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Trihalomethanes Existence Evaluation in Drinking Water of Beni-Suef Governorate and Association Health Risks

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Abstract

In this study, trihalomethanes (THMs) were looked for in drinking water samples taken from the more than 3 million people served by the water treatment facilities in Beni-Suef Governorate. Monthly samples of drinking water were taken during 2017 and 2018 from 5 locations. In the outputs of water treatment plants, THM readings ranged from 27.0 to 88.80 µg/l. The outlets of water treatment plants have chloroform values ranging from 12.1 to 45.80 µg/l. All values of the non-cancer hazard quotient for chloroform that are already below the risk value recommended by general guidance (170x10-3). Dichlorobromomethane levels in water treatment plant exits varied from 8.1 to 31.4 µg/l in all cases. Each and every dichlorobromomethane cancer risk value that is lower than the overall recommended risk value (99.2 106). The range of dibromochloromethane values was less than.Every cancer risk rating for dibromochloromethane is lower than the overall recommended risk value for Class A carcinogens (134.4 x 106). In the current study, all examined water samples demonstrated that bromoform was not found throughout the investigation. All THM cancer risk values are below the overall recommended risk value for Class A carcinogens (165.3 x 106). The study demonstrated that THM levels and its constituent parts complied with Egyptian regulations and that the majority of risk values related to THMs fell within permissible bounds.

Keywords:Trihalomethanes; Drinking water; Risk assessment; Beni-Suef Governorate

1. Introduction

To stop infectious disease outbreaks and avoid problems with public health, water disinfection is a crucial and essential process. Different techniques can be used, but chlorination is the most popular way to disinfect drinking water because it is the most efficient and affordable option. In Egypt chlorination is the main method of disinfection used in treatment plants, given its effectiveness against a wide range of pathogens, including bacteria, viruses and protozoa, and because the technology associated with the process is simpler than any other disinfection technology (Chen, et al., 2003).

In addition to these countries and others, chlorination is frequently utilized in Saudi Arabia (Huang et al., 2005), Iran, India, China (Lee et al., 2002; Yang et al., 1998), and Canada (HC, 2006). Additionally, the technique leaves a residual concentration in the distribution system, which is thought to offer defense against the development of pathogens. However, this residue also generates compounds that could be dangerous.

Since multiple human studies have linked prolonged exposure to high levels of DBP to an increased risk of getting cancer, chlorine may form disinfection byproducts (DBP) that are detrimental to health when it comes into contact with water that includes organic matter. Trihalomethanes, halo-acetic acids, haloketones, and halo-acetonitrile are just a few of the compounds that can be found in DBPs.

Trihalomethanes (THM), however, are generally the most common chlorine disinfection byproducts in drinking water, according to the World Health Organization in 2005. Because of this, the four most important THM species—chloroform, bromodichloromethane (BDCM), bromoform, and dibromochloromethane—were the only ones whose risk evaluation was the subject of this study. Chloroform is the most prevalent type of THM and is present in larger amounts. Numerous investigations on animals show that oral exposure to chloroform causes cancer and that the toxicological effects are the same whether the substance is inhaled or consumed.

The main health effects of bromoform and DBCM are liver and kidney damage as well as nervous system depression. Since it causes cancer in rodents at lower concentrations and more target sites than the other three THMs, BDCM appears to be the most potent

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one. A number of epidemiological and case-control studies of communities who drank chlorinated water also revealed slight but substantial increases in the prevalence of large intestine, rectum, and bladder cancer. As a result, these substances need to be monitored and under control because they are dangerous to the public's health.

Depending on the chemistry and physical characteristics of the substance, different pathways can expose people to disinfection byproducts in drinking water. THM exposure can happen primarily through ingestion. Trihalomethanes are volatile at room temperature (WHO, 2005), so exposure to this pollutant might happen when drinking tap water, taking a shower, washing dishes or clothes, or swimming in pools. As a result, exposure through inhalation is particularly important. Given that this activity comprises the longest exposure times and the water is typically at a high temperature, it has been suggested that the shower is the main source of inhalation exposure.As a result, the study only considered this source when calculating the risk of inhalation. However, research from Cyprus and Kuwait has shown that cleaning the home can lead to higher indoor chloroform concentrations, which may increase THM exposures. Future research may evaluate the risk of THM inhalation by taking into account the exposure from domestic cleaning activities.

The current study set out to assess the risk that residents of the Beni-Suef Governorate might face from ingesting THM.

