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Effect of coagulation dose on direct filtration performance

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الملخص

المياه قليلة العكارة واحدة من أصعب نوعيات المياه التى يمكن معالجتها. في مصر ، مستوى التعكر وخصوصا عند السد العالي منخفض للغاية. يمكن أن يؤدي استخدام عملية الترشيح التقليدية لمعالجة المياه منخفضة التعكر إلى استهلاك معدلات مرتفعة من المواد الكيميائية ، وتكون المساحة المطلوبة كبيرة ، وارتفاع تكاليف الإنشاء وتكاليف الصيانة والتشغيل. الهدف من هذه الدراسة دراسة تأثير جرعة الشبه على أداء الترشيح المباشر حيث يتم استخدام الجرعات 0 و 10 و 15 ملجم/لتر عند مياه ذات مستويات تعكر مختلفة 5 و 10 و NTU 15. وكانت ظروف التشغيل الأخرى: - معدل الترشيح 150 مترمكعب/مترالمربع/اليوم ، حجم الفعال لوسط الترشيح 0.83 مم وعمق الوسط 75 سم. وأظهرت النتائج أن الجرعة المثلى من الشبة لمعالجة المياه ذات عكارة أقل من NTU 15 باستخدام نظام الترشيح المباشر هي 10 ملجم / لتر ،وأن زيادة جرعة الشبة تزيد بشكل كبير من الفواقد وتقلل إنتاجية المرشح. الترشيح المباشر هو عملية ممكنة لمعالجة المياه الخام منخفضة التعكر.

Abstract

Low turbidity water is one of the most difficult water to be coagulated. In Egypt the turbidity level downstream the high dam is very low. Using conventional filtration process for treatment of low turbidity water could results in high chemical consumption, larger required area, high capital cost and high operational costs. The objective of this study is to investigate the effect of alum dose on the direct filtration performance for different raw water turbidity. Alum doses of 0, 10 and 15 mg/l were studied for raw water turbidity of 5, 10 and 15 NTU. Other operating conditions were: - filtration rate 150 m^3/m^2/day, effective media size 0.83 mm and depth 75 cm. The optimum alum dose for treatment of low turbidity water of less than 15 NTU using direct filtration system is 10 mg/l. Increase of alum dose significantly increase the head loss and decrease the filter productivity. Direct filtration is a potential process for treatment of low turbidity raw water.

Key words: direct filtration, alum dose, turbidity.

Introduction

In Egypt the turbidity level downstream the high dam is very low with concentration typically of less than10 NTU. Using conventional filtration process for treatment water has low turbidity levels, could results in high chemical consumption, large required foot print and high capital & operation costs. Therefore direct filtration could be a suitable treatment system for low turbidity water. Direct filtration is normally suitable for treating water with a turbidity of less than 15 NTU (D. Hand et al, 2012). According to Edzwald et al, 1987, direct filtration system is suitable for raw water that have turbidity of less than 20 NTU and the color levels less than 30 unit with a small percentage of algae.

Direct filtration system comprises of rapid mixing, flocculation, filtration and disinfection unit (M. Fouad et al, 2005). Flocculation unit could be eliminated from the system (Degrémont, 1989). Coagulation process is very important steps in the direct filtration process. It required for destabilization of colloids by adding coagulant (Hutchison and Foley, 1974; Habibian and O'Melia, 1975). In order to destabilize the colloids, there are many chemicals are used in water purification. These coagulants could be used as primary coagulant, coagulant aid or filtration aid (McCormick and King, 1982). Aluminum salts, iron salts, and cationic polymers are commonly used in direct filtration system (McCormick and King, 1982). Zhang et al, 2012 reported that direct filtration with low coagulation dose was very effective system for low turbidity water. Polyaluminum Chloride (PACL) is reported to be more effective for direct filtration process than alum (A. Zouboulis et al, 2011). The objective of this study is to investigate the effect of alum dose on the direct filtration performance for different raw water turbidity.

Materials and methods

All experiments were conducted in the Hydraulics laboratory at the Faculty of Engineering, Al-Azhar University. A synthetic water was prepared by using kaolin clay (aluminum silicate $AL_2O_3SiO_2$), the clay was added and mixed with tap water. The mixture was left for a period of time for settling the larger particles, then the supernatant was decanted and was used as a source of turbid water. The turbid water was diluted with tap water to achieve the required turbidity level (Mandloi et al, 2004). The turbidity was measured by using turbidimeter (hi 93703). The turbidimeter range is able to reading from 0 to 1000 FTU, where 1FTU = 1 NTU. The characteristic of raw water are lasted in table 1.1.

Table 1.1: characteristic of raw water used in the study.

