

**DRINKING WATER QUALITY IN ANKARA: A MONITORING STUDY**

**A THESIS SUBMITTED TO  
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES  
OF  
MIDDLE EAST TECHNICAL UNIVERSITY**

**BY**

**GÖZDE TEZCE**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS  
FOR  
THE DEGREE OF MASTER OF SCIENCE  
IN  
ENVIRONMENTAL ENGINEERING**

**DECEMBER 2010**

Approval of the thesis:

**DRINKING WATER QUALITY IN ANKARA: A MONITORING STUDY**

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**I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.**

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## ABSTRACT

### DRINKING WATER QUALITY IN ANKARA: A MONITORING STUDY

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December 2010, 124 pages

Following the event of severe drought experienced in 2007, it was decided to use Kesikkpr Reservoir as an additional source of water supply for the city of Ankara. Thereupon, there have been debates on the quality of Kesikkpr Reservoir water with the claims that some parameters, primarily sulfate and arsenic, were not complying with the quality standards and therefore there was a threat to public health. This study aims to determine whether the water quality in the distribution network in Ankara exceeds water quality standards, and to assess the status of water quality of Ankara. To this end, monthly samples were collected from 24 districts as distribution network water and also from the Kesikkpr Reservoir as source water, and were monitored in terms of certain water quality parameters during the period of July 2008 through June 2009. Sulfate concentration in Kesikkpr Reservoir water was measured as 300-500 mg/l and this high sulfate concentration in the source water led to high sulfate values in distribution system. On the other hand, the arsenic concentration in Kesikkpr water was analyzed between 9-11  $\mu\text{g/l}$  which is lower than the expected high arsenic concentration in Kızılırmak water. Moreover,

monitoring of THM and HAA in distribution network was carried out to follow DBPs formation. The highest THM concentration was observed as 109 µg/l for Bilkent in July 2008. Although for some districts and some months throughout the year THM concentration was higher than the EPA Stage-I (80 µg/l) and Stage-II (40 µg/l) limits, mean annual THM concentrations for districts in distribution system satisfies the standards. Furthermore, the highest HAA<sub>5</sub> concentrations were determined as 75 µg/l for Dikmen in February 2009. However, annual average HAA<sub>5</sub> in any of the districts did not exceed USEPA limit of 60 µg/l. Nonetheless, total/fecal coliform bacteria, which are the indicators of microbiological contamination, were detected in distribution system between the months of July 2008 and January 2009. However, the coliform bacteria did not appear with the increasing residual chlorine in the distribution system since January 2009. Results from this study demonstrate a temporal variability in water quality; indicating water quality deterioration in the distribution system during some months, while almost full compliance with the water quality standards during other months. Overall; due to Kesikköprü raw water, sulfate content appears to be the major concern in the water quality when considered the one-year monitoring period.

Keywords: Drinking water quality monitoring, Kesikköprü Reservoir, Ankara, sulfate, arsenic

## ÖZ

### ANKARA’NIN İÇME SUYU KALİTESİ: İZLEME ÇALIŞMASI

Tezce, Gözde

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Aralık 2010, 124 sayfa

2007 yılında yaşanan şiddetli kuraklığı takiben Kesikköprü Barajının ek bir su kaynağı olarak kullanılmasında karar verilmiştir. Bunun üzerine, Kesikköprü Baraj Suyunun, öncelikli olarak sülfat ve arsenik olmak üzere, bazı parametrelerinin içme suyu standartlarına uygun olmadığı ve bu yüzden insan sağlığı açısından tehdit oluşturduğu yönünde tartışmalar başlamıştır. Bu çalışmada, Ankara ilinin içme suyunun hem kaynakta hem de şebekede bazı seçilmiş öncelikli parametreler yönünden 1 yıl süreyle izlenerek, su kalitesinin belirlenmesini amaçlanmaktadır. Bu amaçla, Ankara’da belirlenen 24 semtten şebeke suyu ve Kesikköprü Barajından kaynak suyu numuneleri aylık olarak alınarak belirli parametreler yönünden Temmuz 2008 ve Haziran 2009 aylarını kapsayan dönemde izlenmiştir. Kesikköprü Baraj suyunda sülfat konsantrasyonu yıllık ortalama 300-500 mg/l olarak ölçülmüş olup, kaynak suyundaki bu yüksek sülfat konsantrasyonu şebekede sülfat değerlerinin yüksek olmasına neden olmuştur. Bununla birlikte, Kesikköprü suyundaki arsenik

konsantrasyonu yıllık ortalama 9-11 µg/l olarak ölçülmüş olup, bu değer Kesikköprü suyunda beklenen yüksek arsenik konsantrasyonunun aksine düşüktür. Ayrıca, dezenfeksiyon yan ürünleri (DYÜ) olarak şebekede THM ve HAA parametreleri izlenmiştir. Şebekede THM değeri en yüksek 109 µg/l olarak Temmuz 2009'de Bilkent semtinde ölçülmüştür. THM değerleri bazı aylarda bazı semtler için USEPA tarafından belirlenen 80 µg/l limit değerini aşmasına rağmen yıllık ortalama THM değerleri tüm semtlerde standart değerinin altında kalmaktadır. HAA<sub>5</sub> konsantrasyonu ise en yüksek Şubat 2009'da Dikmen semtinde 75 µg/l değerinde bulunmasına rağmen yıllık ortalama HAA<sub>5</sub> konsantrasyonu, 60 µg/l olan USEPA limit değerini hiçbir semtte aşmamıştır. Ayrıca, mikrobiyolojik kirlilik göstergesi olarak şebekede yapılan toplam/fekal koliform izlemesine göre Temmuz 2008-Ocak 2009 ayları arasında şebeke suyunda koliform bakteri gözlenmiştir. Ocak 2009 sonra ise şebekede artan bakiye klor miktarı ile koliform bakteri tespit edilmemiştir. Çalışma sonuçları, izlenen parametrelerinin bazı aylarda içme suyu standartlarını aşmış bazı aylarda standartları tam olarak karşılamasıyla, aylar arasında değişiklikler göstermektedir. Genel olarak, Kesikköprü suyundan kaynaklı olarak içme suyunda sülfat esas sorun olarak görülmüştür.

Anahtar Kelimeler: İçme suyu kalitesi izlemesi, Kesikköprü Barajı, Ankara, sülfat, arsenik

*To Masal*

## ACKNOWLEDGMENTS

I would like to express my deepest gratitude to my supervisor Prof. Dr. Ülkü Yetiş for her endless patience, understanding, and supervision. It was an honor to work with her.

I would also like to give my appreciations and thanks to my co-supervisor Prof. Dr. Filiz B. Dilek for her guidance and encouragement throughout my thesis study.

I owe my deepest gratitude to Assist. Prof. Dr. Nuray Ateş for her helps in teaching me the experiments patiently. She was always available to answer my questions and show me the way of solutions.

I wish to express my warm and truthful thanks Aslı Karabacak for always being with me in every moment during this study and for her valuable friendship. She has made available her support at any time in many ways, which was very precious for me.

It is a pleasure to thank Mehmet Dumanoğulları for being a part of this study with his assistance for the collection of water samples during the study and for the measurements on-site. I also wish to express thanks Kemal Demirtaş for laboratory assistance and help me in a number of laboratory analyses.

I also wish to thank Fadime Kara and Çiğdem Kıvılcımdan Moral. I could always find them with all their sincerity, friendship and helpfulness in all meanings whenever I need them.

My sincere thanks are due to Akif Sinan Taşdelen. He was with me in all meanings with all his patience and sacrifice. He was a perfect laboratory partner and friend I have ever had. I would also express my warmly thank my cousin, my peer-editor, Işıl Öndeş Büyükataman, for her support in every part of this study and of my life.

I would like to show my sincerely gratitude to Hilal Zitouni. Her whole-hearted friendship helped me and made me encourage at any difficult moment. Thank her for staying awake all-night and sharing the same feelings with me, beyond, for being my friend.

I am grateful to Barış Korkut, my “Word-Supervisor”, for immense support in formatting the thesis, which would not have been written and completed without his help. He was the one who solve all “format-related” problems and I could reach him at anytime when I was in need.

I would like to express my special and tender appreciation to Gül Mısırlı and Mustafa Gökharman for their valuable advices, support, encourage, and kindness. I am indebted to them to trust me unreservedly and to show me the importance of acting on the square with same intentions to succeed in the face of many difficulties.

I would like to intensely thank my mother Neslihan Tezce, my father Serdar Tezce, my brother Serhan Tezce, my aunts Canan Öndeş and Candan Yılmaz, and my grandmother Saime Saka and all other members of my family for their sacrifices and belief in me. I have always felt their enduring support and love throughout this study and my life.

## TABLE OF CONTENTS

ABSTRACT .....	iv
ÖZ .....	vi
ACKNOWLEDGMENTS .....	ix
TABLE OF CONTENTS .....	xi
LIST OF TABLES .....	xiii
LIST OF FIGURES .....	xv
CHAPTERS	
1. INTRODUCTION .....	1
2. BACKGROUND AND RELATED WORK .....	4
2.1. Historical Background of Water Supply in Ankara .....	4
2.2. Water Quality Standards.....	8
2.3. Monitoring Studies .....	14
3. EXPERIMENTAL WORKS.....	21
3.1. Source Waters.....	21
3.2. Sampling.....	21
3.3. Experimental .....	23
3.4. Analytical Techniques .....	24
3.4.1. UVA <sub>254</sub> Measurement .....	24
3.4.2. DOC Measurement.....	25
3.4.3. SO <sub>4</sub> <sup>2-</sup> Measurement .....	25
3.4.4. Free Residual Chlorine Measurement.....	25
3.4.5. Turbidity Measurement.....	25
3.4.6. Conductivity and pH Measurement .....	26
3.4.7. THM Measurement .....	26
3.4.8. THMFP Analysis: .....	28

3.4.9.	HAA Measurement .....	30
3.4.10.	AOX Measurement.....	32
3.4.11.	Arsenic (As) Measurement.....	32
3.4.12.	Total/Fecal Coliform Measurement .....	33
4.	RESULTS AND DISCUSSION .....	34
4.1.	Source Water .....	34
4.1.1.	Sulfate (SO <sub>4</sub> <sup>-2</sup> ) .....	36
4.1.2.	Arsenic (As) .....	38
4.1.3.	Disinfection By-Products (DBPs).....	40
4.1.4.	Organic Content Parameters .....	42
4.1.5.	Other Parameters.....	44
4.2.	Ankara Distribution System .....	46
4.2.1.	Sulfate (SO <sub>4</sub> <sup>2-</sup> ).....	46
4.2.2.	Arsenic (As) .....	49
4.2.3.	Disinfection By-Products (DBPs).....	54
4.2.4.	Organic Content Parameters .....	60
4.2.5.	Adsorbable Organic Halides (AOX).....	67
4.2.6.	Microbiological Parameters .....	73
4.3	Effect of Kesikköprü reservoir water on the drinking water quality of Ankara.....	81
5.	SUMMARY AND CONCLUSION.....	85
6.	RECOMMENDED FUTURE WORK.....	88
	REFERENCES.....	89
	APPENDIX A.....	94
	APPENDIX B .....	99
	APPENDIX C .....	108
	APPENDIX D .....	113
	APPENDIX E .....	115
	APPENDIX F.....	124

## LIST OF TABLES

### TABLES

Table 2-1 “Storage capacities of the dams supplying drinking water to Ankara” .....	6
Table 2-2 “Drinking Water Quality Parameters (EU - WHO - USEPA)” [3] .....	9
Table 2-3 “Drinking Water Standards in Turkey” [48, 49] .....	10
Table 3-1 “Sampling Districts” .....	22
Table 3-2 “Water Quality Parameters Monitored” .....	24
Table 4-1 “Kesikköprü Raw Water Characteristics; July, 2008” .....	35
Table 4-2 “Kesikköprü Raw Water Characteristics; August, 2008” .....	36
Table 4-3 “Monthly Sulfate in Kesikköprü Raw Water” .....	37
Table 4-4 “Sulfate concentrations of three reservoirs” .....	37
Table 4-5 “Arsenic in Kesikköprü Raw Water in Months” .....	38
Table 4-6 “Arsenic Concentrations in Three Reservoir Waters of Ankara” .....	39
Table 4-7 “THMFP (in $\mu\text{g/l}$ ) for Çamlıdere and Kurtboğazi Reservoirs (1999)” [7] .....	41
Table 4-8 “Conductivity of Kesikköprü Raw Water” .....	45
Table 4-9 “Sulfate Concentration (mg/l) for Districts in Months (July-December 2008)” .....	47
Table 4-10 “Sulfate Concentration (mg/l) for Districts in Months (January-June 2009)” .....	48
Table 4-11 “Arsenic Concentration ( $\mu\text{g/l}$ ) for Districts in Months (July 2008-January 2009)” .....	50
Table 4-12 “Arsenic Concentration ( $\mu\text{g/l}$ ) for Districts in Months (February-June 2009)” .....	51
Table 4-13 “TTHM in Districts for Months (July 2008-January 2009)” .....	54
Table 4-14 “TTHM in Districts for Months (February 2009-June 2009)” .....	55

Table 4-15 “Seasonal TTHM Concentrations in Ankara Districts” .....	56
Table 4-16 “DOC Measurements for Districts in Months (July 2008-December 2008)” .....	62
Table 4-17 “DOC Measurements for Districts in Months (February 2009-June 2009)” .....	63
Table 4-18 “UVA <sub>254</sub> Measurements for Districts in Months” .....	65
Table 4-19 “Seasonal AOX Concentrations in Districts” .....	68
Table 4-20 “Seasonal AOX Concentrations in Districts” .....	69
Table 4-21 “Coliform Analyses in July 2008” .....	74
Table 4-22 “Coliform Analyses in January 2009” .....	75
Table 4-23 “Coliform Analyses in April 2009” .....	76
Table 4-24 “Monthly Free Residual Chlorine (mg/l) in Drinking Water Samples” ..	77
Table 4-25 “Analyses Results of Coliform Bacteria and Residual Chlorine in the Distribution Network” .....	78
Table 4-26 “Analyses Results of Coliform Bacteria and Residual Chlorine in the Distribution Network” .....	79
Table 4-27 “Relation between Residual Chlorine and Sulfate Concentration in Drinking Water Samples” .....	80
Table 4-28 “Summary- Results of Source Water of Ivedik Water Treatment Plant (July 2008)” .....	82
Table D-1 Quality Parameters of Inland Water Sources based on Classes.....	113
Table E-1 “Coliform measurement in August 2008” .....	115
Table E-2 “Coliform measurement in September 2008” .....	116
Table E-3 “Coliform measurement in October 2008” .....	117
Table E-4 “Coliform measurement in November 2008” .....	118
Table E-5 “Coliform measurement in December 2008” .....	119
Table E-6 “Coliform measurement in February 2009” .....	120
Table E-7 “Coliform measurement in March 2009” .....	121
Table E-8 “Coliform measurement in May 2009” .....	122
Table E-9 “Coliform measurement in June 2009” .....	123
Table F-1 “pH measurements in Kesikköprü Reservoir Water” .....	124

