)3

Dose (mg/L)	Turbidity Removal NTU	Removal Percentage %	TDS Values (ppm)	Conductivity us/Cm
20	5.40	42	256	384
25	3.70	60	256	384
30	3.96	57	257	385
35	3.87	58	257	385
40	3.91	58	257	386
45	3.90	58	258	387

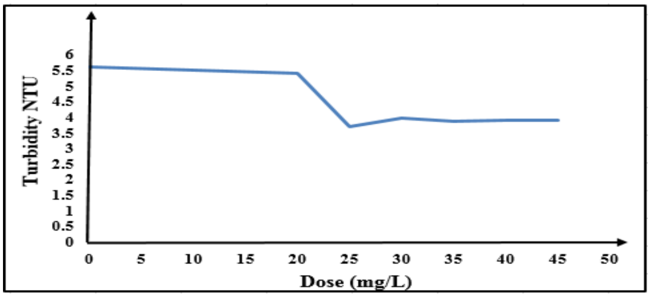

Figure (3) Turbidity and pH in water versus ferric sulfate Fe2 (SO4)3 Dose

3.3. ammonium chloride

Turbidity of raw water = 5.6 NTU, pH of raw water = 8 ppm, and conductivity = 351 µS/Cm. Concentration of coagulant = 1% and pre chlorination = 7.00 ppm. Table (3) and Fig. (4) illustrate the removal efficiencies of ammonium chloride at different doses and the maximum removal efficiency = 43%, was obtained at dose = 20 mg/l

Table (3) Water Turbidity with Various ammonium chloride

Dose (mg/L)	Turbidity Removal NTU	Removal Percentage %	TDS Values (ppm)	Conductivity us/Cm
20	4.10	43	265	398
25	4.70	34	275	412
30	5.00	30	283	424
35	4.99	30	291	436
40	4.70	34	299	448
45	4.70	34	307	461

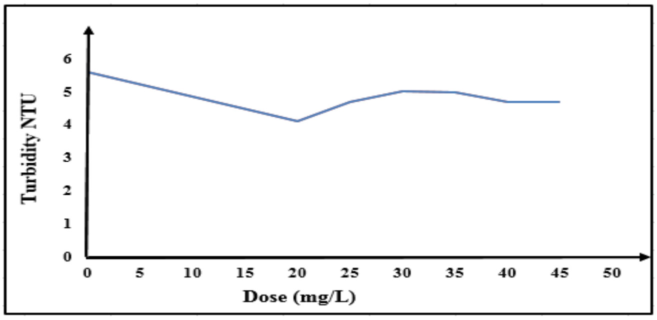

Figure (4)Turbidity and pH in water versus ammonium chloride Doses

3.4. ferrous chloride Fe Cl2

Turbidity of raw water = 5.6 NTU, pH of raw water = 8 ppm, and conductivity = 361 µS/Cm. Concentration of coagulant = 1% and pre chlorination = 7.00 ppm. Table (5) and Fig. (5) illustrate the removal efficiencies of ferrous chloride Fe Cl2at different doses and the maximum removal efficiency = 73%, was obtained at dose = 35 mg/l
Table (4) Water Turbidity with Various ferrous chloride Fe Cl2.

1.1. Dose (mg/L)	Turbidity Removal NTU	Removal Percentage %	TDS Values (ppm)	Conductivity us/Cm
20	2.4	64	245	368
25	2.09	68	246	369
30	2.2	67	247	370
35	1.80	73	247	371
40	1.90	71	249	373
45	2.10	67	249	374

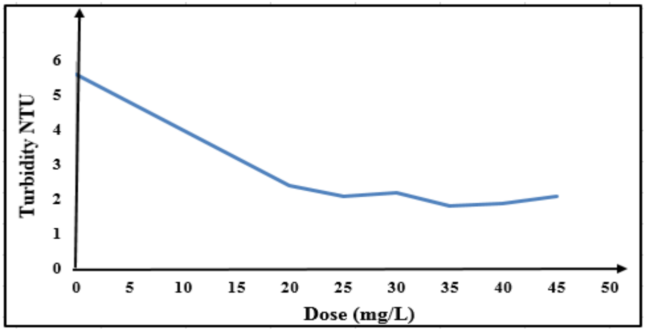

Figure (5) Values of Algae at Various ferrous chloride Fe Cl2 Doses

3.5. aluminium sulfate (alum) Al2 (SO4)3

Turbidity of raw water = 5.6 NTU, pH of raw water = 8 ppm, and conductivity = 361 µS/Cm. Concentration of coagulant = 1% and pre chlorination = 7.00 ppm. Table (5) and Fig. (6) illustrate the removal efficiencies of aluminium sulfate at different doses and the maximum removal efficiency = 77%, was obtained at dose = 23 mg/l

