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Assessment of Different Sourced Water Quality to be Suitable for Human Uses

Mohammed Abdalla Hussein[1*], Esraa Salama Khalifa[1], Samah Saeed Abdel-Azeem[1], Sara Hamdy Hussein[1], Fatma Elzahraa Yasser Hassan[1], Lamis Amin Fahmy[1], Wessam Khaled El-sayed[1], Wael Mahmoud Aboulthana[2], Yasser Hagag Mohamed[3] and Ali AbdelAziz Ali[4]

[1]Dpartment of Medical Labs, Faculty of Medical Sciences, October 6th University, October 6th City, Egypt
[2]Biochemistry Department, Genetic Engineering and Biotechnology Division, National Research Centre, Dokki, Giza, Egypt (Affiliation ID: 60014618)
[3]Central laboratory, Greater Cairo Drinking Water Company (GCWC), Fustat Water Treatment Plant, Cairo, Egypt
[4]Vice president of post graduate studies, October 6 University, Sixth of October City, Egypt

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***Corresponding author:** Mohammed Abdalla Hussein

Abstract

There were two new water sources were identified in Greater Cairo. Ain Alhaya is one of the most common springs that are subjected to continuous increase in the ground water level. Ain El-Khiala is a greenish brown spring located to the south of Ain El-Sira. During the present study, samples were collected from these regions and compared to quality of water collected from River Nile, Ismailia Canal and tap water (chlorinated treated water). The physicochemical parameters, disinfection by-products (DBPs) were measured in the collected samples in addition to microbiological examination. It was showed that quality of water was the same in River Nile and Ismailia Canal. The disinfection by chlorination is effective in water treatment and enhanced the water quality as compared to the other different sourced water although it gives various by-products. As regard to the springs, it was noticed that water quality is highly better in Ain Alhaya than Ain El-Khiala. The study concluded that there were statistical correlations among the physico-chemical, microbiological and organic measurements in different sourced water as compared to river nile and the most significant correlations were noticed among microbiological and organic measurements.

Keywords: Organic Pollutants, Ain Alhaya, Ain Alkhiala, Disinfection By-Products, Algae.

INTRODUCTION

Pollution of ground water is mostly caused by chemicals used in industry, urban wastes and agriculture. It may be caused by nitrate that is one of the most serious issues of environmental concern considered in context of agriculture pollution. Many previous studies have been carried out in the vicinity of the Greater Cairo concerned with the phytoplankton of the River Nile and its tributaries. This study was restricted to physico-chemical analysis of water samples collected from chosen localities [1, 2].

It was found that there were two new water sources (Ain Alhaya and Ain Alkhiala). Ain Alhaya is one of the most common springs in Cairo. This region is subjected to continuous increase in the ground water level. The source of this water is the deep meteoric water (Data supplied by Research Institute of Ground Water "RIGW"). Ain El-Khiala is a spring located to the south of Ain El-Sira. The source of water at this spring is the shallow marine water and characterized by greenish brown color (supplied by RIGW) [3]. These areas were selected to be under study to use these water sources for beneficial purposes. Ground water quality was monitored for ammonium and sulfate and for environmental parameters of dissolved oxygen, pH, conductivity and turbidity. Water of Ain Alkhiala was characterized by lower dissolved oxygen and higher levels of turbidity, conductivity, sulfates and ammonia than that of Ain Alhaya. It was also characterized by the presence of wide range of different algae and protozoa species. Therefore, water of Ain Alkhiala was excluded from the subsequent studies. It was observed that Ain Alkaila region represented wider area than Ain Alhaya (Fig. 1). Different species of fish can live in Ain Alhaya only. The different sources of pollution in Ain Alkaila prevented the fishes to live in this area [4].

