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REUSE OF WATER TREATMENT SLUDGE IN COAGULATION PROCESS FOR THE TREATMENT OF RAW WATER FROM RIVER NILE

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ABSTRACT:
The process of recovery and reuse of water treatment sludge as a coagulant perform a sustainable solution that benefices economically and environmentally. High safety concerns are to be take in consideration during reuse of water sludge in water purification. Most of the previous researchers have applied several full-scale separation methods for an effective purification of coagulant, without pointing to the performance of the coagulant treatment. In this research we studies the characteristics of sludge resulted from the treatment process of raw water from the river Nile, then the produced sludge is chemically treated with an acid in order to reuse it again in coagulation. Acidified water treatment sludge performance in removing turbidity and dissolved organic carbon DOC have been evaluated. The optimum coagulant dose determined for coagulation process of raw Nile water was 36 ml/l, while the optimal pH range concluded for higher turbidity removal was from 6 to 8. The resulted water treatment sludge found to be reliable to use in conventional water treatment process. The study recommended for better performance of coagulation, to add a partial amount (at least 20 % of coagulant dose) of the proper coagulant to the recovered water sludge.

KEY WORDS: Coagulation, Water Treatment Sludge, Sludge Coagulant, Wastewater Reuse, Water Treatment.

اعادة استخدام الحمأة الناتجة من معالجة المياة فى مرحلة تخثر المياه فى معالجة مياه نهر النيل

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الملخص:
تؤدي عملية استعادة وإعادة استخدام الحمأة الناتجة عن عملية معالجة المياه كمخثر إلى حل مستدام يستفيد منه اقتصاديًا وبيئيًا. يجب الأخذ في الاعتبار اهمية تطبيق معايير السلامة أثناء إعادة استخدام حمأة المياه في تنقية المياه. قام معظم الباحثين السابقين بتطبيق العديد من طرق الفصل واسعة النطاق لتنقية فعالة للمخثر ، دون الإشارة إلى درجة أداءه فى مرحلة التخثر. في هذا البحث نقوم بدراسة خصائص الحمأة الناتجة عن عملية معالجة المياه الخام من نهر النيل ، ثم يتم معالجة الحمأة المنتجة كيميائياً بحمض لإعادة استخدامها مرة أخرى في مرحلة التخثر. تم تقييم أداء حمأة معالجة المياه الحمضية في إزالة العكارة والكربون العضوي القابل للتحلل. كانت الجرعة المثلى للمخثر المحددة لمرحلة تخثر اثناء عملية معالجة مياه النيل الخام ٣٦ مل / لتر ، في حين أن نطاق الرقم الهيدروجيني الأمثل الذي تم التوصل إليه لإزالة مستويات أعلى من العكارة كان من ٦ إلى ٨. أوجدت الدراسة قابلية اعادة استخدام الحمأة الناتجة من عملية معالجة المياة التقلييدية

كمخثربديل فى مرحلة تخثر المياه . كما أوصت الدراسة للحصول على أداء أفضل للمخثر ، إضافة كمية جزئية (٢٠ ٪ على الأقل من جرعة التخثر) من التخثر المناسب إلى حمأة المياه المراد إعادة استخدامها.

الكلمات المفتاحية: التخثر ، الحمأة الناتجة من معالجة المياة ، مخثر الحمأة ، إعادة استخدام المياه، معالجة المياه٠

1.INTRODUCTION

Water treatment sludge recovery and reuse as a coagulant, is acting as a sustainable practice that meet with the goals of applying sustainability in water treatment technologies. Several potential benefits to water treatment have offered for the process recovery of coagulant. The most important benefits are the minimisation of the chemical demand needed for coagulation, and the reduction of waste produced from water treatment. The main objective for optimal implementation is to achieve similar degree of quality in water treatment, and to convert process of coagulant recovery as a commercial application [1].