Table (5) Water Turbidity with Various aluminium sulfate (alum) Al2 (SO4)3

Dose (mg/L)	Turbidity Removal NTU	Removal Percentage %	TDS Values (ppm)	Conductivity us/Cm
19	1.8	60	233	349
21	1.6	65	233	350
23	1.4	69	234	351
25	1.3	72	235	352
27	1.6	65	235	353
29	1.6	65	235	353

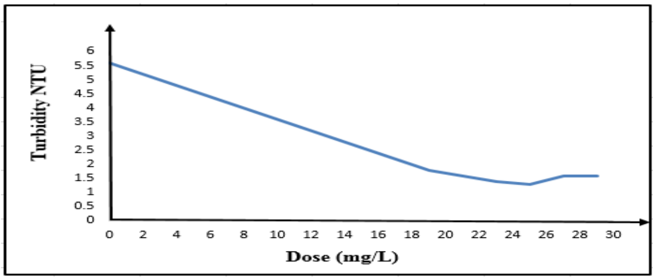

Figure (6) Values of Algae at Various aluminium sulfate Doses

3.6. Chitosan.

Turbidity of raw water = 5.6 NTU, pH of raw water = 8 ppm, and conductivity = 448 µS/Cm. Concentration of coagulant = 1% and pre chlorination = 7.00 ppm. Table (6) and Fig. (7) illustrate the removal efficiencies of aluminium sulfate at different doses and th maximum removal efficiency = 98.6 %, was obtained at dose = 8 mg/l

Table (6) Water Turbidity with Various Chitosan

Dose (mg/L)	Turbidity Removal NTU	Removal Percentage %	TDS Values (ppm)	Conductivity us/Cm
2	2.7	40	237	445
4	2	56	236	444
6	2.15	53	237	445
8	2	56	239	448
10	2.11	54	239	448
12	2.14	52	237	446

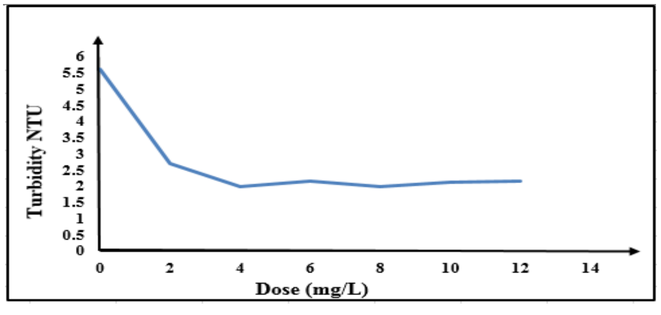

Figure (7) Values of Algae at Various Chitosan Doses

3.7. Alum/Chitosan.

Turbidity of raw water = 5.6 NTU, pH of raw water = 8 ppm, and conductivity = 382 µS/Cm. Concentration of coagulant = 1% and pre-chlorination = 7.00 ppm. Table (7) and Fig. (8) illustrate the removal efficiencies of aluminium sulfate at different doses and the maximum removal efficiency = 99%, was obtained at dose = 15/5 mg/l

Table (7) Water Turbidity with Various Chitosan

Dose (mg/L)	Turbidity Removal NTU	Removal Percentage %	TDS Values (ppm)	Conductivity us/Cm
10/4	0.8	83	204	383
20/4	0.8	83	202	383
10/5	1.2	73	204	382
15/5	0.85	81	203	382
10/6	0.7	84	204	383
5/6	2	56	209	384

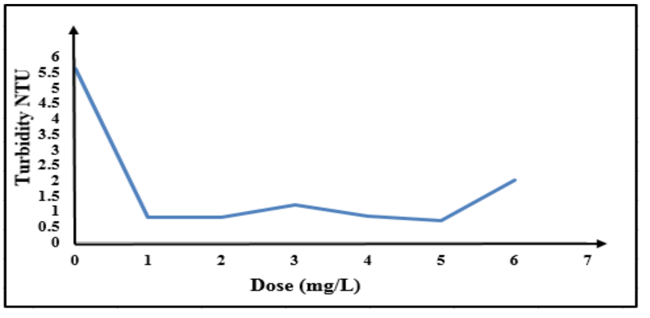

Figure (8) Values of Algae at Various Alum/Chitosan

4. CONCLUSION

- The results of the research can be summarized as follows The best type of coagulant is alum with chitosan removal efficiency = 99% was obtained at dose = 15/5 mg/l.
- The second type is chitosan only removal efficiency =98.6% was obtained at dose = 8 mg/l.
- The third preferable type aluminium sulfate because the highest removal efficiency = 77.32% was obtained at dose =23 mg/l.
- The fours type is ferrous chloride because the maximum removal efficiency of this type was achieved at 73% at

dose of 35 mg/l.