Disinfection for drinking water reduces the risk of pathogenic infection but may pose chemical threat to human health due to disinfection residues and their byproducts (DBPs) when the organic and inorganic precursors are present in water [5]. The trihalomethanes (THMs) are disinfection by-products and suspected human carcinogens present in chlorinated drinking water [6,7]. The increase in THMs was not directly proportional to the applied chlorine dose and increase in water temperature showed a rather limited effect compared to that reported by other investigators [8]. The previous studies suggested that there was relation between THMs, total organic carbon (TOC) and total organic halogen (TOX) [9]. The algae became equally potent as precursors as humic and fulvic acids in THMs production [10]. It showed a linear relationship between chlorine consumption and the activated aromatic content of various humic and fulvic acids extracted from natural waters [11]. It was found that there were species of algae representing major taxonomic groups of phytoplankton, were utilized to investigate the potential of naturally occurring chlorophyll a of living algae to produce THMs during the chlorination process [12]. The biomolecules, including protein, carbohydrates and lipids in these algae species contributed in predicting DBPs formation especially THMs upon chlorination of algal cells [13, 14]. This was confirmed by the TOC values indicating the role of algae in elevation of these DBPs. The TOC did not represent the only factor affecting the TOX values. This indicated the presence of other factors [15] which might involve in elevation of their values.

It is well known that chlorine reacts with natural organic matter to form disinfection by products. The higher the organic load of chlorinated water, the more disinfection byproducts will be formed. However, the amount of disinfection byproducts generated not only depends on the concentration of natural organic matter [16-18]**;** but also on the total algae count [15]. Therefore, the recent studies were directed to search for alternative safe disinfecting agents [19].

Fig-1: Showed that area of Ain Alkaila (Area 1) is wider than that of Ain Alhaya (Area 2) [4]

MATERIALS AND METHODS

The current experimental work was carried out in the central laboratory of Greater Cairo Drinking water Company (GCWC) and Faculty of Medical Sciences, October 6th University.

1. Sampling

Water samples were collected from four regions (River Nile at El-Kanater El-Khayria, Ismailia Canal, Ain alhaya and Ain El-Khiala ponds) in addition to the tap water (chlorinated treated water). The samples were collected by using manual sampler in the dedicated and plastic containers that were rinsed with distilled water after each sampling.

For measurement of Total Trihalomethanes (TTHM), Total Organic Carbon (TOC) and Total Organic Halogen (TOX), the samples placed in brown bottles associated with dechlorinating agent represented by trace of sodium thiosulfate. Moreover, the samples placed in plastic bottles associated with dechlorinating agent represented by trace of sodium thiosulfate for determining total algae count (TAC) and the chlorophyll "a" concentration.

The samples were collected in polyethylene bottles without any preservative for subsequent laboratory chemical analysis. Samples were stored where possible in refrigerators before analysis. All analyses were completed within one week of sample collection [20].

2. Measurements

2.1. The physicochemical Measurements

All these parameters were measured according standard method for the examination of water and wastewater [21]. Triplet analysis was carried out for each parameter and the average values were recorded.

2.1.1. Dissolved Oxygen (DO)

The DO was measured by electrode of the digital instrument. The DO gave indication to measure the oxygen needed for all oxidation, nitrification and decomposition processes.

2.1.2. pH

pH was measured on the spot by using pH-meter model (Janway 3150) after buffer calibration at pH 4 and 10. The pH value gave indication to concentration of the hydrogen ions (H^+) obtained as a result of dissociation or hydrolysis process. It was measured by electrode of pH meter.

2.1.3. Electrical Conductivity (EC)

The conductivity value gave indication to concentration of the minerals in the water matrix and hence ability of the aqueous solution to carry electric current. It was measured by electrode of conductivity meter.

2.1.4. Turbidity

The turbidity value gave indication to small and large particles scattered throughout the matrix. It was measured by turbidimeter.

2.1.5. Sulfates

Sulphate concentration in the water samples were determined by Turbidimetric method. Sulphate ion is precipitated in HC1 medium with $BaCl_2$. To form Barium sulphate $BaSO_4$ crystals of uniform size. Light absorbance of $BaSO_4$ suspension is measured by transmission photometer.

2.1.6. Ammonia

The dissolved ammonium ions in the water samples were determined depending on the nesslerization reaction. The yellowish to brownish color can be measued with spectrophotometer at the wave length 405 nm.

2.1.7. Total Alkalinity

The total alkalinity was calculated by summation of both of carbonate and bicarbonate that were determined immediately after collection of the water samples using phenolphthalein and methyl orange indicators.