Chemical sedimentation of water (Coagulation-flocculation process) followed by clarification process, normally generate of high production of waste products. This product named as water treatment sludge WTS, in the water treatment for drinking water supplies [2]. Raw water usually contaminated by solid (suspended and Colloidal Solids) resulted from several sources of contamination such as the erosion of lands and decaying vegetation. Chemical coagulation are generally responsible of removal of the finer solid particles specially the colloidal solids. Coagulation and flocculation are a combined and sensitive process to many variables such as, type of coagulant, coagulant dose, turbidity and the pH value. To explore the ideal conditions of these factors, jar test experiment was utilised using the one factor at a time OFAT method, that mainly depends on trial and error approach.

The process in this way is varying the levels of one of the factors and at the same time, keeping another factor in constant, making the experiment, observing and discussing the results, and the moves on to examine the next factor. Accordingly, the OFAT method not only dealt with time and the consumed energy, but also it is usually incapable of signifying the suitable combination of effected variables, because of ignoring the interaction between factors [3].

Metal coagulants are the most commonly used in water treatment whatever those based on aluminium, such as Aluminium sulphate $Al_2 (SO_4)_3$. $18H_2 O$ and sodium aluminate $Na_2 Al_2 O_3$, or coagulants based on iron, such as ferrous sulphate $FeSO_4$.$7H_2 O$, ferric chloride FeCl□. Aluminium Sulphate Al□ (SO□)□is the widely used than sodium aluminate Na□Al□O□ because of the high difference in cost. Sodium aluminate usually used as a coagulant aid, and has been found effective in coagulation of highly coloured water surface and in coagulation of lime soda ash softening process. Ferric coagulants give higher efficiencies when used in coagulation process with a wide pH range.

Recovered aluminium and iron coagulants resulted from water and wastewater treatment was investigated before by Xu et al. [4]. Acidified water treatment sludge used in a treatment process of synthesised and surface water from a lake [5]. It showed that acidification of water treatment sludge was very e□ectively in released the coagulant; however, the performance of the recovered coagulants and the effect of dissolved background on it, was not investigated. Most of the previous works studied the use of recovered coagulant with either drinking water or simulated wastewater; do not emphasize with a comprehensive analysis on the e□ect of recovered coagulant on the quality of the resulted water [6]. Alternative applications of water sludge recovery and reuse in the process of removing phosphorus, allow the coagulant reaction be done without any threat to the public health or abusing standards and regulations [7]. Thus, the intensity and the cost of coagulation recovery will reduced [8].

In this research, several approaches had investigated ending with a process of reusing water treatment sludge in the coagulation and flocculation processes for treatment of raw water. The study started with testing the use of a conventional chemical coagulant to be as reference for evaluating the performance of coagulation and flocculation processes for Nile water. Then we began gradually replace the chemical coagulant by the water treatment sludge until we met the required acceptable efficiency of colloidal solids removal using water treatment sludge through variable conditions.

2.MATERIALS AND METHODS

2.1. River Nile
Nile River is the main source of potable water supply for Egypt, the common challenge with securing adequate water share for Egypt's survival and economical improvement should be emphasized [9]. Water samples were taken from Nile river intake in Waraq, Giza. In-situ measurement including pH, conductivity and temperature has done in the intake site. Methods of chemical analysis of water have been discuss in Standard methods for examination water and wastewater [10].

2.2. Coagulation and Flocculation
The main objective for applying coagulation process is to enhance the process of settling of colloidal suspended matters, improve water quality and the removal efficiency of filtration process. Flocculation process gives the time needed for chemical reaction and the formation of the large flocculated particles (Flocs). The study had done on a batch apparatus shown in Fig. 1 in the laboratory representing coagulation and flocculation process. It consists of a flash mixing tank at which the coagulant added and mixed uniformly with the colloidal solids suspended in raw water. The second part of the apparatus is the flocculation tank split into three chambers, and a group of agitators to graduate gentle mixing to promote the growth of the destabilized flocs.

2.3. Optimum pH value and proper coagulant dose.
Aluminium sulphate $Al_2(SO_4)_3 \cdot 18H_2O$ (Alum) were used to determine optimum pH value and the proper dose required for coagulation. Alum doses ranges between 7 to 28 mg/l. the rapid mixing speed is 100 rpm applied for 90 seconds, while the slow stirring speed is 25 rpm applied for 25 minutes. The residual turbidity measured against the added coagulant dose.

