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Formation of trihalomethanes(THM) in moroccan drinking water: A case study in the supply network of the districts of the two biggest cities

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ABSTRACT

In recent years attention has been drawn to various aspects related to the influence of disinfection by-products in distribution systems. The formation of trihalomethanes(THMs) and its species which form the reaction of chlorine with humic substances have caused much alarm because of their carcinogenic and dangerous health effects. In this work, the THM formation is followed during summer and winter in the water treatment plant and the network of the water supply of National Office of Potable Water(ONEP) between the two biggest towns in Morocco: Rabat and Casablanca. The potential formation of THM of the reservoir water is determined.

KEYWORDS

Disinfection;
Drinking water;
Water distribution system;
Trihalomethanes;
Formation potential;
Chlorination.

INTRODUCTION

Two of the main reasons for the disinfection of drinking water are to protect the drinking water from the pollution in the distribution systems and to prevent, or at least control, the regrowth of micro-organisms in the distribution system until the water safely reaches the consumers.

Since the beginning of the 20th century, chlorination has been a key-treatment for improving the microbio logical safety in drinking water. However, an undesired formation of disinfection by-products can result from the reaction of chlorine with natural organic matter and includes products such as trihalomethanes($CHCl_3$, $CHCl_2Br$, $CHClBr_2$, and $CHBr_3$)[10] which might have adverse health effects[9,7,2].

The total concentration of trihalomethanes (THMs) and the formation of individual THM species in chlorinated water depend strongly on the composition of the raw water, on operational parameters during water treatment (pH, temperature) and on the residual chlorine in the distribution system[6,3,8].

The source of concern about disinfection by-products, mainly the THMs which occur in the largest concentrations, has historically been chronic exposures resulting in cancers of the gastro-intestinal tract[1,11]. Recent epidemiological studies have also suggested that THMs may have negative acute reproductive effects, including spontaneous abortion, birth defects, and stillbirths[5,12]. The most current toxicological and some epidemiological studies have suggested that the brominated THMs pose the greatest concern[11,5,4].

Aiming at minimizing the cancer risk, the United States Environmental Protection Agency (USEPA), the World Health Organization(WHO), and the European Union(EU) introduced regulations for THMs in drinking water. Whereas the USEPA and the EU regulate total THM concentrations as 80 and 100μg/L, respectively, the WHO provides guidelines for individual THM compounds[13]. The National Office of Potable Water (ONEP) in Morocco regulates total THM concentrations at 100μg/L.

The aim of this work is to follow the THM formation during summer and winter in the water treatment plant and in the network of the water supply of National Office of Potable Water(ONEP) between the two biggest towns in Morocco: Rabat and Casablanca.

EXPERIMENTAL

The main producer of drinking water in Morocco is the National Office of Potable Water(ONEP). The water treatment plant of Bouregrag (BP) (region of Rabat) is supplied by Sidi Mohamed Ben Abdellah (SMBA) reservoir on the Bouregrag river. This plant supplies a big part of Rabat and Casablanca. The plant of Bouregrag is considered among the biggest plants of Africa. In Bouregrag plant(BP), the water is produced by conventional treatment including coagulation and flocculation, sedimentation, rapid sand filtration, and disinfection. A lime solution is added between sedimentation and filtration to adjust pH value and reduce the corrosivity of the water. The(BP) produces about 9m^3/s.

The study was carried out for the supply network between the reservoir until Casablanca pipeline for a distance of about 100Km. The underground water of Fouarat, Kénitra which only chlorinated was taken as reference.

The samples were taken for several locations (Figure1). TABLE 1 gives the time of stay of the various locations.

The taken samples are analysed to determine the following parameters: temperature, the residual chlorine, turbidity, Absorbable Organo Halogenous (AOX) and THM.

The determined AOX(Absorbable Organo Halogenous) following AFNOR standards(AFNOR NF EN 1485 Oct 1996), include the totally of chlorine, bromine and iodine organically bounded and able to be adsorbed on activated carbon.

