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Chemical enhancement of bahr el baqar drain in Egypt using alum, ferric chloride, cement kiln dust and fly ash

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Abstract

The reuse of the various industrial wastes or by-products had become a general trend all over the world in order to prevent, or at least to reduce the environment pollution. Cement Kiln Dust (CKD) and Fly Ash (FA) considered as no-cost material and are used as a sludge conditioner, stabilizing chemical, and also used to improve the quality of wastewater treatment and irrigation water, thus, the present study was aimed to investigated the effect of different types of traditional coagulant and byproduct materials on Bahr El-Baqar drainage water properties for safe reusing of treated effluent in agricultural purposes and irrigation. The used optimum dose of coagulants and effect of polymer was determined using standard jar test; the optimum dose was 40, 30, 300, and 100 mg/l for Alum, Ferric Chloride, CKD and FA respectively. FA was the most effective coagulant for the removal of Biological oxygen demand (BOD) and Chemical oxygen demand (COD) while for Total Suspended Solids (TSS) almost all tested coagulants have the same removal ratio with small superiority for Ferric Chloride. Addition of polymer enhanced the performance of all test coagulant and the removal of TSS reached 90%, 92%, 86% and 93% for Alum, Ferric Chloride, CKD and FA respectively at a dose of 1 mg/l, according to the performed technical and economical comparison the recommended order of the coagulant is FA, Ferric Chloride, CKD and Alum.

1. Introduction

Sewage discharges are a major component of water pollution contributing to oxygen demand and nutrient loading of the water bodies, promoting toxic algal blooms and leading to a destabilized aquatic ecosystem. The problem is compounded in areas where wastewater treatment systems are simple and not efficient [1]. Because of the direct discharge of treated, untreated and partially treated wastes into streams the capability of reusing of streams water decreased [2].

Bahr El-Baqar drain system in Egypt is shown in figure (1), The main drain starts near the city of Zagazig where it collects the effluents from two secondary drains: Bilbeis Drain and Qalubeya Drain. Water flows through the drain for about 100 km to the southeast sector of the Lake Manzala which is located on the north-eastern edge of the Nile Delta. Lake Manzala is one of the coastal lake systems of the northern Nile Delta. It is surrounded with great areas of wetlands. The fish production is high and once supplied about 30% of Egypt's totals catch [3, 4, 5].

Bahr El-Baqar drain receives and carries the most significant section of the wastewater (about 3 BCM/ year) into Lake Manzala through a very densely populated area of the Eastern Delta passing through

Qalubyia, Sharkia, Ismailia and Port Said Governorates Unfortunately, at the last decades, great areas on both sides of the drain were using its polluted water for irrigation and raising fish. It has a high risk to the surrounding environment [6, 7]. The discharge of industrial, agricultural and municipal wastewaters in Bahr El Baqar drain which farmer uses it in irrigation led to contamination of environment. These soils receive many kinds of pollutants, especially heavy metals such as lead, cadmium, nickel, and mercury, the drain water contains a mix of agriculture drainage (58%), untreated domestic wastewater (40%), untreated industrial wastewater (2%) [8, 9, 10], figure (2) shows schematic diagram of Bahr El Baqar drain.