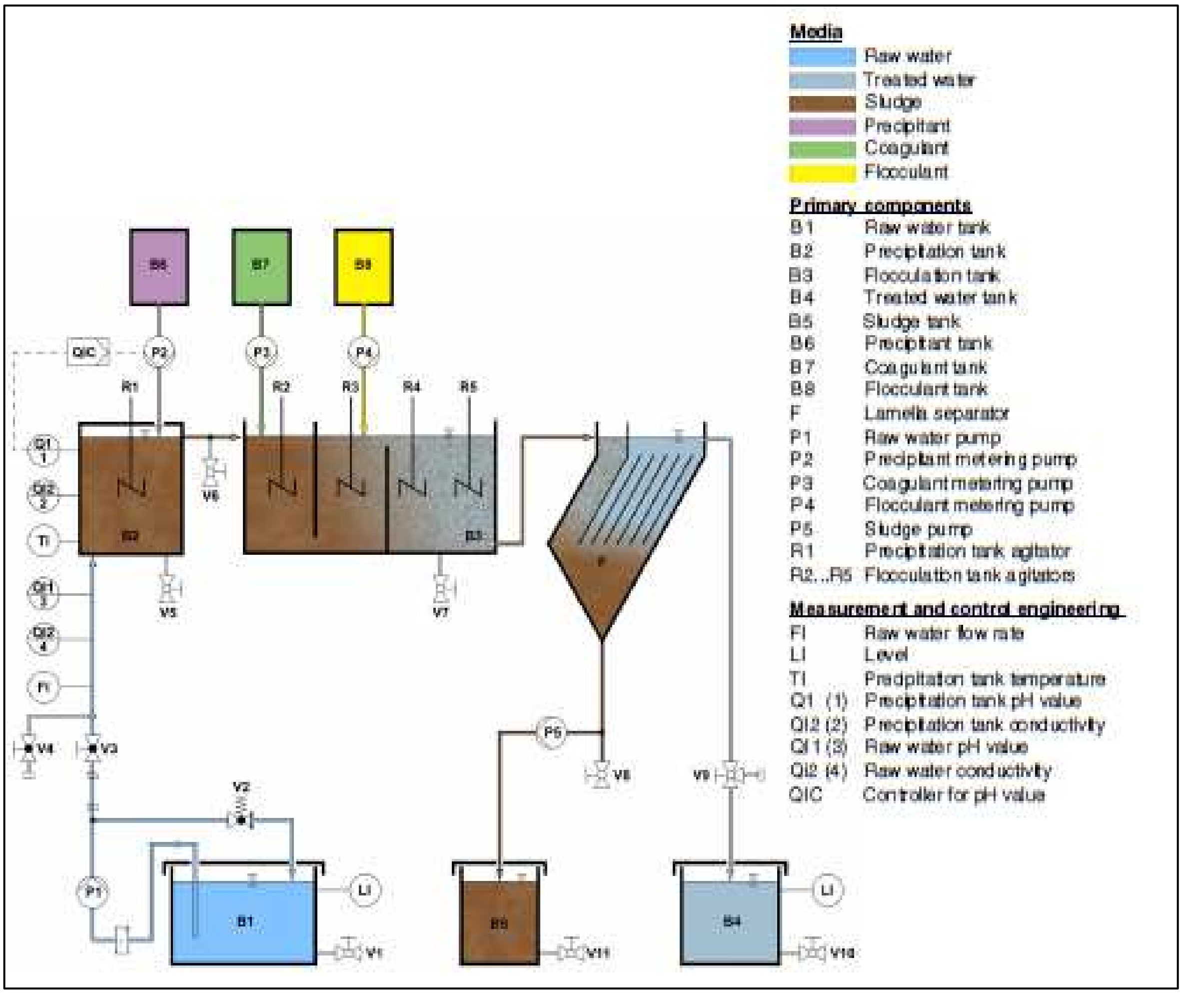

Fig. 1 Lab scale apparatus of Coagulation, Flocculation and Sedimentation Process

2.4. Water treatment Sludge

Sludge resulted from coagulation and flocculation process with alum was been applied to a group of physical and chemical analysis to identify its characteristics before reusing process. Chemical treatment of water treatment sludge WTS were applied using acid in order to improve the removal efficiencies of turbidity and dissolved organic carbons DOC. The acidification process of WTS was to regenerate aluminium or iron salts, and both of Al^{3+} and Fe^{3+} remove turbidity, and so performs better efficiency of coagulation with acidified WTS [11]. The water treatment sludge began gradually added to Alum dose starting with 25% to 100 % of the coagulant dose.