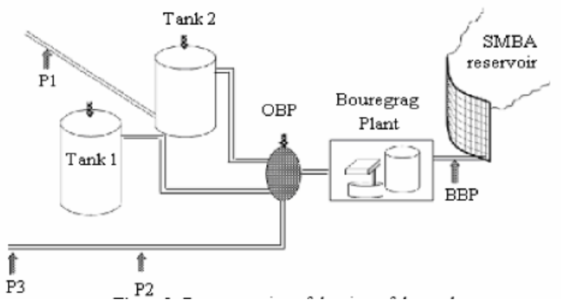

Figure1: Representation of the sites of the study

TABLE 1 : Locations and time of stay

Locations	Symbol	Time of stay (hour)
Before bouregrag plant	BBP	-
Outlet bouregrag plant	OBP	0
Tank 1	T1	72
Tank 2	T2	21
The pipeline at Rabat	P1	22
The pipeline at Bouznika	P2	30
The pipeline at Casablanca	P3	48
Tank 3 (reference)	T3	1

The principle of the analysis method is based on adsorption on activated carbon of the organic substances after acidification by HNO_3. The halides minerals are moved by rinsing with a $NaNO_3$ solution. The combustion of the activated carbon was carried out in a furnace at 800^{0}C, the halides are then moved in an electrochemical cell under a current of oxygen where are analysed by couloumetry.

This method allows to distinguish between the purgeable organo halogenous (POX) which are volatile molecules and the non purgeable organo halogenous (NPOX).

The THM were determined by a normalised method called "head space static" following AFNOR standards (AFNOR T90-125 Sep 1987).

The analysis of THM was carried out using a gas chromatograph HP 6890 equipped with electron capture detector and a column (30m×0.32mm×0.25μm). The detection limit of this method is 1μg/l for $CHCl_3$ and $CHCl_2Br$ and 5μg/l for $CHClBr_2$ and $CHBr_3$.

The turbidity is measured by turbidimetre HACH, 2100N. The residual chlorine is determined by Orthotoloidine method.

RESULTS AND DISCUSSION

Relation between THM and AOX

The experiments were performed during the summer. The AOX and THM contents were followed in the different locations of the study (figure 2).

Figure 2 gives the follow-up of the the AOX and THM contents in different locations

The follow-up of the THM and the AOX from the treatment plant to the different points of the network showed that the increase in the concentration of the THM was accompanied by a similar increase of the AOX concentration.

Evolution of the concentration of THM

The concentration of THM, residual chlorine, turbidity and pH at different locations during the winter and summer season are illustrated in the TABLE 2.

Figure 3 gives the follow-up of the concentration average of the THM in the samples during winter and summer seasons.

The distributions of different haloforms for different samples during the both seasons are represented in figure 4.

Figure 3 shows that the THM formation increases from the BBP to the last pipeline P3. This increase is more marked for P2 and P3 pipeline and for the two seasons. This can be attributed on one hand to the high time of stay for these locations and on the other hand to the high rechlorination operated periodically at these points.

The results show the presence of a little amount of THM in all the sampled locations. The lower value was

TABLE 2: Evolution of the water parameters for the both seasons

location	BBP	OBP	R 1	R 2	P 1	P 2	P 3	R 3
Winter campaigns								
THM(µg/L)	43.6	45	91.5	77	85	111	120	9
Residual chlorine (mg/l)	0.95	0.9	0.72	0.7	0.48	0.43	0.83	0.5
Turbidity (NTU)	0.20	0.20	0.23	0.22	0.26	0.27	0.25	0.24
T°(C)	13.5	13.5	14.2	13.9	16	17	17	17
Summer campaign								
THM (µg/l)	66	75.5	77.5	80	80	119	120	04
Residuel chlorine (mg/l)	1.4	1.1	0.8	1.0	1.0	0.55	0.6	0.5
Turbidity (NTU)	0.18	0.18	0.20	0.30	0.40	0.42	0.42	0.24
T^0(C)	22	22	21	20	24	23	23	23