2. Materials and Methods

2.1 The sampling sites description

Study Area :BeniSuef Governorate is located between latitudes 28˚45' and 29˚25'N and longitudes 30˚45' and 31˚15'E, occupying a part of the lower Nile Valley about 120 km south of Cairo on the west bank of the Nile River. It includes seven Districts namely; BeniSuef (the capital), El-Wasta, Naser, Beba, Ihnasia, Somosta and El-Fashn. (Melegy, et al., 2014).

All samples collected in the period from September 2017 to August 2018, The water samples collected from (s1) Saftelgharbyaelgidida (Ultra Filtration): 29.406362N, 31.168466S, (s2) MydoumEladiema (Direct Filteration): 29.406362N, 31.168466S, (s3) Koumabouradie (Direct Filtration), (s4) American1 (Conventional): 29.06129440395536N 31.09482958188179S, (s5)Tushikie (Conventional): .06129440395536 N 31.09482958188179 S WTPs, All samples were collected in triplicate water samples.

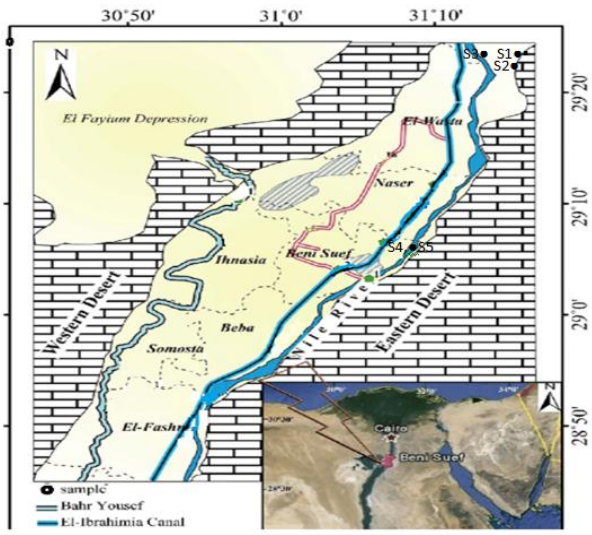

Figure (1): The five sampling sites in Beni-Suef governorate, Egypt.

2.2 Water sampling and analysis

In the current investigation, THMs water samples were collected at the designated locations in 40 ml amber glass bottles, which were filled with the water samples without the presence of air bubbles. The amber bottles were filled with a sodium thiosulfate solution before to sampling in order to remove any residual chlorine and halt the production of THM. Prior to use, all glasses were cleaned with phosphate-free detergent and rinsed with ultrapure water. It was then heated to 150°C for two hours and allowed to cool at ambient temperature. All samples were transported to the water laboratory in ice boxes and stored in amber glass bottles with screw-on lids protected with Teflon. THMs samples were kept in refrigerators at 4° C until the THMs analysis.THMs were extracted and determine according to EPA Method 551.1 and Standard Methods (APHA, 2017, USEPA, 1997, and USEPA, 2005). For extraction the THMs (CHCl3, CHCl2Br, CHClBr2 and CHBr3). 5 mL of n-hexane was added to 25 ml of sample in 40 ml glass vials. The upper phase layer of hexane (organic layer) was separated by manual shaking for 1 minute.

2.3 Reference Materials, Organic Solvents and other Chemicals

2.4 Health risk assessment

A risk assessment model (equation 1) based on US Environmental Protection Agency recommendations was used to determine the

Items	Supplier
I. Reference Materials 1.Trihalomethanes mixture: • Chloroform. • Dichlorobromomethane. • Dibromochloromethane. • Bromoform. **II. Organic solvents** 1. Dichloromethane (pesticide residual grade) 2. n-Hexane (pesticide residual grade) 3. Acetone (HPLC grade**,** 99.9%**)** 4. n- Pentane (HPLC grade, 99.9%) **III. Other chemicals** **1.Chlorine** • Calcium Hypochlorite ($Ca(OCl)_2$, 70 % chlorine)	Accu-standard, Inc (USA) Fisher scientific Fisher scientific Sigma-Aldrich Sigma-Aldrich Misr Chemical Company, Alexandria, Egypt.

Table (1): Reference materials, organic solvents and other chemicals.

lifetime cancer risk (Rci) brought on by exposure to halogen chemicals in drinking water.