- The sixth preferable type is ferrous sulfate the removal efficiency of turbidity is 61.76% at 40 mg/l coagulant dose.
- The seventh preferable type, according to the obtained results is ferric sulfate, the maximum removal efficiency of turbidity = 60 % was gained at a dose of 25 mg/l.
- The last type is the ammonium chloride; the maximum removal efficiency was = 43 % at 20 mg/l.
- There is no significant effect on the values of conductivity and total dissolved salts before and after the coagulation process. Generally, chitosan is the most preferable choice because of its l

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REFERENCES

- B. Eikebrokk and T. Saltnes, ―NOM removal from drinking water by chitosan coagulation and filtration through lightweight expanded cla aggregate filters, ‖ Journal of Water Supply: Research and Technology-AQUA, IWA Publishing 51, vol. 6, pp. 323-332, Sep. 2002.
- S. A. Parsons, B. Jefferson, E. H. Goslan, P. R. Jarvis and D. A. Fearing, ―Natural organic matter — The relationship between character and treatability, ‖ Water Science and Technology: Water Supply, IWA Publishing, vol. 4, pp. 43–48, 2004
- B. Meyssami and A. B. Kasaeian, ―Use of coagulants in treatment of olive oil wastewater model solutions by induced air flotation, ‖ Bioresource Technology Journal, Elsevier, vol. 96, pp. 303–307, 2005.
- B. B. Mamba, R. W. Krause, B. Matsebula, and J. Haarhoff, ―Monitoring natural organic matter and-disinfection by-products at different stages in two South African water treatment plants, ‖ Water SA, vol. 35, pp. 122–128, 2009
- Guidelines for Drinking-Water Quality, 1st addendum to 3rd ed. World Health Organization, 2006, vol. 1.
- E. W. Dungumaro, ―Socioeconomic differentials and availability of domestic water in Africa, ‖ Journal of Physics and Chemistry of the Earth, vol. 32, pp. 1141–1147, 2007.
- F. Renaul, B. Sancey, P. M. Badot, and G. Crini, ―Chitosan for coagulation/flocculation processes–an eco-friendly approach, ‖ European Polymer Journal, vol. 12, pp. 221–239, 2008F. Renaul, B. Sancey, P. M. Badot, and G. Crini, ―Chitosan for coagulation/flocculation processes–an eco-friendly approach, ‖ European Polymer Journal, vol. 12, pp. 221–239, 2008
- Lilian de Souza Fermino, Alessandra de Castro Silva Pedrangelo, Priscilla Kohiyama de Matos Silva, Rafaella Eloisa Candido de Azevedo, Natália Ueda Yamaguchi and Rosa Maria Ribeiro "Water Treatment with Conventional and Alternat Coagulants", Chemical Engineering Transactions- Vol. 57, pp. 1189-1194, 2017
- Xu, jie; Zhao, Gao, Baoyus and Zhao Qian, "Enhanced Algae Removal by Ti- Based Coagulant – Comparison with Conventional Al and Fe Based Coagulants", Environmental Science and Pollution Research, International, Heidelberg, Vol. 25, No. 13, pp. 13147-13158, 2018.
- Zhu, Guocheng; Liu, Junfei and Bian, Yonging.,"Evaluation of Cationic Polyacrylamide- Based Hybrid Cagulation for the Removal of Dissolved Organic Nitrogen" Environmental Science and Pollution Research, International, Heidelberg, Vol. 25, No. 15, pp 14447-14459,2018.
- Lohr, SC and Cox ME., "The Influence of Vegetation and Soil Type on the Speciation of Iron in Soil Water", European Journal of Soil Science, Vol. 63, No. 3, pp.377–388, 2012.
- Post and VEA., "Electrical Conductivity as a Proxy for Groundwater Density in Coastal Aquifers Ground Water", Vol. 50, No. 5, pp. 785-792, 2012.
- Peter Gebbie., "An Operator's Guide to Water Treatment Coagulants", 31st Annual Qld Water Industry Workshop – Operations Skills University Central Queensland – Rockhampton, pp 14-20, 2006.
- R. Lamsal, M. E. Walsh, and G. A. Gagnon, ―Comparison of advanced oxidation processes for the removal of natural organic matter, ‖ Water Research Journal, vol. 45, pp. 3263-3269, 2011.
- C. D. Goss and B. Gorczyca, ―Removal of natural organic matter fractions by two potable water treatment systems: Dual membrane filtration and conventional lime soda softening, ‖ IOWA Specialty Conference on Natural Organic Matter, 2011.
- A. Soros, Chitosan Coagulation for Household Water Treatment in Developing Countries, University of North Carolina at Chapel Hill Graduate School: Chapel Hill, NC, 2015.
- F. W. Pontius, ―Chitosan as a drinking water treatment coagulant, ‖ American Journal of Civil Engineering, vol. 4, pp. 205-215, 2016.