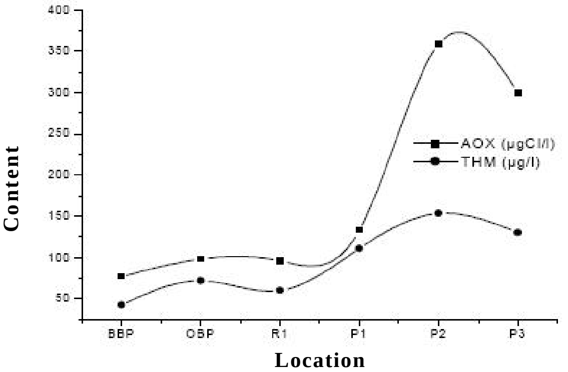

Figure 2: Variation of THM and AOX

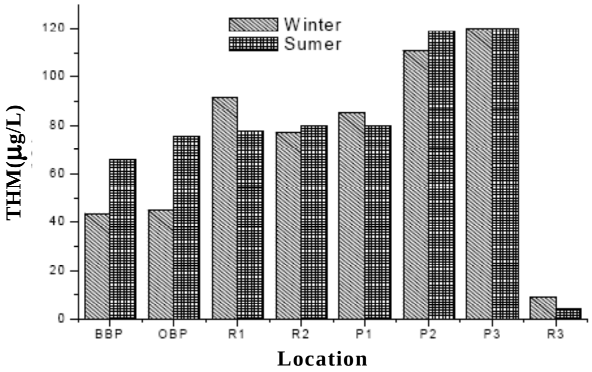

Figure 3 : Evolution of the THM for the both seasons

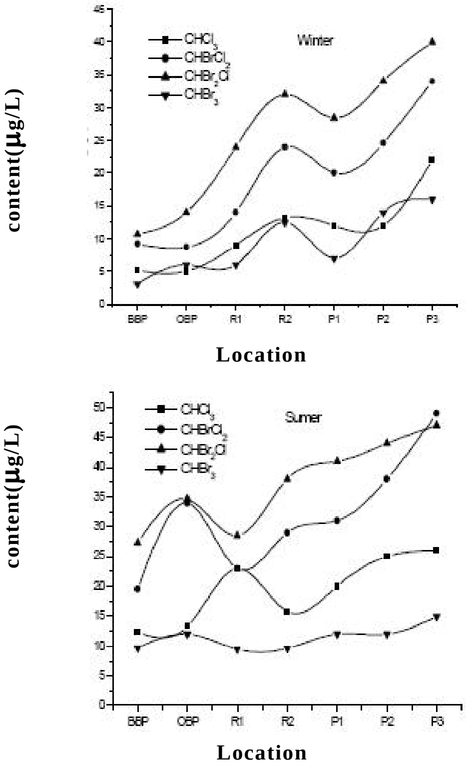

Figure 4 : Distribution of the THM in winter and summer

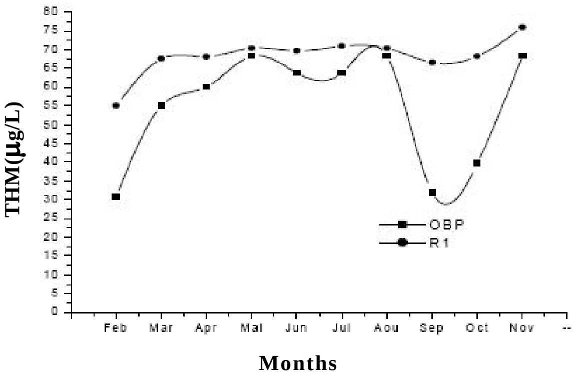

Figure 5 : Evolution of THM

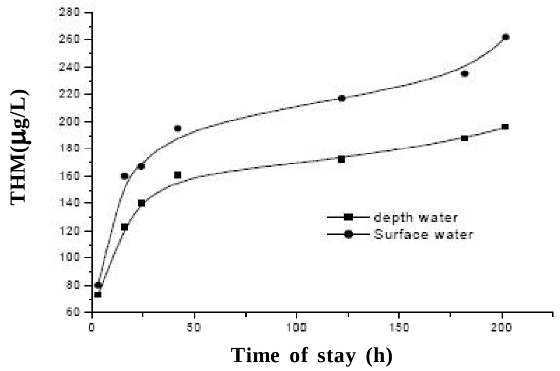

Figure 6: Potential of formation of the THM

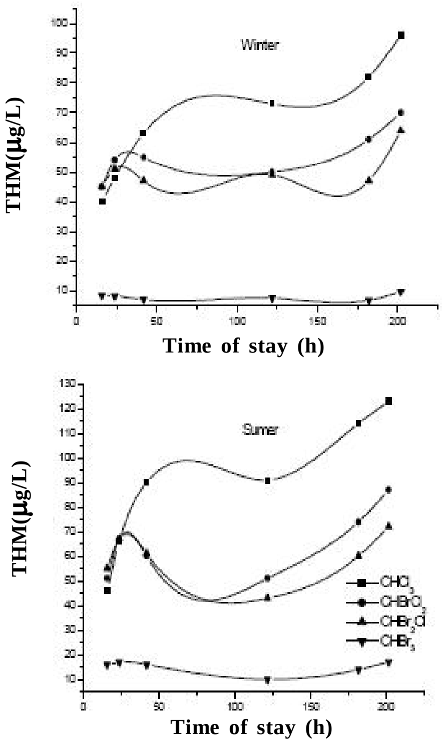

Figure 7: Potential of formation of different THM on the depth and the surface water

observed in reference T3 where the underground water is only chlorinated.

The analysis of results of the two campaign shows that the THM formation is practically the same for the two seasons and for the various locations, despite the relatively high formation of THM at the outlet of the plant. The amount of THM remains practically lower than the standards for the two seasons and the various locations.

Figure 4 shows the season does not have any influence on the distribution of THM. The highest amount of the produced THM corresponds to $CHClBr_2$ followed by $CHCl_2Br$. The content of chloroform and bromoform were practically the same.

Figure 5 gives the THM formation during nine months for OBP and T1 locations. Despite, the slight increase in summer, the content remains lower than the standards for the two locations. The lower value observed in September and October in the case of T1 is attributed to the use the activated carbon during this period.

Potential of formation of THM

