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PROSPECT OF DISINFECTION BYPRODUCTS IN WATER RESOURCES OF ZABOL

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Abstract

The natural organic compounds in water resources produce the highly toxic and carcinogenic secondary disinfection compounds such as halomethanes (THMs) and haloacetic acids (HAAs) during the chlorination process. The properties of organic compounds in water resources not only depend on the time but also the place. In this research, the formation of disinfection byproducts was studied by determining the concentration of dissolved organic carbon (DOC) as a main component of natural organic compounds (NOM) present in the raw water of Chahnimeh lakes in Zabol city which supply the drinking water for Sistan and Baluchishtan province. To achieve this purpose, 7 cumultive samples were prepared from Chahnimeh lakes in Zabol city during 8 months from October to May in 2015-2016. Also, the quality of samples was analyzed regarding to the amount of NTU, pH, UV_{254}, EC, DOC, SUVA and the dry remained compounds. The results showed that the concentration of dissolved organic carbon is averagely about 7.52 mg/L. The approximate amount of total organic carbon and the average of SUVA parameter are about 13.04 mg/L and 6.66 L/mg.m, respectively.

The highest and lowest concentrations of DOC were in March and December, respectively, and totally they did not follow the special time changes. The results revealed that the high proportion of SUVA parameter produces the disinfection byproducts such as toxic THMs more than HAAs.

Keywords: Dissolved Organic Carbon, Organic Matterials, Disinfection Byproducts, Zabol.

