"Effect of chlorination and coagulation materials in water from decanted wastewater on drinking water quality in Badr City"

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Abstract

Drinking water and industries wastewater treatment is supposed to be one of the most important sources of soluble aluminum and algae in environment. Therefore, selected treatments and cost-efficient techniques should be developed to control the spread of pollution into the environment. In the same time, wastewater reuse must be considered as a part of a general integrated water resource management plan in places that face water scarcity. In this view, experiments were conducted in which the removal of soluble aluminum and algae, from water was monitored. The data showed that as the coagulant dose increased the turbidity was sharply decreased and by using 50 mg/l of alum sulfate dose gave suitable turbidity for all mixing ratio 3-15%. In addition, the data showed that, the use of 50 mg/l of alum sulfate dose is the most suitable concentration to give the lowest level of alum after and algal count with mixing ratio of 5-7%.

Keywords: wastewater recycle; turbidity; Alum; algae; drinking water.

1. Introduction

Water treatment plants are constructed in order to remove turbid and organic compounds in an efficient way by coagulation and by filtration. Water treatment plants produce many wastewaters resulted from its operations (clarifier sediments and filter backwashing). In the same time, water scarcity and deterioration in the quality of water resources in many countries have led to the recognition that water shortage and water pollution control should be solved by a careful water resource management that incorporates advanced technologies (Brenner et al., 2000).

Wastewater (WW) is considered the most important pollutant in drinking water industry, not only because of its high aluminum load, but also for the volume...
generated. The amount of WW produced is related to the productivity of treated water (20%). This productivity is also related to the type of water processed. The release of untreated WW into the environment, particularly without treatment, is a major threat to public health. Hence, indirect reuse of wastewater has been practiced for centuries around the globe. Planned reuse of this resource has been documented as early as the 16th century in Europe (Gabriel, 2011). Wastewater treatment can produce new water resources for various uses and prevent water pollution and health hazards. While pollution prevention is a global necessity, the use of treated wastewater as a new water resource is a management issue particular to semi-arid countries due to the increasing water shortages (Hassouna et al., 1994; Mousa et al., 2007).

Coagulation and flocculation remain the most important steps in water treatment, allowing the removal of particles and natural organic matter (Xu et al., 2012). The research to increase coagulation–flocculation efficiency also focuses on the improvement of operation parameters, such as dosing method, dosing time and shear force applied. Recently, Yu et al. found that two-stage coagulant addition of alum could enhance floc re-growth after breakage due to freshly precipitated aluminum hydroxide [Yu et al., 2010a&b]. The result was meaningful because it overcame the disadvantage of irreversible breakage of flocs, which has been be confirmed by many previous researches (McCurdy et al., 2004, Yukselen and Gregory, 2002, Hermawan et al., 2004).

The general objective of this paper was the study the effect of wastewater reuse on the quality of drinking water intake. For study wastewater mixing purpose, Jar test experiments were designed to identify the wastewater mixing effect on water intake characters. The goal was to investigate the occurrence of initial concentration of aluminum in the wastewater and intake water samples and the effect of different wastewater mixing ratio and aluminum sulfate coagulant addition with respect to the removals of aluminum, turbidity, alkalinity and algae. Finally, aluminum removal as a function of the water reuse efficiency was investigated.

2. Materials and Methods
2.1. Sampling of water and wastewater:

The water sample was collected in accordance with World Health Organization guidelines (WHO, 1997). Weakly grab water samples were taken from resource of Badr Water treatment plant, El-Behera Water Company, Egypt. The El-Rayah El-Nassery works as water resources at the point located in 69km away from mouse point. Raw water samples were collected under the surface where
care was taken not to disturb the bottom of water source or along the canal side. The samples were collected from January 2011 to December 2011. For reuse of wastewater, samples were collected from the surface of wastewater collecting tank (10X16X6 m (WxLxD)) that received its wastewater from drinking water treatment plant clarifiers and filter backwashing process. These samples were designed as decanted wastewater (DWW) and collected during 6 months from January 2012 to June 2012.

