Improvement of drinking water characteristics in treatment plants in El–Behira governorate

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The aim of this research was the study of the efficiency of the GAC filtration process in removing the organic substances and THMs compounds. The experimental work of this study was divided into three phases depending on the type of the feeding water. The feeding water in the first phase was water after the coagulation and sedimentation processes for both coke and GAC filtration. To study the effect of the absence of the coagulation process on the performance of the GAC filtration, raw water, after filtration by using filter paper, was used in the second phase. In the third phase, filtered water with pre – chlorination and without post – chlorination was used to study the effect of pre – chlorination on the behavior of GAC filtration in removing TOC and the effect of the adsorption process on THMs compounds. The results of the pilot plant studies showed that coke has a negative effect on TOC removal; organic matters can be removed by the adsorption process and the removal of TOC was proportional to the thickness of the GAC layer. The GAC filtration removed the THMs compounds completely (100% removal efficiency) and the removal of THMs was better than the removal of TOC. Besides, the GAC filtration has a positive effect on the reduction of the pH value, alkalinity, turbidity, chlorides, sulfate, calcium hardness and total hardness, but has no effect on the sodium concentration. Using three types of the feeding water showed that the water supply should be pretreated by chemical coagulation before GAC filtration. The reaction of chlorine gave negative effects on the adsorption process and a better quality of treated water will be expected by using GAC filtration after the conventional sand filter.

يهدف هذا البحث إلي دراسة استخدام الكربون العادي والكربون المنشط ومدي كفاءتهما في إزالة المواد العضوية والمركبات العضوية السامة (التراي هالوميثان) من مياه الشرب وكذلك تأثيره علي الخصائص الاخري للمياه في المراحل المختلفة للمعالجة ذلك بالاضافة إلي دراسة تأثير سمك طبقه الكربون. تم اعداد نموذج بحثي معملي في المعمل المركزي لشركه البحيرة لمياه الشرب والصرف، وتم الاعتماد علي تغذية النموذج المعملي بمياه من المحطة الرئيسية بدمنهور (محطة عقد ٤). تم تقسيم خطة العمل إلي ثلاث مراحل مختلفه بأستخدام ثلاثة أنواع من المياه في مراحل معالجة مختلفة.في المرحلة الأولي تم استخدام المياه بعد عمليه الترويب والترسيب بدون كلور ابتدائي لدراسة مدي تأثير وجود عملية الترويب وغياب الكلور الابتدائي علي كفاءة الكربون العادي ثم الكربون النشط وبعدها مباشرة تم استبعاد الكربون العادي واستخدام الكربون النشط فقط ولدراسة مدي كفاءة الكربون النشط عند غياب كلا العمليتين تم استخدام المياه العكرة بعد الترشيح بورق الترشيح وبدون الترويب والكلور الابتدائي في المرحله الثانيه، في المرحله الثالثه فقد تم استخدام المياه بعد عمليه الترشيح والمضاف لها كلور ابتدائي لدراسة تأثير وجود كلا العمليتين. ومن البحث المعملي اتضح ان الكربون العادي له تأثير سلبي علي أزاله المواد العضوية، بل يمكن إزالتها بعمليه الامتزاز باستخدام الكربون النشط، وأن كفاءة الازاله تزيد بزيادة سمك طبقه الكربون النشط. الكربون المنشط، له القدرة علي أزاله مركبات التراى هالوميثان نهائيا من المياه و كفاءة أزاله هذه المركبات كانت أفضل من أزاله المواد العضوية. كما أن الكربون النشط له تأثير ايجابي علي تقليل القلوية و العكاره والكلوريدات والكبريتات و عسر المياه ، وليس له تأثير واضح علي عنصر الصوديوم. ونتيجه لاستخدام المياه في ثلاث مراحل مختلفه من المعالجه اتضح انه يجب معالجه المياه بأستخدام عمليه الترويب قبل استخدام الكربون المنشط وان الكلور الابتدائي له تأثير سلبي علي كفاءة الكربون المنشط في ازاله المواد العضويه و للحصول علي جوده عالية للمياه يتم استخدام الكربون المنشط بعد المرشح الرملي وذلك لانه كلما قل تركيز الملوثات الداخلة للكربون المنشط زادت كفاءته في ازاله المواد العضويه.