Sedimentation is one of the important stages inside any conventional water purification plant. It usually accomplished by a stage of chemical addition of compounds that may be rich with iron or aluminium, that resulted with a high concentration of these elements in the resulted water sludge. [12]. To identify the thermal stability of sludge, a thermal gravimetric analysis (TGA) conducted with a temperature ranged between 16°C to 1000°C, using TSDSC 16 equipment. [13]. Fourier transfer infrared analysis of sample carried out using FTIR spectrometer Nicolet 6700.

2.5. Coagulation and Flocculation Performance

In this research, the dissolved organic carbon removal through a several concentrations of the acidified water treatment sludge investigated. The concentrations of total organic carbon TOC and dissolved organic carbon DOC are the measuring parameters that offers an indication on the natural organic matter NOM. Aromatic organic compounds are determined by using the ultraviolet adsorption at 254 nm (UV254). The Specific Ultraviolet Absorption at 254 nm

(SUV254) is determined by the division of the sample's ultraviolet absorption at a wavelength of 254 nm (UV 254) (path width = 1 m) by its concentration of dissolved organic carbon DOC (mg/L). [14]. In addition to the performance evaluation of the using water treatment sludge, we studied the effect of pH value on the sludge performance ranging from a low value 5 to a higher value 8.

3. RESULTS AND DISCUSSION

3.1. Raw water characteristics

The samples of raw water taken from river Nile have examined to identify its degree of quality. Table 1 represent the results of water quality analysis of river Nile samples. The results shows that most of the measured parameters average level are below the standard limits mentioned of the Egyptian Law no. 48/1982, except the Turbidity. The percentage of increase in the average level of Turbidity was 6.85%.

Table 1 Raw water characteristics and Egyptian standards limits according to law 48/1982

Parameter	Range	Egyptian limit
Temperature	17 – 28 °C	5 °C above normal
pH	7.4-8.6	7.0-8.5
Turbidity	2.7-11 NTU	5 NTU
TDS	143-317 mg/l	500 mg/l
Conductivity	280 – 430 µS/cm	
Alkalinity (CaCo3)	112 – 170 mg/l	200 mg/l
Total Hardness (CaCo3)	110 – 258 mg/l	200 mg/l
BOD	1.2 – 7.7 mg/l	6 mg/l
COD	2.4 – 11.8 mg/l	10 mg/l
DO	7.2 – 12 mg/l	>= 5

3.2. Coagulant dose

The process of determination of the proper Alum dose required for coagulation process of raw Nile water obtained an optimum dose of 36 ml/l. the optimum dose were identified with the dose which achieve the maximum accepted removal efficiency for turbidity. Water treatment sludge resulted from applying the optimum coagulant dose were used in the coagulation process of raw Nile water Samples.

3.3. Water treatment Sludge characteristics:

The characteristics of sludge resulted from water treatment process of raw water form Nile River represented in Table 2. The resulted WTS always influenced by the source of surface water or the groundwater coming from deep-water wells. In addition, the type of soil in the water source and any chemically based products or other materials disposed into water source may affect the WTS characteristics [15] [16]. Thus, it is obligatory to describe the sludge from each water treatment plant (WTP) for recycling and reuse uses [17].The concentration of aluminium and iron are 117.76 and 80 mg/g from the dry sludge. Those concentrations the represent about 15 % of total mass of the dry sludge, can help in coagulation process.