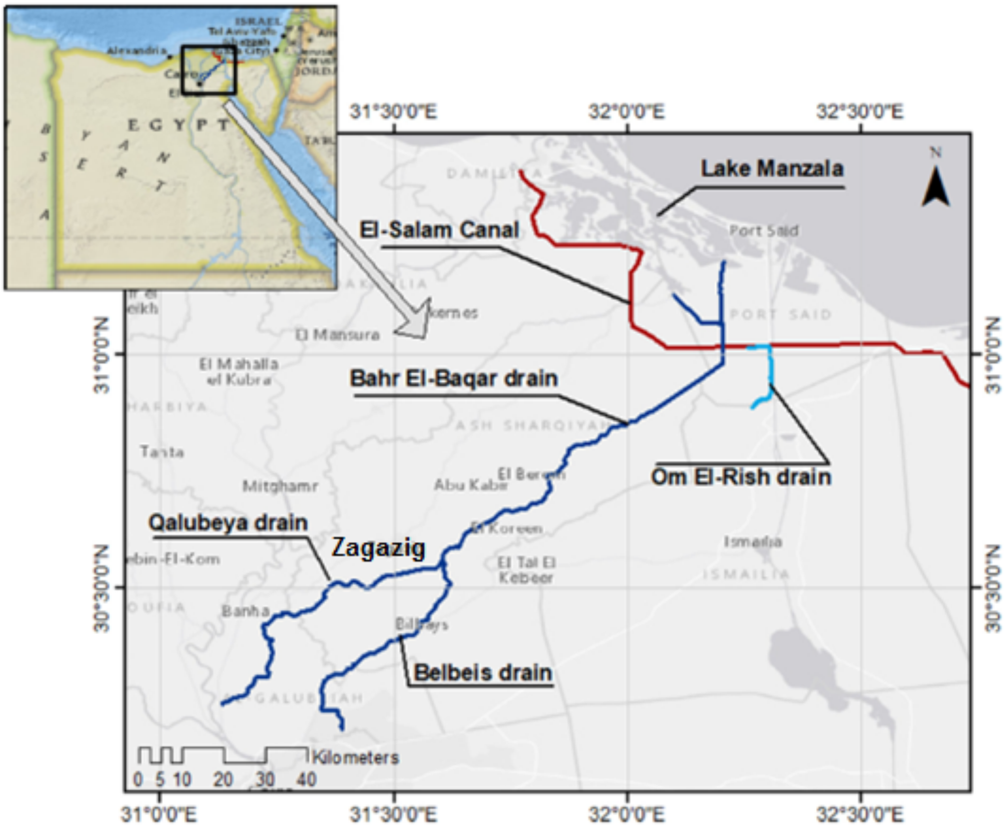

Figure 1. Bahr El Baqar drain [5]

The purpose of drainage and wastewater treatment is to remove solids (suspended, colloidal and floated), biodegradable organic matters, nutrients and elimination of pathogenic microorganisms. Water quality criteria for irrigation generally take into account characteristics such as crop tolerance to salinity, sodium concentration, and phytotoxic trace elements. It is important to reuse both drainage and treated wastewater in order to blocking the gap in water needs [11, 12].

Chemical coagulation promotes flocculation of colloidal particles into a more readily settleable floc in a chemically enhanced treatment process. Some chemicals cause precipitation by chemically or physically modifying the solubility of many dissolved solids. Thus, the removal efficiencies of BOD, TSS, and total phosphorous (TP) are increased. Traditionally, lime and metal salts such as alum (aluminum sulfate), ferric chloride, ferric sulfate, ferrous chloride, and ferrous sulfate have been utilized as coagulants. In recent years, polymers (long-molecular-chain organic compounds) have been used in conjunction with or in lieu of metal salts to enhance the coagulation and flocculation process. Additionally, alum polymers such as polyaluminum chloride, polyaluminum chlorohydrate, and polyaluminum sulfate are gaining popularity [13, 14, 15, 16]