Equation 2 was used to calculate the non-cancer hazard quotient (HIi), which was used to calculate the risk posed by chloroform as a secondary carcinogen. Utilizing the reference dose value provided by IRIS, which is thought to be protective against carcinogenic effects, the hazard quotient for chloroform was calculated.

$$R_a \equiv \frac{EF \times ED}{BW \times AT} \times C_{ai} \times IR_a \times Sf_i \quad (1)$$

$$HI_i \equiv \frac{EF \times ED}{BW \times AT} \times \frac{C_{ai} \times IR_a}{RfD_i} \quad (2)$$

Where:

Cai: chemical concentration in water (mg/l)
IRa: intake rate (2 L/d)
EF: exposure frequency (d/a, event/year)
ED: exposure duration (year)
BW: body weight (70 kg)
AT: average time (25550 d)
Sfi:the specific cancer slope factor (mg/kg-d)-1 forbromide compounds
RfDi: the reference dose for chloroform (mg/kg.d)

Statistical analysis

Data are statistically analyzed using ANOVAtwo-way test.

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3- Results and Discussion

The collected water samples from some of water treatment plants (Saftelgharbyaelgidida WTP, MydoumEladiema WTP, Koumabouradie WTP, American 1 WTP, and Tushikie WTP) in BeniSuefgovernorate during the study (Sep. 17 to Aug. 18) were analyzed to determine the levels of trihalomethanes and evaluate the association human risks, the observation was illustrated in Tables (3, 4, 5 and 6) and Figures (2, 3,4 and 5).

Table (2): Quality control data for trihalomethanes compounds

No.	Parameter	MDL (µg/l)	LOQ (µg/l)	Accuracy (%)	Precision (RPM)	Bias (±µg/l)
1	**Chloroform (CF)**	0.1	0.1	98.4	4.6	0.05
2	**Dibromochloromethane (DBCM)**	0.1	0.1	96.2	4.8	0.05
3	**Dichlorobromomethane (DCBM)**	0.1	0.1	94.8	4.4	0.04
4	**Bromoform (BF)**	0.1	0.1	97.2	4.3	0.08

MDL: Minimum detection limit**, LOQ:** Limit of quantation

Table (3) summarizes the concentrations of Chloroform. The average values of chloroform were 0.0301, 0.0282, 0.0336, 0.0309 and 0.032 mg/l, in Saftelgharbyaelgidida, MydoumEladiema, Koumabouradie, American 1, and Tushikie WTPs, respectively, as shown in Table (3). The human risk values of chloroform were 17.1, 16.0, 19.0, 17.5 and 18.1(x 10-3), in Saftelgharbyaelgidida, MydoumEladiema, Koumabouradie, American 1, and Tushikie WTPs, respectively, as shown in Table (3) and Figure (2).

Table (3): The levels of Chloroform in WTPs outlets and associated risks

Date	Saft El Garbyia WTP		MydoumEladiema WTP		Koumabouradie WTP		American1 WTP		Tushikie WTP	
	C_{ai}(mg/l)	HIix 10^{-3}	C_{ai}(mg/l)	HIix 10-3	C_{ai}(mg/l)	HIix 10^{-3}	C_{ai}(mg/l)	HIix 10-3	Cai(mg/l)	HIix 10-3
Nov. 2017	0.0250	14.2	0.0132	7.5	0.0257	14.6	0.0282	16.0	0.0355	20.1
Dec. 2017	0.0187	10.6	0.0142	8.1	0.0328	18.6	0.0256	14.5	0.0328	18.6
Jan. 2018	0.0260	14.8	0.0170	9.6	0.0280	15.9	0.0300	17.0	0.0230	13.0
Feb. 2018	0.0300	17.0	0.0190	10.8	0.0300	17.0	0.0290	16.5	0.0240	13.6
Mar. 2018	0.0122	6.9	0.0220	12.5	0.0303	17.2	0.0267	15.1	0.0270	15.3
Apr. 2018	0.0121	6.9	0.0250	14.2	0.0310	17.6	0.0291	16.5	0.0310	17.6
Avg.Winter	0.0207	11.7	0.0184	10.5	0.0296	16.8	0.0281	15.9	0.0289	16.4
May. 2018	0.0250	14.2	0.0320	18.1	0.0360	20.4	0.0320	18.2	0.0335	19.0
Jun. 2018	0.0402	22.8	0.0341	19.3	0.0388	22.0	0.0322	18.3	0.0338	19.2
Jul. 2018	0.0456	25.9	0.0410	23.3	0.0390	22.1	0.0331	18.8	0.0340	19.3
Aug. 2018	0.0458	26.0	0.0425	24.1	0.0392	22.2	0.0338	19.2	0.0338	19.2