2.2. Microbiological Examination

All the media, reagents and procedures were prepared according to the standard methods for the examination of water and wastewater. The total coliform (TC) occurred by standard total coliform membrane filter procedure and the fecal coliform (FC) detected by fecal coliform membrane filter procedure.

The total algae count (TAC) measured using counting cell to enumerate plankton to limit the volume and area for ready calculation of population densities. The low magnification method is the most suitable method for the plankton counting. It is easily manipulated providing with reasonably reproducible data. The chlorophyll "a" concentration measured in all the treatment plants and during the fourth season only using the spectrophotometric technique filtered after acidification [21]. The chlorophyll "a" extraction was carried out in subdued light to avoid degradation by centrifuging large volume of water and the chlorophyll "a" concentrated in the extract with aqueous acetone followed by determining the optical density (absorbance).

2.3. Disinfection By-Products (DBPs) Quantification

2.3.1. Methods

The samples were analyzed after the chlorination process to determine level of Total Trihalomethanes (TTHMs) that was detected by using simple liquid-liquid extraction gas chromatographic method (GC/ECD, EPA method 501.2). Total Organic Halogen (TOX) concentration was detected by shaking method (ISO method 9562) using TOX analyzer. Total Organicc Carbon (TOC) concentration was determined by UV-persulfate TOC analyzer (EPA method 415.1).

2.3.2. Equipments

HP gas chromatograph equipped with auto-injector and 30 meter DB-1701 fused silica capillary column and an electron capture detector (ECD) was used for analysis of TTHMs. Data acquisition and processing were controlled by chemstation. High purity (99.99 %) grade gases were used. Helium was used as a carrier gas; nitrogen was used as make-up gas. Oxygen gas was used for furnace heating. All sample extracts including standards and blanks were injected in splitless mode.

2.3.3. Standards

Concentrations of TTHMs were calculated by using external standard calibration method. A certified mixture standards of THMs including (chloroform, bromodichloromethane, dibromochloromethane and bromoform) were obtained from Suppelco Inc was used.

2.3.4. The operating conditions of the gas chromatograph

The injector temperature was 220 °C in splitless mode. ECD temperature was 320 °C. Carrier gas flow was 1 ml/minute and make-up gas flow was 60 ml/minute. Capillary column temperature program was: start with 40ºC, ramp 10 ºC/minute to100 °C and holding for 5 min.

2.3.5. Quality Control and Data Analysis

A procedural blank and the certified standards were analyzed routinely with each batch of samples. The detection limits of the methods were verified and carefully noticed. The linearity response of ECD for THMs compounds, in area count, was observed. It was showed that the ECD was responding linearly for all compounds during the current experiment. Mean concentrations of individual compounds in addition to sum of compounds were calculated.

3. STATISTICAL ANALYSIS

All data were statistically analyzed by one-way analysis of variance test (one-way ANOVA) using the Statistical Package for Social Sciences (SPSS for windows, version 11.0) followed by Bonferoni test. Results were expressed as mean ± standard error (SE). The differences between the samples were considered statistically significant when a "P" value of less than 0.05.

RESULTS AND DISCUSSION

It was observed that Ain El-Khiala region represented wider area than Ain Alhaya (Fig. 1). Different species of fish can live in Ain Alhaya only. The different sources of pollution in Ain El-Khiala prevented the fishes to live in this area. Natural organic matter (NOM) in ground waters mainly consists of partially decomposed plant material and most is found as dissolved organic matter such as humic substances (HS), hydrophillic acids, and simple organic compounds. HS make up 50 - 80% of the dissolved organic matter in natural waters [22], and ground waters rich in NOM can be termed humic ground waters. The water in Ain El-Khiala is characterized by yellow to brown colour. This may be due to presence of HS [23].

pH value is the logarithm of reciprocal of hydrogen ion activity in moles per liter. In water matrix, the variations in pH value from 7 are mainly due to hydrolysis of salts of strong bases and weak acids or vice versa. Dissolved gases such as carbon dioxide, hydrogen sulphide and ammonia also affect the pH of water. The overall pH range of natural water is generally between 6 and 8. pH. The pH less than 6.5 is not a health hazard, but it may cause corrosion that destroys pumps, pipes and metallic plumbing fixtures [19].