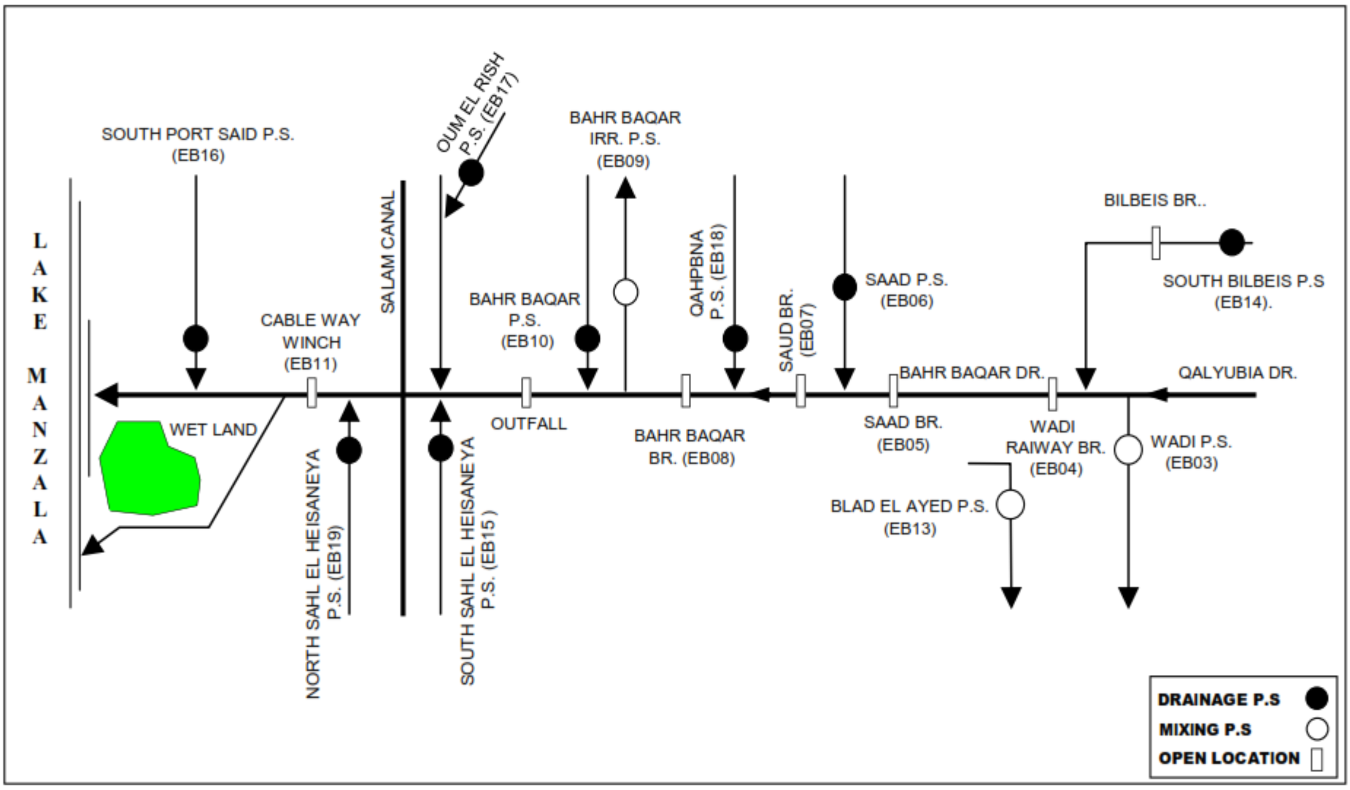

Figure 2. Schematic diagram of Bahr El Baqar drain [10]

Cement kiln dust (CKD) and Fly Ash (FA) are fine grains industrial byproducts produced from cement clinker production and burning of coal during the production of electricity with global production of 5.7 and 750 million tons per year respectively [17, 18]. The reuse of the various industrial wastes or by-products particularly the solid wastes had become a general trend all over the world in order to prevent, or at least to reduce the environmental pollution, CKD and FA considered as no-cost material and are used as a sludge conditioner and stabilizing chemical [19, 20, 21, 22, 23], and also used to improve the quality of wastewater treatment and irrigation water [11, 24, 25, 26, 27, 28, 29] also Fly ash was investigated to produce a composite coagulant containing aluminum (Al) and iron (Fe) salts which proved to be effective coagulant for treatment of wastewater [30].

Thus, the present study was aimed to treat Bahr El-Baqar drainage water using different types of traditional coagulant and byproduct materials for safe reusing of treated effluent in agricultural purposes and irrigation.

2. Methodology

All the tests were performed in triplicate and shown results is the average values.

2.1 Polluted stream characteristics

Samples from Bahr El Baqar Drain were collected over a year, 2 samples every month with total no of samples of 24, location of sampling point was after the connection with Om El Rish Drain (fig 1 and 2). pH, BOD, Soluble BOD (sBOD), particulate BOD (pBOD), COD, Soluble COD (sCOD), particulate COD (pCOD), total suspended solids (TSS), and volatile solids (VS), were measured for each sample according to the standard methods for the examination of water and wastewater [31].

2.2 Used Chemicals

The used chemicals is this research were collected from different sources, Alum and Ferric chloride were commercially available and a standard solution were prepared with concentration 10% for Alum and 40% for Ferric Chloride, The used CKD was collected from Helwan Portland Cement Factory, the FA collected from SIKA EYGPT; both chemicals were added as powder (dry feeding), the chemical composition of CKD and FA mentioned in details in [22, 23 and 29], while the used Polymer (Zetage 7563) is also commercially available and being used also in dry state [32].