Sep. 2017	0.0373	21.2	0.0392	22.2	0.0294	16.7	0.0356	20.2	0.0382	21.7
Oct. 2017	0.0435	24.7	0.0394	22.4	0.0426	24.2	0.0356	20.2	0.0372	21.1
Avg.Summer	0.0396	22.5	0.0380	21.6	0.0375	21.3	0.0337	19.2	0.0351	19.9
Average	0.0301	17.1	0.0282	16.0	0.0336	19.0	0.0309	17.5	0.0320	18.1
Min	0.0121	6.9	0.0132	7.5	0.0257	14.6	0.0256	14.5	0.023	13.0
Max	0.0458	26.0	0.0425	24.1	0.0426	24.2	0.0356	20.2	0.0382	21.7
St. Dev.	0.012	6.516	0.010	5.936	0.005	2.823	0.003	1.792	0.004	2.554
Control	**0.3**	**170**								

All values of The hazard quotient for chloroformwhich has already lower than the general guidance risk(170 × 10−3). The ANOVA test (two factors without replication) showed that, the seasonal variation effects on the formation of chloroform compounds are the major than the type of technology used for water purification, as indicated in Table (7).

Table (4) summarizes the concentrations of DCBM. The average values of DCBM were 0.0179, 0.0168, 0.0191, 0.0172 and 0.0184 mg/l in Saftelgharbyaelgidida, MydoumEladiema, Koumabouradie, American 1, and Tushikie WTPs, respectively, as shown in Table (4). The human risk values of DCBM were 29.6, 27.8, 31.5, 28.4 and 30.4(x 10-6), in Saftelgharbyaelgidida, MydoumEladiema, Koumabouradie, American 1, and Tushikie WTPs, respectively, as shown in Table (4) and Figure (3). All values of DBCM cancer risks which has already lower than the general guidance risk value for Class A carcinogens (99.2 × 10−6).

The ANOVA test (two factors without replication) showed that, the seasonal variation effects on the formation of DCBM compounds are the major than the type of technology used for water purification, as indicated in Table (6). Due to the lack of available parameters, most of the studies focus on the risks associated with chloroform; and in

Numerous studies have recently been carried out to evaluate the potential cancer risks associated with exposure to THMs in drinking water. When employing high bromide raw water in water treatment systems, the treatment procedures may remove certain organic precursors and subsequently reduce the levels of organic precursors, which results in a rise in the Br/organic ratio after the treatments.
fewer cases chloroform and bromodichloromethane are used as the target compounds (WHO, 2005). However, the presence of bromide in raw water leads to the formation of brominated-THMs, including bromodichloromethane, chlorodibromomethane, and bromoform.

Table(5) summarizes the concentrations of DBCM.The average values of DBCM were 11.7, 9.4, 11.5, 10.0 and 10.3 µg/l in Saftelgharbyaelgidida, MydoumEladiema, Koumabouradie, American 1, and Tushikie WTPs, respectively, as shown in Table (5). The human risk values of DBCM were 26.3, 21.1, 25.7, 22.5 and 23.0(x10-6), in Saftelgharbyaelgidida, MydoumEladiema, Koumabouradie, American 1, and Tushikie WTPs, respectively, as shown in Table (5) and Figure (4). All values of DBCM cancer risks which has already lower than the general guidance risk value for Class A carcinogens (134.4 × 10−6).

Table (4): The levels of DCBM in WTPs outlets and associated risks

Date	Saft El Garbyia WTP		MydoumEladiema WTP		Koumabouradie WTP		American 1 WTP		Tushikie WTP	
	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}
Nov. 2017	0.0160	26.5	0.0117	19.4	0.0188	31.0	0.0170	28.1	0.0149	24.7
Dec. 2017	0.0081	13.3	0.0091	15.1	0.0199	32.9	0.0144	23.7	0.0203	33.6
Jan. 2018	0.0190	31.4	0.0102	16.9	0.0140	23.1	0.0162	26.8	0.0142	23.5
Feb. 2018	0.0175	28.9	0.0118	19.4	0.0137	22.6	0.0159	26.3	0.0149	24.7
Mar. 2018	0.0092	15.3	0.0112	18.5	0.0166	27.4	0.0142	23.5	0.0160	26.5
Apr. 2018	0.0082	13.6	0.0113	18.7	0.0170	28.1	0.0120	19.8	0.0120	19.8
Avg.Winter	0.0130	21.5	0.0109	18.0	0.0167	27.5	0.0149	24.7	0.0154	25.5
May. 2018	0.0151	25.0	0.0133	22.0	0.0180	29.8	0.0110	18.2	0.0130	21.5
Jun. 2018	0.0245	40.5	0.0241	39.8	0.0223	36.9	0.0208	34.4	0.0238	39.3
Jul. 2018	0.0241	39.8	0.0230	38.0	0.0230	38.0	0.0192	31.7	0.0240	39.7
Aug. 2018	0.0240	39.7	0.0223	36.9	0.0221	36.5	0.0198	32.7	0.0198	32.7
Sep. 2017	0.0246	40.7	0.0314	51.9	0.0193	31.9	0.0231	38.2	0.0245	40.5
Oct. 2017	0.0248	41.0	0.0222	36.7	0.0245	40.5	0.0224	37.0	0.0234	38.7
Avg.Summer	0.0229	37.8	0.0227	37.6	0.0215	35.6	0.0194	32.0	0.0214	35.4
Average	0.0179	29.6	0.0168	27.8	0.0191	31.6	0.0172	28.4	0.0184	30.4
min	0.0081	13.3	0.0091	15.1	0.0137	22.6	0.0110	18.2	0.0120	19.8
max	0.0248	41.0	0.0314	51.9	0.0245	40.5	0.0231	38.2	0.0245	40.5
St. Dev.	0.006	10.252	0.007	11.361	0.003	5.302	0.004	5.935	0.004	7.174
Control	0.06	99.2								

