DRINKING WATER QUALITY REMEDIATION USING A NOVEL OXIDIZING MATERIAL

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ABSTRACT

Drinking water treatment is a vital process to provide consumers with safe and healthy water. Conventional treatment using chlorine and alum as treatment chemicals has many quality problems as chlorine disinfection by-products and residual aluminum, so looking for an alternative for both chlorine and alum is still a main topic for the water researchers. A potential alternative is a ferrate (VI) salt (e.g. potassium ferrate), which is a very strong oxidant; under acidic conditions, the redox potential of ferrate (VI) ions is the strongest among all oxidants/disinfectants used for water and wastewater treatment. In addition, it acts as a coagulant; during the oxidation/disinfection process, ferrate (VI) ions are reduced to Fe (III) ions or ferric hydroxide, and this simultaneously generates a coagulant in a single dosing and mixing unit process. This study represents an attempt to use these properties to remove ammonia from water resources using a single dose of ferrate and hence save energy of chlorine and alum dosing. Potassium ferrate by 30 ppm dose achieves removal of ammonia, turbidity and total coliform by 92.2%, 82.1%, and 99.99% respectively, which is higher than using both alum and chlorine with doses 40 and 80 ppm. Potassium Ferrate was found to achieve (27.3%) reduction in the energy consumption of the mobile water treatment plant and produce water with improved quality than using chlorine/alum. Potassium Ferrate achieves the reduction in the use of slurry discharge pump by about (40%) from using alum and chlorine because Potassium Ferrate produces less slurry by 40 % if compared with alum as a coagulant. THMs formed after treatment with ferrate found to be 70% lesser than that formed when chlorine is used.

Keywords: : Drinking, Water, Quality, Potassium Ferrate, Energy, Coagulant.

1 INTRODUCTION

(CIA WORLD FACTBOOK 2014) Drinking water industry consumes considerable amount about 7% out of 26.91 million kW the total electricity in Egypt (2010 estimated) so saving of some energy in water industry would directly effect on the electricity situation.

(World Bank 2011) Water and sewer tariffs in Egypt are among the lowest tariffs in the world. Despite their affordability, almost half the bills are not paid and politicians are reluctant to increase tariffs, especially since the Arab Spring, thus only a fraction of costs is recovered through revenues from tariffs. The shortfall in revenues is partly made up by government subsidies for investment and operations at the tune of USD 2.5 billion per year, of which only about 10 percent is financed by external donors, the government subsidies shrink to 750 million per year for the past three years this increase the gap between the revenue and expenses.

After the last actions taking by the government to reform the subsides in June 2014 and editing exchange rate of local currency 2016, the prices of heavily subsidized energy products raised up to 200 percent, and so the annual electricity tariff paid by the holding company and its affiliated companies increased by 504 million pounds annually, that put a lot of challenge on the shoulders of the holding company to take all the necessary actions to reduce and save energy.

In general, all water treatment processes aim to remove suspended solids which increase turbidity and cause change in color and odor also to remove pathogens. All drinking water entering a distribution system that has been treated and is otherwise ready for consumption must contain a disinfectant residual that persists throughout the distribution system unless a point of entry treatment approach is used as permitted by the Regulation, The presence of chlorine residual in drinking water indicates that: 1) a sufficient amount of chlorine was added initially to the water to inactivate the bacteria and some viruses that cause diarrheal disease; and, 2) the water is protected from recontamination during storage. The presence of free residual chlorine in drinking water is correlated with the absence of disease-causing organisms, and thus is a measure of the potability of water this could replaced by presence of residual ferrate together with 0.5 mg/L residual chlorine

Chemical dosing in water treatment plant is an important and main step in water treatment industry. The chemical dosing done using pumps to deliver both chlorine (for disinfection) and alum (for coagulation). The dosing pumps, slurry discharge pumps and pumps used to operate and wash the activated carbon filter consume a considerable amount of water treatment plant electricity about (8 %) of the energy needed to operate the treatment plant. Table (1) Shows the distribution and capacities of water treatment plants belongs to Cairo Water Company from the table the average consumption of energy for the production of a cubic meter of drinking water is 400 watt, this cost about 0.3 LE only for electricity this represent (24%) of the real production cost of the cubic meter. The using of alum produce slurry which need finally to be discharged out of the treatment plant which also consume a considerable amount of energy to discharge.

Table 1. Distribution and capacities of water treatment plants belongs to Cairo Water Company.