## LIST OF FIGURES

### FIGURES

Figure 2-1 “Water Supply Planning of Ankara in 1936” [10] .....	5
Figure 3-1 “Map of the sampling locations” .....	22
Figure 4-1 “THMFP in Kesikköprü Reservoir Water” .....	40
Figure 4-2 “DOC Concentrations in Kesikköprü Reservoir in months” .....	43
Figure 4-3 “Monthly Average Sulfate Concentrations in Drinking Water” .....	49
Figure 4-4: “Average As concentration in months for all districts” .....	52
Figure 4-5 “Annual Average TTHM of 24 Districts” .....	57
Figure 4-6 “Percentage of TTHM Compounds of GOP in Months” .....	58
Figure 4-7 “Annual Average HAA Concentrations in Districts of Ankara” .....	59
Figure 4-8 “Annual Average HAA <sub>5</sub> Concentrations in Districts of Ankara” .....	60
Figure 4-9 “Monthly Average DOC concentration in Drinking Water Samples of Ankara” .....	64
Figure 4-10 “Monthly Average UVA <sub>254</sub> in Distribution Network” .....	66
Figure 4-11 “SUVA in distribution network in months” .....	66
Figure 4-12 “Annual Average AOX concentration in drinking water samples” .....	70
Figure 4-13 “HAA <sub>5</sub> , THM and AOX for Yıldız” .....	71
Figure 4-14 “HAA <sub>5</sub> , THM and AOX for 100. Yıl” .....	71
Figure 4-15 “HAA <sub>5</sub> , THM and AOX for Demetevler” .....	72
Figure 4-16 “HAA <sub>5</sub> , THM and AOX for Tandoğan” .....	72
Figure B-1 “TTHM Concentration for districts in July 2008” .....	99
Figure B-2 “TTHM Concentration for districts in September 2008” .....	100
Figure B-3 “TTHM Concentration for districts in October 2008” .....	100
Figure B-4 “TTHM Concentration for districts in November 2008” .....	101
Figure B-5 “TTHM Concentration for districts in December 2008” .....	101
Figure B-6 “TTHM Concentration for districts in January 2009” .....	102

Figure B-7 “TTHM Concentration for districts in February 2009” .....	102
Figure B-8 “TTHM Concentration for districts in March 2009” .....	103
Figure B-9 “TTHM Concentration for districts in April 2009” .....	103
Figure B-10 “TTHM Concentration for districts in May 2009” .....	104
Figure B-11 “TTHM Concentration for districts in June 2009” .....	104
Figure B-12 “Percentage of TTHM Compounds of Bahçelievler in Months” .....	105
Figure B-13 “Percentage of TTHM Compounds of Demetevler in Months” .....	105
Figure B-14 “Percentage of TTHM Compounds of Eryaman in Months” .....	106
Figure B-15 “Percentage of TTHM Compounds of Abidinpaşa in Months” .....	106
Figure B-16 “Percentage of TTHM Compounds of Yıldız in Months” .....	107
Figure C-1 “HAA <sub>5</sub> Concentration for districts in October 2008” .....	108
Figure C-2 “HAA <sub>5</sub> Concentration for districts in November 2008” .....	109
Figure C-3 “HAA <sub>5</sub> Concentration for districts in December 2008” .....	109
Figure C-4 “HAA <sub>5</sub> Concentration for districts in January 2009” .....	110
Figure C-5 “HAA <sub>5</sub> Concentration for districts in February 2009” .....	110
Figure C-6 “HAA <sub>5</sub> Concentration for districts in April 2009” .....	111
Figure C-7 “HAA <sub>5</sub> Concentration for districts in May 2009” .....	111
Figure C-8 “HAA <sub>5</sub> Concentration for districts in June 2009” .....	112

## NOMENCLATURE

AOX	: Adsorbable Organic Halides
As	: Arsenic
DBP	: Disinfection By-Products
DOC	: Dissolved Organic Carbon
HAA	: Haloacetic Acid
IWTP	: Ivedik Water Treatment Plant
MoH	: Ministry of Health
NOM	: Natural Organic Matter
SHW	: State Hydraulic Works
SUVA	: Specific Ultraviolet Absorbance
THMFP	: Trihalomethane Formation Potential
TTHM	: Total Trihalomethane
USEPA	: United States Environmental Protection Agency
UVA	: Ultraviolet Absorbance
WHO	: World Health Organization
WIHCR	: Regulation Concerning Water Intended for Human Consumption of MoH

## CHAPTER 1

### INTRODUCTION

Water is crucial for sustaining the life on earth. Thus, people must access to water and it must be supplied to communities satisfactorily. However, the safety of water is the important factor to be considered [1]. Since supplying reliable and safe drinking water is a vital issue, assessment of drinking water quality is required to be able to ensure safe drinking-water supply to community. Consequently, certain and critical water quality parameters must be monitored in order to assess the water quality.

Monitoring is a way of regular testing of certain quality parameters determined in national and international based guidelines and regulations. Therefore, monitoring is an essential tool to determine whether drinking water standards are complied with.

The raw water can exhibit a fair variation in its characteristics due to natural and human factors and this variation has an effect on the efficiency of treatment and thus the safe drinking water supply to the community [3]. Therefore, drinking water quality is directly affected from and related to the quality of source water [2]. Moreover, an important point to be considered to serve a new source for a community before the selection of that source for drinking is that the quality of the water is satisfactory or treatable for drinking [1]. Due to all these reasons, monitoring for water quality parameters must be performed in both raw water used as source and the taps of drinking water.

Due to the water scarcity in Ankara Reservoirs, namely, Kurtboğazı and Çamlıdere Reservoirs, in 2007, sufficient drinking water could not be supplied to the city of Ankara. For some groups this scarcity of water was associated with the fact that the

location of Ankara was not suitable place for urbanization [10]. However, old settlements of Ankara had solved the water problem for years by transferring water from sources. Some groups introduced that the water shortage was a result of global warming and drought [10]. However, rather than the reasons of the water shortage, the solution of the situation had the priority.

Alternative sources for supplying drinking water to Ankara was started to be investigated to solve the water scarcity problem. Due to the urgency of the situation, a decision on the solution was made and the solution found was implemented in a very short time. However, before the raw water can be considered as suitable for human consumption, survey should be made to determine the suitability of the source and the amount of treatment required. Therefore, the guiding principle is that a new public water supply should not be approved without a survey made [6]. The solution to the problem was the Kızılırmak Project. With the implementation of the proposed project, Kızılırmak water was conveyed from Kesikköprü Reservoir to Ivedik Water Treatment Plant (IWTP) where it was mixed and treated together with Çamlıdere and Kurtboğazi Reservoir waters and then was distributed to the city between March of 2008 and February of 2009.

After the use of Kesikköprü Raw water as a source of drinking water for Ankara, the water supply quality in Ankara was on debate that its quality was not satisfying the drinking water quality standards and thus it is threatening the public health. The discussions were especially on the sulfate and arsenic concentrations in Kesikköprü Reservoir water. It was argued that the water had high concentrations of arsenic (As), sulfate ( $\text{SO}_4^{2-}$ ) and chloride ( $\text{Cl}^-$ ). Moreover, disinfection by products (DBPs), such as trihalomethanes (THMs), haloacetic acids (HAAs), were also important because of the possibility of reaction between natural organic matters (NOMs) and chlorine during the disinfection process in the treatment plant. Therefore, water quality of Kesikköprü Reservoir and its effect on the drinking water quality in Ankara have become questionable.

Up to date, several monitoring studies have been performed by Tokmak et al. [16] and Gür [7] on the sources and the drinking water of Ankara. However, these studies were generally on the investigation of the NOM content and the formation of DBPs in water and more importantly, excluded Kesikköprü Reservoir water. In addition to these studies, General Directorate of State Hydraulics Works (SHW) conducted a monitoring study in Kesikköprü Reservoir water in terms of physical, chemical, biological and microbiological quality parameters and reported that the values of chloride, sulfate and hardness in Kesikköprü Reservoir water were very high [25].

The purpose of this study is to determine and evaluate the water supply quality of Ankara by monitoring the water quality parameters in both Kesikköprü Raw Water, and the distribution system for one-year period. The water quality parameters chosen for the analysis of Kesikköprü water are  $\text{SO}_4^{2-}$ , As, trihalomethane formation potential (THMFP), as being primarily parameters, and dissolved organic carbon (DOC), adsorbable organic halides (AOX), turbidity, conductivity and pH. The parameters for the drinking water samples are; primarily THMs, HAAs,  $\text{SO}_4^{2-}$ , As, DOC, AOX,  $\text{UVA}_{254}$ , total coliform, fecal coliform, residual chlorine and pH.

This thesis consists of five chapters following the introduction. The next chapter gives information about the history of Ankara's water and summarizes the related works on water quality. Experimental works performed during the study are explained in the third chapter. The fourth chapter presents the results of the monitoring experiments and discusses the results. The conclusion and recommended future works are stated in the fifth and sixth chapters, respectively. The appendices compose of the calibration curves for THM and HAA measurements, graphs showing monthly variation of THM in districts and detailed measurement results for some parameters.

## CHAPTER 2

### BACKGROUND AND RELATED WORK

#### 2.1. Historical Background of Water Supply in Ankara

Ankara is an ancient city which has been selected as a settlement area since prehistoric times. Old settlements of Ankara used water by carrying from Elmadağ for their water source. In B.C. 25, Romans, who were the administrators of the city, constructed water baths and dams. Moreover, the first water system transporting water to Ankara was built by Romans [10].

In 1923, Ankara was made the capital of Turkey and the city population was approximately 30.000. However, existing water sources could not meet the water demand of Ankara because of the rapid increase in the population of the city. Therefore, water supply plans and works to satisfy the water demand of Ankara were started in 1925 and an intake structure, Kusunlar Intake Structure near Kayaş-Kusunlar Village, was constructed in 1926. Then, “Ankara Drinking Water Commission” was established in 1931 and the commission developed a plan (Jansen Plan) between 1931-1936. The water supply planning of Ankara in 1936 by the commission can be seen in Figure 2-1. However, water shortage occurred in the years of 1940-1950 because the population of Ankara increased faster than the predicted one [4, 10].

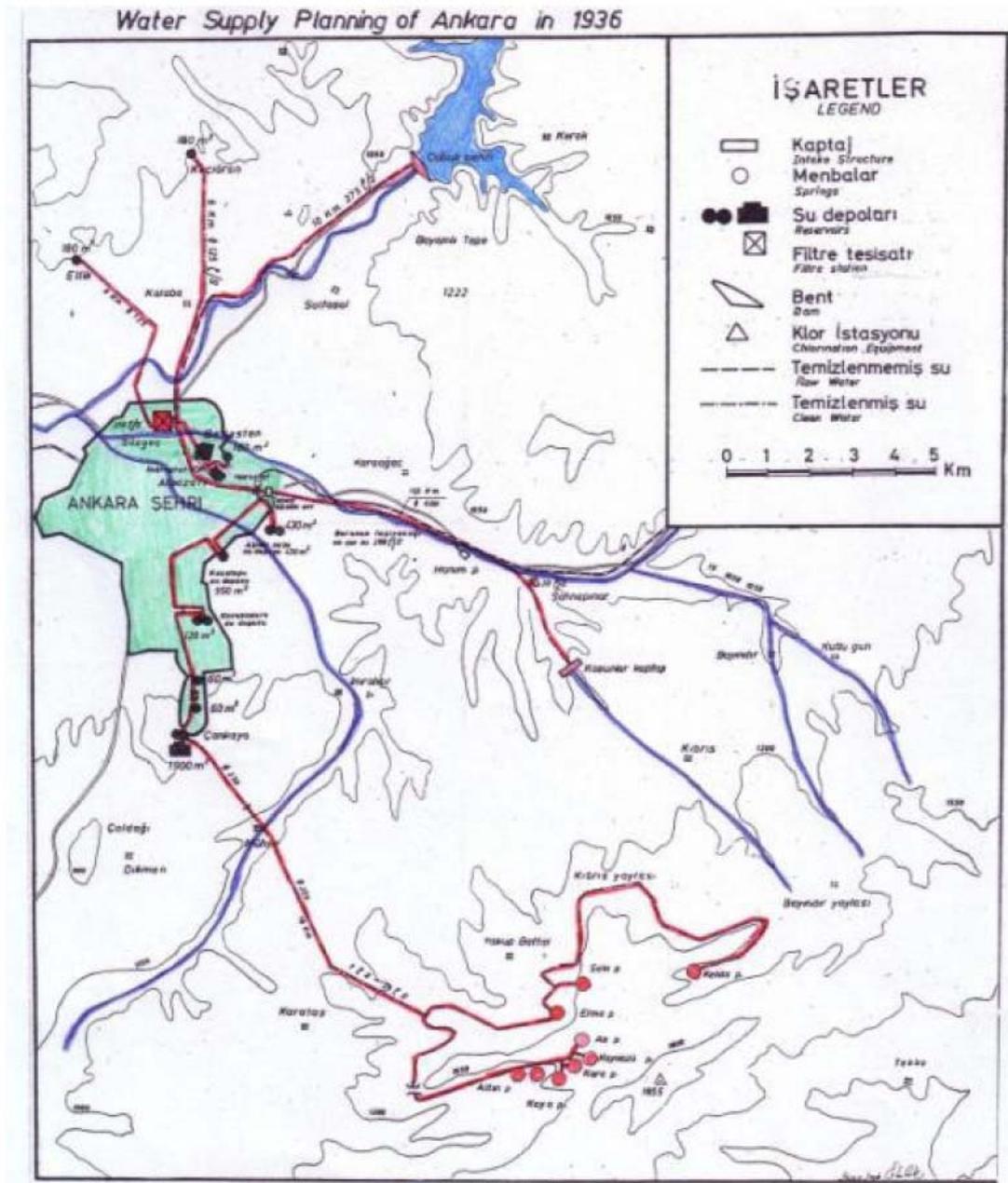


Figure 2-1 “Water Supply Planning of Ankara in 1936” [10]

A comprehensive plan was prepared by General Directorate of State Hydraulics Works (SHW) as the “Master plan for Water and Sewerage System of Ankara”. This plan prepared for the years of 1970-2020 was developed to satisfy the water demand of Ankara until the year of 2020. In this plan, the increase in the population of Ankara and water demand of the city based on the population increase was predicted.

Depending on the calculations, reservoirs and associated years to put them into service were defined. According to this plan; Kurtboğazı Reservoir, Çamlıdere Reservoir, Eğrekkaya Reservoir and Akyar Reservoir were put into service in the years of 1974, 1985, 1992 and 2000, respectively. Moreover, in the scope of the master plan, the first stage of Ivedik Water Treatment Plant (IWTP) of Ankara was get into operation in 1984 [4]. Currently, IWTP receives water from Kurtboğazı and Çamlıdere Reservoirs in equal proportions.

Until 2008, there were seven reservoirs supplying drinking water to Ankara, namely Çubuk-I, Çubuk-II, Bayındır, Çamlıdere, Kurtboğazı, Eğrekkaya, and Akyar Reservoirs. However, two of the reservoirs, Çubuk-I and Bayındır Dams, are no longer in service because of the contamination and deficiency in their capacities. The storage capacities of these reservoirs are given in Table 2-1 [4].

**Table 2-1 “Storage capacities of the dams supplying drinking water to Ankara”**

<b>Name of the Reservoirs</b>	<b>Storage Capacities (m<sup>3</sup>)</b>
Çamlıdere	1 billion 220 million
Kurtboğazı	92 million
Eğrekkaya	85 million
Akyar	47 million
Çubuk –II	25 million

The amount of water that can be collected in Çamlıdere Reservoir is, in fact, only about 130-150 million m<sup>3</sup>. But, the storage capacity is reported to be much higher (Table 2-1) due to its capability to store additional water from Işıklı Reservoir [4].

The master plan for Ankara Water Supply stated Işıklı Reservoir System (as Gerede Project) to be implemented as stages between the years of 1993 and 2010. In 2000 the second stage and in 2010 the third stage of the proposed reservoir system were planned to be put into operation based on the Master Plan in 1968. However, in 1994 the Master Plan was revised to rearrange the way of transmission of Gerede water from Işıklı System to Çamlıdere Reservoir. Moreover, the period of the master plan was extended and the revised Master Plan covered the water supply projects of

Ankara until 2050. Kesikköprü Reservoir (Kızılırmak Project) was also planned in the revised Master Plan as to be implemented in 2028. Kesikköprü Reservoir had been primarily planned also in water supply plans of Ankara in 1936 (Figure 2-1).