2.3 Optimum coagulant doses

This stage was used to determine the optimum coagulant dosage according to the slandered Jar test procedure; six laboratory beakers with capacity of 1 liter were filled with raw stream water. Coagulants were applied to beakers with the following dosages, Alum (0, 10, 20, 30, 40, and 50 mg/l), Ferric Chloride (0, 10, 20, 30, 40, and 50 mg/l), CKD (0, 100, 200, 300, 400, and 500 mg/l) and FA (0, 50, 100, 150, 200, and 250 mg/l), samples with applied dosage was stirred rapidly with a speed of 200 rpm for 1 minute followed by a slow agitation for 15min at a speed of 20 rpm, then samples were allowed to settle for 30 min then supernatant samples are decanted and pH, TSS, BOD and COD determined, the best result will be the dose that has produced the most rapidly-settling floc in the shortest time.

2.4 Effect of Polymer

Based on the optimum dose obtained from the previous experiments, the jar test repeated with only one exception, polymer was added after the flash mixing stage and two doses of polymer were tested 0.5 and 1 mg/l.

3. Results and Discussion

3.1 Drain water characteristics

Table (1) shows the statistical analysis of drain water characteristics and table (2) shows the permissible limits according to Egyptian Law (48/1982) and effluent requirement based on degree of treatment, for BOD the average value was 41± 4.87 mg/l which is equivalent to secondary treatment degree and compatible with the limits of discharge to drains, but does not applicable for discharge to River Nile or direct irrigation reuse, for COD the average value was 97.50± 18.35 mg/l which is higher than secondary treatment degree and does not applicable for discharge to drains, River Nile or direct irrigation reuse, for TSS the average value was 43± 27.84 mg/l which is equivalent to secondary treatment degree and compatible with the limits of discharge to drains, but also does not applicable for discharge to River Nile or direct irrigation reuse, these results complies with the data collected for Bahr El Baqar drain [3, 7, 10, 33, 34, 35]. Based on these data enhancement for the drain water is required in order to be compatible for the reuse purposes.

Table 1. Statistical analysis of stream water characteristics

Parameters	pH	BOD mg/l	sBOD mg/l	pBOD mg/l	COD mg/l	sCOD mg/l	pCOD mg/l	TSS mg/l	VSS/TSS %
Max	7.80	48	26	33	146	57	104	100	72
Min	7.20	32	11	19	87	31	38	21	58
Average	7.5	41	13.5	27.5	97.5	42	53	43	65
Std	0.18	4.87	4.22	4.05	18.35	8.45	21.42	27.84	2

Table 2. Environmental standards for the treated sewage and discharge limit for Egyptian law (48/1982)

Treatment degree	pH	BOD (mg/l)	COD (mg/l)	TSS (mg/l)
Primary treatment	6-9	300	600	350
Secondary treatment	6-9	40	80	40
Tertiary treatment	6-9	30	40	20
Discharge limit to drains	6-9	60	80	50
Discharge limit to River Nile	6-9	30	40	30

3.2 Optimum coagulant dose

Figure (3) shows the jar test effluent concentrations for the used coagulants, while Table (3) shows the optimum dose of different used coagulants and the removal ratio of different parameters, For Alum the optimum dose was 40 mg/l with removal ratios of 51%, 48% and 69% for BOD, COD and TSS respectively, while pH dropped from 7.5 to 7, For Ferric Chloride the optimum dose was 30 mg/l with removal ratios of 56%, 60% and 74% for BOD, COD and TSS respectively, also pH dropped from 7.5 to 7, For CKD the optimum dose was 300 mg/l with removal ratios of 60%, 60% and 68% for BOD, COD and TSS respectively, while pH increased from 7.5 to 8.1, and For FA the optimum dose was 100 mg/l with removal ratios of 64%, 68% and 69% for BOD, COD and TSS respectively, while pH increased from 7.5 to 7.70, based on these results it was found that the use of FA with dose 100 mg/l is the most effective coagulant for the removal of BOD and COD while for TSS almost all tested coagulants have the same removal ratio with small superiority for Ferric Chloride. The increase in the removal ratio of BOD and COD is mainly due to the adsorption capacity of CKD and FA which complies with the results of Mahmoud [11] who studied the chemical enhancement of primary treatment using aluminum sulfate (alum), cement kiln dust (CKD), and cationic polymer, also it complies with [30, 34, 36].