Introduction

The presence of organic compounds in the water as a significant factor, which affects the water quality, is always problematic in the water treatment plants that supply the urban water (1). The organic compounds originate from natural and artificial resources, are nearly present in all aqueous media with different concentrations, and have different reactivity, structures and colors. Due to the severe reactivity, natural organic compounds can produce new organic materials during the water purification and water transformation (2). Organic compounds alone are not harmful but due to the reaction with chlorine and producing toxic and carcinogenic disinfection byproducts, they are vitally important. In the past, the importance of organic compounds present in drinking water was related to the creation of colour and discontent of customers (2, 3). Among natural resources, organic compounds are the total amount of organic compounds (total organic carbon (TOC)) which increase biological activities such as metabolisms of algae, protozoa, actinomycetes, and microorganisms. These faunae produce compounds such as methylisoborneol (MIB) and geosmin in aqueous solutions which cause taste and smell in the water. Decomposition and decadence of compounds by bacteria and larger animals such as fishes and other sea creatures and also the composition of their cellular texture are the main cause of organic compound formation in the water. The organic compounds also enter the aqueous media through different ways by humans such as disposal of chemical waste in landfill sites, accidental leakage during storage and transport of chemicals, waste from manufacturing and commercial industries, direct discharge of wastewater obtained from treatment plants into water resources or indirect discharge to groundwater (2). These compounds react with organic and inorganic pollutants and may change their toxicity in the water. Due to the reaction with disinfectants material specially chlorine, this type of organic compounds can reduce the effects of disinfectants on the microorganisms, cause regrowth of microorganisms in the treatment or distribution network, and form carcinogenic disinfection byproducts (DBPs) such as trihalomethanes (THMs) and haloacetic acids (HAAs) (3, 4). It has been proven that the formation of byproducts depends on the concentration of organic compounds. However, some other factors such as the type of organic compounds and water purification methods affect the formation of byproducts. Therefore, removal and control of natural organic compounds before the disinfection process are essential (5). Of obvious problems caused by the presence of organic compounds in the water are increasing the tranformaton of heavy metals and toxic artificial compounds (6), reducing the desired effects of common water purification processes on the removal of pollutants (7), corrosion of steel systems (8), adverse effects on the coagulation process (9), undesirable effects on the adsorption process (10), unwanted effects on the performance of membranes (11), the regrowth of microorganisms in the water supply system and water storage tanks (12, 13), increased rates of disinfectants for water treatment, and the reaction of humic acid compounds with disinfectants during the disinfection process which produces more than 600 types of disinfection byproducts such as THM and HAA causing bladder cancer and cancer of the end part of large intestine (14, 15). Nowadays, the most important reason for the removal of these compounds from the drinking water by applying strict disinfection laws is preventing the DBPs formation and control of THMs and HAAs so that their permitted amounts in the drinking water reported by the Department of Environment in America are 80 and 60 μg/L, respectively, in the first step and 40 and 30 μg/L, respectively, in the econd step (16). The World Health Organization (WHO) has also reported the maximum permitted amount of THMs in drinking water about 100 μg/L (17). Also, the institute of Standards and Industrial Research of Iran have conducted some research in this area so that the maximum permitted amounts of the precursor compounds manufacturing trihalomethanes in the drinking water have been reported about 0.1, 0.1, 0.06, and 0.3 mg/L for bromoform, dibromochloromethane, dibromodichloromethane, and chloroform, respectively (18). According to the research carried out in recent two decades, the presence of these compounds in the drinking water resources is increasing, and it should be reduced or removed from the drinking water resources before the disinfection process (15, 19, and 20). Due to the complexity of natural organic compounds, their routine analysis is not possible. As a result, substitute parameters have been used. A substitute parameter is a parameter which is immediately measurable, does not need the special equipment and education, does not have the special calculation and presents a proper calculation of desired parameter. The common parameters related to this area are total organic carbon (TOC), dissolved organic carbon (DOC), UV absorption at the wavelength of 254 nm and specific UV absorbance (SUVA) (2). The total organic carbon indicates the total amount of organic carbon in the water samples. In this method, the natural organic compounds are totally oxidized to carbon dioxide, and the obtained carbon dioxide is measured. The total organic carbon is not equal to the concentration of natural organic compounds but it is a substitute parameter, and indicates the concentration of natural organic compounds till their elemental composition is not changed (24). According to the elemental composition, the concentration of natural organic compounds is usually twice the TOC concentration. To measure the DOC in water samples in which TOC was determined, first, they should be filtered using a 0.45 μm filter. The DOC parameter is a part of total organic carbon, and its concentration is equal or lower than the TOC (2). The UV absorption at the wavelength of 253.7 nm is considered as an index of the total concentration of organic compounds which absorb UV radiation of humic and aromatic compounds. The measuring organic content of a water sample by UV is a quick, affordable, and automatic process (25). The more DOC leads to the more UV_{254} absorption. The special adsorption of UV (SUVA) (L/mg.m) is calculated by division of UV absorption at the wavelength of 254 (m^{-1}) on the amount of DOC in the sample (mg/L). The SUVA parameter is an appropriate index for the description of organic compounds regarding to the hydrophobic and hydrophilic properties (26). According to the relationship between the concentration of organic compounds in the water and the formation potential of disinfection byproducts, the formation potential of disinfection byproducts can be calculated by measuring the concentration of organic compounds using total organic carbon, UV_{254}, and SUVA. In the past, some research was conducted to determine the amount of dissolved organic carbon in the water resources in Zabol city. So, this study can investigate its trend (27, 28). Since this type of study has not been done about the raw water entering the drinking water treatment plants in Zabol city, this research has been carried out to measure the amount of organic compounds which are present in the raw water before entering the drinking water treatment plants in Zabol city.

Materials and methods

The samples were prepared from the Chahnimeh lakes in Zabol city during 8 months from October 2015 to May 2016 according to the recommendations of the Standard Methods for the Examination of Water and Wastewater book. After recording the initial pH of samples and due to the satbilization, Based on previous study, all pH decreased to lower than 2 using phosphoric acid (29).

The dissolved organic carbon was measured according to the 5310B method of the Standard Methods for the Examination of Water and Wastewater book using a TOC analyzer device (ANA TOC Series Π model). To determine the pH, Ec and DOC, the Standard Methods for the Examination of Water and Wastewater book was used (30). The UV absorption at the wavelength of 254 nm (UV_{254}) was measured using a spectrophotometer device (UV visible T80 model). The standard solution of potassium hydrogen phthalate (KHP) was used for the prepration of reference samples and calibration curves (31). The concentration changes of organic compounds were determined using the calibration curve with the regretion coeficient of R = 0.9918 according to the equation 1.