Gerede Project has not been implemented as proposed in the Master Plan because of the conflict between SHW and Ankara Greater Municipality in 1990s. Although SHW insisted on the Gerede Project and stated that there would be water shortage in Ankara unless the Gerede Project was implemented, the project was not accomplished. Then, in 2007, water deficiency was experienced in Ankara as predicted; and thus, alternative water sources started to be evaluated. The Kızılırmak Project was found as the solution of the water shortage problem of Ankara and Kesikköprü-Kızılırmak system was put into service in 2007 [10]. Drinking water quality debates on Kesikköprü-Kızılırmak system, especially focusing on sulfate and arsenic, raised with the implementation of the project.

In fact, the master plan prepared in 1968 was explicated the Kızılırmak Project as an alternative source for Ankara. It was reported in the plan that alternative ways to convey water from Kesikköprü Reservoir to Ivedik Water Treatment Plant should have been considered to reduce the transportation cost of water, the proper technologies for the treatment of Kesikköprü Raw water should have been investigated because of the characteristics of raw water, especially sulfate and chloride concentrations, and the requirements of downstream of Kızılırmak in terms of irrigation, water supply and hydroelectric power should be determined before transferring water from Kızılırmak [11].

## **2.2. Water Quality Standards**

Drinking water standards are established in order to be able to supply water at a certain quality level to a community continuously [8]. Parameters to be monitored and the limit values determined for the parameters have been updated by the day since the health effects of chemical and biological compounds existing in raw and drinking waters are understood more clearly with the obtaining and enhancement of the available data on the compounds [9].

WHO guidelines, US National Primary and Secondary Drinking Water Standards, and European Standards are the most commonly accepted ones for drinking water standards in international and national based. Water quality parameters listed in these guidelines are presented in Table 2.2. In Turkey, there exists two regulations, namely, TS266 [48] and Regulation Concerning Water Intended for Human Consumption (WIHCR) [49]. Water quality parameters listed in these national regulations are presented in Table 2.3.

Table 2-2 “Drinking Water Quality Parameters (EU - WHO - USEPA)” [3]

Parameter	EU	WHO	USEPA Primary	USEPA Secondary
Arsenic	10 µg/l	10 µg/l	10 µg/l	-
Boron	1.0 mg/l	0.3 mg/l	-	-
Bromate	10 µg/l	-	10 µg/l	-
Cadmium	5.0 µg/l	3.0 µg/l	5.0 µg/l	-
Chromium	50 µg/l	50 µg/l	10 µg/l	-
Copper	2.0 mg/l	2.0 mg/l	1.3 mg/l	1.0 mg/l
Cyanide	50 µg/l	70 µg/l	200 µg/l (as free cyanide)	-
Lead	10 µg/l	10 µg/l	15 µg/l	-
Nitrate	50 mg/l	50 mg/l (total nitrogen)	10 mg/l (measured as Nitrogen)	-
Nitrite	0.5 mg/l	50 mg/l (total nitrogen)	1 mg/l (as Nitrogen)	-
Trihalomethanes (Total)	100 µg/l	-	80 µg/l	-
Color	No abnormal change	Not mentioned	-	-
Conductivity	2500 µS/cm	-	-	-
pH	≥6.5, ≤9.5	No guideline	-	6.5 - 8.5
Odor	No abnormal change	-	-	-
Sulfate	250 mg/l	250 mg/l	-	250
Sodium	200 mg/l	200 mg/l	-	-
Taste	No abnormal change	-	-	-
Total Coliform	0/100 ml	-	5.0 percent	-
DOC	No abnormal change	-	-	-
Turbidity	No abnormal change. Normally < 1.0 NTU	Not mentioned	*	-
Hardness	-	-	-	-
Chloride	-	-	250	250

\*Turbidity: At no time can turbidity (cloudiness of water) go above 5 NTU

Table 2-3 “Drinking Water Standards in Turkey” [48, 49]

Parameter	TS 266	Regulation Concerning Water Intended for Human Consumption of Ministry of Health
Alkalinity	-	-
Arsenic	10 µg/l	10 µg/l
Iron	200 µg/l	200 µg/l
Nickel	20 µg/l	20 µg/l
Zinc	-	-
Conductivity	2500 µmho/cm	2500 µmho/cm
Chloride	250 mg/l	250 mg/l
Phosphorus	-	-
Hardness	-	-
Boron	1.0 mg/l	1.0 mg/l
Bromate	10 µg/l	10 µg/l
Cadmium	5.0 µg/l	5.0 µg/l
Chromium	50 µg/l	50 µg/l
Copper	2.0 mg/l	2.0 mg/l
Cyanide	50 µg/l	50 µg/l
Lead	10 µg/l	25 µg/l (until 31.12.2012)
Nitrate	50 mg/l (as NO <sub>3</sub> )	50 mg/l (as NO <sub>3</sub> )
Nitrite	0.5 mg/l (as NO <sub>2</sub> )	0.5 mg/l (as NO <sub>2</sub> )
Trihalomethanes (Total)	-	150 µg/l (until 31.12.2012)
Color	No abnormal change	No abnormal change
pH	>6.5, <9.5	≥6.5, ≤9.5
Odor	No abnormal change	No abnormal change
Sulfate	250	250
Fecal Coliform	0	0
Total Coliform	0	0
DOC	No abnormal change	No abnormal change
Turbidity	1 NTU	No abnormal change

General health effect information for the SO<sub>4</sub><sup>2-</sup> and As which are the major pollutants concerned in Kesikkörü reservoir water, as well as DBPs, are summarized below.

### Sulfate (SO<sub>4</sub><sup>2-</sup>):

Sulfate generally occurs in all natural waters. Sulfate is present in raw waters in a natural way resulting from the dissolving into water as a result of contact with sulfate minerals containing rocks and soil or due to municipal or industrial discharges from the industries such as pulp and paper mills, textile mills [12].

Sulfate does not have a toxic effect reported. Although WHO has not set a health-related guide value for sulfate which is considered not to pose an adverse health risk at the concentrations normally observed in drinking water [6], the health concerns related sulfate have been raised as a result of the reports on the diarrhea associated with the ingestion of water having high sulfate concentration [12].

In a study conducted by Chien et al. [14] to investigate the diarrhea effect of sulfate, three infants were exposed to water containing high sulfate concentration with 630 mg/l, 720 mg/l and 1150 mg/l, separately. As to the study it should be regarded as that the consumption of water containing sulfate concentration higher than 400 mg/l especially for infants was unsuitable. However, according to the results of the study it could not be concluded that the diarrhea was directly and solely related to the high sulfate concentration in water.

The studies conducted to determine adverse health effects of high sulfate concentration have showed that exposure to high level of sulfate concentration in water result some effects on people, but there has been not obtained a strong evidence of causing diarrhea [13].

In another study investigating the diarrhea effect of sulfate, a comparison was done between two groups. One group was exposed to drinking water having sulfate concentration 264 mg/l and higher, while the other group consumed tap water with very low sulfate concentration. Although there were some complains from the first

group, a direct and strong connection between sulfate and diarrhea was reported as result of the study [12].

Sulfate was also reported as having laxative effect. Magnesium and sodium sulfate are stated as strong laxatives. Therefore, suddenly occurring slight increase in sulfate concentration results in a purgative effect, although moderately high value of sulfate concentration in water consumed can be tolerated by human body [9]. This laxative effect was reported in a survey. In the survey, most of the people consuming water containing 1000 mg/l or higher value of sulfate concentration complained from the laxative effects [12].

Except the health effects of high sulfate concentration, sulfate in drinking water can result in quality problems such as a noticeable taste and odor. Moreover, sulfate rich in drinking water can contribute to the corrosion of distribution network pipelines [12]. It is generally considered that 50 mg/l of sulfate as likely corrosive [3]. Therefore, although a health-based guideline value for sulfate in drinking has not existed yet, sulfate concentration is limited in standards because of the exact and possible effect of sulfate.

#### Arsenic (As):

Arsenic can exist in water naturally. The common sources of arsenic in drinking water can be listed as by USEPA, 2006); erosion of natural deposits, runoff from orchards, and runoff from glass and electronics production wastes.

Arsenic can occur in both inorganic and organic forms in water. Inorganic forms of arsenic commonly found in drinking water are arsenite (As III) and arsenate (As V). As III is oxidized and more toxic form of arsenic compared to As (V) [3].

Arsenic is classified as carcinogenic due its reported health effects. It is documented by Chen et al. [17] that arsenic leads to skin cancer and increase the risk of bladder, lung, kidney, liver, colon and prostate cancers.

Yoshida et al. [19] investigated chronic arsenic poisoning and the related health effects. The study concluded that skin lesions, neurological effects, hypertension, peripheral vascular disease, cardiovascular disease, respiratory disease, diabetes mellitus, and malignancies including skin cancer were the chronic effect of arsenic from drinking water.

#### Disinfection-By Products (DBPs):

Disinfection is a process which has two main purposes. Killing or inactivation of pathogens from raw water is the primary purpose while the secondary purpose of the disinfection is to prevent regrowth of microorganism during the travel of water in distribution system by providing a disinfectant in finished water. However, disinfectants used for disinfection of water react with natural organic matter (NOM) or bromide in water, and as a result of the reactions, disinfection by-products (DBPs) are formed in water [26]. First, the relationship between NOM and formation of chloroform, and identification of other THMs in chlorinated drinking waters were reported by Rook in 1974 [5]. After that, although more than 700 DBPs have been discovered [29], trihalomethanes (THMs) and haloacetic acids (HAAs) are the commonest ones in drinking water [3, 26]. Four THM species in drinking water are chloroform ( $\text{CHCl}_3$ ), bromodichloromethane ( $\text{CHBrCl}_2$ ), dibromochloromethane ( $\text{CHBr}_2\text{Cl}$ ) and bromoform ( $\text{CHBr}_3$ ), being the most common chlorofom [3]. HAAs constitute of nine compounds, namely bromochloroacetic acid (BCAA), bromodichloroacetic acid (BDCAA), chlorodibromoacetic acid (CDBAA), dibromoacetic acid (DBAA), dichloroacetic acid (DCAA), monobromoacetic acid (MBAA), monochloroacetic acid (MCAA), tribromoacetic acid (TBAA), and trichloroacetic acid (TCAA). DCAA and TCAA are the most common compounds of HAAs in drinking water. BCAA, MCAA and DBAA are the other HAA compounds

found at lower levels in drinking water are the other common compounds of HAAs. These five compounds of HAAs are denoted as HAA<sub>5</sub> [30].

After the identification of chloroform in drinking water, several epidemiological and toxicological studies were carried out to investigate health effects of chlorinated disinfection by-products in drinking water. WHO reported in 1984 that there was an evidence of being relation between long-term exposure to THMs at low levels in drinking water, and the cancers of rectal, intestinal and bladder [31]. Another study on DBPs health effect evaluated 12 epidemiological studies and reported that 9% of bladder cancer cases and 15% of the rectal cancer cases could be interpreted as the result of being exposure to chlorinated water and chlorinated by-products in water [32]. In a study conducted in 1998, it was also indicated that THMs in drinking water was correlated with spontaneous abortion [33].

A study was reviewed epidemiological studies on health effects of chlorinated by-products and it was summarized the effects of most common compounds of THMs and HAAs. The health effects of chloroform was listed as cancer, liver, kidney and reproductive effect and nervous system, liver, kidney and reproductive effect was given as the health effects of dibromochloromethane. The health effects of bromodichloromethane and bromoform were recorded as cancer, liver, kidney and reproductive effects. As being the most common HAAs compounds, DCAA and TCAA were reported having the health effects of cancer, reproductive and developmental effects, and liver, kidney spleen and developmental effects, respectively [34].

### **2.3. Monitoring Studies**

A monitoring study was carried out in Greece for four months, from January and April 2001, in order to assess the drinking water quality in terms of specific parameters; namely conductivity, total dissolved solids and pH, chloride, potassium,

calcium, magnesium and sodium, heavy metals (cadmium, copper, lead, chromium and nickel), fluoride, bromide, nitrates, nitrites, ammonium, sulfate, phosphate, and dissolved organic carbon (DOC). The sample collection was done from the taps of drinking water and from municipal water supplies. The results of the monitored parameters were compared to the standards in EU Directives of 98/83/EC to determine the quality of subjected drinking water. The study found that certain percentages of the samples did not comply with the standards in terms of the parameters which were lead, chloride, nickel, ammonium, sodium, fluoride, sulfate, nitrates and conductivity. According to the monitoring data obtained as a result of the study showed that the quality of drinking water was poor. This situation was correlated with the contamination in water sources [2].

The treatment requirements and the water quality after treatment depend on the raw water quality. Uyak et al. [15] carried out a study showing the seasonal variations of organic content and the reactivity of the organic matter with treatment chemical. A sampling program was followed in the monitoring study such that samples were collected from the raw water and from certain points through the treatment plants. Investigation was primarily on organic matter content and DBPs. For this purpose, dissolved organic carbon (DOC),  $UVA_{254}$ , THMFP and HAAFP were measured for 10 months. In order to characterize the surface water supplies, the raw waters were monitored in terms of physical and chemical quality parameters, such as pH, turbidity, conductivity, alkalinity, hardness and temperature. The study showed that the reactivity of organic matter, as a result of the reactivity THMFP and HAAFP, changed throughout the monitoring period depending on the temperature.

Another monitoring study on source water was conducted by Gür [7] to determine the seasonal variation of the characteristics and THMFP of Çamlıdere and Kurtboğazı Reservoir Waters. In this study, Çamlıdere and Kurtboğazı Reservoir water were analyzed to characterize the water. For this purpose,  $UVA_{254}$ , non purgeable organic carbon (NPOC) (or DOC) and THMFP were the parameters primarily investigated in the water with the other quality parameters of color,

turbidity, suspended solids, pH, alkalinity, coliform, iron, magnesium, calcium, hardness and AOX. In order to determine the THMFP for both raw waters, chlorination tests were applied to the raw waters and THM concentrations of the chlorine dosages (5, 8, 10 and 12 mg/l). It was observed that the highest THMFP for Çamlıdere Reservoir water was 70 µg/l in February, 1999 and the THMFP for Kurtboğazı Reservoir water was the highest in March, 1999 as 73 µg/l, which was lower than the Environmental Protection Agency (EPA) stage I limit of 80 µg/l. It was also determined that THMFP for the reservoir waters increased for higher chlorine dosages. THM concentrations were higher for the water samples having higher chlorine concentration. Moreover, the NPOC measurements were done from July, 1998 to June, 1999 for the reservoirs. It was stated that for Çamlıdere Reservoir NPOC changed around the concentration of 4 mg/l, which was normal for unpolluted-fresh surface water, and it was higher in summer months showing the highest concentration in June, 1999 with 5.180 mg/l. Furthermore, the study showed that UVA<sub>254</sub> and NPOC were surrogate parameters for THMFP. In the study, NPOC, UVA<sub>254</sub> and THMFP values for certain chlorine dosages were correlated and it was figured out that there was a good correlation between NPOC and THMFP. According to the measurement results, the highest correlation was obtained for 5 mg/l chlorine dosage with the coefficient of determination value of 0.971.