The data reported in Table 1 showed that the pH values were significantly ($P \leq 0.05$) lower in Ain Alhaya and Ain El-Khiala regions. This can be attributed to the discharge of effluents which loaded with a large amount of organic acids. It is noted that the relatively higher values can be attained as the temperature decrease, which may be attributed to the photosynthetic activity and decrease of the amount of dissolved CO2 gas in water [24].

The increase in pH values in waters of river nile and Ismailia Canal might be due to the dense of vegetation and phytoplankton, which were accompanied byphotosynthetic activity and consumption of CO2 with expected pH elevation [25].

It was found that the decrease in DO in water of Ain Alhaya and Ain El-Khiala and might be due to the elevation of water temperature and the increase in oxidative processes of organic matter [26] and due to its consumption by the oxidation of nitrogenous compounds. This finding was fully confirmed with the increase in ammonia. DO was correlated negatively with ammonia, but positively with pH [27].

Prolonged exposure to low DO level will increase organism's susceptibility to other environmental stress. The exposure to <2 mg/L for days may kill most of biota in the aquatic system. The introduction of excess of organic matter may result in a depletion of oxygen from an aquatic system mainly during warm stagnant condition [28].

The DO values generally showed an increase with chlorinated water. This may be attributed to activities of air movement which allowing more transfer of oxygen across the air-water interface and also is due turbulence in the flowing water [29]. Relatively lower temperature in autumn may increase the ability of water to hold dissolved oxygen [30].

As shown in Table 1, the conductivity increased in the chlorinated water. This was in agreement with many previous studies. When chlorine is introduced into the water, quantity of the electrolytes or total dissolved solids in the water rises, which in turn raises the conductivity of the water. High-conductivity tap water includes various substances such as chlorine that diminish the taste of the water. In addition, the conductivity is directly proportional to the chlorine dose [19].

The Turbidity in water is the reduction of transparency due to the presence of particulate matter such as clay or silt, finely divided organic matter, plankton or other microscopic organisms. These cause light to be scattered and absorbed rather than transmitted in straight lines through the sample. The colloidal material exerts turbidity provides adsorption sites for chemicals that may be harmful or cause undesirable tastes and odors. During the current study, the turbidity value decreased in the chlorinated water. This might be attributed to decreasing the total particle counts, heterotrophic plate counts and epi-fluorescence direct cell counts [31]. The latter author suggested that turbidity and particle counts were directly proportional.

As recorded in Table 1, the turbidity was significantly ($P \leq 0.05$) lower in Ain Alhaya and chlorinated water. The decrease in turbidity may refer to decreasing the total particle counts, heterotrophic plate counts and epifluorescence direct cell counts and it was suggested that turbidity and particle counts were directly proportional [31].

The chlorination maintained the total and calcium hardness due to maintaining the minerals soluble in the chloride forms and this caused increase in the total hardness [19].

As compiled in Table 1, it was found that the chlorides increased in the chlorinated water. This was in accordance with Skoog *et al*. [32], who reported that the chlorides increased directly with increasing the chlorine dose in a dose dependent manner. This might refer to involving of chlorine in formation of byproducts as chloroform which consequently leads to elevation of the chlorides.

Ammonia plays an important part in the nitrogen cycle of many biological and industrial processes [33]. Ammonium ions showed significant positive correlation with temperature. It was suggested that there was increase in ammonia with temperature increase and with EC. It was correlated negatively with pH [34]. When ammonia was present in groundwater, even at low concentrations, it can be linked to various water quality problems and their removal is essential.

As shown in Table 1, it was found that the electric conductivity in water of Ain El-Khiala is higher than that of Ain Alhaya. Waters in both of Ain Alhaya and Ain El-Khiala were loaded with very high concentrations of ammonia. Water in Ain Alkaila contains much higher concentration of ammonia than Ain Alhaya. This was in agreement with Hussein *et al*. [4], who concluded that water of Ain Alkaila loaded with wide range of environmental pollutants in addition to the different protozoa species. This increased all the physic-chemical measurements. Therefore, this type of water excluded from the research area. All the further experimental studies were directed to remove the dissolved salt from water of Ain Alhaya and might be added as possible tool to solve problems of Ain Alhaya to be used for drinking purposes.