Plant name	Designed Capicaty (m3/day)	Actual Capicty (m3/day)	Electricity Consumption (Mwh/day)
Rod El Farag	870,000	841,275	77.766
Al Amiria	450,000	463,895	218.16
Mostorod	1,150,000	1,082,354	79.92
Al Roda	144,000	180,813	72.9
Al Fustat	900,000	1,081,037	38.88
Helwan North	350,000	335,817	38.4
Kafr Elelow	80,000	61,840	16.2
Al Tibeen	200,000 filtered+150,000 Calarified for industry	181,571 filtered+85,000 Calarified for industry	250.41
Shoubra El Khema	400,000	400,421	22.98
Al Obour	660,000	611,504	77.76
Al Maady	200,000	156,837	226.8

(Optimization WordPress 2014) Potassium Ferrate is a truly unique compound that offers a friendly and economical impact, alternative to conventional water and wastewater treatment technologies. For many applications, the capital equipment cost and aggregate operating expenses associated with Potassium Ferrate are appreciably less than other methods of treatment.

(Graham, et. al. 2008) Potassium Ferrate synthesis uses commercially available chemicals already found in most water and wastewater treatment plants, and a Potassium Ferrate treatment system utilizes less real estate and consumes less energy. In terms of its impact on the environment, Potassium Ferrate is a genuinely green technology that is both effective and affordable.

In a single application, Potassium Ferrate can simultaneously perform as an oxidant, coagulant, and disinfectant. Potassium Ferrate is more powerful than other oxidants such as ozone and chlorine dioxide. It can replace coagulants such as ferric chloride, alum and polymers for the removal of metals, non-metals and humic acids. It outperforms other disinfectants such as UV, hydrogen peroxide, and chlorine and can kill many chlorine resistant organisms such as aerobic spore-formers and sulphite-reducing clostridia. Potassium Ferrate is a versatile, powerful, multi-use water and wastewater treatment technology this mean the ability to replace both chlorine and alum dosing process by Potassium Ferrate single step dosing to save energy and achieve disinfection by lower dose and limited production of slurry.

Chemical dosing in water treatment plant is an important and an essential step in water treatment industry. The dosing pumps consume a considerable amount of water treatment plant energy about (8 %) of the energy needed to operate the treatment plant.

In a single application, Potassium Ferrate can simultaneously perform as an oxidant, coagulant, and disinfectant. Potassium Ferrate is more powerful than other oxidants such as ozone and chlorine dioxide. It can replace coagulants such as ferric chloride, alum and polymers for the removal of metals, non-metals and humic acids. It outperforms other disinfectants such as UV, hydrogen peroxide, and chlorine; it can kill many chlorine resistant organisms such as aerobic spore-formers and sulphite-reducing clostridia.

Potassium Ferrate is a multi-function chemical reagent has the potential to perform oxidation, coagulation, and disinfection in one single treatment step.

No single unit process is currently available which can successfully and efficiently achieve the regulatory requirements and consequently a combination of processes is required. Therefore, the aims of this paper are: Saving the dosing energy used for both alum and chlorine by using a novel multifunctional green coagulant Potassium Ferrate. Saving energy of slurry discharge (potassium Potassium Ferrate produce low slurry). Saving the cost by using low and effective dose of Potassium Ferrate instead of using (chlorine/alum). Eliminating the risk of producing hazardous chemical byproducts. Lowering capital, running costs, and less management are required, comparing with the conventional two-unit system using disinfectant and coagulant separately.

2 APPROACH

Our practices were done on both lab and pilot scale by using a mobile water treatment pilot plant from Alexandria Company for water. This pilot plant allows the using of the same treatment steps by the same sequence in conventional treatment with ability to change the raw water source. A survey was done through Rossita Branch to detect the critical and most polluted point to undertake the experimental work on it. Jar test was conducted in bench scale to detect the optimum dose of Potassium Ferrate used to achieve both chemical and microbiological treatment. The superior performance of Potassium Ferrate (VI) was demonstrated via comparison between using Potassium Ferrate only instead of both alum and chlorine through many experiments. The practical aspect of many of them was to demonstrate the feasibility of the online generation and application of Potassium Ferrate (VI) for water treatment, which could lead to the implementation of Potassium Ferrate (VI) technology in water and wastewater treatment practice.