(Eq 1) (HS)= 30.48×ABS-2.0549, r= 0.9918

The amount of SUVA (L/mg.m) was obtained from the division of UV_{254} (m^{-1}) on the amount of DOC (mg/L) (32). To adjust the pH, a pH meter device (Denver Ultra basic-UB10 model made in US) and solutions of perchloric acid and sodium hydroxide with the concentrations of 0.1 and 1 N, respectively, were used. The determination of salt concentrations in the samples was done *via* a conductivity meter device TWT-Cond 1310 model made in Germany.

Results and discussion

The results obtained from the analysis of dissolved organic carbon and UV absorption in water samples in the Zabol city have been presented in Table 1. As can be seen in the Table, the minimum and maximum concentrations of dissolved organic carbon were 5.42 and 10.87 mg/L, respectively, and the average concentration was 7.52 mg/L while the average of SUVA index was 6.66 mg/L. Figure 1 indicates the seasonal changes of dissolved organic carbon concentration and UV absorption in the samples. The maximum and minimum concentrations of dissolved organic carbon were 10.37 and 4.72 mg/L in March and December 2015, respectively. The maximum and minimum UV adsorptions at the wavelength of 254 nm were 0.304 and 0.817 cm^{-1} in March and December, respectively.

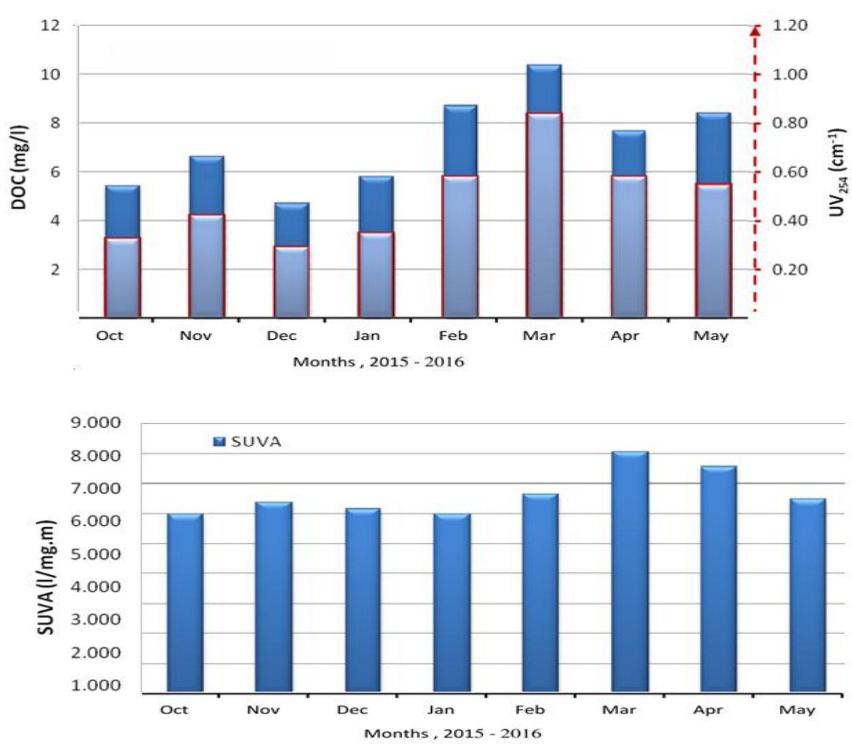

Figure-1. The seasonal changes of DOC concentration, UV absorption (UV_{254}) and SUVA in samples.

Table-1: The results achieved from DOC analysis and UV_{254} of samples.