Keywords: COKE, Activated Carbon, Adsorption process, Organic matters, Trihalomethane compounds

1. Introduction

Color-causing humic ubstances have long been a problem for the water supply. Studies have shown that Humic Substances Form Trihalomethanes (THMS) and other halogenated organic compounds during chlorination of water supplies [1]. As THMs are possible cancerous substances, the removal of THM precursors is important in treating drinking water. However, these compounds are generally difficult to remove by the conventional drinking water treatment processes such as coagulation, sedimentation and filtration. Thus, the development of an alternative process for the removal of THM precursors is becoming urgent [2]. Granular Activated Carbon (GAC) treatment is one of the processes used for removing many of these organic contaminants that are present in water supplies [3]. Fig. 1 shows a sketch of the internal pore structure of activated carbon.

Treatment mechanisms of activated carbon are adsorption, chemical reaction and biological reaction. Adsorption occurs when the attraction at the adsorption surface is stronger than the solution forces available to keep the contaminants dissolved in solution. This process involves three consecutive steps for the transport of a compound from the bulk solution to an adsorption site of a porous adsorbent such as activated carbon as shown in fig. 2. Although the physical adsorption phenomena tends to be the dominant interaction for many organic compounds on activated carbon, chemical reactions significant to disinfection can occur on a carbon surface as well [4, 5].

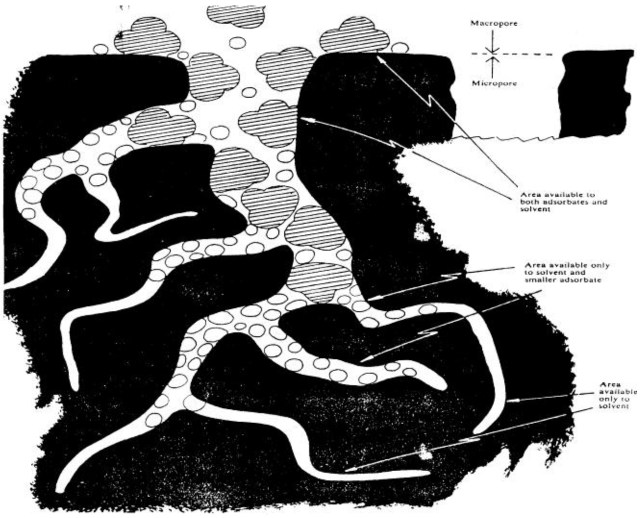

Fig. 1. Sketch of the internal pore structure of activated carbon.

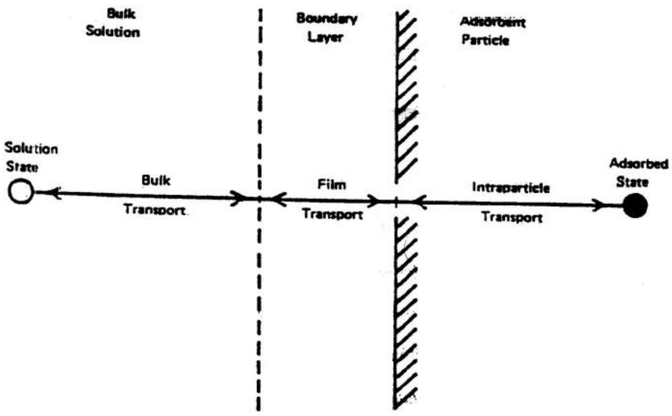

Fig. 2. Transport steps in adsorption by porous adsorbent.

2. Materials and methods

2.1. Bench scale experimental apparatus

The bench scale used in this study was installed in the Central Laboratory in ELbehira water and drainage treatment Company. Fig. 3 shows a photograph of the bench scale model which was used in this study. As shown, the bench scale model consists of two fixed Perspex columns each 5 cm in diameter and one meter height. The two columns were fed with water via an upper tank of 40 liter capacity.

2.2. The influent water

In this study, the influent water was obtained from the Cont 4 treatment plant in Damanhor city. The clarification process in this plant is worked by a sludge blanket system. The operating conditions at the Cont. 4 plant as follows:

- Coagulant (Alum) dose = 80 -100 mg/L
- Initial chlorine dose = 3.5 – 5 mg/L
- Final chlorine dose = 2 – 4 mg/L
- Two rectangular clarified tanks , each divided into 11 channels
- Detention time for clarified tanks = 2 hr
- Six filters (four in operation , one under washing and the sixth is standby)
- Rate of filtration = 100 L / m^2 / sec
- Maximum flow rate = 1200 L / sec

The alum and chlorine doses depend on the characteristics of the incoming raw water and the range of its pollution.