The removal ratios of Alum and Ferric Chloride comply with the recommended values of [13, 14, 15, 16], and Abdul Aziz [37] how studied the use of Alum, Ferric Chloride and Ferrous Sulphate as coagulants in removing suspended solids, color and COD from semi-aerobic landfill leachate at controlled pH.

Ahmad [38] found that increasing of Alum and Ferric chloride dose had a diverse effect on the pH level but in the other hand pH level directly proportional with the increase dosage of CKD and FA.

Table 3. Optimum doses and removal ratios for different coagulants

Coagulant	Optimum Dose (mg/l)	Effluent pH	Removal ratio		
			BOD	COD	TSS
Alum	40	7.00	51%	48%	69%
Ferric Chloride	30	7.00	56%	60%	74%
CKD	300	8.10	60%	60%	68%
FA	100	7.70	64%	68%	69%

3.3 Effect of Polymer

Table (4) shows the removal ratios of different parameters after addition of polyelectrolyte, the use of polymer enhanced the performance of all test coagulant and the removal of TSS reached 90%, 92%, 86% and 93% for Alum, Ferric Chloride, CKD and FA respectively, on the other hand the enhancement in removal of BOD and COD was much lower this is mainly due to the soluble fraction of the both parameters, from economical point of view it is recommended to use polymer dose of 0.5 mg/l based on the fact that increasing the polymer dose from 0.5 to 1 mg/l will double the running cost of the process while the removal ration does not increased proportionally. These results comply also with [11, 30, 36].