The effect of source water characteristics on drinking water quality in terms of THM formation is seen in a following study performed by Tokmak et al. [16]. They investigated THM occurrence in Ankara distribution network system and associated cancer risk in water. 22 districts receiving water from Ankara Ivedik Water Treatment Plant were selected for sampling locations. In order to characterize the raw water, NPOC, alkalinity, pH, turbidity, color, hardness, suspended solids and bromine were measured in Çamlıdere and Kurtboğazı Reservoir Waters. Moreover, NPOC and THM formation potential were analyzed in the finished water sample from IWTP. NPOC concentrations in Çamlıdere and Kurtboğazı waters were 4.1 mg/l and 4.4 mg/l on annual average, respectively. The NPOC level was determined at the inlet of IWTP (in raw water) as 4.26 mg/l on average. The annual average of

THMFP at the outlet of the treatment plant was determined as  $35.0 \pm 3.0 \mu\text{g/l}$  and only chloroform and bromodichloromethane were the compounds analyzed in the finished water samples. The study showed that THM concentrations in distribution system of Ankara were generally below the USEPA (Stage I limit  $80 \mu\text{g/l}$  and Stage II limit  $40 \mu\text{g/l}$ ) and EU ( $100 \mu\text{g/l}$ ) limits although THM levels changed seasonally and by districts. It was detected that total THM concentrations varied between  $25$  and  $74 \mu\text{g/l}$  in winter,  $28$  and  $73 \mu\text{g/l}$  in spring, and  $25$  and  $110 \mu\text{g/l}$  in summer; thus, the higher THM concentrations occurred in warm months compared to cold ones. The highest THM concentration was observed in Konutkent, which was the farthest district from IWTP among the sampling districts, in summer 1999. Therefore, it was also verified with the study that THM concentration increased with long contact time during the period of travel to far districts.

Another study performed by Ateş et al. [23] is on the occurrence of DBPs for surface waters in Turkey. In this study, the formation of THM, HAA and AOX concentrations were measured in the sources of drinking water collected monthly during a year (2004) from 29 different locations, including Çamlıdere and Kurtboğazi source waters, throughout Turkey after chlorination of the filtered raw water samples. DOC,  $\text{UVA}_{254}$ , bromide, pH and total hardness were the typical quality parameters analyzed in the filtered raw water samples before chlorination in order to characterize the water samples. The measurement results showed that all surface waters had low DOC with the DOC concentrations changing between  $0.91$  and  $4.42 \text{ mg/l}$ . The annual average DOC concentration for Çamlıdere and Kurtboğazi source waters were  $3.58 \pm 0.53$  and  $3.51 \pm 0.60 \text{ mg/l}$ , respectively. Moreover, Specific UV absorbance (SUVA equals to  $\text{UVA}_{254}/\text{DOC}$ ) for the 29 drinking source water samples was calculated. The SUVA values in all source waters were low to medium and the annual average SUVA for all the waters were  $1.722 \text{ l/mg m}$  with the maximum annual SUVA in Kurtboğazi water as  $2.893 \text{ l/mg m}$ . Bromide concentration were detected as below  $20 \mu\text{g/l}$  for 24 raw waters including Çamlıdere and Kurtboğazi raw waters. The annual THM concentrations changed between  $21$ - $189 \mu\text{g/l}$ . The average concentrations of THM for Çamlıdere water for spring,

summer, autumn and winter were 82, 128, 147 and 116  $\mu\text{g/l}$ , respectively. The similar change in seasonal variation of THM concentrations in Kurtboğazı water was observed as the average concentrations for spring, summer, autumn and winter were 95, 121, 158 and 110  $\mu\text{g/l}$ , respectively. The highest THM concentrations were detected in autumn and chloroform was found the major THM specie. It was stated that average HAA concentration for 29 source waters varied 18-149  $\mu\text{g/l}$  annually and chlorinated species dominated over brominated species because of low bromide concentration in source waters. It was also concluded that while a good correlation was obtained between THM and HAA, THM-AOX and HAA-AOX correlation was found to be poor.

Rodriguez et al. [30] investigated chlorination DBPs, THMs and HAAs, in the drinking water distribution system of Province of Quebec City, Canada whose weather conditions were highly variable between summer and winter. It was commented that the significant difference in temperature was important for surface water. The monitoring study was conducted for 14 months. For the study, 5 sampling points changing in distance were selected and the water samples. The water samples were also collected from raw water and clean water (from the point before post-chlorination). The monitored parameters for raw water were  $\text{UV}_{254}$ , TOC, pH, turbidity and temperature, while  $\text{UV}_{254}$ , TOC, pH,  $\text{Cl}_2$ , THMs and HAAs were the parameters monitored in the drinking water samples collected from distribution system. The average annual values for the raw water were 7.13, 2.81 NTU, 3.20  $\text{mg/l}$ , and  $0.154 \text{ cm}^{-1}$  for pH, turbidity, TOC and  $\text{UV}_{254}$ , respectively. Turbidity, TOC and  $\text{UV}_{254}$  values were detected generally below in winter than in other seasons for the raw water. THMs and HAAs were measured monthly for the drinking water samples. Bromoform, one of the THM specie, was not detected in the water samples, while only DCAA and TCAA of HAA species were detected in the distribution system. The study concluded that seasonal variations and spatial changes for THM and HAA concentrations in drinking water were significant. It was observed in the study that while THM concentration in distribution system increased with the spatial change, it become stable in the system extremities. However, the similar increase

was not obtained for HAA concentration in the distribution system. The results showed that HAA concentration decreased with coming close to the system extremities.

Sajidu et al. [20] performed a monitoring study to determine the water quality of streams in Blantyre, Malawi. After determination of sampling locations, water was collected by grab sampling. Phosphates, nitrates, sulfate and metals were analyzed in the study. The analyzed results showed that the concentration of certain metals of lead, cadmium, iron, manganese, zinc, chromium and nickel in water samples were higher than the WHO drinking water standards; nitrates, sulfate, pH and TDS values satisfied the corresponding standards. However, biochemical oxygen demand (BOD<sub>5</sub>) was observed higher than the limit concentration determined by standards. The study showed that streams in Blantyre City were polluted by heavy metal and nutrients. This situation was associated to industrial discharges, and agricultural activities. In order to control the pollution, regular monitoring for the city streams was recommended in the study.

In a study, water quality monitoring studies in Turkey was investigated. Since State Hydraulic Works (SHW) is the responsible party for inland water resources in Turkey, water quality monitoring, data collection and water management issues were discussed and evaluated based on the monitoring system of SHW. It was stated that in 2006, 1150 stations were present for water monitoring and the monitoring frequency of each station was determined as 6 times in a year on average. The monitoring parameters were another issue investigated in the study and it was reported that the parameters were grouped as A, B, C, and D and 45 different quality parameter in the Turkish Water Pollution Control Regulation were monitored. Group A comprises most important inorganic parameters such as nitrate, nitrite, phosphate, boron, etc. Group B includes organic parameters (BOD, TOC, etc.). Heavy metal (e.g. arsenic, mercury) forms Group C, while bacteriological parameters (e.g. total coliform) are in Group D. Moreover, it was mentioned that THM was investigated at the inlet and outlet of drinking water treatment plant apart from the other determined

quality parameters because of its significant importance to public health. Data collection and reporting were the other issues discussed in the study that all data collected from monitoring performed by SHW were stored in the Water Quality Database by SHW and they were published in national and international scientific publications, seminar proceedings and reports [50].

One of the monitoring studies conducted by SHW was on the water quality of Hirfanlı and Kesikköprü Reservoir waters. In this study, Kesikköprü Reservoir water was analyzed in terms of certain water quality parameters such as color, turbidity, pH, conductivity, chloride, and sulfate. According to the analyses results, sulfate and chloride concentrations were 339.2 mg/l and 240.6 mg/l on average, respectively. The report determined that the obvious characteristic of Kızılırmak basin was the high salt concentration in its water. Moreover, the report stated the reservoir water of Kesikköprü was categorized as Class-II based on inland water sources classification in WPCR in terms of bacteriological aspect. The report also concluded that chloride, sulfate and hardness values were very high due to the natural structure of Kızılırmak River [25].

## CHAPTER 3

### EXPERIMENTAL WORKS

#### 3.1. Source Waters

In this study, Kesikköprü Reservoir water was used as the raw water sample. This water is conveyed to IWTP of Ankara and it is mixed with the other source water, namely, Çamlidere and Kurtboğazı Reservoir water, with different and changing ratios, depending on their quality. Therefore, Çamlidere ve Kurtboğazı Reservoir waters were also used as raw water samples for some selected parameter analysis, though major concern in this study was Kesikköprü Reservoir water.

After the treatment of these three source waters at IWTP, the outlet water is distributed to Ankara City as drinking water. Water samples taken from 24 districts which receive water from IWTP were used as distribution network water samples.

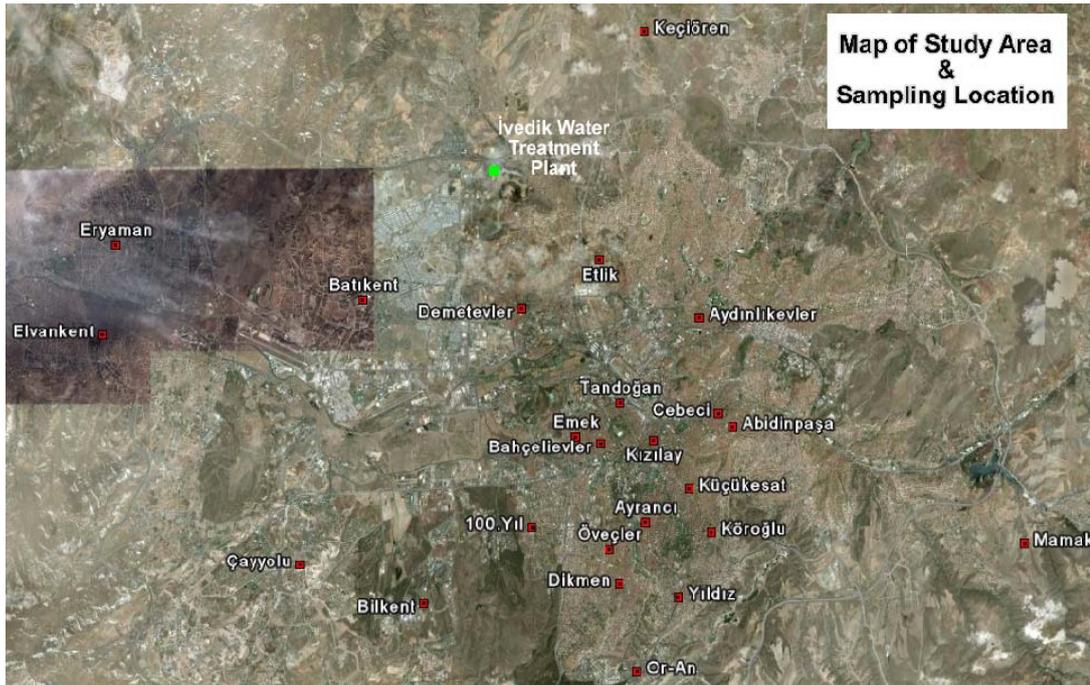
#### 3.2. Sampling

Distribution network samples were collected from the taps of 24 different districts in Ankara and each month the water samples were taken from the same addresses. The names of the 24 sampling districts and the map showing the 24 sampling districts locations are presented in Table 3-1 and in Figure 3-1, respectively. These 24 districts were selected considering that drinking water is being supplied from Ivedik Water Treatment Plant. Moreover, while determining the sampling points, it was

taken into consideration that the sampling locations did not have storage tanks and drinking water was directly coming from the distribution pipes.

**Table 3-1 “Sampling Districts”**

1. Kızılay	13. Abidinpaşa
2. Küçükesat	14. Öveçler
3. Bahçelievler	15. Keçiören
4. Aydınlıkevler	16. Yıldız
5. Demetevler	17. Cebeci
6. Eryaman	18. Mamak (Natoyolu)
7. Tandoğan	19. Gazi Osman Paşa (GOP)
8. Or-An	20. Batıkent
9. 100. Yıl	21. Emek
10. Etlik	22. Ayrancı
11. Bilkent	23. Çayyolu
12. Dikmen	24. Elvankent



**Figure 3-1 “Map of the sampling locations”**

Three different types of sampling bottles were used for the distribution network water samples:

- For bacteriological analysis: 250 ml sterilized plastic bottles containing 10 mg/l of sodium thiosulfate
- For DBPs analysis: 500 ml plastic bottles containing 20 mg/l of sodium thiosulfate
- For other monitoring parameter analysis: 500 ml plastic bottles without sodium thiosulfate

The sampling bottles were used one-time only. The sampling bottles with sodium thiosulfate were used for DBPs and coliform analysis to allow quenching the reaction with preexisting chlorine. Before taking the samples, the taps were sterilized with fire and then let the water flow for about 2-3 minutes to stabilize the water flow. Finally, the sampling bottles were fully filled with the water.

For the Kesikköprü Reservoir water samples, 3-liter plastic bottles were used. Samples were taken from locations near to water intake structures of the reservoirs. Before filling the sampling bottle, the bottle was rinsed with the sampled water. Then, the bottles were fully filled, not leaving any space at the top of the bottles and the bottle caps were tightly screwed. Since the samples were taken using plastic gloves, the caps of the sampling bottles were not touched with hands.

### **3.3. Experimental**

For the first two months of the monitoring study, water samples were collected from Kesikköprü, Çamlıdere and Kurtboğazi Reservoirs in order to have a general characterization for the water quality of the other reservoirs supplying water to Ankara in terms of many quality parameters. Since the major concern was Kesikköprü Reservoir and its results on Ankara drinking water quality, source water samples were taken from only Kesikköprü Reservoir for the rest of the 1-year monitoring period.

Water quality parameters monitored for both the drinking water samples (taken from the taps of the 24 districts in Ankara) and the source water samples (taken from Kesikköprü Reservoir) are indicated in Table 3.2.

**Table 3-2 “Water Quality Parameters Monitored”**

<b>Parameter</b>	<b>Kesikköprü Reservoir</b>	<b>Distribution Network</b>
SO <sub>4</sub>	+	+
As	+	+
THMFP	+	NA
THM	NA	+
HAA	NA	+
AOX	+	+
DOC	+	+
Residual Chlorine	NA	+
UVA <sub>254</sub>	-	+
Conductivity	+	-
Turbidity	+	-
Total/Fecal Coliform	-	+

Residual chlorine and pH measurements were performed on-site immediately after taking the water samples. Total coliform and fecal coliform analysis were done as soon as the collected water samples were brought to the laboratory.

All the other measurement and experiments were done within two weeks in order not to let the water samples be putrefied. During this period, samples were stored at 4 °C.

### **3.4. Analytical Techniques**

#### **3.4.1. UVA<sub>254</sub> Measurement**

UVA analyses were performed at 254 nm with Varian Carry UV – Visible Spectrophotometer 100 Conc. UVA measurements were performed by calibrating the spectrophotometer with ultra-pure water and then placing the water samples in 1 cm width quartz cells. Each sample was measured twice and the average of the measured values was taken.

### 3.4.2. DOC Measurement

DOC measurements were performed by Shimadzu 5000A TOC Analyzer according to the Standard Method 5310 B, high temperature combustion method. 10 ml of sample is placed into a 25 mL of glass tube for the measurement. Before the analysis of sample, 1/25 of HCl was added to the sample and it was purged for about 2-3 minutes. Then, the sample was measured by the analyzer. Each sample was measured three times and the average of all measurements was taken. The analyzer temperature is 720°C, injection volume is 200 µl and catalyst type: TN/TP.

### 3.4.3. SO<sub>4</sub><sup>2-</sup> Measurement

Sulfate (SO<sub>4</sub><sup>2-</sup>) was measured with Hach Dr 2000 Spectrophotometer. A 25 ml of sample was placed into the cell adding one SulfaVer 4 reagent powder pillow. Then, the sample was measured using the spectrophotometer at 450 nm.

### 3.4.4. Free Residual Chlorine Measurement

Residual chlorine was measured with Hach Dr 2000 Spectrophotometer, Method 80, based on SM 4500, Colorimetric Method. A 25 ml of sample was placed into cell adding DPD Free Chlorine powder pillow. Then, the sample was shaken for 20 seconds and measured by the spectrophotometer at 530 nm.