To determine the kinetic of the THM formation, a chlorination was carried out at laboratory on two water samples of the reservoir(SMBA). The first sample was taken on surface and the other one in the depth of the reservoir. The two samples were taken in June. The chlorination was made by CHCOCl to have a residual chlorine of 20mg/l.

Results of figure 6 show a rapid formation of THM during the first 24 hours and for the both samples. Thus the kinetic decreases and the THM formation reaches a level. After 72 hours, the amount of produced THM exceeds 200μg/l for the surface water and 170μg/l for the depth water indicating that the surface water is richer on organic matter than the depth water.

Figure 7 shows that the distribution of the produced THM was the same for the two sampled water. The higher amount of produced THM was $CHCl_3$ followed by $CHBrCl_2$, $CHBr_2Cl$ and $CHBr_3$.

CONCLUSION

The water chlorination is an important operation for disinfection of the water supply. However, this operation must be carried out rigorously and carefully to avoid the potential formation of THM in the case of excess of chlorine and organic matter.

The follow-up of the THM formation from the reservoir SMBA to the pipelines of Casablanca show the presence of lower amount of THM in various controlled locations. These amounts still lower than the maximum standards.

Moreover, in this case, the THM formation is practically independent of the season.

However, the potential formation of THM in the water reservoir remains higher. A value of 200µg/l of THM can be obtained when using a higher amount of chlorine such 20mg/l of residual chlorine.

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