2.2. Physical and chemical analyses of water resource samples:

The quality of resource water samples was determined after some measurements such as pH (2510 platinum electrode), turbidity as Nephelometric turbidity units (NTU) (2130), chloride (mg/l) (4500 Argentometric method), total alkalinity(mg/l) (2320B titration method), total Hardness (mg/l) (2340B EDTA titration), silicate (mg/l) (4500C Molybdosilicate method), phosphate(mg/l) (4500D Stannous chloride method), sulfate (mg/l) (4500E Turbidimetric method). Nitrogen forms as free ammonia (mg/l) (4500C Sodium Nitroprussiude method), and Nitrite (4500B colorimetric method) were measured. All the physicochemical analyses were in duplicates and determined by the procedures recommended in the standard methods for the examination of water and wastewater (APHA, 2005).

2.3. Water algae analysis:

One liter sample in dark brown glass was concentrated by centrifugation at 1000 rpm for 20 minutes. The settled sample concentrate was agitated and the sub-sample was withdrawn with a one ml accurately calibrated pipette. A counting cell (Sedgwick Rafter) was used under microscope supplied with video camera (Sony, Japan). The calculation of water sample algae was done according to APHA (2005).

Calculation: \( \text{No/ml} = \frac{C \times 1000 \, \text{mm}^3}{A \times D \times F} \)

Where: \( C \)= number of organisms counted,
\( A \)= area of field (Whipple grid image area), mm2,
\( D \)= depth of a field (Sedgwick- Rafter cell depth), mm.,
\( F \)= number of fields counted.

2.4. Examination the effects of wastewater mixing ratio on raw water:

Recycled solution (RS) was prepared from raw water (Badr water treatment plant) and DWW by different concentrations as 3, 5, 7, 10 and 15% (v/v of DWW/raw water). The Jar test was used for examination the coagulant effects on the RS. The optimum dose point of coagulants from 10, 20, 30, 40, 50 and 60 mg/l alum sulfate was run with different RS ratio. Turbidity, total alkalinity, pH, aluminum, algal count was measured for different recycled solutions before and
after the treatment with alum sulfate as a coagulant following the method of Mousa et al. (2012).

The Alum sulfate (AS) coagulant used in bench-scale tests were reagent grade. AS was produced by a local factory and contained 17% Al₂O₃. These materials are now used in water treatment industries of Egypt. In the present study, the coagulation process was optimized mainly with regard to coagulant dosage and turbidity removal efficiency. To determine the optimum coagulant dosage for turbidity removal, jar tests were conducted using dosages from 30 to 80mg/L. Concentrated alum solution (Al₂(SO₄)₃), was added to double distilled water (1g per 100 ml) and thoroughly mixed. This diluted solution could then be used to accurately dose water samples. For example, to achieve a 30 mg/l dose, 20.8 ml of this solution would need to be added to a 1000 ml water sample (Pritchard et al., 2010).

2.5. Jar test and water recycling protocol:

Alum is normally used to treat turbid river water. One liter of RS with different ratio of DWW was placed into 6 beakers provided with the apparatus (JLT6, Leaching test Jar test, VELP SCIENTIFICA, EUROPE, Italy). One ml of chlorine was added to each 1000 ml beaker different dosage of alum sulfate (10, 20, 30, 40, 50 and 60 ml as coagulant solution for each beaker were added under set speed at 150-200 rpm and, rapid mix was run for 30-60 second. After the (rapid mixing) step, the mixing speed was adjusted to about 40 rpm and flocculated for 20 minutes. After the flocculation period, the paddles were removed and allowed solids to settle for 30 minutes. A limited amount of samples were taken from 6 beakers for make analyses (Turbidity-pH- total alkalinity-aluminum and algae). The optimum alum doses were determined for both experiments (with and without DWW mixing).