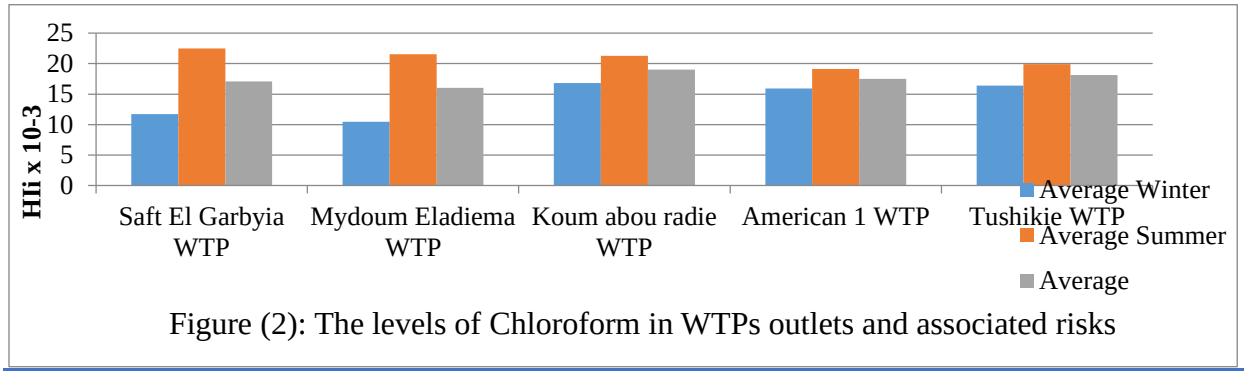

Figure (2): The levels of Chloroform in WTPs outlets and associated risks

Date	Saft El Garbyia WTP	MydoumEladiema WTP	Koumabouradie WTP	American 1 WTP	Tushikie WTP

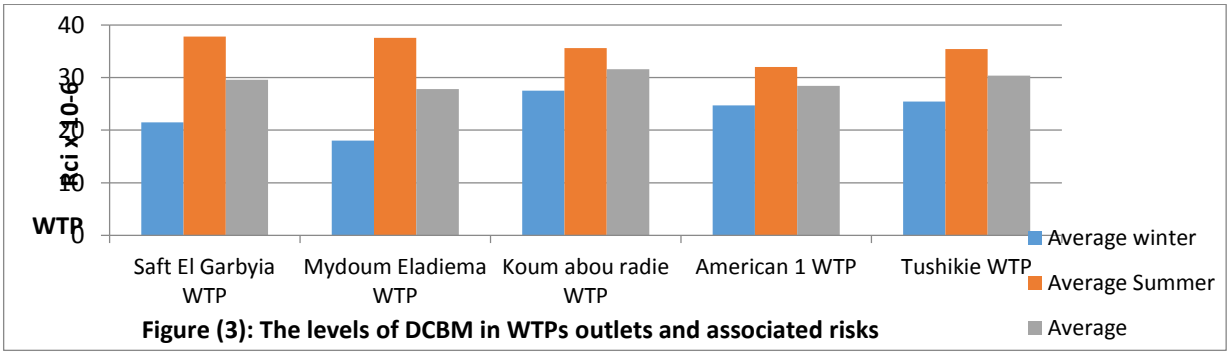

Figure (3): The levels of DCBM in WTPs outlets and associated risks

The ANOVA test (two factors without replication) showed that, the seasonal variation effects on the formation of DBCM compounds are the major than the type of technology used for water purification, as indicated in Table (7). After chlorination, this would result in the shift of THM species from chlorinated-THMs to brominated-THMs. Black et al.,1996 have shown that greater degrees of risks are associated with chlorination of raw water with higher bromide and organic carbon concentrations.