### 3.4.5. Turbidity Measurement

Turbidity was measured with Hach 2100 N Turbidimeter, based on the USEPA Method 180.1- Determination of Turbidity by Nephelometry. The sample was placed into the 30 ml of sample cell and measured three times. The average of the three readings was taken as the turbidity result of the sample.

#### 3.4.6. Conductivity and pH Measurement

The measurements for conductivity and pH were performed using Hach SensION 5 Conductivity and pH meter.

#### 3.4.7. THM Measurement

THM analyses were done according to the procedure of EPA Method 501.2 [21] – Liquid-Liquid Extraction and Measurement with Gas Chromatography (GC) Electron Capture Detector (ECD). With this method four THM compounds, namely Chloroform, Bromodichloromethane, Chlorodibromomethane, and Bromoform, were detected in the samples. For the analysis, a Varian CP3800 model GC with ECD having the properties of CPO-Sil8 column, length 24 m, ID 0.32 mm, film thickness 0.25  $\mu\text{m}$  was used. Ultra high purity Helium and Nitrogen gases were the carrier and make-up gases for the THM measurement with GC, respectively.

For THM measurement, 10 ml sample was placed into a cylindrical 25 ml glass tube and 2 ml of pentane was added to the sample. The sample and pentane were shaken for 2 minutes and then waited for phase separation for about 3-5 minutes. After obtaining phase separation, the upper phase was transferred into 2 ml vials having screw caps with PTFE septa using Pasteur pipettes. The extracted samples in the 2 ml vials were stored into refrigerator at +4°C until they were measured with GC. The GC analyses were done after extraction. Each sample was measured twice. The GC operating conditions for THM measurement were as follows:

Injector Temperature: 280°C

Detector Temperature: 290 °C

Injection volume: 1  $\mu\text{l}$

Total run for the measurement: 13.5 min with the temperature program of 40 °C for 2 min, 4 °C/min ramp to 80 °C, 20 °C/min ramp to 110 °C.

*THM Standard Solution Preparation:*

Supelco THM Test Mixture with 2000 µg/ml TTHM was used to prepare the THM standard solutions. The test mixture contains 1924 µg/ml of Bromodichloromethane, 1885 µg/ml of Bromoform, 1938 µg/ml of Chloroform, and 1867 µg/ml of Dibromochloromethane in 1 ml of methanol. The standard solutions with the concentrations of 2.5, 5, 10, 25, 50, 100 and 250 µg/l were prepared using the THM test mixture purchased and ultra-pure water.

$$C_1 * V_1 = C_2 * V_2$$

$C_1$  = the concentration of the solution obtained

$C_2$  = the concentration of the solution desired

$V_1$  = the volume needed

$V_2$  = the volume that the desired concentration in.

*Example for 250 µg/l THM standard solution:*

The Supelco test mixture concentration was 2000 µg/ml and the standard solution was prepared in a 100 ml flask with 250 µg/l.

$$2000 \text{ µg/ml} * V_1 = 250 \text{ µg/l} * 100 \text{ ml}$$

$$V_1 = 12.5 \text{ µl}$$

The calculated volume was transferred to the 100 ml flask to obtain the desired standard concentration and it was completed to 100 ml with double distilled water (high purity water).

The other standard solutions with different concentrations were obtained by the same procedure. The THM standard solution concentrations are given in the Table 3-3.

**Table 3-3 “THM Standard Solution Concentrations”**

<b>Peak Name</b>	2.5 µg/l	5.0 µg/l	10.0 µg/l	25.0 µg/l	50.0 µg/l	100.0 µg/l	250.0 µg/l
Chloroform	2.445	4.89	9.78	24.45	48.9	97.8	244.5
Bromodichloroform	2.59	5.18	10.36	25.9	51.8	103.6	259
Dibromochloroform	2.515	5.03	10.06	25.15	50.3	100.6	251.5
Bromoform	2.49	4.98	9.96	24.9	49.8	99.6	249

The prepared THM solutions of 1 µl with different concentration were analyzed with the GC. The corresponding areas of the 4 THM species peaks were noted and peak area versus THM standard solution concentrations (using the known concentrations in Table.3.3) were drawn to obtain the calibration curves. In order to determine the THM concentrations in the samples these prepared calibration curves were used. The calibration curves plotted for each THM compound for July and October months are illustrated in Appendix.A as an example.

#### **3.4.8. THMFP Analysis:**

For the reservoir water samples, THMFP analyses were performed according to USEPA Method 501 and Standard Method 6232 B. The water samples were chlorinated to measure the THMFP which shows the maximum potential of the sample to form THM.

In order to determine the chlorine demand of the source water, 13% Sodium Hypochlorite (NaOCl) solution, purchased from Fluka, was used. First to determine the chlorine concentration in the stock solution a solution with 1/250 was prepared by adding 1 ml of stock NaOCl solution into 250 ml of double distilled water. Then the solutions with 1/100, 1/200 and 1/500 ratios were prepared by diluting the prepared 1/250 of chlorine solution. After preparing the solutions, the chlorine amounts in the solutions were measured by Hach Dr 2000 Spectrophotometer, Colorimetric method. The solution giving  $1\pm 0.4$  was selected and the chlorine amount (A) was found in that solution by multiplying the solution dilution with the

measured chlorine concentration by the spectrophotometer. For example, if the chlorine concentration was measured as 1.01 mg/l in the solution with 1/500 dilution by colorimetric method, the chlorine concentration was calculated in that solution as  $500 \times 1.01 = 500.05$  mg/l. This concentration gives the actual chlorine concentration in the stock chlorine solution (1/250).

To calculate the required amount of the chlorine solution added DOC of the water sample was needed. The solutions having different chlorine concentration were prepared. These solutions were prepared by calculating the chlorine concentration for the different Cl/DOC ratios (Cl/DOC=0.75, Cl/DOC = 1.00, Cl/DOC = 1.25, Cl/DOC = 1.50). For example; to prepare the solution having the ratio of Cl/DOC = 0.75, first, Cl amount was found by using the DOC of the water sample (Cl=DOC\*0.75). After finding the Cl concentration (B), the required solution was prepared into dark brown narrow glass bottle having 62 ml of volume by adding the necessary volume of chlorine solution.

$$62 \text{ ml} * B = A * ?$$

? : The necessary volume of chlorine stock solution to be added into the bottle

Following this procedure, 4 solutions having different Cl/DOC ratios were prepared and these solutions were incubated for 24 hours at 20°C. After 24-hour waiting which represents the typical residence time in a drinking water network, residual free chlorine in the 4 solutions were measured by Hach Dr 2000 Spectrophotometer, Colorimetric method (Method 80, based on SM 4500). The solution showing  $1 \pm 0.4$  value was used for THMFP analysis. Therefore, in order to determine THMFP of the source water, the liquid-liquid extraction and measurement with GC method described above (Sec 3.4.7) was applied to the selected chlorination solution. Then, 1 day-THMFP was found for the source water.

### 3.4.9. HAA Measurement

HAA measurements were performed according to USEPA 552.3 Method [21]. With this method, nine HAA compounds namely bromochloroacetic acid, bromodichloroacetic acid, chlorodibromoacetic acid, dibromoacetic acid, dichloroacetic acid, monobromoacetic acid, monochloroacetic acid, tribromoacetic acid, trichloroacetic acid, were detected in the drinking water samples. 25 ml of samples were put into narrow, brown glass of 42 ml volume. Then, 2 ml concentrated sulfuric acid was added to the samples to decrease the pH below 0.5 and 11 g sodium sulfate was added to the samples. The samples were shaken until it dissolves. Then, 4 mL Methyl Tert-Butyl Ether (MTBE) was added to the samples for extraction and the samples were shaken for 3 minutes at room temperature. After shaking the samples, it was allowed the phase separation to occur for 5 minutes. After 5 minutes waiting, 3 ml of upper MTBE phases were transferred into 15 ml glass tubes having PTFE faced septa screw caps by using Pasteur pipettes and 3 ml of 10% sulfuric acid in methanol (acidic methanol solution) were added to the tubes. The tubes were placed into 50 ( $\pm 2$ )°C-water bath for 2 hours. After 2 hours, it was allowed the samples to cool and then, 7 ml of 150 g/l Na<sub>2</sub>SO<sub>4</sub> solution (sodium sulfate solution) were added to each tube. After shaking the tubes for about 10 seconds and waiting for the phase separation, the lower phase from the each tube was removed and discarded with a long Pasteur pipettes. Then, 1 ml of saturated sodium bicarbonate solution was added to the each tube and the tubes were shaken for 5 times (5 seconds for each time). However, after the first time shaking, the cap of the tube was loosened for CO<sub>2</sub> release. Then, phase separation was waited for about 2 minutes. Finally, 1 ml of the upper layer of the each tube was extracted and transferred to 2 ml auto-sampler vial. The vials were stored in the refrigerator at +4°C until they were analyzed by GC.

GC analyses for HAA measurements were done by a Varian CP3800 GC with ECD. The operating conditions for the HAA measurements were as follows:

Injector temperature: 200°C

Detector temperature: 290°C

Injection volume: 1 µl

Total run: 42 minutes with the temperature program of 40°C for 20 min, 120 °C with 5°C/min rate, 3 min hold, 150°C with 10°C/min.

#### *HAA Standard Solution preparation*

The standard solutions were prepared to obtain calibration curves at 7 different points (0.3, 3, 12, 30, 60, 120 and 300 µg/l). In order to obtain calibration standards at certain concentration the test mixture purchased by Supelco (2000 µg/ml total HAA concentration) was used. The determined calibration standard concentrations were obtained by doing the following calculation:

$$C_1 * V_1 = C_2 * V_2$$

To obtain the standard solution with 300 µg/l HAA concentration in 100 ml volume, 15 µl of volume from Supelco HAA test mixture was transferred to 100 ml flask and it was diluted to 100 ml with DDW. The other determined concentrations of calibration standards were prepared with same manner. Then, the standard solutions prepared at the determined concentrations were extracted and analyzed by applying the same procedure for HAA measurements above.

The prepared HAA solutions of 1 µl with different concentration were analyzed with GC. The corresponding areas of the nine HAA species peaks were detected and peak areas versus HAA standard solution concentrations (using the known concentrations in Table.3.4) were plotted to obtain the calibration curves for HAA. In order to calculate the HAA concentrations in the samples, these prepared calibration curves were used.

**Table 3-4 “HAA Standard Solution Concentrations”**

<b>Peak Name</b>	0.3 µg/l	3.0 µg/l	12.0 µg/l	30.0 µg/l	60.0 µg/l	120.0 µg/l	300.0 µg/l
Chloro acetic acid	0.301	3.010	12.04	30.1	60.2	120.4	301.0
Bromo acetic acid	2.203	2.030	8.12	20.3	40.6	81.2	203.0
Dichloro acetic acid	3.307	3.065	12.26	30.65	61.3	122.6	306.5
Trichloro acetic acid	0.200	1.995	7.98	19.95	39.9	79.8	199.5
Bromochloro acetic acid	0.098	0.980	3.92	9.8	19.6	39.2	98.0
Dibromo acetic acid	0.105	1.050	4.20	10.5	21.0	42.0	105.0
Bromodichloro acetic acid	0.202	2.015	8.06	20.15	40.3	80.6	101.5
Dibromochloro acetic acid	0.506	5.055	20.22	50.55	101.1	202.2	505.5
Tribromo acetic acid	1.017	10.170	40.68	101.7	203.4	406.8	101.7

#### **3.4.10. AOX Measurement**

AOX measurements were done by a Euroglass AOX Analyzer as described in ISO 9562. The AOX Analyzer operating conditions were as follows:

1 min drying at 200°C

4 min combustion at 1000 °C

5 min cooling

The samples were prepared for the AOX measurements. A 100 ml of sample was put into a 200 ml of Erlenmeyer's balloon and 5 ml NaNO<sub>3</sub><sup>-</sup> was added to the sample. Next, nitric acid was used in order to decrease the pH to 2. Then, 1 g of activated carbon was also added and the prepared sample in the Erlenmeyer's balloon was shaken with a horizontal shaker for 1 hour. After 1 hour shaking, the sample was filtered and then measured by the AOX analyzer.

#### **3.4.11. Arsenic (As) Measurement**

Samples were prepared in 100 ml volume of Erlenmeyer's balloons for the As measurement. 10 ml samples were put into the Erlenmeyer's balloons and 1 ml

ascorbic acid was added to each sample to be measured. After 30 minutes waiting, the prepared samples were measured by Perkin Elmer AAnalyst 400 Atomic Absorption Spectrometer (AAS) + MHS Hydrur System.

#### 3.4.12. Total/Fecal Coliform Measurement

Membrane filter method (Standard Method 9222 B) was applied to determine total/fecal coliform in the samples. For this method, Millipore standard, sterile, cellulose acetate membrane filters with pore size of 0.45  $\mu\text{m}$  and nutrient media purchased from stores were used. The sampling bottles used for coliform analysis were with sodium thiosulfate in order to neutralize any residual halogens and to prevent any bacterial reactions during the transportation of the samples to the laboratory [21].

For fecal coliform analysis absorbent pad was placed into nutrient dish and the pad was saturated with the nutrient (M-FC medium) while absorbent pad was saturated with the nutrient (M-Endo medium) for total coliform. Then, 100 ml of water sample was filtered through the membrane filters for both fecal and total coliform and the filtered papers were placed onto the saturated pads. The dishes prepared were inverted and incubated at  $44.2 \pm 0.2$  °C for  $24 \pm 2$  hours for fecal coliform, at  $35 \pm 0.2$  °C for  $24 \pm 2$  hours for total coliform analysis. After the incubation, fecal coliform bacteria on the nutrient media were shades of blue and total coliform bacteria on the nutrient media were pink, metallic red color. The number of the colonies was counted.

## CHAPTER 4

### RESULTS AND DISCUSSION

Kesikköprü Reservoir Water and Ankara Distribution Network water samples were collected monthly and both the source water and the drinking water quality were monitored for one year, starting from July 2008 to June 2009, in terms of certain water quality parameters. THMFP,  $\text{SO}_4^{2-}$ , As, DOC, turbidity, conductivity and pH are the quality parameters monitored for the reservoir water. The parameters monitored for the drinking water samples are DPBs (THMs and HAAs), total coliform/fecal coliform,  $\text{SO}_4^{2-}$ , As, DOC,  $\text{UVA}_{254}$ , AOX, residual chlorine and pH.

#### 4.1. Source Water

Kesikköprü reservoir water is conveyed to Ivedik Water Treatment Plant of Ankara and it is mixed with the other source water, namely, Çamlıdere and Kurtboğazi Reservoir water, with different and changing ratios. After the treatment of these source waters, the outlet water is distributed to Ankara City as drinking water. When the monitoring study was started in July 2008, Kesikköprü Reservoir Water was being used as supplementary source water for about three months. Nevertheless, due to the increasing amount in rainfall to Ankara, the usage of Kesikköprü Reservoir was terminated since February 2009.

At the beginning of the analyses, the first two months of the monitoring study, July and August 2008, several quality parameters were measured to determine the characteristics of Kesikköprü Reservoir water. Results of the analyses for June 2008 and August 2008 are presented in Table.4.1 and Table.4.2, respectively.