3. Results and Discussion

The annual intake water characterization survey results were mentioned in Table (1). The results expressed in the form of annual averages, winter and summer values for duration of January 2011 to December 2011. The differences between summer and winter seasons were shown on the bases of different parameters. Turbidity, chloride, total alkalinity, total hardness, nitrite, ammonia and total silicate of winter season recorded more than summer season. Our previous data showed that the water level in canal was lower in winter season that lead to increase
in salts concentrations. In the same time, Badr drinking water treatment plant practices to use 60 mg/l to 80 mg/l of alum sulfate as coagulant.

Table (1) physicochemical analyses and algal indicators of Badr drinking water treatment intake water through January 2011 to December 2011.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Annual average</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.75</td>
<td>7.73</td>
<td>7.77</td>
</tr>
<tr>
<td>Turbidity</td>
<td>3.7</td>
<td>4.1</td>
<td>3.4</td>
</tr>
<tr>
<td>Chloride</td>
<td>26</td>
<td>27</td>
<td>25</td>
</tr>
<tr>
<td>Total alkalinity</td>
<td>144</td>
<td>146</td>
<td>140</td>
</tr>
<tr>
<td>Total hardness</td>
<td>154</td>
<td>158</td>
<td>150</td>
</tr>
<tr>
<td>Calcium hardness</td>
<td>85</td>
<td>87</td>
<td>82</td>
</tr>
<tr>
<td>Phosphate</td>
<td>0.24</td>
<td>0.22</td>
<td>0.26</td>
</tr>
<tr>
<td>Sulfate</td>
<td>40.27</td>
<td>40.33</td>
<td>40.21</td>
</tr>
<tr>
<td>Nitrite</td>
<td>0.1</td>
<td>0.12</td>
<td>0.09</td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.11</td>
<td>0.12</td>
<td>0.10</td>
</tr>
<tr>
<td>Total silicate</td>
<td>3.1</td>
<td>3.40</td>
<td>2.80</td>
</tr>
<tr>
<td>Iron</td>
<td>0.194</td>
<td>0.19</td>
<td>0.20</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.08</td>
<td>0.06</td>
<td>0.09</td>
</tr>
<tr>
<td>Total algae</td>
<td>2150</td>
<td>2050</td>
<td>2300</td>
</tr>
</tbody>
</table>

3.1. Effect of wastewater mixing intensity

Table (2) describes the effect of mixing ratio of decanted wastewater samples (DWW) on the intake water obtained from the Badr water treatment plant. Since the Badr water treatment plant wastewater had a high level of residual aluminum, it is important to investigate the effect of aluminum on the mixing formation. Fig. 5 shows the presence of aluminum in the wastewater samples at the applied different mixing ratio (3%, 5%, 7%, 10% 15% and 100%), which was represented by mg/l values.

Key parameters of DWW show a residual aluminum in the range 0.9–0.60 mg/l and an algal count in the interval 2202–6732 count/l. Comparing the aluminum load of water resources with aluminum load of DWW, we can conclude that the load is equivalent to the pollution load of one ten to twenty times the volume of common water resources (Metcalf and Eddy, 2003). Because the wastewater is decanting and including residual coagulant, DWW showed low levels of a turbidity degrees and an algal count.
Table (2) the characterization of resulted water of mixing different concentration of DWW (3%, 5%, 7%, 10% and 15%) with raw water.