- H. Chopra and G. Ruhi, —Eco friendly chitosan: an efficient material for water purification, || The Pharma Innovation Journal, vol. 5, no. 1, pp. 92-95, 2016.
- Hamdon, R. S. M. A., Salem, A., Ahmed, H. G. I., & El-Zahar, M. M. H. (2022). Use of Chitosan for Enhancing the Process of Surface Water Purification in Egypt. International Journal of Environmental Science and Development, 13(2), 26–34.
- EL- Dosoky SH. M., El-Zahar M. H., Saleh M.Y., "The Usage of Date Pits for Treatment of Thickened Sludge", Journal of Waste Management and Disposal, SCHOLARINA, ISSN: 2641-8827, April 25, 2019.
- M. Yousef Saleh, M. El-Zahar, S. EL- Dosoky, "The Usage of Nitrogen Gas and Alum for Sludge Dewatering", ICAPCMT 2019, International Conference on Agricultural Pollution Control, Management and Technology Conference, Venice, Italy, April 11-12, 2019.
- Mamdouh Y. Saleh, Medhat H. Elzahar, Moustafa H. Omran, 2017 "Industrial Wastewater Treatment Improvements Using Limestone", 4th International Conference on Environmental Studies and Research "Smart Sustainable Environment", Environmental Studies and Research Institute, Sadat City, Held in Sharm Elsheikh, Egypt, March, 27-29, 2017.
- Mamdouh Y. Saleh, Medhat H. Elzahar, Moustafa H. Omran, 2015 "Industrial Wastewater Treatment Improvements Using Activated Carbon", International Conference on Environmental Science and Engineering, Miami, USA, March, 10-11, 2015.
- Mamdouh Yousef Saleh, Gaber El Enany, Medhat Elzahar, Mohamed Z. Elshikhipy 2014 "Industrial Wastewater Treatment Using High Rate Activated Sludge and Alum Additive", International Journal of Environmental Science and Development, Singapore, ISSN: 2010-0264, Vol. 5, No. 6, Accepted April, 22, 2014, December, 2014.
- Mamdouh Yousef Saleh, Gaber El Enany, Medhat Elzahar, Eng. Mohamed Z. Elshikhipy, Rana Hamouda 2014 "Removal of Lead in High Rate Activated Sludge System", World Academy of Science, Engineering and Technology, Vol. 8, 2014-03-01.
- Mamdouh Yousef Saleh, Gaber El Enany, Medhat Elzahar, Mohamed Z. Elshikhipy 2014 "Use of Alum for Removal of Total dissolved Solids and Total Iron in High Rate Activated Sludge System", International Journal of Environmental Engineering Science and Technology Research Vol. 2, No. 3, March 2014, PP: 1 - 12, ISSN: 2326 – 3113.
- Mamdouh Y. Saleh, Shaymaa EL-Dosoky, Medhat Elzahar 2012 "Wastewater Treatment by Oxidation Ponds in Port Said Treatment Plant (Control of Algae)", Port Said Engineering Research Journal, Vol. 16, No. 2, September 2012, PP: 109-118, ISSN: 111-6603, September 2012, Port Said, Egypt.
- Elzahar, M.M.H., Bassyouni, M. Removal of direct dyes from wastewater using chitosan and polyacrylamide blends. Sci Rep 13, 15750 (2023). https://doi.org/10.1038/s41598-023-42960-y