3 RESULTS AND DISCUSSIONS

3.1 A Survey on Rossita Branch

The area of this study extended about 200 km in Rosetta branch, starting from El Ikhsas village up to Edfina barrage, and about 40 km in EL Mahmudiya Canal with starting from El Suif WTP to El Attaf village 14 sites were chosen. Samples were collected from the middle of the waterway in each of the Rosetta branch and EL Mahmudiya Canal. Samples were collected at a sample rate of 5 kilometers with a total 48 sample. As shown in Figure (1).

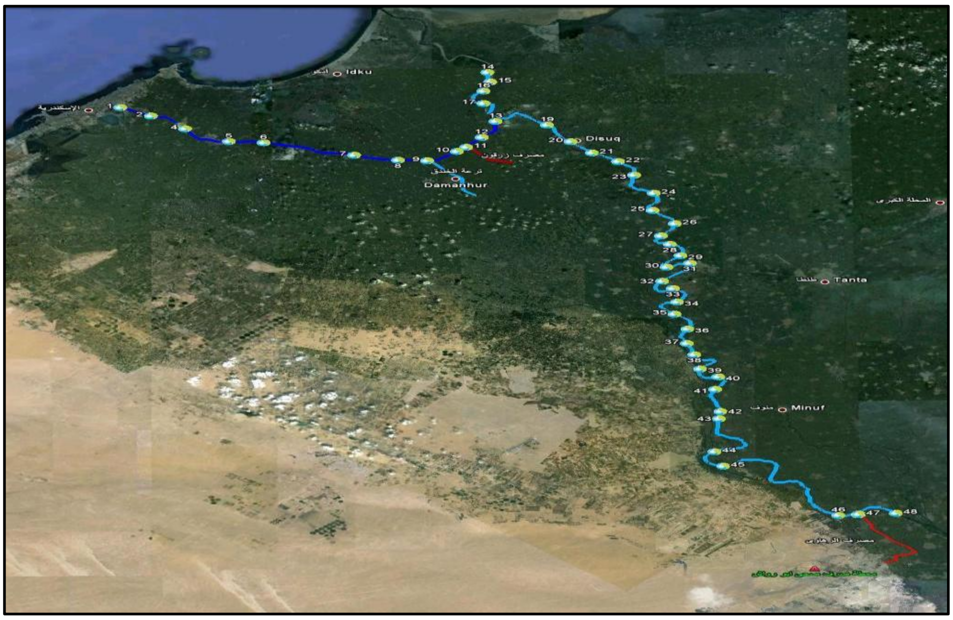

Figure 1. The sampling points on EL Mahmudiya canal.

Physical and chemical analyses were carried out according to "Standard Methods for Examination of Water and Wastewater". Field parameters (temperature, pH, electric conductivity (EC), dissolved oxygen (DO) and total dissolved solids (TDS) were measured in-site using multi-probe system. ammonia, nitrite and nitrate were carried out by a colorimetric method and the chloride done by argenometeric method. The following table (2) shows the results of Physical and chemical analyses of the water of 14 sites from EL Mahmudiya canal.

Table 2. Results of physical & chemical analyses of water samples collected from EL Mahmudiya Canal.

No.	Position	pH	Turbidity NTU	Cond. Ms / cm	TDS mg / L	DO mg / L	Ammonia mg / L	Nitrite mg / L	Nitrate mg / L	chloride mg / L	Temp. oC
Standards and limits for discharges on water bodies		7-8.5				more than 5	less than 0.5		less than 45		ordinary
1	El Suif Intake	7.35	13.7	679	339.5	4.14	2.96	0.446	1.2	60	19.9
2	Khorshed	7.2	6.12	669	334.5	3.31	3.74	0.463	1.1	65	21

3	Khadra village	7.3	5.9	651	325.5	3.47	3.97	0.408	0.98	66	21.4
4	kafer eldawar 2 intake	7.43	7.17	666	333	3.73	3.96	0.407	0.96	67	21.2
5	Kafr al dawar 1 intake	7.47	8.27	676	338	4.4	3.97	0.396	0.95	68	21.7
6	EL Suif WTP	7.55	8.42	682	341	3.54	5.43	0.265	0.83	65	20.3
7	Abo Homos WTP	7.56	8.72	679	339.5	4.02	4.3	0.227	0.78	65	19.5
8	Hamdy basha village	7.67	11.8	666	333	4.8	5.13	0.2	0.68	66	20.1
9	Khandak canal	7.57	9.59	470	235	7.56	1.23	0.088	0.59	65	17.2
10	after Zarkon drian by 5 km	7.63	10.9	813	406.5	4.26	6.79	0.167	0.65	66	17.5
11	Zarkon	7.63	9.63	820	410	5.18	7.91	0.173	0.75	67	18.8
12	Fisha WTP	7.63	8.25	817	408.5	4.81	6.62	0.157	0.67	70	17.2
13	Attef village	7.66	7.15	812	406	4.67	7.87	0.188	0.52	71	16.4
14	Edfina Aqueduct	7.4	4.85	793	396.5	4.35	2.8	0.45	2.03	84	16.6