Parameter	Value
Turbidity; NTU	5, 10 and 15 NTU
Alkalinity; mg/l as $CaCO_3$	89 – 102 mg/l as $CaCo_3$
Temperature ℃	20℃
PH	7.9 - 8.1

Pilot scale filtration system description

The pilot plant filtration system is shown in Figure 1. Feed pump was used to pump the raw water from the storage reservoir to the rapid mixing tank. Rapid mixing unit with dimension of 12.5 × 12.5 × 19.2 cm is used for coagulation process. The unit is designed based on detention time of 60 sec at filtration rate of 150 m^3/m^2/day and 36 sec at filtration rate of 250 m^3/m^2/day.

The rapid mixing tank was equipped with alum dosing system and mechanical mixer with power of 1.5 Watt, the system achieve velocity gradient of 700 S^{-1}. The filter unit was constructed from acrylic material with circular cross section. The inside diameter of filter unit was 19.2 cm and the height was 3.5 m. The filter was divided in two segments. The height of lower segment was 1.5 m and the height of upper segment was 2 m. the two segments were connected together by bolts flange. In the upper part trough was used to control the water distribution inside the filter and prevent scouring of the media due to water fall from the top and to collect dirty water during backwashing process. To measure the head losses through layer of media, filter unit was equipped with five piezometers, the distance between them 15 cm. The circular acrylic pipe is fixed in wall by three an arms steel and installed from the bottom on a screen. The underdrain system consists of screen was made from steel plate containing a number of holes each hole 3 mm and it's a fixed on a quadrilateral stand. Through the underdrain system the filtered water collect during normal filtration operation and distribute backwash water and air during the backwash process, where the rate of water required for backwash was 55.7 $m^3/m^2/hr$ and the rate of air required for backwash was 40 $m^3/m^2/hr$.

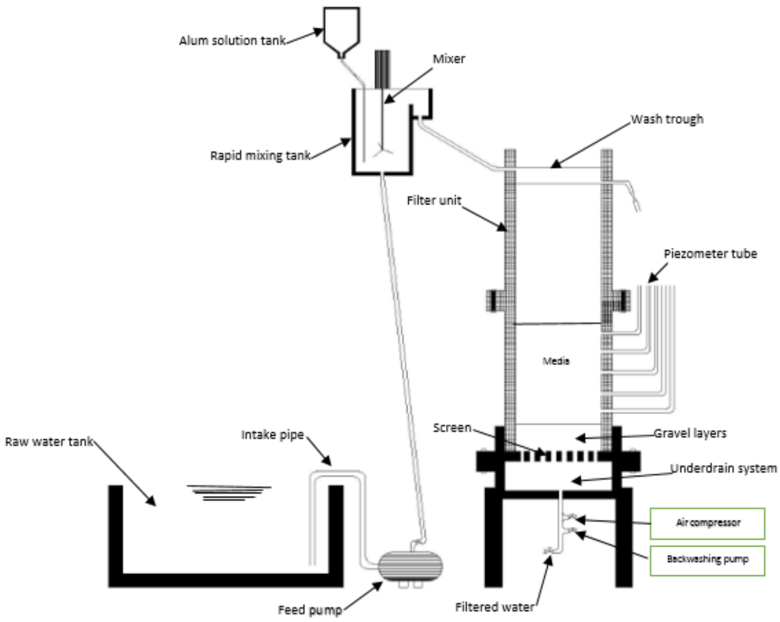

Figure 1: Schematic of pilot scale filtration system.

Filtration media characteristics:

Characteristics of these media that was used in this study are listed in the table 1.2.

Table 1.2: The characteristic of filtration media used in the study.

Filtration media	Media
Effective size (d_{10}); mm	0.83
d60; mm	1.06
Uniformity coefficient (U.C);dimensionless	1.28
Porosity %	42 %
Specific gravity (S.G); dimensionless	2.55
Density; gm/cm^3	2.55
Grain shape (Sphericity)	0.75

Results and discussion

Effects of coagulant dose on the performance of direct filtration.

In order to study the effect of coagulation process on the direct filtration process, alum dose of 0, 10 and 15 mg/l were studied. The effect of alum doses were studied at raw water turbidity of 5, 10 and 15 NTU. Other operating conditions were kept unchanged as filtration rate was 150 m^3/m^2/day, effective media size was 0.83 mm and depth 75 cm. Filtered water quality in terms of turbidity was monitored throughout the filtration phase The filtration was stopped after 8 hours of continues operation.

Effects of coagulant dose on filtered water quality

In order to study the effect of coagulation process on the direct filtration process in terms of filtered water quality, alum dose of 0, 10 and 15 mg/l were studied for raw water turbidity of 5, 10 and 15 NTU. Other operating conditions were; filtration rate was 150 m^3/m^2/day, effective media size was 0.83 mm and depth 75 cm. Filtered water quality in terms of turbidity was monitored throughout the filtration phase The filtration was stopped after 8 hours of continues operation. Figure 2, shows the effects of coagulant dose on the performance of direct filtration in terms of filtrate turbidity after 8 hours of filtration. As shown in the figure the filtered water turbidity at zero mg/l alum dose was 3.78 NTU at first raw water turbidity 5 NTU, 9.34 NTU at second raw water turbidity 10 NTU and 15 at third raw water turbidity 15 NTU.