Ammonia needs to be removed before water is disinfected with chlorine, as it reacts with chlorine and produces chloramines, which have recently been found to be carcinogenic. Also, the presence of ammonia in water systems leads to oxygen depletion, eutrophication of surface water and toxicity for fish and therefore, there was no living fish in Ain El-Khiala water [35, 36].

The T. alkalinity decreased significantly ($P \leq 0.05$) when compared to nile water. Therefore, the titration required small volume of sulfuric acid to neutralize the alkalinity and reach the end point. This gives indication to normal role of chlorine in the treatment process [19].

The microbiological data showed that the TAC increased significantly ($P \leq 0.05$) associated with increasing the chlorophyll "a" concentration (Tables 2 and 3). This was completely related to the DBPs produced after the chlorination process. The TOC represent one of the factors affecting the DBPs especially the THMs produced during the chlorination process [15].

Data illustrated in Table 2, it was found that the plate count in nile water was about 1373.33 ± 14.53 colony forming unit and the chlorine was able to inhibit the bacterial growth making the plate count less than 1. Moreover, it was noticed that TAC decreased significantly ($P \leq 0.05$) in the chlorinated water as compared to nile water.

The pour plate method confirmed that the chlorine is effective the bacterial growth as shown in the Table 2. This was in agreement with the study carried out by Hussein *et al*. [19], who postulated that the chlorine inhibit the bacterial growth completely at any chlorine dose.

The TOC level used as indicator of the presence of organic matter in drinking water. The fulvic and humic acid components of the TOC are important precursors for THMs [37]. It was found that the higher the TOC value, the higher the levels of THMs formation. Increasing the TOC levels resulted in substationally increased total THMs production [38]. There is correlation among TAC, TOC, TTHMs and TOX. This was in agreement with many previous studies [39].

During the present study, the DBPs (TTHMs and TOX) increased significantly ($P \leq 0.05$) in the chlorinated water. This was in agreement with the previous studies which were suggested that the chlorine was able to inhibit the algal growth making the total algae count less than 1 at any chlorine dose [15].

This might be due to variation in the water quality (pH and temperature), treatment conditions (disinfectant dose and contact time) or increase in the organic pollutants [37]. This increase may be due to the increase in the algal growth. All the algae species are rich in chlorophyll contents especially chlorophyll "a". This represented potent as precursors as humic and fulvic acids in production of these DBPs. This increasing yield could be due to the release of breakdown products of cell constituents [13].

The DBPs especially THMs could be dependent on the variation of the cellular biochemical composition (protein, lipids and carbohydrate) of the algae. The relative percentage of the cellular biochemical composition in the different algae may have a major influence as DBPs precursors [13]. The bacterial contamination may be cause of the increase in some of DBPs [40]. The bacteria may be associated with algae in elevation of the DBPs but their contribution to the overall DBPs formation was likely to be minor relative to that from algae [41].

The THMs did not represent the only by-products which cause elevation of the TOX and also the increase in TOC may not be associated with increase in the TOX. This suggested that there were other factors added to the TOC to enhance the TOX values. These findings can indicate that algae might be added to organic impurities as a significant contributor to DBPs precursor. There were other factors in addition to the TOC involved in elevation of the TOX values. Finally the DBPs affected by many factors related to the treatment conditions and/or seasonal factors [15]. The current study supported that there was statistical correlations among the physico-chemical, microbiological and organic measurements in different sourced water as compared to river Nile (Table 4) and the most significant correlations were noticed among microbiological and organic measurements.