<table>
<thead>
<tr>
<th>% of DWW mix (RS)</th>
<th>Alkalinity</th>
<th>pH</th>
<th>Turbidity</th>
<th>Residual alum</th>
<th>Algal count</th>
</tr>
</thead>
<tbody>
<tr>
<td>3%</td>
<td>140</td>
<td>8.43</td>
<td>4.0</td>
<td>0.014</td>
<td>2700</td>
</tr>
<tr>
<td>5%</td>
<td>140</td>
<td>8.28</td>
<td>4.5</td>
<td>0.021</td>
<td>2500</td>
</tr>
<tr>
<td>7%</td>
<td>140</td>
<td>8.20</td>
<td>4.7</td>
<td>0.028</td>
<td>2400</td>
</tr>
<tr>
<td>10%</td>
<td>140</td>
<td>8.15</td>
<td>5.0</td>
<td>0.043</td>
<td>2300</td>
</tr>
<tr>
<td>15%</td>
<td>130</td>
<td>8.15</td>
<td>5.5</td>
<td>0.059</td>
<td>2200</td>
</tr>
<tr>
<td>100% DWW</td>
<td>100</td>
<td>8.10</td>
<td>5.7</td>
<td>0.40</td>
<td>2200</td>
</tr>
<tr>
<td>Raw water</td>
<td>140</td>
<td>7.75</td>
<td>3.7</td>
<td>0.01</td>
<td>2150</td>
</tr>
</tbody>
</table>

3.2. Effect of alum concentrations on water characterization after mixing different concentration of wastewater to raw water:

Jar tests are used in water treatment plants to determine the optimum dose of a coagulant which was alum sulfate. Results of the test are dependent on current raw water Turbidity, which may vary day-to-day. For pH parameter, the addition of different concentrations of alum sulfate doses on the 3%, 5%, 7%, 10% and 15% mixing ratio of DWW to raw water, it was found that as alum sulfate doses increased pH decreased. The pH was decreased from 8.43 (without alum dose) to 7.81 after addition of 60 mg/l of alum sulfate. Also, the data indicated that the all alum sulfate doses had gradually decreases effect on pH and all were suitable to obtain the favorite pH for different mixing ratio of wastewater as shown in Fig. 1.
Figure (1) pH Effect of different concentration alum sulfate doses addition to the different mixing ratio of wastewater and raw water.

Upon addition of different concentrations of alum sulfate doses on the different mixing ratio of DWW to raw water, it was found that as alum sulfate doses increased the alkalinity decreased. The alkalinity was decreased from 140 mg/l (without alum dose) to 126 mg/l after addition up to 60 mg/l of alum sulfate. The data indicated that the 50 mg/l of alum sulfate is the most suitable dose to obtain the favorite alkalinity reduction for the most mixing ratio of wastewater as shown in Fig. 2. But for the 15% mixing ratio, the 30mg/l coagulant was the most suitable dose to get required results.

![Figure 2](image)

**Figure (2) Total Alkalinity (mg/l) effect of different concentration alum sulfate doses addition to the different mixing ratio of wastewater and raw water.**

For the different concentrations of coagulant doses on different mixing ratio of DWW to raw water, it was found that as coagulant doses increased the turbidity decreased as shown in Fig.3. The turbidity was decreased from 5 NUT (without alum dose) to 1NUT after addition of 50 mg/l of alum sulfate. At concentration of coagulant of 30mg/l, the data indicated that there were gradual decreases in turbidity degree for different mixing ratio. Upon addition of 50 mg/l of alum sulfate is the most suitable dose to obtain the lowest water turbidity for mixing ratio of wastewater recycling.
Figure (3) Turbidity (NTU) effect of different concentration alum sulfate doses addition to the different mixing ratio of wastewater and raw water.