Fig. 3. Photograph of the bench scale model.

2.3. Experimental schedules

The experimental work was divided into two stages. Two stages were carried out to investigate the removal of organic matters and THM compounds. The first stage was carried out in the period from October 2003 to February 2004. In this stage two types of carbon were used, coke and granular activated carbon. Coke was used in two different thicknesses (10 cms and 30 cms) and water was fed after the sedimentation process without pre – chlorination. GAC was used in two different thicknesses (10 cms and 30 cms) and three different types of fed water were used, water after sedimentation without pre–chlorination, raw water after the filtration by using filter paper without coagulation and water after filtration process with pre–chlorination and without post – chlorination. The second stage was carried out in the period from February 2004 to May 2004. The same types of feeding water were used, but the characteristics of these waters were worse than those of the first stage. During this stage influent TOC concentrations in the raw and treated water were higher than the standard limits of drinking water. GAC was used in two different thicknesses (20 cms and 40 cms).

3. Results and discussion

3.1. TOC removal by coke

Fig. 4 shows that the TOC concentrations increased in the effluent through the coke filter. The concentration of TOC increased with coke thickness at 10 cms and 30 cms to about (0.2 – 0.4) ppm and (0.4-.05) ppm respectively. It is evident that with increasing coke thickness the effluent TOC increased.

3.2. The effect of GACfilter on TOC removal

Fig. 5 shows the percentage of TOC removal profiles for water after the sedimentation process without pre – chlorination, using different thicknesses of the GAC filter. For this type of water, the GAC filter with a 10 cms thickness gave a removal efficiency of 55 % in the first sample, and this percentage decreased to 34 % in the last sample. For the GAC filter with a 20 cms thickness the removal efficiency was 66 % at the first sample. This removal efficiency decreased to 39 % in the last sample. It is evident that TOC removal efficiency gradually slowed down because the adsorption abilities for the activated carbon decreased as the volume of the activated pores decreased. A GAC filter with 30 and 40 cm thicknesses of gave a removal efficiency greater than that of

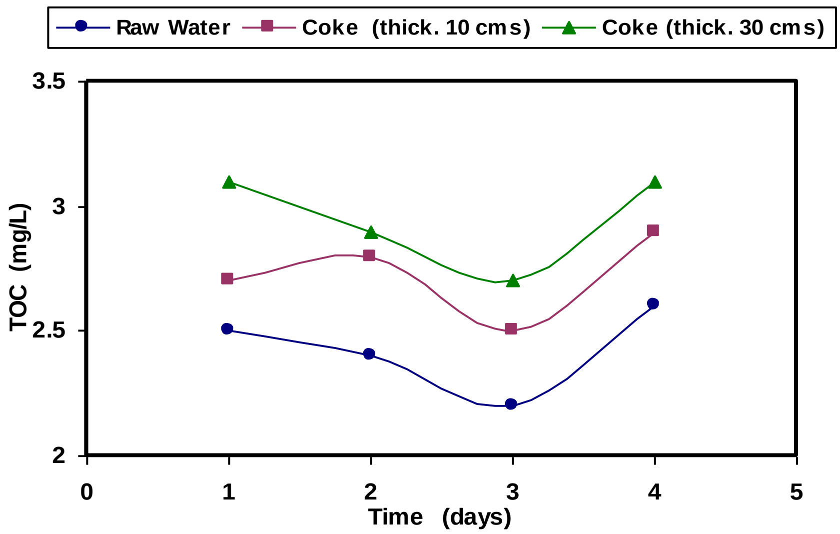

Fig. 4. TOC concentration for influent and effluent through coke filter (thickness 10 cms and 30 cms).

GAC thickness 10 cms or 20 cms. The removal efficiency of TOC in the last sample was 50 % for the GAC filter with a 30 cms thickness and 60 % for a 40 cms thickness. These results indicate that, after 25 days, the removal efficiency of TOC decreased in the10 and 20 cms thickness GAC filter. The removal efficiency of TOC was improved by using a GAC filter with 30 and 40 cms thickness. No significant difference in the adsorption efficiency was noted when the concentration of TOC in the water resource was increased to more than the standard limits.