Greater hazards have been linked to chlorinating raw water with higher bromide and organic carbon concentrations, according to research by Black et al. in 1996.

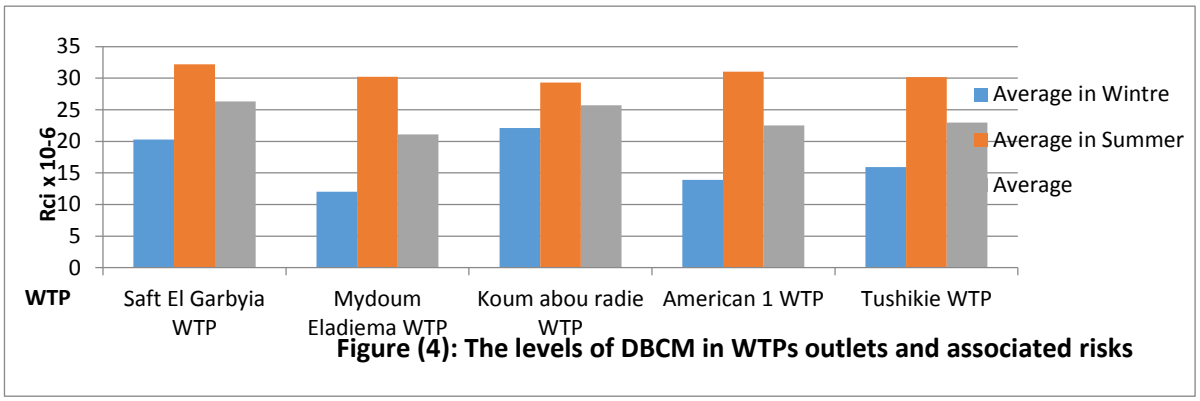

Figure (4): The levels of DBCM in WTPs outlets and associated risks

	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}
Nov. 2017	0.0090	20.2	0.0053	11.9	0.0097	21.6	0.0062	13.9	0.0052	11.6
Dec. 2017	0.0056	12.6	0.0053	11.9	0.0087	19.4	0.0000	0.0	0.0066	14.8
Jan. 2018	0.0122	27.3	0.0044	9.9	0.0110	24.6	0.0095	21.3	0.0082	18.4
Feb. 2018	0.0143	32.0	0.0058	13.0	0.0099	22.1	0.0087	19.5	0.0086	19.2
Mar. 2018	0.0066	14.8	0.0056	12.6	0.0092	20.5	0.0064	14.3	0.0066	14.8
Apr. 2018	0.0067	15.0	0.0057	12.8	0.0110	24.6	0.0065	14.6	0.0075	16.8
Avg.Winter	0.0091	20.3	0.0054	12.0	0.0099	22.1	0.0062	13.9	0.0071	15.9
May. 2018	0.0112	25.1	0.0059	13.1	0.0074	16.6	0.0073	16.4	0.0000	0.0
Jun. 2018	0.0142	31.8	0.0135	30.2	0.0132	29.6	0.0162	36.3	0.0172	38.5
Jul. 2018	0.0136	30.5	0.0139	31.1	0.0139	31.1	0.0155	34.7	0.0182	40.8
Aug. 2018	0.0133	29.8	0.0141	31.6	0.0142	31.8	0.0141	31.6	0.0141	31.6
Sep. 2017	0.0168	37.6	0.0182	40.8	0.0126	28.2	0.0144	32.3	0.0147	32.9
Oct. 2017	0.0172	38.5	0.0155	34.7	0.0172	38.5	0.0156	34.9	0.0166	37.2
Avg.Summer	0.0144	32.2	0.0135	30.3	0.0131	29.3	0.0139	31.0	0.0135	30.2
Average	0.0117	26.3	0.0094	21.1	0.0115	25.7	0.0100	22.5	0.0103	23.0
min	0.0056	12.6	0.0044	9.9	0.0074	16.6	0.0000	0.0	0.0000	0.0

max	0.0172	38.5	0.0182	40.8	0.0172	38.5	0.0162	36.3	0.0182	40.8
St. Dev.	0.004	8.138	0.005	10.687	0.003	5.728	0.005	10.609	0.005	11.651
Control	0.06	134.4								