From Table (2), the results show that the level of ammonia in EL Mahmudiya Canal is a maximum at Attef village = 7.87 ppm after Zarkon drain. Which main that the drain has a large effect on EL

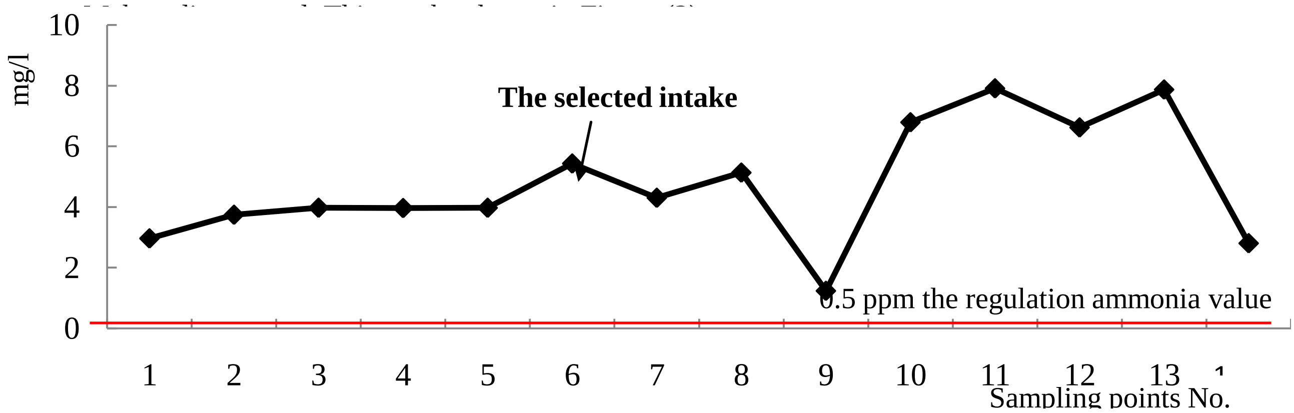

Figure 2. Level of ammonia a long EL Mahmudiya canal.

The survey results demonstrate that the ammonia level at EL Mahmudiya canal is around 5 ppm with high concentration of both nitrate and nitrite, this will lead to using of a higher doses of chlorine around 60 ppm in order to reach the break point, and so a higher energy consumption up to 600% of the regular chlorine dose <10 ppm.

3.2 Jar test using Potassium Ferrate

The selected raw water from EL Mahmudiya canal was then distributed into 6 beakers to conduct jar test on it, in order to select the optimum Potassium Ferrate dose (which achieve removal of ammonia and pathogens). The used Potassium Ferrate was prepared in the lab using Wet method for preparation using the following chemicals (ferric chloride, sodium hydroxide and potassium permanganate from Merck Co.). Tests were carried out using 1000 mL samples. After flash mixing began the Potassium Ferrate (VI) doses were added. The presence of Potassium Ferrate in the samples was tested using potassium iodide (KI). Once the Potassium Ferrate had reacted in the fast mixing step for 1 minute, the mixing speed was then reduced to allow coagulation for about 20 minutes, and finally sedimentation of flocs for 6 minutes. Samples were then tested for the following parameter (ammonia, turbidity and total bacterial count). By the same way the selected raw water from EL Mahmudiya canal was then distributed into 6 beakers to conduct jar test using chlorine as disinfectant and alum as coagulant. Tests were carried out using 1000 mL samples. After flash mixing began the chlorine/alum doses were added, the mixing speed was then reduced to allow coagulation, and finally sedimentation of flocs. Samples were then tested for the following parameter (ammonia, turbidity and Total bacterial count). The following figure (3) shows a comparison between the optimum dose of Potassium Ferrate and different doses of both (Chlorine/Alum).