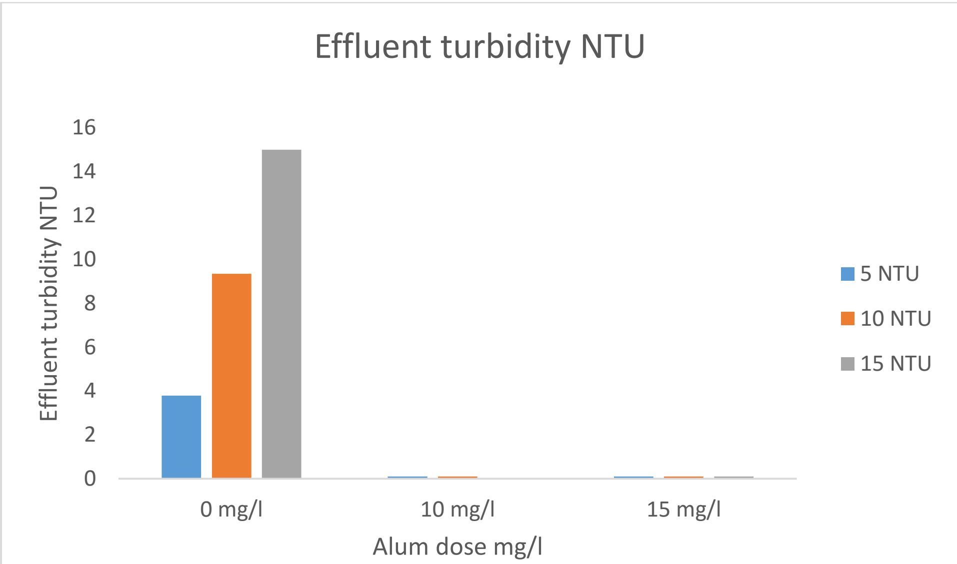

Figure 2: Effect of alum dose on filtered water quality

However, the filtered water turbidity was less than 0.1 NTU for alum dose of 10 and 15 mg/l. This could be ascribed to the destabilization of negative charges and enhancement of the attraction forces. Hutchison and Foley, 1974; Habibian and O'Melia, 1975 reported that the use of coagulant is very important for the direct filtration performance due to the destabilization of colloids. It is worth mentioning that, amount of alkalinity was consumed in order to occurrence the chemical reaction of alum to form aluminum hydroxide. The amount of alkalinity consumed at alum dose of 15 mg/l was 6.82 mg/l as $CaCo_3$, 4.54 mg/l as $CaCo_3$ and 2.47 mg/l as $CaCo_3$. As shown from the results increasing the alum dose from 10 to 15 mg/l did not significantly increase the direct filtration performance. Based on that, the optimum alum dose is 10 mg/l.

Effects of coagulant dose on filter head loss

To study the effect of coagulant dose on the head loss, doses were varied in the range of 0, 10 and 15 mg/l for raw water turbidity of 5, 10 and 15 NTU. Other operating conditions were; filtration rate was 150 m^3/m^2/day, effective media size was 0.83 mm and depth 75 cm. Filter performance in terms of head loss was monitored throughout the filtration phase. The filtration was stopped after 8 hours of continues operation. Figure 3 shows the effect of alum dose on the head loss at different initial turbidity. As the alum dose increase from 0 to 15 mg/l, the head loss increases. In addition the rate of increase is increasing as the raw water turbidity increase.