Parameters	Concentration			
	Min	Avereage	Max	SD
UV_{254}) cm^{-1}(	0.304	0.438	0,817	0.18
DOC) mg/l(	5.42	7.52	10.87	1.20
SUVA) l/mg-m(	5.97	6.66	8.07	0.76
Hydrophilic fractional	1.70	2.85	5.47	1.31
Hydrophobic fractional	3.35	4.83	6.28	1.76
pH	7.30	7.73	8.2	0.20
TDS	445.70	471.45	510.51	40.38
EC	785	730.15	840	70.32
NTU	7.14	12.76	17.56	6.83

The amount of DOC in most of water is about 80 to 90% of TOC or maximum equal to TOC (2). According to the results obtained from this research, it can be reported that the amount of TOC in all samples is lower than 13.04 mg/L. In most of studies, a logical relationship between TOC and the formation of trihalomethanes (HMFP) has been emphasized so that in the research conducted by Krasner *et al.* in 1996 if the TOC concentration is low, the formation of C will be 50 μg THFP/mg while in the water with higher amounts of TOC will be about 50 to 100 μg THFP/mg (31). In other studies, carried out by Kim and Yu in 2005 and Panyapiyopol in 2005, it has been reported that the seasonal changes will have considerable effects on the formation potential of THMs and HAAs caused by the different reactions of organic compounds (5, 14). In addition, it can be estimated that if the suitable purification is not performed for the water containing high concentrations of organic compounds and chlorine is used as a disinfectant agent, the possibility of the presence of trihalomethanes as disinfection byproducts will be about 50 μg/L per mg of C/L. In other research conducted by Bazrafshan and coworkers, the concentration of organic carbon and formation potential of disinfection byproducts for the water entering the treatment plant in Zahedan was investigated, and similar results have been reported (27). Therefore, this water resource is now noteworthy, and the quality of this resource should be improved to supply the drinking water. Since the SUVA parameter determined in this research is higher than 4, it can be concluded that the proportion of hydrophobic components in the structure of organic compounds present in the water samples is more and definitely the possibility of trihalomethane formation is more than the formation of haloacetic acids. Averagely, the maount of hydrophobic components changes from 51.36 to 72%. Therefore, the hydrophobic part of natural organic compounds in the water is dominant. In the study carried out by Fearing *et al.*, it has been reported that the concentration of dissolved organic carbon in the treatment plant changed from 7.8 to 11.2 mg/L (3). Panyapiyopol and coworkers reported that the water in the treatment plant in the Bangkok, Tailand, has the hydrophobic and hydrophilic components about 66 and 44%, respectively (14). In the other studies, the seasonal changes of organic compounds in the aqueous solutions have been investigated that in some of them the useful results have been reported. In the research conducted by Matilainen *et al.* for the removal of natural organic compounds during different steps of water purification, the concentration of TOC increased from 5.1 in fall to 6.3 mg/L in summer. Also, they reported that the amount of UV_{254} was variable and its maximum amount was in spring and winter (33). In the other research carried out in USA, it has been reported that the concentration of total organic carbon in a lake was between 8.6 and 11.6 mg/L while the amount of UV_{254} was between 0.136 and 0.103 m^{-1}, and the hydrophobic part contains about half of TOC (22). As reported in another study, the amount of NOMs present in the Han River in North Korea was 3.12 mg/L according to the dissolved organic carbon, and UV_{254} was equal to 37 m^{-1}.

The amount of SUVA parameter was 1.185 L/mg.m in this research and it has been reported that in all samples, 55 to 70% of samples are natural organic compounds which form the hydrophilic part so the formation potential of haloacetic acids is more than trihalomethanes (33). Also, the results indicated that the concentration changes of natural organic compounds of the Chahnimeh lakes in Zabol city do not follow the special seasonal changes that Similar results have been reported in other study (34). In this case if use advanced treatment such as reverse osmosis and electrodialysis, there is not any concern about drinking used of it (35).

Conclusion

The concentration of natural organic compounds in the water Chahnimeh lakes in Zabol city is high and does not follow the special seasonal changes. If the removal process of organic compounds in the treatment plants, which use these resources for supplying the drinking water, is inefficient and chlorine is used as a disinfectant agent, the carcinogenic disinfection byproducts such as toxic THMs are definitely present in the water. Also, it is indicated that in the water Chahnimeh lakes in Zabol city, the hydrophobic part of total organic carbon is more than the hydrophilic part so the concentration of trihalomethane disinfection byproducts is more than the concentration of haloacetic acid disinfection byproducts.

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