Fig. 6 shows the percentage of the TOC removal profiles for filtered raw water by using different thicknesses of the GAC filter. Remarkable the decrease in the TOC concentrations was noted after GAC filtering with different thicknesses. At the beginning stage, up to 17 days of operation, the removal efficiency of TOC was enough to comply with the standard limits. Removal efficiencies at this time were 45%, 58%, 60% and 65% for thickness 10 cms, 20 cms, 30 cms and 40 cms, respectively. The removal efficiency of TOC after this period decreased and the effluent TOC concentrations were higher than the standard limits. It is concluded that bed depth should be increased to achieve strict water quality standard, and the water supply should be pretreated by chemical coagulation to reduce the loading of pollutants on GAC filter. So using a GAC filter after filtering the raw water was not an economic process.

Fig. 7 shows % TOC removal profiles for water after the filtration process with pre – chlorination and without post – chlorination by using different thicknesses of GAC filter. For this type of water, the GAC filter with thickness of 10 cms gave a removal efficiency of TOC equaling 43 % in the first sample and this percentage decreased to 36 % in the last sample. For a GAC filter with a thickness of 20 cms, the removal efficiency was 48 % in the first sample. This removal efficiency decreased to 43 % after 27 days of operation.

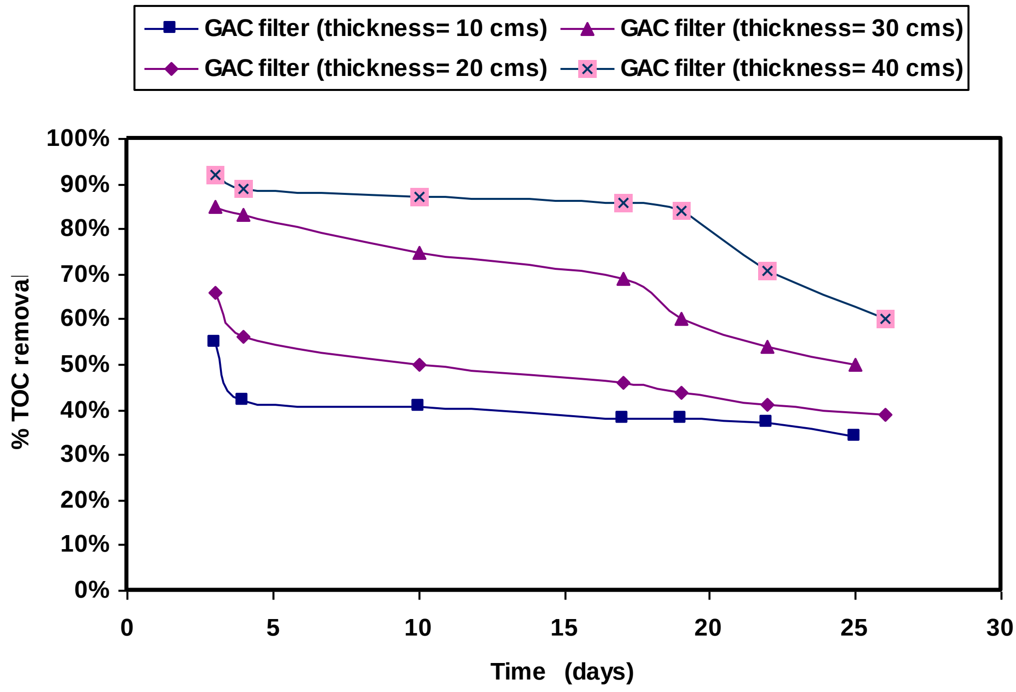

Fig. 5. Relation between % TOC removal and the thickness of GAC filter for water after the sedimentation process without pre – chlorination.