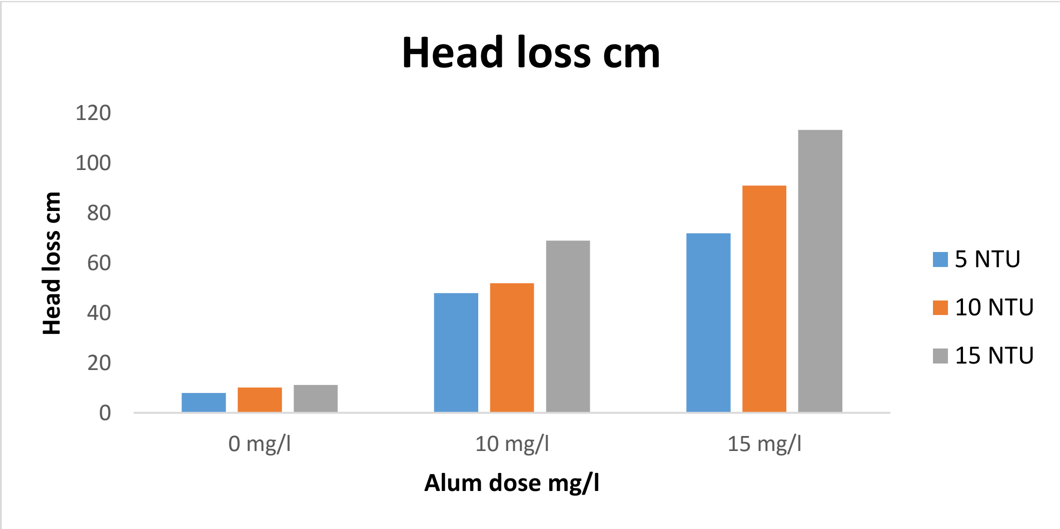

Figure 3: Effect of alum dose on the head loss at different turbidity.

This can be explained due to the proportional relationship between floc size and alum dose (Hutchison and Foley, 1974). When alum dose increase, the floc size increases. This may be due the effect of floc sweeping phenomena at high dose of aluminum hydroxide (M. Peterson et al, 1983). When alum dose is more than the optimum dose, the excess alum hydrolyze into insoluble hydroxides in which the small particles are entrapped in the hydroxide floc structure and form larger floc (S. Qasim, 2000). The larger flocs cannot penetrate the pore space between filtration media and thus rapidly accumulate on the surface of filtration media and cause excessive head loss (Ching and Yan Li, 1997). The excessive alum dose cause faster development of head loss and earlier terminal breakthrough of turbidity (J. Cleasby et al, 1984).

Effect of coagulation dose on the filter productivity

Productivity is the rate of filtered water produced per minute or during the filtration cycle. To study the effect of coagulant dose on the filter productivity, doses were varied in the range of 0, 10 and 15 mg/l for raw water turbidity of 5, 10 and 15 NTU. Other operating conditions were; filtration rate was 150 m^3/m^2/day, effective media size was 0.83 mm and depth 75 cm. Filter performance in terms of filter productivity was monitored throughout the filtration phase. The filtration was stopped after 8 hours of continues operation. Figure 4 shows the effect of alum dose on the filter productivity at different initial turbidity. When the productivity is decreased, this means that the bed became the less permeability and therefore it is expected that the filters is experienced from clogging. As alum dose increase from 10 to 15 mg/l, filter productivity decreased accordingly. This is could be ascribed to the accumulation of floc at the top of the filter. So, the straining action will be predominate filtration mechanism (Bradford et al., 2005). It is also noted that at raw water turbidity increased, the filter productivity also decrease.

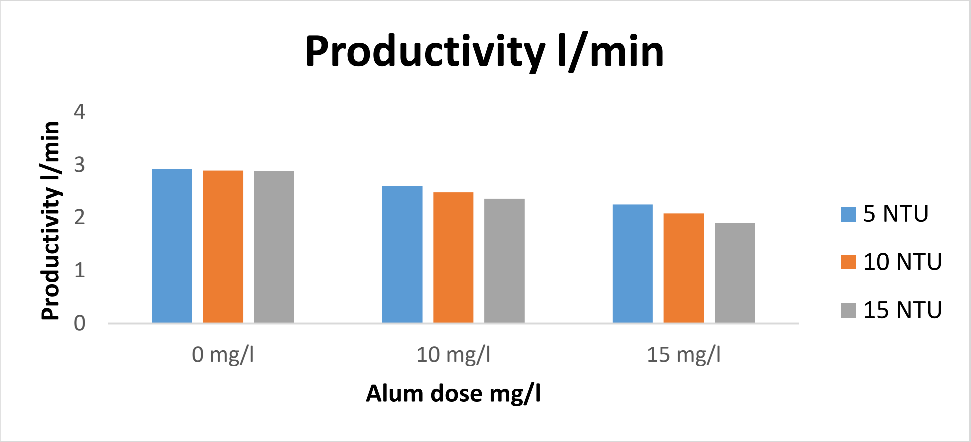

Figure 4: Effect of alum dose and raw water turbidity on the productivity of filter.

Based on the results, use of coagulant dose is important for ensure the successful of direct filtration process, to achieve effluent quality compatible with the local regulation (effluent turbidity less than 0.1NTU). However, increase coagulant dose from 0 to 10 mg/l, significantly improve effluent quality, increase alum dose further did not significantly the effluent quality but significantly increase head loss and decrease filter productivity. Increase of raw water turbidity significantly increase the head loss and decrease the productivity of filter.

Conclusion:

- Direct filtration is a potential process for treatment of low turbidity raw water.
- The optimum alum dose for treatment of low turbidity water of less than 15 NTU using direct filtration system is 10 mg/l.
- Increase of alum dose significantly increase the head loss and decrease the filter productivity.

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