**Table 4-1 “Kesikköprü Raw Water Characteristics; July, 2008”**

<b>Parameters</b>	<b>Unit</b>	<b>Value</b>
Alkalinity	mg/l CaCO <sub>3</sub>	140
As	µg/l	13.01
NH <sub>3</sub> -N	mg/l	<0.2
AOX	mg/l	0.0081
B	mg/l	0.2
Br <sub>2</sub>	mg/l	0.04
Turbidity	NTU	1.34
F-	mg/l	0.35
Conductivity	µmho/cm	1910
Cl-	mg/l	239.24
NO <sub>3</sub> -N	mg/l	<0.06
NO <sub>2</sub> -N	mg/l	<0.01
PO <sub>4</sub> -P	mg/l	<0.05
Total Hardness	mg/l CaCO <sub>3</sub>	470
SO <sub>4</sub> <sup>2-</sup>	mg/l	312
THMFP	µg/l	67
DOC	mg/l	5.03
Fecal Coliform	/100ml	6
Total Coliform	/100ml	126

The results presented in Table 4.1 and 4.2 are compared with WPCR dated on 31.12.2004, No.25687 to classify Kesikköprü water. According to the table showing “Quality Parameters for Inland Water Source Classes” in the WPCR (given in Table D-1 in Appendix-D), sulfate concentration must be 200 mg/l for Class-I and Class-II waters. However, sulfate concentration in Kesikköprü water was measured as 312 mg/l in July 2008 and 482 mg/l in August 2008, which are higher than 200 mg/l. Moreover, chloride concentration in Kesikköprü water was around 250 mg/l as shown in Table 4.1 and 4.2. When the chloride concentration is discussed based on WPCR, chloride in Kesikköprü water is higher than the one in Class-I waters with 25 mg/l. Furthermore, limit value of conductivity for Class-I waters in WPCR is set as 1000 µS/cm. As seen from the Tables 4.1 and 4.2, conductivity in Kesikköprü water does not satisfy the conductivity limit for Class-I waters. Nevertheless, Arsenic in Kesikköprü was measured as 13.01 µg/l in July 2008 and this arsenic concentration is lower than the arsenic concentration for Class-I waters in WPCR (20 µg/l).

**Table 4-2 “Kesikköprü Raw Water Characteristics; August, 2008”**

<b>Parameters</b>	<b>Unit</b>	<b>Value*</b>
pH		8.3 ±0.0
Conductivity	µmho/cm	1032 ±11
Hardness	mg/l CaCO <sub>3</sub>	392 ±17
Turbidity	NTU	2.61 ±1.15
Alkalinity	mg/l CaCO <sub>3</sub>	57.5 ±2.12
Cl <sup>-</sup>	mg/l	260 ±3
SO <sub>4</sub> <sup>2-</sup>	mg/l	482 ±34
PO <sub>4</sub> -P	mg/l	<0.020
NO <sub>3</sub> -N	mg/l	0.015 ±0.01
DOC	mg/l	7.705 ±0.32
Total Cr	µg/l	1.575 ±0.02
Fe	µg/l	51.37 ±0.88
Ni	µg/l	6.23 ±0.14
Cd	µg/l	0.05 ±0.01

\*Results are the averages of the two parallel samples taken from Kesikköprü Reservoir

Considering the measurement results which were done for Kesikköprü Reservoir water in July 2008 and August 2008, certain quality parameters were determined for further monitoring. Beside the parameters sulfate, conductivity and arsenic, THM formation potential (THMFP) of Kesikköprü Reservoir water was monitored for one year in this study, because of their carcinogenic effects; THMs are the important parameters which are regulated in the WIHCR as 150 µg/l until the date of 31.12.2012.

The results of the parameters sulfate, arsenic, THMFP, DOC, turbidity, conductivity and pH of the analyses are presented in the following subsections.

#### 4.1.1. Sulfate (SO<sub>4</sub><sup>2-</sup>)

Sulfate measurements in the Kesikköprü Reservoir water samples changed in months and were generally between 300-500 mg/l (Table 4-3).

**Table 4-3 “Monthly Sulfate in Kesikköprü Raw Water”**

<b>Months</b>	<b>SO<sub>4</sub><sup>2-</sup> (mg/l)</b>
July (2008)	310
August (2008)	506
October (2008)	325
December (2008)	540
January (2009)	420
February (2009)	360
March (2009)	380
April (2009)	390
May (2009)	410
June (2009)	420
<b>Average (Annual)</b>	<b>406</b>

Sulfate concentration in Kesikköprü Reservoir water is higher than the concentration in Çamlıdere Reservoir water and Kurtboğazi Reservoir water as illustrated in Table 4.4.

**Table 4-4 “Sulfate concentrations of three reservoirs”**

<b>Reservoirs</b>	<b>SO<sub>4</sub><sup>2-</sup> (mg/l) / July 2008</b>
Kesikköprü Reservoir	310
Çamlıdere Reservoir	22
Kurtboğazi Reservoir	20

As observed from the Table 4.4 sulfate concentration in Kesikköprü raw water is much higher than the concentration in Çamlıdere and Kurtboğazi raw water. Sulfate in surface waters generally occur naturally as a result of contact of water with rocks and soils containing sulfate minerals as well as from being the results of municipal or industrial discharges [12]. Therefore, the reason of the difference in the three reservoirs of Ankara can be explained naturally with the characteristics of the water streams of the reservoirs, and soil type of the catchment areas of the reservoirs. High sulfate concentration in Kesikköprü water originates from the natural characteristics of Kızılırmak River itself, which is replenished by the run-off from gypsum rich soils of Kızılırmak basin [25]. The water is supplied to Çamlıdere Reservoir from Acun Stream, Gürlük Stream, Çay Stream and Eşik Stream. According to the monitoring study done by SHW in 1995, the sulfate concentration in Acun Stream, Gürlük Stream, Çay Stream and Eşik Stream were 34.5 mg/l, 19.7 mg/l, 21.9 mg/l and 13.0

mg/l on annual average, respectively [28]. Thus, the sulfate concentration in the water sources of Çamlıdere Reservoir is around 20 mg/l on average. Moreover, the streams supplying water to Kurtboğazı Reservoir have also the sulfate concentration in a similar way with Çamlıdere Reservoir. Kurtboğazı Reservoir is fed by Mera Stream, Pazar Stream and Ova Stream having the sulfate concentration 22.9 mg/l, 33.9 mg/l and 39.0 mg/l on annual average, respectively, according to the study conducted by SHW in 1994-1995 [28].

When considered the limit of sulfate concentration given for surface water classification in WPCR, Çamlıdere and Kurtboğazı Reservoir waters are classified as Class-I since their sulfate concentrations are much lower than 200 mg/l limit value for Class-I surface waters.

#### 4.1.2. Arsenic (As)

Arsenic measurement results changing with months in the Kesikköprü water samples are illustrated in Table 4-5. Concentration of As in Kesikköprü Reservoir water samples was 11.08 µg/l on annual average. Arsenic can occur due to natural characteristic of river zone as being the result of interaction of water/rock-soil, or of anthropogenic activities (industrial discharges). Arsenic in river water alters according to the composition of surface recharges, the contributions from baseflow and bedrock lithology [37].

**Table 4-5 “Arsenic in Kesikköprü Raw Water in Months”**

<b>Months</b>	<b>As (µg/l)</b>
July 2008	13.01
January 2009	9.78
February 2009	8.09
March 2009	9.97
April 2009	10.12
May 2009	14.76
June 2009	11.82
<b>Average</b>	<b>11.08</b>

According to the results in Table 4.5, As concentration increased in spring and is generally higher in warm seasons compared to cold ones. This increase in As concentration is due to the spring runoff resulting higher interaction of water/rock and transporting water from rock surroundings.

The arsenic values measured in the three reservoir water in July 2008, are illustrated in Table.4.6. When As concentrations in Çamlıdere and Kurtboğazi Reservoir water are compared with the one in Kesikköprü Reservoir water, it is observed that As in Çamlıdere is almost two times higher than in Kesikköprü, while Kurtboğazi has almost two times lower As value than Kesikköprü has.

**Table 4-6 “Arsenic Concentrations in Three Reservoir Waters of Ankara”**

<b>Reservoirs</b>	<b>As (µg/l) / July 2008</b>
Kesikköprü Reservoir	10.4
Çamlıdere Reservoir	22.8
Kurtboğazi Reservoir	5.9

The higher As concentration in Çamlıdere Reservoir as compared to the other reservoirs can be the consequent of baseline situation, and stream structure supplying water to Çamlıdere Reservoir, namely the As concentration in the streams feeding the reservoir. In a study done by SHW in 1995, as a water quality parameter arsenic was analyzed in the streams supplying water to Çamlıdere Reservoir. According to the study, As was measured for June, August and October, 1995 and determined on average of the three-month measurements as 41 mg/l, 11 mg/l, 32 mg/l and 16 mg/l for Acun Stream, Gürlük Stream, Çay Stream and Eşik Stream, respectively [28].

When Kesikköprü Reservoir water is mixed with Çamlıdere and Kurtboğazi Reservoirs water in IWTP, As concentration changes according to the mixing ratios of the reservoirs. Since Kesikköprü Reservoir water has lower As concentration compared to Çamlıdere Reservoir has, it can be anticipated that Kesikköprü Reservoir water leads to a decrease in the average As concentration at the mixing point of the three reservoir water in IWTP. For the first month of the study, in July 2008, water samples were collected from the inlet of Kesikköprü Reservoir, of

Çamlıdere Reservoir, of Kurtboğazı Reservoir and of mixing point of three reservoir waters at IWTP, and As concentrations in the collected 4 samples were detected as 10.39 µg/l, 22.76 µg/l, 5.86 µg/l and 10.8 µg/l, respectively.

#### 4.1.3. Disinfection By-Products (DBPs)

DBPs are formed as a result of the reactions between natural organic matters (NOM) present in water with the disinfectants used in water. Types and amounts of DBPs are known to change with NOM concentration originally present in water, type of the disinfectant used, chlorine residual, reaction time, pH and concentration [26].

##### *Trihalomethane Formation Potential (THMFP)*

THMFP is in source water to determine the maximum potential of the water to form THM. The THMFP in Kesikköprü reservoir water in months are shown as a bar graph in Figure 4-1.

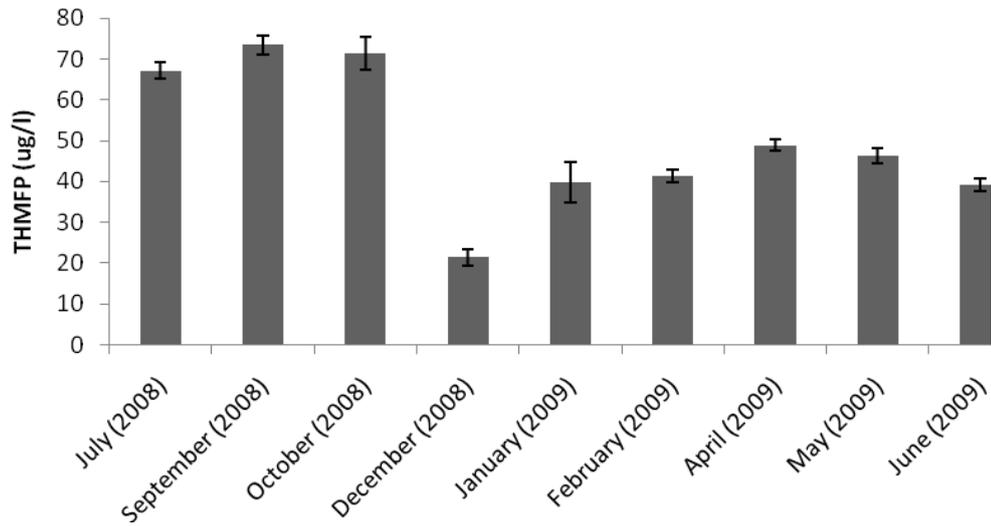


Figure 4-1 “THMFP in Kesikköprü Reservoir Water”

The measured values in the raw water indicate the formation potential of THMs in Kesikköprü water for one-day. Thus, the THM concentrations in the districts can be measured higher than the THMFP of the source water because the contact time is the parameter affecting THM formation. THM formation in water increases with the reaction time [16]. Moreover, Kesikköprü is just one of the sources supplying drinking water to Ankara. Since the organic content and other water characteristics are different in different sources, the THM concentrations change in the distribution network. NOM concentration, pH of water and temperature are the factors influencing THM formation [22, 23].

The THMFP concentration was measured as 67 µg/l in July 2008 and the concentrations were slightly higher in fall months of 2008 than in July 2008. THMFP concentrations in September 2008 and October 2008 were 74 µg/l and 72 µg/l, respectively. There was a decrease in the concentration of THMFP of Kesikköprü Raw water in winter months and then in spring months there was a slight increase in the concentration. However, the THMFP concentrations have the highest values in summer and fall seasons.

In a study done by Gür [7] for THMFP of Çamlıdere and Kurtboğazi Reservoirs, THMFP was monitored for both reservoirs in February, March, April, and May, 1999 and the highest THMFP values determined for the reservoirs in each monitoring months are presented in Table 4-7.

**Table 4-7 “THMFP (in µg/l) for Çamlıdere and Kurtboğazi Reservoirs (1999)” [7]**

<b>Months</b>	<b>Çamlıdere Reservoir</b>	<b>Kurtboğazi Reservoir</b>
February 1999	70	47
March 1999	34	73
April 1999	32	68
May 1999	49	60

As depicted from the Table 4-7, the highest THMFP were found in February for Çamlıdere Reservoir with 70 µg/l, and in March for Kurtboğazi Reservoir with 73 µg/l. When THMFP values for Kesikköprü Reservoir with the ones for Çamlıdere

and Kurtboğazı Reservoirs, it can be observed that THMFP values in three reservoirs are similar in general. However, the highest THMFP was observed in different months for the reservoirs. When the waters from the three reservoirs are mixed at IWTP, THM for the water at the outlet of the IWTP is expected to be accordance with the THMFP of the reservoirs. In July 2008, water samples collected from the inlet point of Kesikköprü Reservoir, Çamlıdere Reservoir, Kurtboğazı Reservoir of IWTP and from the mixing point of the three reservoirs at IWTP were analyzed for THMFP concentrations, which were determined as 67 µg/l, 138 µg/l, 117 µg/l and 128 µg/l, respectively. Since THM formation potential of Çamlıdere and Kurtboğazı Reservoirs are found higher compared to Kesikköprü Reservoir has, an increase in THMFP in the mixed water sample of the three reservoirs was observed.

#### 4.1.4. Organic Content Parameters

##### *Dissolved Organic Carbon (DOC)*

DOC in source waters originates from decaying NOM or from artificial sources. Since DOC is the amount of carbon bound in an organic compound, it is a good indicator for identifying the amount of NOM in the water source [3, 26].

DOC concentrations measured for Kesikköprü Raw water in months are depicted from Figure 4-2.

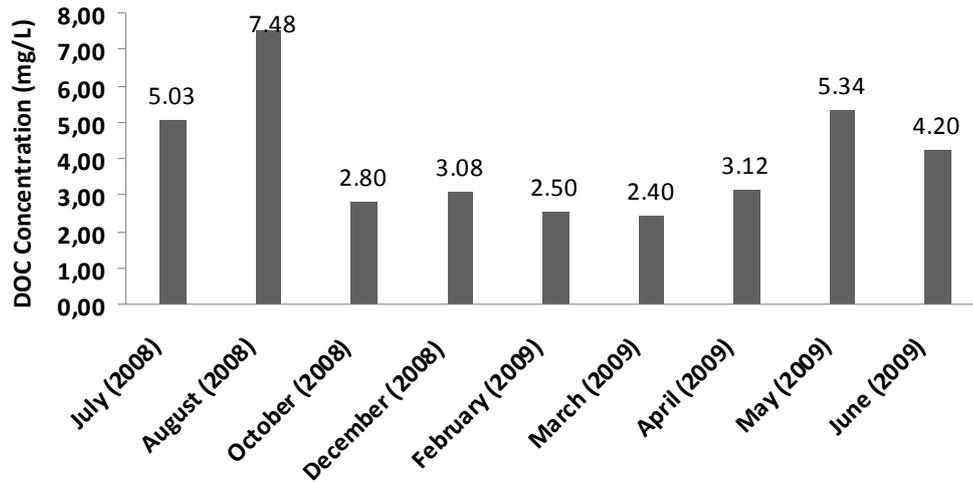


Figure 4-2 “DOC Concentrations in Kesikköprü Reservoir in months”

DOC concentration in Kesikköprü water increases in spring and summer months and the concentration is the highest in August, 2008. Average DOC concentration in summer months (June, July, and August) is 5.57 mg/l and the concentration decreases in fall and winter. Generally, DOC values follow a trend such that they increase in spring reaching maximum in fall and decrease in winter. The reason of expecting highest DOC value in summer and early fall months is of the primary biological production and of leaching humic substances from watershed with the highest organic content in summer and early fall months [7]. The annual average DOC concentration of Kesikköprü Reservoir is determined as 3.99 mg/l. DOC concentration is generally below 5 mg/l for unpolluted-fresh waters and the average DOC in Kesikköprü water is below this limit.