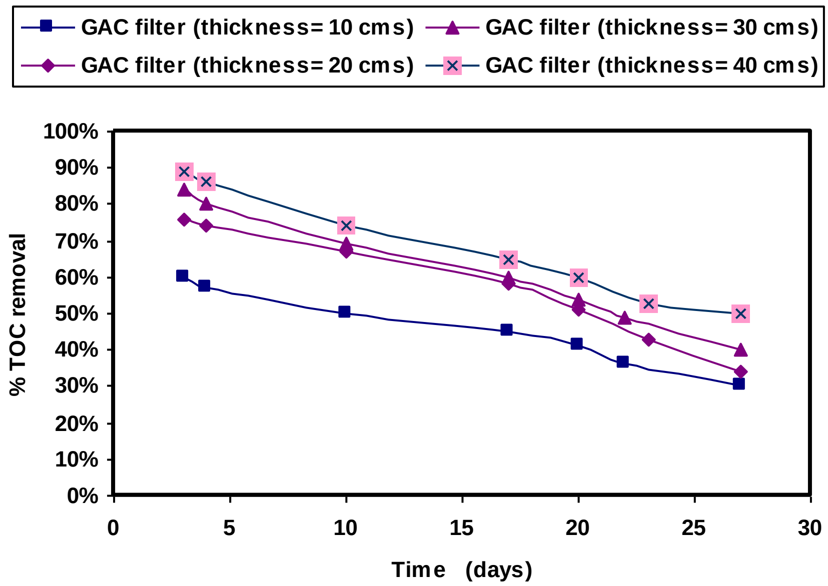

Fig. 6. Relation between % TOC removal and the thickness of the GAC filter for raw water after filtration using filter paper.

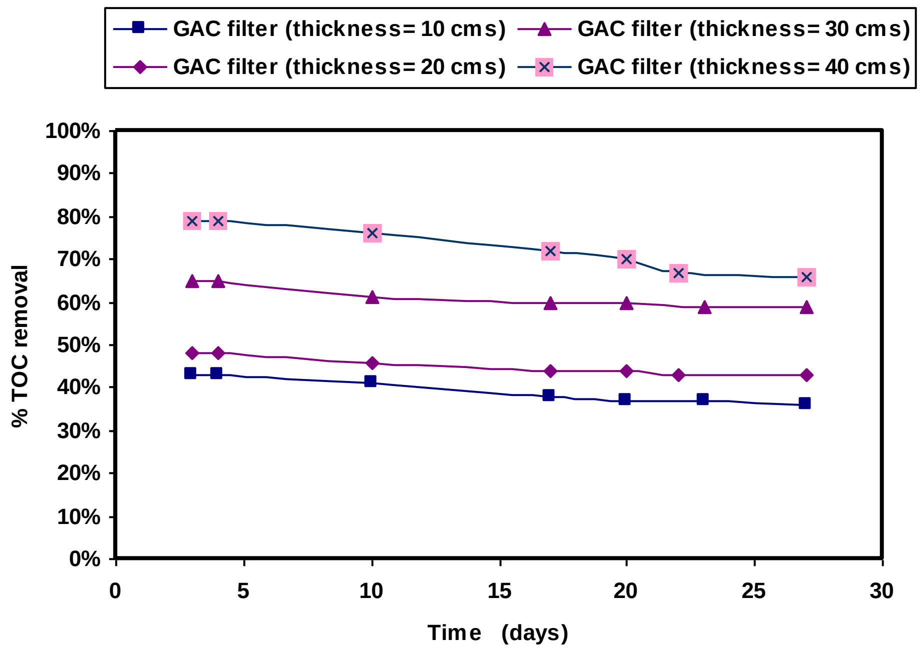

Fig. 7. Relation between the % TOC removal and the thickness of the GAC filter for water after filtration and with pre chlorination.

A GAC filter with thicknessesof 30 cms and 40 cms gave a removal efficiency of TOC greater than that with using thickness of 10 or 20 cms of GAC filter. The removal efficiency of TOC in the last sample was 59 % for a thickness of 30 cms, and 66 % for a thickness of 40 cms. These results indicate that the removal efficiency of TOC was improved by using GAC filter with thicknesses of 30 cms and 40 cms. A significant difference in the adsorption efficiency was not noted when the concentration of TOC was increased to more than the standard limits.

Treated water quality using a GAC filter after settling the water, or after filtering, was good enough to comply with the standard limits of drinking water. At the beginning stage of the GAC filtering operation, the removal efficiency of the first process (settled water followed by GAC filtration) was higher than the second process (filtered water with pre – chlorination). Therefore, it can be concluded that the reaction with chlorine gives negative effects on the adsorption behavior of organics.

After 27 days of operation, the removal efficiency of the second process was higher than that for the first. Therefore, better quality of treated water will be expected by using a GAC filter after conventional sand filter. It can be concluded that the smaller loading of pollutants to GAC filter will result in long intervals of reactivation or replacement of GAC. So, simply it means that a GAC filter should be applied as a final process in water treatment.