Table 2 The characteristics of WTS

Parameter	Value	Unit
pH	7.65	
Total Solids	4.86	% WTS
Organic Matters	694.40	mg/g dry Sludge
Al	117.76	mg/g dry Sludge
Fe	80.00	mg/g dry Sludge
Ca	27.26	mg/g dry Sludge
Mg	15.36	mg/g dry Sludge
K	23.30	mg/g dry Sludge
P	53.89	mg/g dry Sludge
Na	11.52	mg/g dry Sludge
Si	256.00	mg/g dry Sludge

FTIR spectrum of water treatment sludge presented in Fig. 2. The range of wave number between 3402 and 2831 cm^{-1} indicates the bonding O-H stretching functional group. The WTS owned comparable adsorbent bands at wave number ranges of 1670-1600 cm^{-1}, 1050-1150 cm^{-1}, 940-900 cm^{-1} that are specified to be C=O stretch, C-O bonding, C=C bonding. The same wave number in adsorbent bands ranges of 800-770 cm^{-1} and 760-740 cm^{-1} used to be additionally observe in the FTIR spectrum of WTS in which both demonstrated C-H bonding [18].

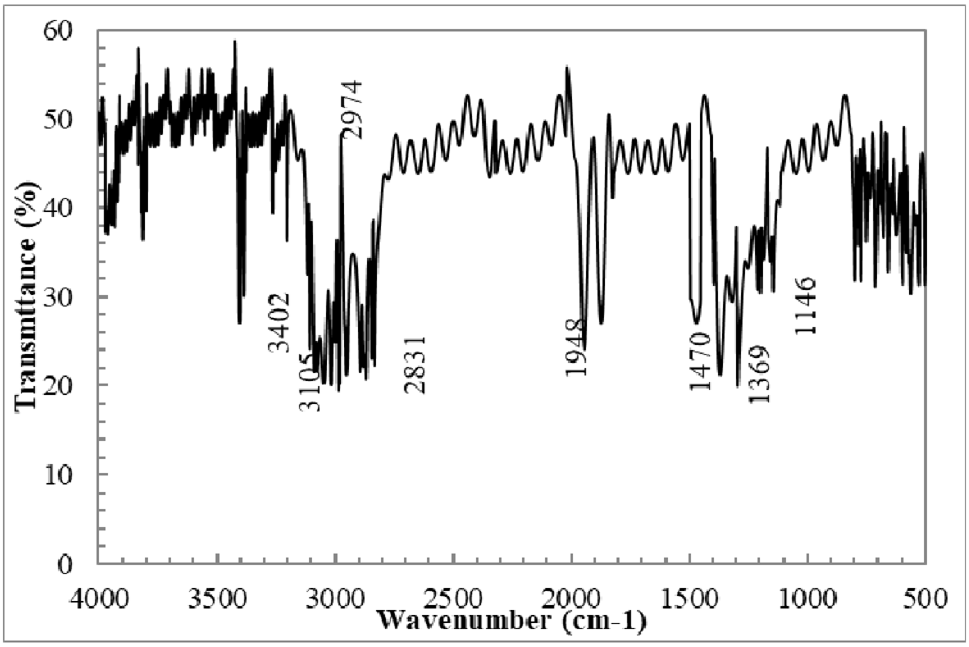

Fig.2 FTIR spectrum of water treatment sludge

The TGA graphical profile of the WTS shown in Fig. 3. The moisture of the sample removed by increase in the sample temperature by 20°C, which indicate the presence of free and unbound water. The water molecules adjacent to aluminium hydroxide expelled at a temperature between 200°C and 400°C. In order to evolving Carbon dioxide, temperature should be greater than 650°C [13].