Table-1: Data showing the physico-chemical measurements in different sourced water as compared to river Nile

	River Nile	Ismailia Canal	Chlorinated	Ain Alhaya	Ain El-Khiala
pH	8.28 ± 0.02	8.26 ± 0.03	7.45 ± 0.00^{ab}	7.90 ± 0.00^{abc}	7.70 ± 0.00^{abcd}
DO	7.88 ± 0.02	7.94 ± 0.03	8.36 ± 0.01^{ab}	7.70 ± 0.12^{c}	2.28 ± 0.02^{abcd}
Cond.	428.67 ± 2.33	432.67 ± 3.93	441.00 ± 2.08	11833.33 ± 88.19^{abc}	85833.33 ± 600.93^{abcd}
Tur.	12.11 ± 0.08	12.10 ± 0.13	1.18 ± 0.01^{ab}	1.60 ± 0.01^{ab}	109.33 ± 0.67^{abcd}
T. Hardness	136.33 ± 0.67	134.00 ± 0.58	135.33 ± 1.45	3576.67 ± 17.64^{abc}	25433.33 ± 233.33^{abcd}
Ca Hardness	85.00 ± 0.00	84.00 ± 0.00	87.00 ± 0.58	2476.67 ± 14.53^{abc}	17800.00 ± 152.75^{abcd}
Mg Hardness	51.33 ± 0.67	50.00 ± 0.58	48.33 ± 1.20	1100.00 ± 5.77^{abc}	7633.33 ± 133.33^{abcd}
Chlorides	23.67 ± 0.33	23.33 ± 0.88	36.33 ± 0.67	9273.33 ± 14.53^{abc}	18383.33 ± 60.09^{abcd}
Sulphates	28.67 ± 0.67	29.00 ± 0.58	49.33 ± 0.33	11760.00 ± 30.55^{abc}	23766.67 ± 145.30^{abcd}
Ammonia	0.07 ± 0.00	0.07 ± 0.00	0.02 ± 0.00	3.20 ± 0.03^{abc}	28.51 ± 0.44^{abcd}
T. Alkalinity	136.67 ± 0.67	136.33 ± 0.67	83.67 ± 0.67^{ab}	1.56 ± 0.01^{abc}	1.98 ± 0.02^{abc}

Values were expressed as mean ± standard error, a: compared to River Nile, b: compared to Ismailia Canal, c: compared to chlorinated water, d: compared to Ain Alhaya at P≤0.05.

Table-2: Data showing the microbiological measurements in different sourced water as compared to river Nile

	River Nile	Ismailia Canal	Chlorinated	Ain Alhaya	Ain El-Khiala
TC	13733.33 ± 145.30	13666.67 ± 120.19	0.00 ± 0.00^{ab}	4416.67 ± 44.10^{abc}	16833.33 ± 88.19^{abcd}
FC	445.00 ± 2.89	446.00 ± 1.00	0.00 ± 0.00^{ab}	2150.00 ± 28.87^{abc}	2440.00 ± 45.83^{abcd}
Plate Count	1373.33 ± 14.53	1370.00 ± 5.77	0.00 ± 0.00^{ab}	496.67 ± 7.26^{abc}	2010.00 ± 20.82^{abcd}
TAC (U/L)	13733.33 ± 145.30	13666.67 ± 120.19	0.00 ± 0.00^{ab}	4416.67 ± 44.10^{abc}	16833.33 ± 88.19^{abcd}

Values were expressed as mean ± standard error, a: compared to River Nile, b: compared to Ismailia Canal, c: compared to chlorinated water, d: compared to Ain Alhaya at P≤0.05.

Table-3: Data showing the organic measurements in different sourced water as compared to river Nile

	River Nile	Ismailia Canal	Chlorinated	Ain Alhaya	Ain El-Khiala
Chlorophyll "a"	430.00 ± 2.89	432.33 ± 2.67	35.07 ± 0.61^{ab}	135.00 ± 5.20^{abc}	552.00 ± 6.25^{abcd}
TOC (ppm)	5.28 ± 0.02	5.30 ± 0.01	3.68 ± 0.02^{ab}	10.31 ± 0.03^{abc}	19.89 ± 0.13^{abcd}
THM (ppp)	0.00 ± 0.00	0.00 ± 0.00	75.31 ± 2.82^{ab}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}
TOX (ppm)	0.00 ± 0.00	0.00 ± 0.00	0.23 ± 0.01^{ab}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}

Values were expressed as mean ± standard error, a: compared to River Nile, b: compared to Ismailia Canal, c: compared to chlorinated water, d: compared to Ain Alhaya at P≤0.05.