3.3. The effect of GAC filter on THMs removal

Fig. 8 shows the percentage of THMs removal profiles for water after a filtration process with pre – chlorination and without post– chlorination using different thicknesses of a GAC filter. For this type of water, the removal efficiency of THMs was enough to comply with the standard limits of drinking water. Average removal efficiencies were 96% and 99% for thicknesses of 10 cms and 20 cms respectively, and it was almost equal to 100% for both 30 cms and 40 cms thicknesses. These results indicate that the GAC filter has the ability to remove THMs from drinking water, and the removal efficiency was improved by using greater thicknesses of GAC filter. From the economic point of view, a GAC filter with a thickness of 20 cms was enough to comply with the standard limits of drinking water for THMs concentration.

Even though the removal efficiency of TOC was 66 % after 27 days of operation and after the same period, the GAC column was still removing 100% of THMs, it can be concluded that

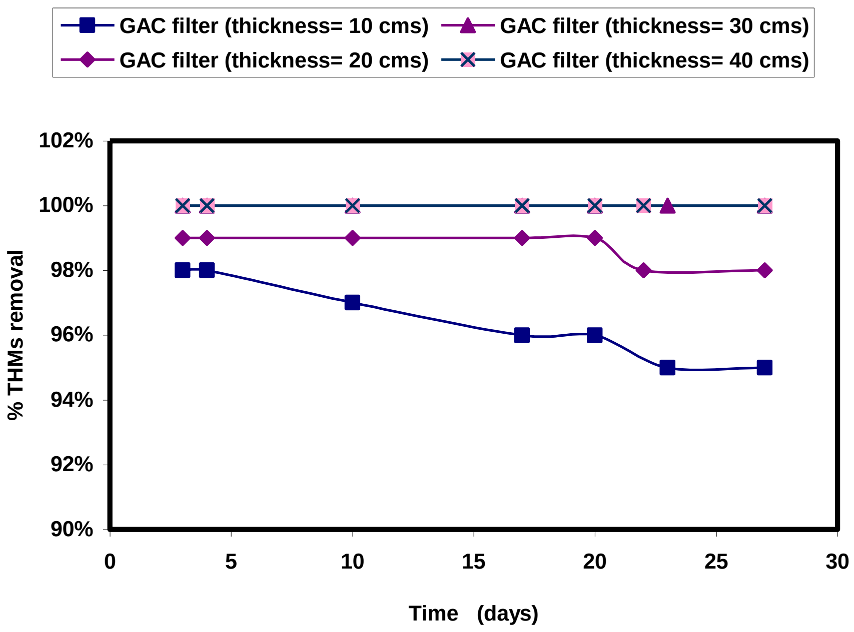

Fig. 8. Relation between % THMs removal and the thickness of the GAC filter for water after a filtration process with pre chlorination.

THMs were removed better than TOC. It is clear that, if the main objective of using GAC is removing TOC, then the GAC thickness must be not less than 40 cms, but if it is removing THMs, it is enough to use a 20 cms thickness.

4. Conclusions

Based on the observations and the results obtained from this study the following points were concluded.

1. Coke has a negative effect on TOC removal
2. Organics can be removed by an adsorption process and the removal of TOC was proportional to the thickness of the GAC layer.
3. Using filtered raw water (without coagulation) followed by GAC filtration was not an economic process, especially when the TOC concentrations were high (February to May) and then the bed depth of the GAC filter should be increased. So, the water supply should be pretreated with chemical coagulation before a GAC filter.
4. At the beginning stages of the GAC filtration operation, using settled water followed by GAC filtration gave removal efficiencies greater than those using filtered water with pre – chlorination followed by GAC filtration. Therefore, the reaction of chlorine gave negative effects on the adsorption process.
5. Reduction of removal efficiencies for settled water followed by GAC filtration was higher than that in filtered water with pre – chlorination. Therefore, better quality of treated water will be expected by using a GAC filter after the conventional sand filter, and low loading of pollutants to a GAC filter will result in long intervals of reactivation or replacement of GAC.
6. The GAC filter removed THMs compounds completely (100% removal efficiency) and the removal of THMs was better than the removal of TOC.

List of abbreviations

GAC is the Granular Activated Carbon,
THMs is the TriHaloMethene compounds, and
TOC is the Total Organic Carbon.

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