Table (5): The levels of DBCM in WTPs outlets and associated risks

Table (6) summarizes the concentrations of TTHM. The average values of TTHMs were 0.0598, 0.0544, 0.0642, 0.0586 and 0.0607 mg/l, in Saftelgharbyaelgidida, MydoumEladiema, Koumabouradie, American 1, and Tushikie WTPs, respectively, as shown in Table (6). The human risk values of TTHMs were 98.8, 90.0, 106.2, 96.9 and 100.3 (x10-6), in Saftelgharbyaelgidida, MydoumEladiema, Koumabouradie, American 1, and Tushikie WTPs, respectively, as shown in Table (6) and Figure (5). All values of THMs cancer risks which has already lower than the general guidance risk value for Class A carcinogens (165.3 × 10−6) as shown in Table (6) and Figure (5).The ANOVA test (two factors without replication) showed that, the seasonal variation effects on the formation of TTHMs compounds are the major than the type of technology used for water purification, as indicated in Table (7).

In Hong Kong, Lee et al. (2004) assessed the cancer risks and hazard index of THMs through various modes of exposure, and they found that oral intake had a higher risk than cutaneous absorption and inhalation. Similar findings were reported by Tokmak et al. (2004), who came to the conclusion that oral intake of chloroform posed the greatest danger.

The greatest observed increase in blood or exhaled breath THM concentrations in participants was attributed to showering, bathing, and hand washing, according to Little et al. (1992), who measured the THM concentrations in blood and exhaled air for participants before and after exposures to THMs through various activities. Villanueva et al. (2006) studied long-term exposure to THMs through ingestion, inhalation, and skin absorption in a case-control study of bladder cancer and shown that the degree of individual exposure to trihalomethanes depended on the method of exposure.They also stated that classifying the exposure to all THMs (TTHMs) incorrectly may result from evaluating just one exposure route, such as ingestion. THMs are generally well absorbed, metabolized, and quickly removed by animals after oral or inhalation exposure, according to reports. The difference in the concentration and speciation of THMs present in the waters may be the cause of the three exposure pathways' relevance being graded differently in the research.