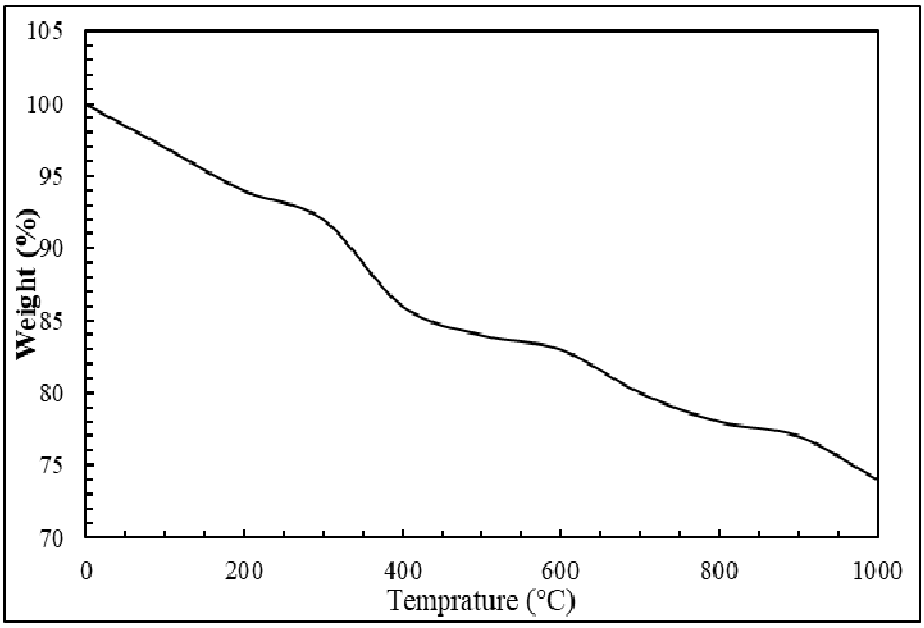

Fig.3 TGA profile of dried water treatment sludge

3.4. Effect of pH value on WTS coagulant performance

The coagulation process is depending on the relevance between coagulant dose, pH value and the amount of colloidal solids in water. Turbidity removal from raw water using a gradually increased percentage of chemically treated WTS measured at six different pH value. Fig. 4 represents the results of turbidity removal after coagulation process starting with the use of Alum coagulant only, and end with totally used of the prepared coagulant sludge. The results shows that the higher turbidity removal efficiency after the start of using the coagulant sludge (20% of the coagulant dose) was 86.67% at pH 7. However, the lowest removal turbidity occurred at coagulant sludge (100% of coagulant dose) with value 60.18 % at pH 5.

Charging Neutralization in acidic region was the hegemonic mechanism for polyferric chloride and humic acid removed effectively. However, the turbidity removal efficiency decreased. When the pH is greater than 6, the spreading became the dominant mechanism and the turbidity removal efficiency was high. In this case, humic acid removal was decreased [19]. The increase of pH value cause an initial increase in the efficiencies of removing chemical oxygen demand COD and turbidity, and then start to decrease when the pH value raised to a higher level [20].

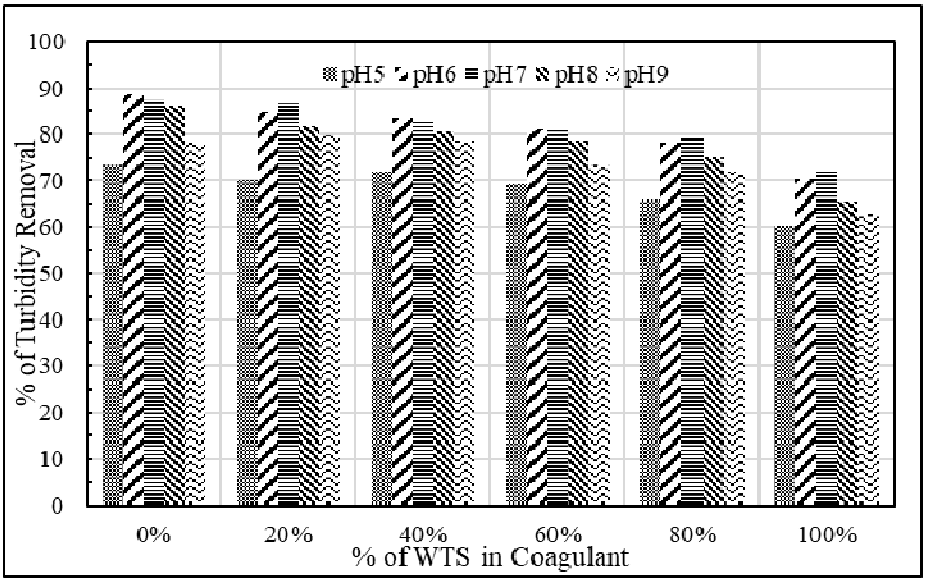

Fig. 4 Percentage of turbidity removal at different WTS coagulant dosage with different pH values