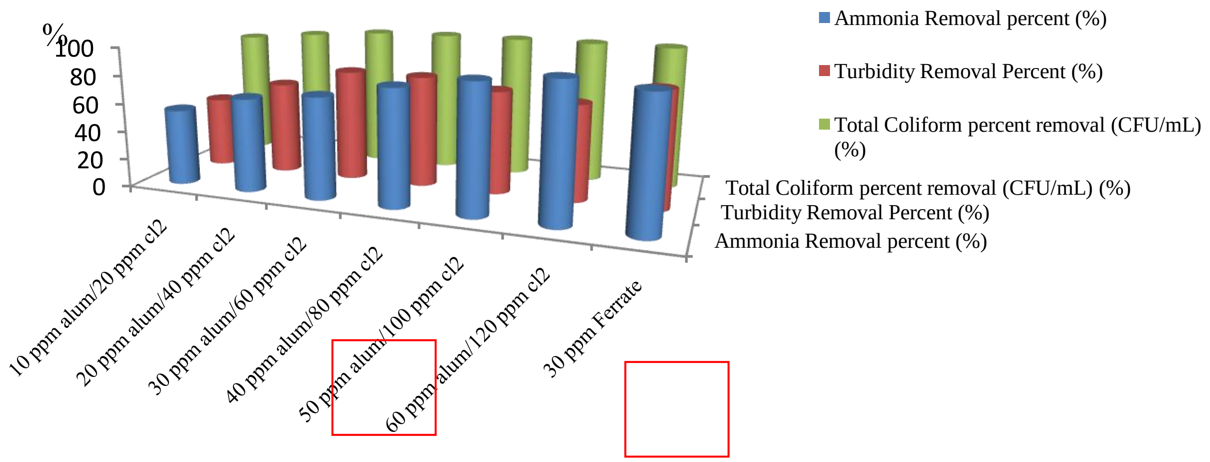

Figure 3. A comparison between the optimum dose of Potassium Ferrate and different doses of both (Chlorine/Alum).

It's obvious from the figure that Potassium Ferrate by 30 ppm dose achieves removal of ammonia, turbidity and total coliform by 92.2%, 82.1% and 99.99% respectively which is higher than using of both alum and chlorine with doses 40 and 80 ppm. The produced slurry from Potassium Ferrate was found to be 10 ml which is less than the volume of slurry produced when (chlorine/alum) was used = 16 ml. From the bench scale results it is clear that using of Potassium Ferrate will save energy by replacing both alum and chlorine pumps by only one dosing pump for delivering Potassium Ferrate. Also, from the amount of slurry results the using of Potassium Ferrate will save energy used to discharge the slurry because Potassium Ferrate produce less slurry by 40 % from using alum as a coagulant.

3.3 Mobile Pilot Application

The mobile pilot water treatment plant is a pilot system that contains all treatment steps in the same train as in the large scale, which allows the simulation for the treatment plant and allows making experiments in the level of a small scale as in the water treatment plant. Pilot units are used in feasibility studies. They enable the acquisition of data to confirm the viability of the process, the projected operational costs and the full scale design parameters.

The mobile pilot water treatment plant contains the following components as shown in the following flow diagram. See figure (4).

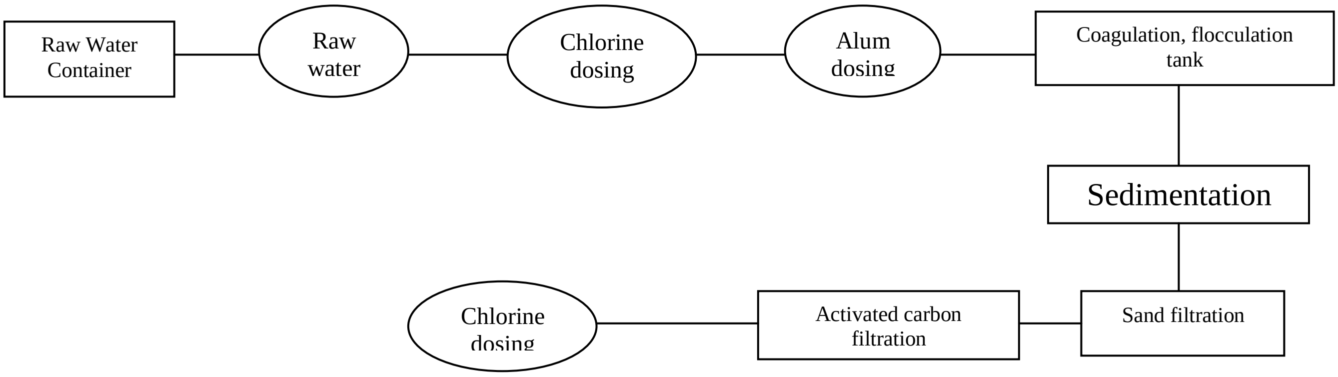

Figure 4. Mobile pilot water treatment plant flow diagram.