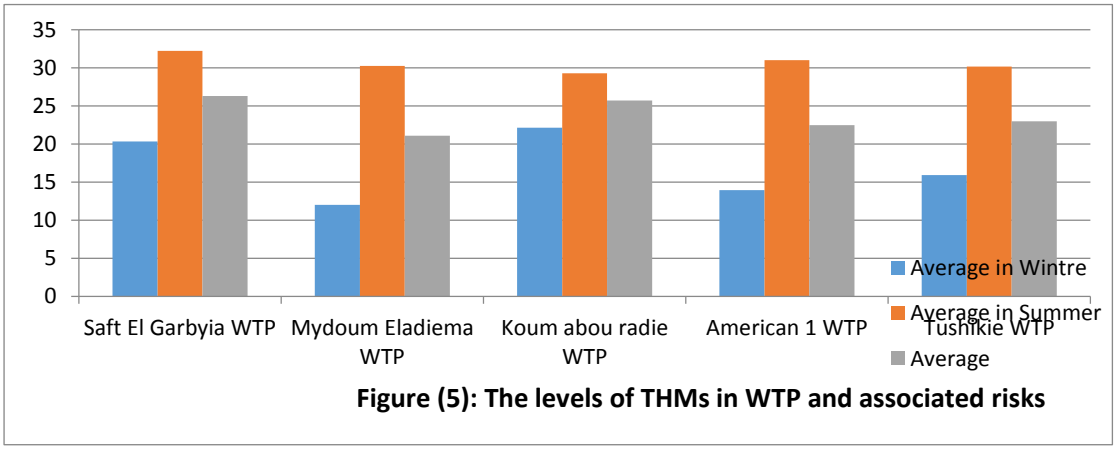

Figure (5): The levels of THMs in WTP and associated risks

Table (6): The levels of THMs WTP and associated risks

Date	Saft El Garbyia WTP		MydoumEladiema WTP		Koumabouradie WTP		American 1 WTP		Tushikie WTP	
	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}	C_{ai}(mg/l)	Rcix 10^{-6}
Nov. 2017	0.0500	82.7	0.0303	50.0	0.0541	89.5	0.0514	85.0	0.0556	91.9
Dec. 2017	0.0324	53.6	0.0287	47.4	0.0613	101.3	0.0400	66.1	0.0597	98.7
Jan. 2018	0.0572	94.6	0.0316	52.2	0.0530	87.6	0.0557	92.1	0.0454	75.1
Feb. 2018	0.0618	102.1	0.0366	60.4	0.0536	88.5	0.0536	88.6	0.0475	78.5
Mar. 2018	0.0281	46.4	0.0388	64.2	0.0561	92.7	0.0473	78.2	0.0496	82.0
Apr. 2018	0.0270	44.7	0.0420	69.4	0.0590	97.5	0.0476	78.7	0.0505	83.5
Avg. Winter	0.0427	70.7	0.0346	57.3	0.0562	92.9	0.0493	81.5	0.0514	85.0
May.2018	0.0513	84.8	0.0511	84.5	0.0612	101.2	0.0563	93.1	0.0465	76.9
Jun. 2018	0.0789	130.4	0.0717	118.5	0.0740	122.3	0.0692	114.4	0.0748	123.7
Jul. 2018	0.0833	137.7	0.0779	128.8	0.0759	125.5	0.0678	112.1	0.0762	126.0
Aug. 2018	0.0831	137.4	0.0789	130.4	0.0755	124.8	0.0677	111.9	0.0677	111.9
Sep. 2017	0.0787	130.1	0.0888	146.8	0.0613	101.3	0.0731	120.9	0.0774	128.0
Oct. 2017	0.0855	141.4	0.0771	127.5	0.0856	141.5	0.0736	121.7	0.0772	127.6
Avg.Summer	0.0768	127.0	0.0742	122.8	0.0723	119.4	0.0680	112.4	0.0700	115.7
Average	0.0598	98.8	0.0544	90.0	0.0642	106.2	0.0586	96.9	0.0607	100.3
Min	0.0270	44.7	0.0287	47.4	0.0530	87.6	0.0400	66.1	0.0454	75.1
Max	0.0855	141.4	0.0888	146.8	0.0856	141.5	0.0736	121.7	0.0774	128.0
St. Dev.	0.022	34.414	0.021	35.423	0.010	16.570	0.011	17.542	0.012	20.133
Control	0.1	165.3								

- **Conclusions**

This study's risk evaluation of THMs revealed that ingesting them was the primary exposure route. The average concentrations of TTHMs in the Saft-elgharbyaelgidida, MydoumEladiema, Koum-abouradie, American 1, and Tushikie WTPs were 0.05977, 0.054447, 0.064213, 0.058607, and 0.060671 mg/l, respectively. The human risk values of TTHMs were 98.8, 90.0, 106.2, 96.9 and 100.3 (x 10-6), in Saft-elgharbya-elgidida, MydoumEladiema, Koumabouradie, American 2, and Tushikie WTPs, respectively. All THM cancer risk values are below the overall recommended risk value for Class A carcinogens (165.3x 106).The findings of this study can be used to understand and reduce the risks of cancer for people who drink water containing THMs. It is advised to utilize disinfection techniques other than chlorination, such as ozonation, due to the high content of THM in drinking water. Additionally, it is advised to utilize a granular activated carbon (GAC) column following chlorination to lower the concentration of THM. The ANOVA test (two factors without replication) revealed that the type of technology used for water purification had less of an impact on the creation of TTHM compounds than seasonal variation.

Table (7):ANOVA test

ANOVA test (Saft El arbyia WTP)						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Months	11623.87	35	332.1106	3.481308	4.48E-06	1.590645
THMs Components	49378.67	2	24689.33	258.8029	4.58E-33	3.127676
Error	6677.875	70	95.39821			
Total	67680.41	107				
ANOVA (MaydoumEladeima WTP)						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Months	13399.48	35	382.8422	4.254928	1.29E-07	1.590645
THMs Components	42102.76	2	21051.38	233.9662	1.01E-31	3.127676
Error	6298.333	70	89.97618			
Total	61800.57	107				
ANOVA (KoumAbouRadie WTP)						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Months	2880.155	35	82.29015	3.930025	5.55E-07	1.590645
THMs Components	58522.81	2	29261.4	1397.47	3.8E-57	3.127676
Error	1465.718	70	20.93883			
Total	62868.68	107				
ANOVA (American Eladiema WTP)						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Months	4425.087	35	126.431	6.63304	1.11E-11	1.590645
THMs Components	48542.11	2	24271.05	1273.349	9.06E-56	3.127676
Error	1334.256	70	19.0608			
Total	54301.45	107				
ANOVA (Elteshiki WTP)						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Months	5706.758	35	163.0502	6.537195	1.56E-11	1.590645
THMs Components	52843.93	2	26421.97	1059.34	4.7E-53	3.127676
Error	1745.935	70	24.94192			
Total	60296.63	107				

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