3.5. DOC concentration

The necessity of removing dissolved organic carbon DOC from potable water is to ensure fixed supply of residual disinfectant, and to reduce the rate of formation of treatment by-products through the water distribution networks that include a stable amount of free residual chlorine for disinfection. [21]. Fig. 5 represents the DOC concentrations in raw water, after coagulation and flocculation, and after plain sedimentation using various concentration of WTS coagulant. The DOC removal after coagulation and flocculation ranges between 61.82 % at (100% WTS) and 78.01 % at (20% WTS). However the total percentage of DOC removal ranged from 66.36 % at (100% WTS), and 82.26 % at (20% WTS). The use of acidified water treatment sludge gradually as coagulant gives DOC removal performance near the removal performance when using Alum coagulant with a percentage of 80% from the coagulant dose.

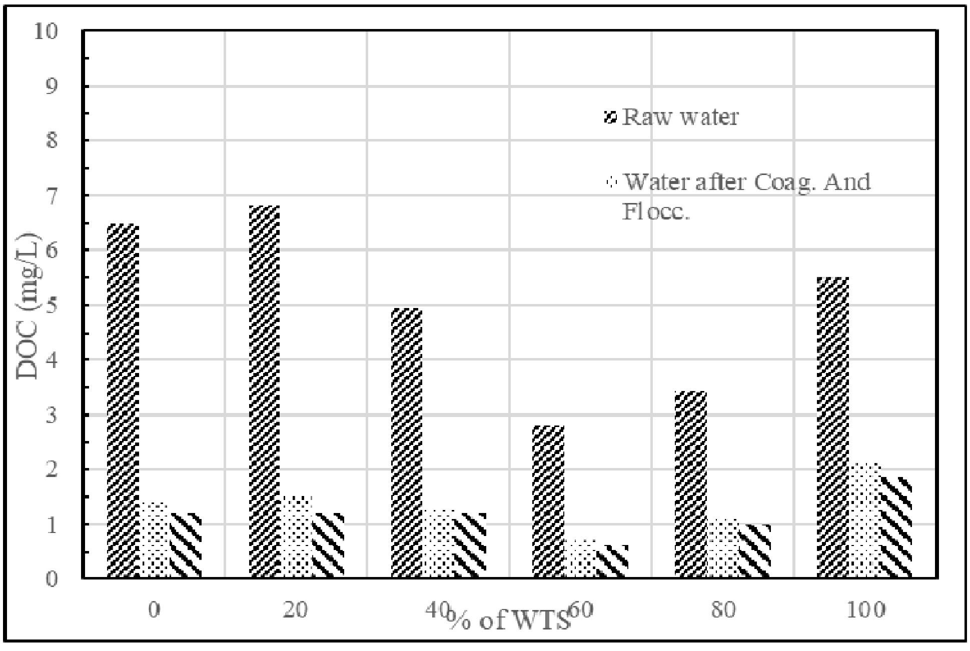

Fig. 5 DOC concentrations

4. CONCLUSION

After acidification of the water treatment sludge produced from the coagulation and flocculation process of Nile water using Aluminium sulphate $Al_2(SO_4)_3 . 18H_2O$, it gives the better-accepted performance on DOC and turbidity removal. The pH is effective factor that influences the coagulation performance, especially the turbidity removal. The research concluded that the better pH range for higher turbidity removal was from 6 to 8. The pH range is suitable to the pH range of the raw water Nile. Based on the raw water characteristics, we confirmed that it is very useful to apply coagulation using acidified WTS in coagulation process for water from river Nile. Based on the results, it recommended using 20 to 40 % from alum in addition to the chemically treated WTS to take place in coagulation process that performs better performance. The understanding of the recovery process of Alum coagulant in treatment of water from river Nile were improved, to be a sustainable solution by which it reduce economical cost and enhance the environment protection.

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