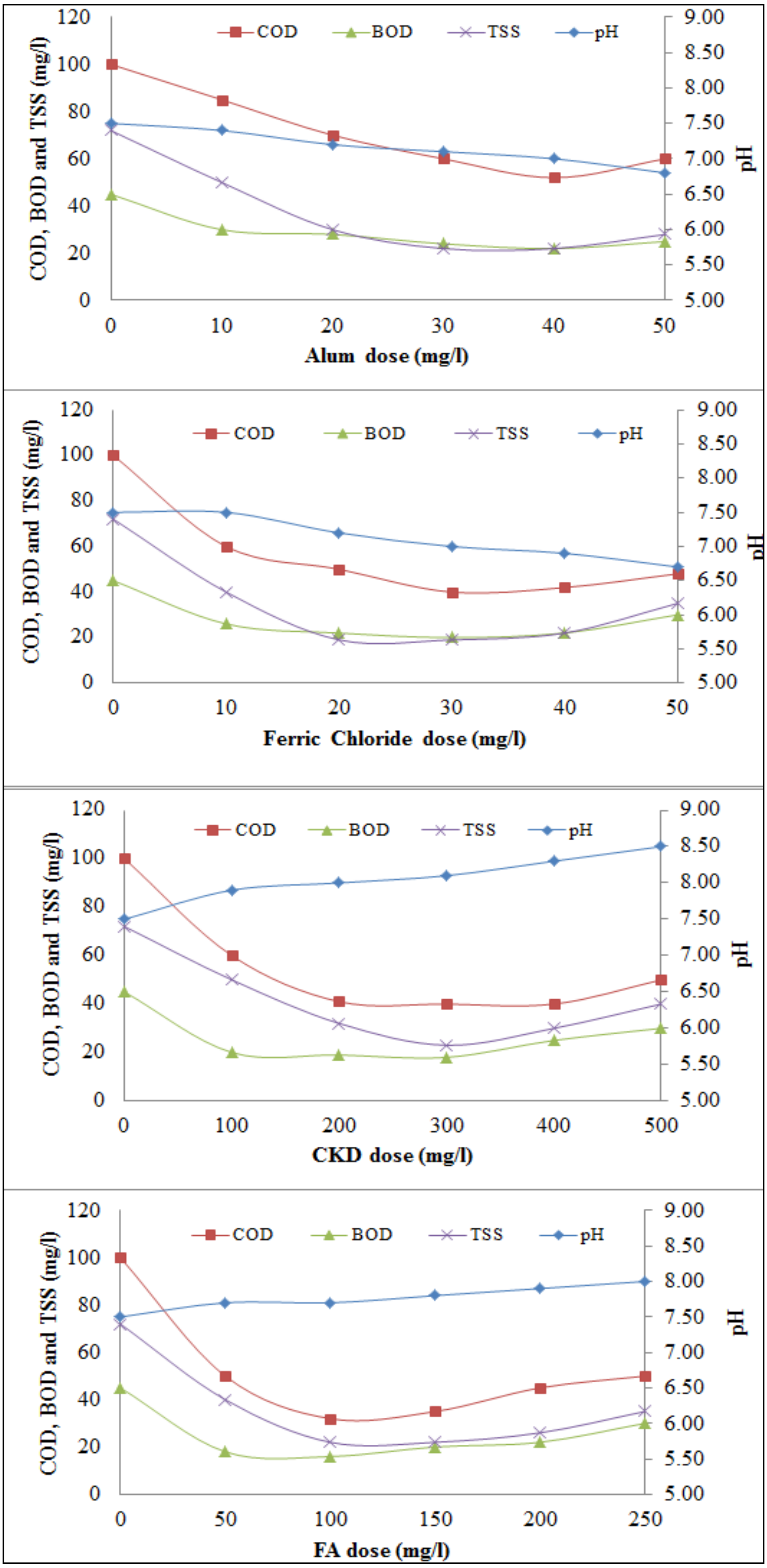

Figure 3. Jar test effluent concentrations for the used coagulants

Table 4. Effect of polyelectrolyte on pollutants removal ratio

Coagulant	Polymer dose (mg/l)	Removal ratio		
		BOD	COD	TSS
Alum 40 mg/l	0	51%	48%	69%
	0.5	56%	52%	83%
	1	60%	58%	90%
Ferric Chloride 20 mg/l	0	51%	50%	74%
	0.5	64%	60%	83%
	1	64%	65%	92%
CKD 300 mg/l	0	60%	60%	68%
	0.5	62%	65%	78%
	1	64%	68%	86%
FA 100 mg/l	0	64%	68%	69%
	0.5	67%	70%	90%
	1	69%	70%	93%

3.4 Technical and economic comparison

Results shows that using of different types of coagulant is effective for reducing of pollutants concentration with the following order FA, Ferric Chloride, CKD and Alum, the cost of FA and CKD could be considered almost 0.01 $/ton (collection and staking), cost of Alum and Ferric Chloride are 250 and 255-300 $/ton respectively [39, 40, 41] while transportation cost per ton for all coagulant will be equal. Regarding simplicity and requirement for skillful works handling and operations related to Alum and Ferric Chloride is more sophisticated than CKD and FA.

The main problem associated with the use of chemicals additives in the treatment process was the increase in the sludge production; Mamais [42] reported an increase in the total suspended solids concentration of approximately 3.3 (gr.SS/gr.Al^{3+}) and 2.0 (gr.SS/gr.Fe^{3+}) added, respectively, while Aboulfotoh [22, 23] reported an increase in sludge production by 1 (gr.SS/gr) of CKA or FA used, Although the required dose of FA is greater than the dose of Alum and Ferric Chloride but the expected sludge production will be close, while CKD will produce the largest amount, it is worth to be mentioned that CKD and FA sludge had a much better dewaterability properties than alum and Ferric Chloride sludge [22, 23]. Table (5) shows order of tested coagulant based on different consideration, according to this comparison the order of the coagulants is FA, Ferric Chloride, CKD and Alum.

Table5. Order of coagulants used based on main consideration

Coagulant	Performance	Cost	Area required for storage	Additional sludge production	Precautions for Handling and storage
Alum	4	4	2	3	2
Ferric Chloride	2	3	1	1	2
CKD	3	2	4	4	1
FA	1	1	3	2	1

Conclusion

Coagulation of Bahr El Baqar drain using Alum, Ferric Chloride, CKD and FA for degrading the organic pollutants proved to be effective for reducing BOD, COD, and TSS as shown in the following points:

- The optimum dose was 40, 30, 300, and 100 mg/l for Alum, Ferric Chloride, CKD and FA respectively.
- FA was the most effective coagulant for the removal of BOD and COD.
- All tested coagulants have almost the same removal ratio for TSS with small superiority for Ferric Chloride.
- Addition of polymer enhanced the performance of all test coagulant and it is recommended to use polymer dose of 0.5 mg/l
- The recommended order of the coagulant is FA, Ferric Chloride, CKD and Alum.

Disclosure statement: *Conflict of Interest:* The authors declare that there are no conflicts of interest. *Compliance with Ethical Standards:* This article does not contain any studies involving human or animal subjects.

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