According to the study in 1999 [7], DOC concentration in Çamlıdere Reservoir varies between 3.80 mg/l and 5.18 mg/l, and it was around 4.0 mg/l on average. In addition, Kurtboğazı Reservoir had DOC concentration changing from 3.5 mg/l to 5.6 mg/l, and DOC concentration was around 4 mg/l for also Kurtboğazı Reservoir based on the study results in 1999. When DOC content of the three reservoirs are compared each other, it can be mentioned that DOC of Kesikköprü Reservoir is slightly lower than DOC in Çamlıdere and Kurtboğazı Reservoirs in general, but on average the

three reservoirs have DOC concentration about 4.0 mg/l on average with minor differences in months. Moreover, DOC variation was very similar in seasons for all three reservoir with higher concentrations in summer and spring.

#### 4.1.5. Other Parameters

##### *Turbidity*

Turbidity is a physical characteristic of water being a visual indication of suspended matter in water. Turbidity in water is generally caused by clay and silt particles, discharges of sewage or industrial wastes, and the presence of microorganisms in large numbers.

Turbidity of Kesikköprü water is nearly 2.0 NTU on the average of the monitoring year. The measured turbidity values for Kesikköprü water are 1.34 NTU, 1.80 NTU, 0.62 NTU, 1.52 NTU, 1.74 NTU, 1.03 NTU, 4.57 NTU for July 2008, August 2008, October 2008, February 2009, April 2009, May 2009, and June 2009, respectively. The highest turbidity is detected for June, 2009.

According to the study on the water quality of Çamlıdere and Kurtboğazı Reservoirs, the turbidity values varied between 1.3 NTU (April, 1998) and 17.5 (November, 1998) for Çamlıdere Reservoir, and 2.2 NTU (August, 1998) and 12.5 (April, 1999) NTU for Kurtboğazı Reservoir. In the study, it was observed that variation in turbidity and turbidity values were similar for Çamlıdere and Kurtboğazı Reservoirs. It was stated in the study that higher turbidity values were detected in spring and autumn than in summer and winter for both reservoir. However, there is not any high variation in turbidity values of Kesikköprü Reservoir between months, but a slight increase in turbidity is observed in spring compared to winter also for Kesikköprü Reservoir. The turbidity increase in spring is interpreted with the effect of temperature increase. When the temperature starts to raise, the flow of rivers increase

with the melting of ice, and as a result, turbid materials (colloidal and soil particles) are transported with the streams [7].

### *Conductivity*

Conductivity is a way of measuring the ability of water to conduct an electric current. Conductivity is affected by the degree of dissociation of dissolved solids into ions, the amount of electrical charge on each ion, ion mobility and temperature of sample. Thus, conductivity for a water body is associated with the concentration of total dissolved solids and major ions [24]. Conductivity is also an important parameter required to be monitored since it may limit the usage of the source for drinking water [28], because high chloride in water result in corrosive effect due to interactions with other ions [3].

Conductivity values of Kesikköprü water in months are given in Table 4-7. As seen from this table, conductivity values measured change between 1032  $\mu\text{mho/cm}$  and 1910  $\mu\text{mho/cm}$  within the monitoring period, with an average value of 1600  $\mu\text{mho/cm}$ .

**Table 4-8 “Conductivity of Kesikköprü Raw Water”**

<b>Months</b>	<b>Conductivity (<math>\mu\text{mho/cm}</math>)</b>
July 2008	1910
August 2008	1032
October 2008	1470
February 2009	1741
April 2009	1645
May 2009	1709
June 2009	1693
<b>Average</b>	<b>1600</b>

The high conductivity of Kesikköprü raw water can be interpreted as the result of high sulfate and chloride concentrations in the water because high concentrations of either sulfate or chloride ions add to the electrical conductivity of water.

Conductivity values for Çamlıdere and Kurtboğazi Reservoirs are 210  $\mu\text{mho/cm}$  and 220  $\mu\text{mho/cm}$ , respectively, based on the measurements of this study in July, 2008. Moreover, conductivity for Çamlıdere and Kurtboğazi Reservoirs are around 170  $\mu\text{mho/cm}$  and 220  $\mu\text{mho/cm}$ , respectively, according to the quality investigation study on these reservoirs in 1995 [28]. When the conductivity values of Çamlıdere and Kurtboğazi Reservoirs are compared with of Kesikköprü Reservoir, it is obviously stated that Kesikköprü Reservoir has much higher electrical conductivity than the other two reservoirs have.

### *pH*

Generally, the presence of carbonates and bicarbonates contacting with rocks and stones is the reason of being a pH value higher than 7 in raw water [23]. According to Turkish Water Pollution Control Regulation (WPCR), the raw water pH is between 6.0 and 9.0 in general. Source water having pH of 6.5-9.5 is classified as Class I-II source waters based on WPCR.

The pH measured in Kesikköprü Raw water changed between the values of 8 and 8.5, which is in the range of Class-I-II raw water according to the Turkish Regulation. The pH values measured for Kesikköprü Reservoir in months is given in Table F-1 in Appendix.F. The pH for both Çamlıdere and Kurtboğazi Reservoir waters change between 7 and 8.5 according to the monitoring study done by Gür [7].

## **4.2. Ankara Distribution System**

### **4.2.1. Sulfate ( $\text{SO}_4^{2-}$ )**

For the first month of the study, July 2008,  $\text{SO}_4^{2-}$  concentration in districts was variable changing between 21 mg/l (for Eryaman and Cebeci), and 120 mg/l (for Demetevler) and it was around 70 mg/l on average. Then,  $\text{SO}_4^{2-}$  concentration followed an increasing trend in general by months, which is that the average concentration in districts was about 250 mg/l until February 2009. Between the

months of July 2008 and February 2009 (excluding February) the highest average sulfate concentration varied from 215 mg/l (for Küçükesat district) to 276 mg/l (for Emek District). However,  $\text{SO}_4^{2-}$  concentration for districts showed a decrease to concentration of 36 mg/l on average of the months between February 2009 and June 2009.  $\text{SO}_4^{2-}$  concentration for each district in each month is presented in Table 4.9 and Table 4.10.

**Table 4-9 “Sulfate Concentration (mg/l) for Districts in Months (July-December 2008)”**

<b>Months Districts</b>	<b>July 2008</b>	<b>August 2008</b>	<b>September 2008</b>	<b>October 2008</b>	<b>November 2008</b>	<b>December 2008</b>
Kızılay	78		295	290	335	280
Küçükesat	30	160	235	290	270	230
Bahçelievler	80		295	280	320	300
Aydınlıkevler	48	165	265	310	285	240
Demetevler	120		280	270	285	275
Eryaman	21	170	290	320	285	250
Tandoğan	89		300	275	335	310
Or-An	84	170	240	275	330	220
100. Yıl	38	155	310	265	330	265
Etlik	76	140	290	310	345	280
Bilkent	93	185	315	275	290	275
Dikmen	23	170	310	300	290	290
Abidinpaşa	56		285	300	340	270
Öveçler	89	210	220	300	315	235
Keçiören	20	150	290	275	370	275
Yıldız	80		255	285	335	245
Cebeci	21	145	325	295	330	285
Mamak	72	130	295	285	310	275
GOP	80		290	300	355	295
Batıkent	66	205	305	305	285	235
Emek	113		285	300	340	305
Ayrancı	47		285	315	335	265
Çayyolu	69	160	305	305	300	260
Elvankent	118		310	290	310	295

Table 4-10 “Sulfate Concentration (mg/l) for Districts in Months (January-June 2009)”

Months Districts	January 2009	February 2009	March 2009	April 2009	May 2009	June 2009
Kızılay	280	20	44	41	35	
Küçükesat	290	25	44	37	35	36
Bahçelievler	300	30	45	42	36	
Aydınlıkevler	285	20	40	40	36	
Demetevler	295	15	40	38	36	
Eryaman	295	25	45	38	45	
Tandoğan	290	5	42	38	37	
Or-An	285	20	50	42	36	
100. Yıl	300	10	40	40	34	
Etlik	305	5	42	40	36	
Bilkent	300	35				
Dikmen	305	35	44	40	38	
Abidinpaşa	300	35	44	40	34	
Öveçler	295	35	39	38	33	25
Keçiören	285	33	43	39	34	31
Yıldız	295	38	45	39	36	
Cebeci	310	36	46	36	35	36
Mamak	285	35	45	45	37	37
GOP	300	35	44	42	35	37
Batıkent	310	34	38	33	43	
Emek	310	31	46	29	36	
Ayrançı	305	33	45	40	36	41
Çayyolu	300	38	34	36	34	
Elvankent	300	31	34	41	35	

As observed from the tables above,  $SO_4^{2-}$  concentration in the distribution network samples decreased sharply as of February 2009 and declined to 27 mg/l as mean value. In the following months, after February 2009, when the experiments were proceeding, the sulfate concentrations changed between 30-40 mg/l. In order to observe the general change in  $SO_4^{2-}$  concentration for distribution network Figure 4.3 is depicted by taking the average sulfate concentrations in distribution network for each month.

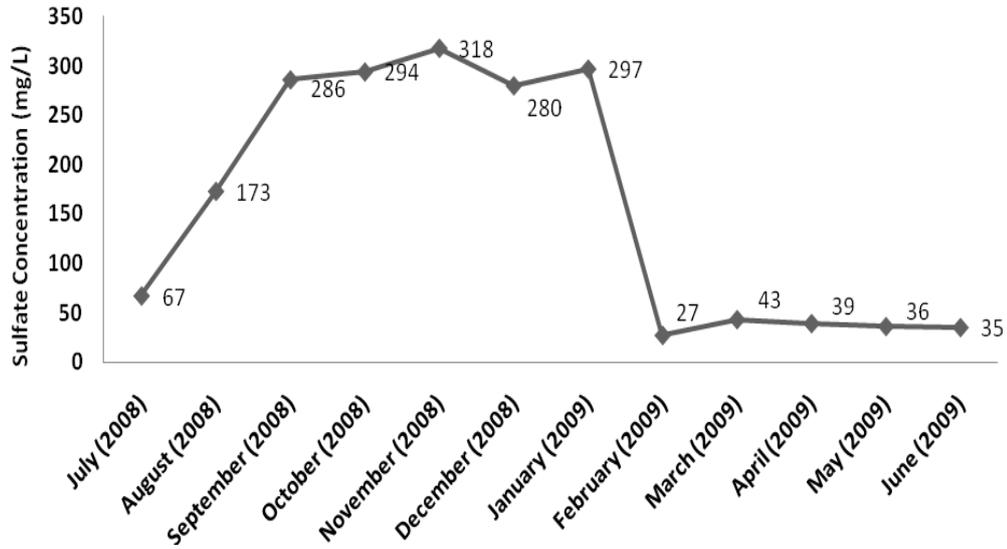


Figure 4-3 “Monthly Average Sulfate Concentrations in Drinking Water”

The sharp decrease in sulfate concentration observed between the months of January and February 2009 is the reflection of source water change. After January 2009, the usage of Kesikköprü Reservoir as the source water to Ankara was ceased. Thus, Çamlıdere and Kurtboğazı Reservoirs have been the suppliers of drinking water to Ankara since February 2009, and as a result of this, the characteristic of the water using as source for Ankara has changed. Since Kesikköprü Reservoir water has much higher sulfate concentration compared to Çamlıdere and Kurtboğazı Reservoirs as given in Table 4.4, the sulfate concentration in distribution network of Ankara decreases with February 2009.

#### 4.2.2. Arsenic (As)

Arsenic (As) concentration was determined for some of the 24 districts for the first two months of the study. Then, for all districts As was measured regularly.

Arsenic concentration was found 5.7 µg/l in Dikmen as highest concentration, and 2.9 µg/l in Bahçelievler as the lowest concentration in July 2008. In August 2008, As concentration changed between 2.14 µg/l and 3.59 µg/l for measured districts

showing lower concentration values as compared to the previous month. Between the months of October 2008 and January 2009 (including) As concentration in all districts was measured at around 2-3 µg/l with the highest concentration 4.31 µg/l in Elvankent in November 2008. Arsenic concentrations detected in each district for the months from July 2008 to January 2009 are shown in Table 4-11.

**Table 4-11 “Arsenic Concentration (µg/l) for Districts in Months (July 2008-January 2009)”**

<b>Months Districts</b>	<b>July 2008</b>	<b>September 2008</b>	<b>October 2008</b>	<b>November 2008</b>	<b>December 2008</b>	<b>January 2009</b>
Kızılay			1.72	2.14	2.25	2.44
Küçükesat	3.80		0.52	2.48	3.31	2.57
Bahçelievler	2.90		1.30	1.88	2.34	2.72
Aydınlıkevler		2.95	1.91	3.30	2.65	2.54
Demetevler		2.15	1.67	3.70	3.95	2.49
Eryaman			2.10	2.81	1.67	2.38
Tandoğan			2.53	2.90	2.63	2.26
Or-An	3.60		2.55	2.69	2.45	2.49
100. Yıl			1.74	2.65	2.16	2.20
Etlik			1.77	3.81	2.70	2.31
Bilkent			1.70	3.25	2.97	2.37
Dikmen	5.70	3.59	1.84	2.63	2.73	2.68
Abidinpaşa			2.14	2.41	2.27	2.23
Öveçler			2.48	3.53	3.01	2.38
Keçiören		2.57	2.61	2.46	2.59	2.18
Yıldız			2.53	3.65	2.88	2.43
Cebeci			2.05	3.85	2.44	2.63
Mamak	4.80		2.49	2.68	2.51	2.77
GOP			2.38	2.78	3.32	2.28
Batıkent		2.14	1.85	3.13	1.98	2.11
Emek			2.57	3.12	2.35	2.20
Ayrancı			2.05	3.21	1.97	2.58
Çayyolu	4.40		1.93	2.51	2.32	2.47
Elvankent			1.71	4.31	2.61	2.27

\*Blank indicate that measurement not done

As in districts showed a different variation with February 2009 when compared to the monitoring period between July 2008 and January 2009. For the rest of the monitoring period starting from February 2009, As concentration in districts changed around the value of 0.5 µg/l on average for all districts. As concentrations for each district for each month from February 2009 to June 2009 are tabulated in Table 4-12.