Table-4: Significant correlations among the physico-chemical, microbiological and organic measurements in different sourced water as compared to river nile

TOX	-0.000**	0.090	0.101	0.151	0.099	0.100	0.097	-0.001**	-0.001**	0.117	0.317
THM	-0.000**	0.089	0.100	0.150	0.098	0.099	0.096	-0.001**	-0.001**	0.116	0.313
TOC	0.11	-0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.906
Chlorophy "a"	0.010**	-0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.319
TAC	0.010**	-0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.361
Plate Count	0.007**	-0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.404
FC	0.000**	0.193	0.193	0.323	0.189	0.191	0.184	0.000**	0.000**	0.219	-0.025*
TC	0.005**	-0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.411
T. Alkali	0.474	0.302	0.343	0.173	0.348	0.346	0.353	0.419	0.453	0.308	-
Ammonia	0.243	-0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	-	0.308
Sulph,	0.008**	-0.000**	0.000**	0.001**	0.000**	0.000**	0.000**	0.000**	-	0.000**	0.453
Chlor.	0.007**	-0.000**	0.000**	0.001**	0.000**	0.000**	0.000**	-	0.000**	0.000**	0.419
Mg Hard.	0.213	-0.000**	0.000**	0.000**	0.000**	0.000**	-	0.000**	0.000**	0.000**	0.353
Ca Hard.	0.217	-0.000**	0.000**	0.000**	0.000**	-	0.000**	0.000**	0.000**	0.000**	0.346
T. Hard.	0.216	-0.000**	0.000**	0.000**	-	0.000**	0.000**	0.000**	0.000**	0.000**	0.348
Tur.	0.275	-0.000**	0.000**	-	0.000**	0.000**	0.000**	0.001**	0.001**	0.000**	0.173
Cond.	0.219	-0.000**	-	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.343
DO	0.192	-	-0.000**	-0.000**	-0.000**	-0.000**	-0.000**	-0.000**	-0.000**	-0.000**	0.302
pH	-	0.192	0.219	0.275	0.216	0.217	0.213	0.007**	0.008**	0.243	0.474
	pH	**DO**	**Cond.**	**Tur.**	**T. Hard.**	**Ca Hard.**	**Mg Hard.**	**Chlor.**	**Sulph,**	**Ammonia**	**T. Alkali**

TC	FC	Plate Count	TAC	Chlorophy "a"	TOC	THM	TOX
0.005**	0.000**	0.007**	0.010**	0.010**	0.11	-0.000**	-0.000**
-0.000**	0.193	-0.000**	-0.000**	-0.000**	-0.000**	0.089	0.09
0.000**	0.193	0.000**	0.000**	0.000**	0.000**	0.100	0.101
0.000**	0.323	0.000**	0.000**	0.000**	0.000**	0.150	0.151
0.000**	0.189	0.000**	0.000**	0.000**	0.000**	0.098	0.099
0.000**	0.191	0.000**	0.000**	0.000**	0.000**	0.099	0.100
0.000**	0.184	0.000**	0.000**	0.000**	0.000**	0.096	0.097
0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	-0.001**	-0.001**
0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	-0.001**	-0.001**
0.000**	0.219	0.000**	0.000**	0.000**	0.000**	0.116	0.117
0.411	-0.025*	0.404	0.361	0.319	0.906	0.313	0.317
-	0.025*	0.000**	0.000**	0.000**	0.000**	-0.002**	-0.002**
0.025*	-	0.030**	0.037*	0.044*	0.004	-0.000**	-0.000**
0.000**	0.030**	-	0.000**	0.000**	0.000**	-0.003**	-0.003**
0.000**	0.037*	0.000	-	0.000**	0.000**	-0.004**	-0.004**
0.000**	0.044*	0.000**	0.000**	-	0.000**	-0.004**	-0.004**
0.000**	0.004	0.000**	0.000**	0.000**	-	-0.002**	-0.002**
-0.002**	-0.000**	-0.003**	-0.004**	-0.004**	-0.002**	-	0.000**
-0.002**	-0.000**	-0.003**	-0.004**	-0.004**	-0.002**	0.000**	-

*Significant correlation at P<0.05; **High significant correlation at P<0.01. Yellow cell indicates non-significant correlation, Orange cell indicates negative correlation, Green cell indicates positive correlation

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