For the point of view of residual aluminum and upon addition of different concentrations of alum sulfate doses on the mixing water, it was found that as alum sulfate doses increased the residual alum concentration increased. Residual alum concentration was increased from 0.059 mg/l (without alum dose) to 0.371 mg/l after addition of 30 mg/l of alum sulfate. After that the alum concentration decreased to an average 0.198 mg/l with 60 mg/l alum sulfate dose addition. The data indicated that the 50 mg/l of alum sulfate is the most suitable dose to obtain the lowest levels of residual alum concentration for different mixing ratio of DWW and was shown in Fig. 4.
Upon addition of different concentrations of alum sulfate doses on various mixing ratio of DWW, it was found that as alum sulfate doses increased the algal count decreased. The algal count was decreased from 2500 unit/l (without alum dose) to 600 Unit/l after addition of 60 mg/l of alum sulfate. The data indicated that the 50, mg/l of alum sulfate was the most suitable dose to obtain the favorite algal count reduction for different mixing ratio as shown in Fig. 5.
Figure (5) Total algal count (unit/l) effect of different concentration alum sulfate doses addition to the different mixing ratio of wastewater and raw water.

Water reuse must be considered as a part of a general integrated water resource management plan (Mousa and Abdel-Rahman, 2016). A sustainable approach for water management is recognized its multidimensional character (Thomas and Durham, 2003). In order to ensure safe reuse, the study of the potential reuse of wastewater should consider all chemical, geological, geochemical, environmental, and public health parameters. The basic consideration in the search for potential applications for the proposed safe reuse of wastewater from treatment plants is prevention of their disposal into aquatic receptors (drainages, the sea), for environmental reasons (Kalavrouziotis and Apostolopoulos, 2007). So, further research at more environmentally relevant concentrations is needed.

4. Conclusions

Water reuse must be considered as a part of a general integrated water resource management plan. This study has been focused on the reusing of DWW to eliminate it is adverse effects on environment and water management to enhance the water resources. Both aluminum and algae was the most variables indicator in the process. The obtained results provide information to improve the practical application of alum sulfate coagulant in the wastewater recycle. Considering the water treatment reuse of its wastewater, the present study gave feasible information of the mixing ratio effect on the quality of intake water in order to obtain new water resources of raw water in Badr City plant for drinking water treatment. So, the reusing of the
DWW will lead to maximization of the raw water resources, saving in water treatment coast as it is contain residue of aluminum sulfate and chlorine. Another advantage of reusing DWW is to eliminate the adverse effects on environment.

The mixing effect was aimed to improve the algal count in the obtained solution, which induced the potential of flocculation/coagulation processes and growth of flocculants. The resulting removal of total alkalinity and turbidity content was effectively enhanced in this process. Jar tests are used in water treatment plants to determine the optimum dose of a coagulant which was alum sulfate. Results obtained from the tests are dependent on current raw water turbidity, which may vary day-to-day.

For alkalinity, it was found that the alkalinity decreased from 140 mg/l to 126 mg/l, with alum sulfate dose 50 mg/l for all mixing ratio (3-10 %) of DWW. Regarding the pH parameter, the data indicated that as alum sulfate increased the pH deceased, the pH was decreased from 8.31(with out alum sulfate dose) to 7.8 with high level of alum sulfate dose (60 mg/l). The effect of alum sulfate dose on the turbidity was studied. The data showed that as the coagulant dose increased the turbidity was sharply decreased and by using 50 mg/l of alum sulfate dose gave suitable turbidity for all mixing ratio 3-15%.

The residual aluminum in drinking water depends on the type of coagulant used. The data showed that, the use of 50 mg/l of alum sulfate dose is the most suitable concentration to give the lowest level of alum after mixing ratio of 5-7 %. For algae count, the data indicate that using of 50 mg/l of alum sulfate dose is the most suitable concentration to give the favorite algae count reduction for all mixing ratio (3-15 %).

In conclusion, the DWW can be used as anew water resource by recycling it on the raw water with different mixing ratio up to 15 %, the limiting factor of mixing ratio is residual aluminum in drinking water, the data showed that the mixing ratio of 5-7 % is suitable ratio to mix the DWW to raw water as all parameters below the Egyptian guidelines and WHO limits, and can be used stably as drinking water. The high mixing ratio of 10-15 % leads to increase the residual aluminum in drinking
water to be more than the recommended concentration (0.2 mg/l) in Egyptian guidelines and WHO limits.

References