Using of Potassium Ferrate allows producing of water by improved quality and with only addition of Potassium Ferrate instead of the following three steps chlorine dosing, alum dosing and activated carbon as shown in the following figure (5).

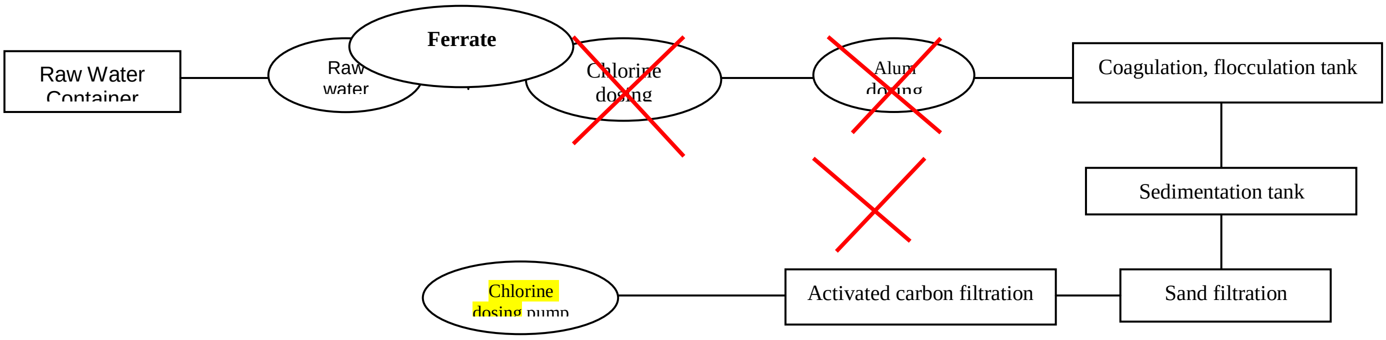

Figure 5. Mobile water treatment plant in case of using Potassium Ferrate.

Using of Potassium Ferrate achieved saving in energy by total (27.3%) from the total energy required for operating the pilot plant, this is by saving the energy of alum, chlorine dosing pump and also saving the energy of activated carbon filter backwash pump. Potassium Ferrate achieve reduction in use of slurry discharge pump by about (40%) from using alum and chlorine because Potassium Ferrate produce less slurry by 40 % from using alum as a coagulant. To protect the water from contamination in the networks about 0.4 mg/L residual chliorine is maintain in the distrubited water together with the present residualferrate.

4 CONCLUSIONS

Potassium Ferrate is a multi-function chemical reagent has the potential to perform oxidation, coagulation, and disinfection in one single treatment step. A survey along Rossita branch (from River Nile) was done to detect the most polluted site (hot spot), in order to carry out the experimental work on it. This point was at EL Suif water treatment plant intake in EL Mahmudiya canal.

The experimental work was done first in bench scale using jar test to select the optimum Potassium Ferrate dose to compare the gained results with the results of using both (chlorine/alum), the result shows that Potassium Ferrate prove itself as a possible alternative of both (chlorine/alum) because a lower dose of Potassium Ferrate (30 ppm) achieve improved water quality if compared with traditional treatment using chlorine and alum, Potassium Ferrate achieve removal of ammonia, turbidity and total coliform by 92.2%, 82.1% and 99.99% respectively which is higher than using of both alum and chlorine with doses 40 and 80 ppm. The produced slurry from Potassium Ferrate was found to be 10 ml which is less than the volume of slurry produced when (chlorine/alum) was used = 16 ml. Additional experimental work was done in a mobile water treatment plant and the energy consumption was compared incase of using Potassium Ferrate and chlorine/alum the Potassium Ferrate was found to achieve (27.3%) reduction in the energy consumption of the mobile water treatment plant and produce water with improved quality than using chlorine/alum. Potassium Ferrate achieve reduction in use of slurry discharge pump by about (40%) from using alum and chlorine because Potassium Ferrate produce less slurry by 40 % if compared with alum as a coagulant.

RECOMMENDATION

- Using of Potassium Ferrate as a multifunction green coagulant instead of both chlorine/alum to save the energy required for dosing.
- Making further attempts to use Potassium Ferrate on large scale.
- More work should be done to produce Potassium Ferrate on site to save the cost of chemical transportation and storage.

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