**Table 4-12 “Arsenic Concentration ( $\mu\text{g/l}$ ) for Districts in Months (February-June 2009)”**

<b>Months Districts</b>	<b>February 2009</b>	<b>March 2009</b>	<b>April 2009</b>	<b>May 2009</b>	<b>June 2009</b>
Kızılay	0.43	0.43	0.43	0.36	0.36
Küçükesat		0.44	0.23	0.53	0.26
Bahçelievler	0.53	0.36	0.13	0.72	0.28
Aydınlıkevler	0.61	0.46	1.00	0.45	1.11
Demetevler	0.68	0.53	3.06	0.27	0.41
Eryaman	1.18	0.60	1.85	5.22	0.27
Tandoğan	0.77	0.45	0.21	0.43	0.50
Or-An	0.65	0.40	0.07	0.23	0.55
100. Yıl	0.65	0.53	0.52	0.52	0.66
Etlik	0.69	0.50	0.24	0.75	0.34
Bilkent	0.52				
Dikmen	0.66	0.44	0.13	0.59	0.45
Abidinpaşa	0.86	0.43	0.03	0.49	0.92
Öveçler	1.09	0.62	0.16	0.39	0.53
Keçiören	0.41	0.35	0.26	5.01	0.65
Yıldız	0.49	0.30	0.19	0.54	0.32
Cebeci	0.42	0.46	0.05	0.43	0.53
Mamak	0.79	0.42	0.08	0.16	0.53
GOP	0.81	0.56	0.16	0.49	0.47
Batıkent	0.66	0.49	0.18	0.55	0.28
Emek	0.63	0.49	0.53	0.33	0.28
Ayrancı	1.12	0.48	0.15	0.24	0.33
Çayyolu	0.49	0.86	0.09	0.31	0.28
Elvankent	0.72	1.03	0.41	0.66	0.64

\*Blank indicate that measurement not done

A general As change in the distribution network can be depicted from Figure 4-4  
Considering the average As concentrations in 24 districts for each monitoring months

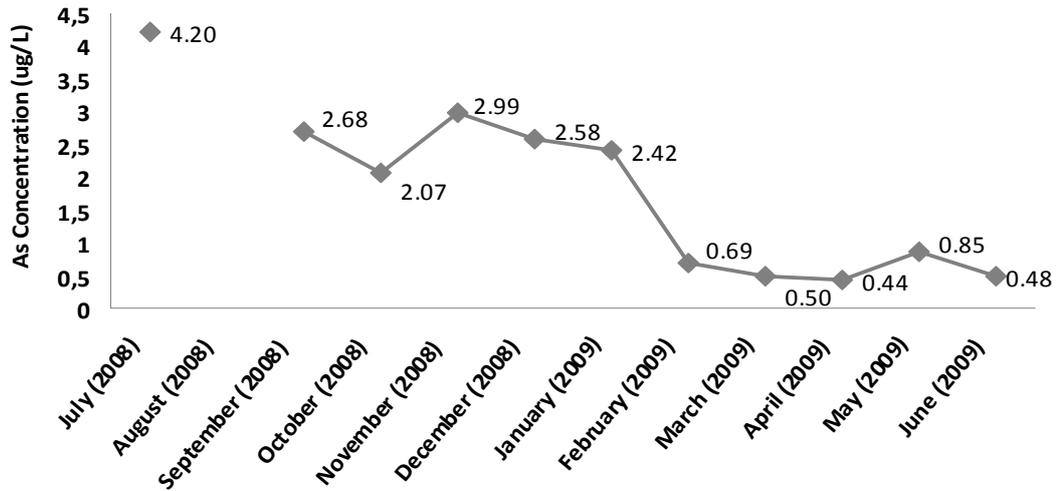


Figure 4-4: “Average As concentration in months for all districts”

As observed from Figure 4-4, the average arsenic in the drinking water samples decreases sharply in February, 2009. This figured decrease in As concentration is the time of the change in the reservoirs of Ankara.

With the month of February 2009 the line of Kesikköprü reservoir for drinking water supply to Ankara was put out of operation. Therefore, Çamlıdere and Kurtboğazi Reservoirs were the sources for drinking water in Ankara. When arsenic concentration in Kesikköprü and other two reservoir waters is considered, the observed decrease in arsenic concentration in distribution network is not expected as figured out from Figure 4-4, because As in Kesikköprü water is lower than the arsenic value in Çamlıdere and Kurtboğazi Reservoirs and Kesikköprü Reservoir results a decrease in As concentration when the three reservoir are mixed for water supply as stated in the Section 4.1.2. Therefore, it can be predicted a higher arsenic concentration in distribution network in February 2009 due to cutting off Kesikköprü Reservoir water after February 2009. Coagulation/flocculation-filtration, activated alumina or carbon adsorption, ion exchange and membrane processes are listed as the available treatment technologies for arsenic removal from water [42]. Coagulation/flocculation process is applied to water in Ankara IWTP. Therefore, arsenic removal from the treatment of water is expected to occur after the treatment

at IWTP. The result of analyses done in July 2008 is a supporting example for arsenic removal. As was measured as 10.8 µg/l at the point of mixing the water from three reservoirs at IWTP and after the treatment at the plant, at the outlet of IWTP, As was detected 2.18 µg/l in concentration. Consequently, it can be considered that arsenic removal percentage is not high when Kesikköprü Reservoir water exists at the treatment plant. This unexpected situation in arsenic concentration might be interpreted as being the result of Arsenic speciation (trivalent or pentavalent form of As in water) in Kesikköprü and the other reservoir waters.

Arsenic is an element which can exist in atmosphere, soil and rock, natural water and organisms, and is very mobile through the environment. It can occur under both oxidizing and reducing conditions and exist at several oxidation states. Trivalent arsenite (As (III)) and pentavalent arsenate (As (V)) are the inorganic forms of As being mostly found forms in natural waters. Redox potential and pH are the factors affecting arsenic speciation [37]. Arsenate is generally present as  $\text{HAsO}_4^{2-}$  and  $\text{H}_2\text{AsO}_4^-$ , while arsenite is present as  $\text{H}_3\text{AsO}_3^0$  and predominance of these species change depending on oxidizing/reducing conditions and pH. Under oxidizing conditions,  $\text{H}_2\text{AsO}_4^-$  dominates at low pH (pH <6.9) and  $\text{HAsO}_4^{2-}$  dominates at higher pH value (pH higher than 6.9 to pH about 11). Under reducing conditions,  $\text{H}_3\text{AsO}_3^0$  is dominant at pH lower than 9.2 [37, 43]. Kesikköprü was found to have pH value of around 8-8.5 in general as stated in the Section 4.1.5. Thus, either arsenate or arsenite can dominate in water depending on the oxidizing/reducing conditions in water when considered the general pH of Kesikköprü water. According to several studies on the arsenic and its toxicity, As (III) is much more toxic as well as more mobile than As (V) [38-39]. Moreover, Gupta et al. [40] and Schneiter et al. [41] reported that the removal of trivalent arsenic from drinking water was more difficult than pentavalent arsenic. Since As (V) is present in water as negatively charge ion at pH higher than 2.2, it can be easily removed from water by means of electrostatic attraction with positively charge metal hydroxides [46]. Thus, arsenite is first oxidized to arsenate in order to obtain higher efficiency in arsenic removal from water due to the fact that As (III) is neutral until pH 9.

### 4.2.3. Disinfection By-Products (DBPs)

Although more than 700 DBPs have been identified, trihalomethanes (THMs) and haloacetic Acids (HAAs) form the main groups of DBPs because they mostly occur in chlorinated waters as the products of the reaction NOM with chlorine in water [16]. Thus, THMs and HAAs were monitored in distribution network samples.

#### *Trihalomethanes (THMs)*

Total THM (TTHM) measurements were performed for 24 districts in the months from July 2008 to June 2009. The TTHM measurements for each district in months are given in a tabular form in Table 4-13 and 4-14, and the figures showing TTHM in districts for each month are presented in Figure B-1 – Figure B-11 in Appendix.B.

**Table 4-13 “TTHM in Districts for Months (July 2008-January 2009)”**

Months Districts	July 2008	September 2008	October 2008	November 2008	December 2008	January 2009
Kızılay	80	14 ±1	65 ±5	32 ±4	25 ±2	8 ±1
Küçüksat	109		38 ±2	27 ±2	21 ±1	18 ±1
Bahçelievler	76	37 ±3	46 ±2	41 ±1	21 ±1	23 ±1
Aydınlıkevler	86		40 ±2	38 ±2	26 ±1	31 ±2
Demetevler	68	35 ±3	36 ±2	31 ±1	17 ±1	19 ±1
Eryaman	99	45 ±3	51 ±3	34 ±1	41 ±3	24 ±1
Tandoğan	92	18 ±1	39 ±2	41 ±2	27 ±1	19 ±1
Or-An	93		36 ±2	23 ±1	23 ±1	25 ±2
100. Yıl	101		55 ±3	38 ±1	33 ±1	19 ±1
Etlık	64		42 ±2	25 ±1	25 ±1	20 ±1
Bilkent	87	89 ±5	51 ±3	32 ±1	24 ±1	21 ±1
Dikmen	91	14 ±1	42 ±2	28 ±1	26 ±1	30 ±2
Abidinpaşa	94	50 ±4	45 ±2	37 ±1	32 ±2	22 ±1
Öveçler	81		37 ±2	28 ±1	24 ±1	20 ±1
Keçiören	88	11 ±1	42 ±3	27 ±1	24 ±1	22 ±1
Yıldız	77	30 ±2	40 ±2	25 ±1	25 ±1	34 ±2
Cebeci	96		36 ±2	29 ±1	23 ±1	29 ±2
Mamak	72		57 ±4	31 ±1	24 ±1	20 ±1
GOP	79	46 ±4	48 ±3	31 ±2	23 ±1	31 ±2
Batıkent	100	42 ±3	42 ±2	27 ±1	22 ±1	35 ±2
Emek	58	36 ±3	36 ±2	26 ±1	20 ±1	26 ±1
Ayrancı	80		36 ±2	26 ±2	21 ±1	27 ±1
Çayyolu	85		42 ±2	28 ±1	28 ±1	36 ±2
Elvankent	67		42 ±3	27 ±1	22 ±1	22 ±1

\*Blank indicate that measurement not done

**Table 4-14 “TTHM in Districts for Months (February 2009-June 2009)”**

Months Districts	February 2009	March 2009	April 2009	May 2009	June 2009
Kızılay		10 ±1	6 ±1	27 ±3	26 ±3
Küçükkesat		14 ±1	20 ±2	26 ±3	28 ±3
Bahçelievler	25 ±4	10 ±1	5 ±1	28 ±3	27 ±3
Aydınlıkevler	37 ±5	15 ±2	23 ±2	24 ±3	23 ±2
Demetevler	40 ±4	15 ±2	18 ±2	20 ±2	22 ±2
Eryaman	47 ±4	24 ±3	21 ±2	26 ±3	23 ±2
Tandoğan	40 ±4	14 ±2	30 ±3	32 ±3	19 ±2
Or-An	38 ±3	20 ±2	24 ±2	25 ±3	23 ±2
100. Yıl	41 ±3	15 ±2	23 ±2	25 ±3	24 ±3
Etlık	27 ±4	14 ±2	13 ±1	36 ±4	38 ±4
Bilkent	25 ±3				
Dikmen	36 ±4	14 ±2	26 ±3	31 ±3	26 ±3
Abidinpaşa	30 ±4	19 ±2	26 ±3	31 ±3	32 ±3
Öveçler	36 ±4	11 ±1	29 ±3	30 ±3	35 ±4
Keçiören	35 ±3	9 ±1	35 ±4	34 ±4	26 ±3
Yıldız	37 ±3	16 ±2	27 ±3	29 ±3	35 ±4
Cebeci	25 ±3	13 ±1	32 ±3	31 ±3	29 ±3
Mamak	27 ±2	16 ±2	31 ±3	21 ±2	34 ±4
GOP	27 ±3	9 ±1	30 ±3	46 ±5	42 ±4
Batıkent	25 ±3	21 ±2	30 ±3	41 ±4	31 ±3
Emek	27 ±3	15 ±2	26 ±3	27 ±3	31 ±3
Ayrancı	32 ±4	18 ±2	32 ±3	24 ±2	28 ±3
Çayyolu	27 ±3	6 ±1	27 ±3	36 ±4	31 ±3
Elvankent	35 ±4	15 ±2	27 ±3	32 ±3	34 ±3

\*Blank indicate that measurement not done

In order to see the seasonal variation of THM values measured at different districts, TTHM values given in Table 4-13 and 4-14 above, are grouped according to the corresponding months and seasonal average values are obtained as presented in Table 4-15.

**Table 4-15 “Seasonal TTHM Concentrations in Ankara Districts”**

Districts	TTHM ( $\mu\text{g/L}$ ) Ave. Winter	TTHM ( $\mu\text{g/L}$ ) Ave. Fall	TTHM ( $\mu\text{g/L}$ ) Ave. Summer	TTHM ( $\mu\text{g/L}$ ) Ave. Spring
Kızılay	22	49	53	19
Küçükesat	21	33	69	20
Bahçelievler	25	43	51	19
Aydınlıkevler	26	39	54	21
Demetevler	17	33	45	17
Eryaman	30	43	61	24
Tandoğan	23	40	55	25
Or-An	23	30	58	23
100. Yıl	21	47	63	21
Etlik	23	33	51	21
Bilkent	27	42	44	
Dikmen	30	35	59	24
Abidinpaşa	30	41	63	25
Öveçler	26	32	58	23
Keçiören	26	35	57	26
Yıldız	32	33	56	24
Cebeci	29	33	63	25
Mamak	26	44	53	23
GOP	30	40	60	28
Batıkent	30	35	65	31
Emek	26	31	45	23
Ayrançı	27	31	54	24
Çayyolu	34	35	58	23
Elvankent	25	35	51	25

\*Winter months: December, January, February. Summer Months: June, July. Fall Months: September, October, November. Spring Months: March, April, May.

When examined the seasonal variations tabulated above, it is noticed that TTHM concentrations were higher in summer and fall as compared to the concentrations in spring and winter for all districts. This situation is in accordance with the similar previous monitoring studies on DBP formation performed by Tokmak et al. [16], Rodriguez et al. [30], Golfinopoulos et al. [35] and Chen et al. [36].

The annual average TTHM measured in the 24 sampled districts is also shown in the Figure 4-5 to observe THM concentration change in different districts.

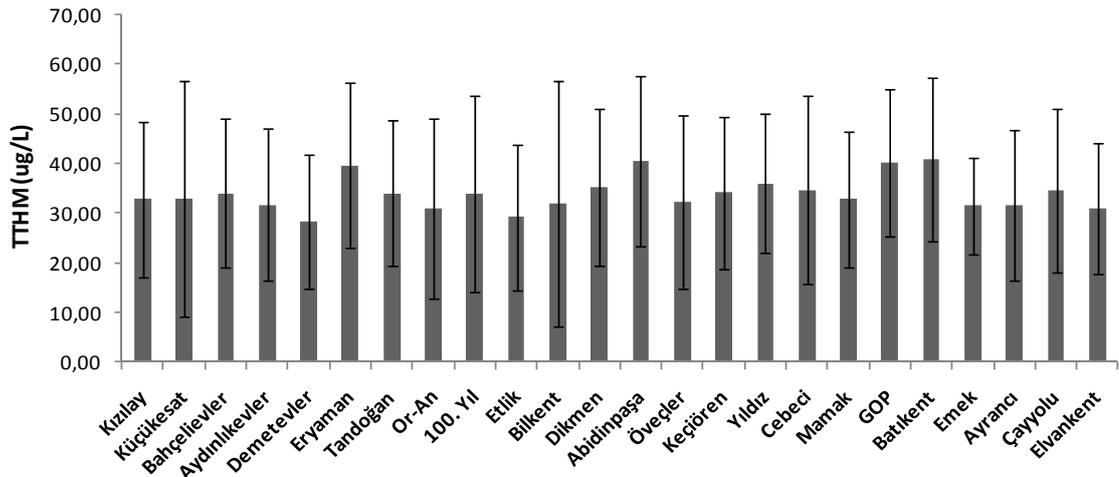
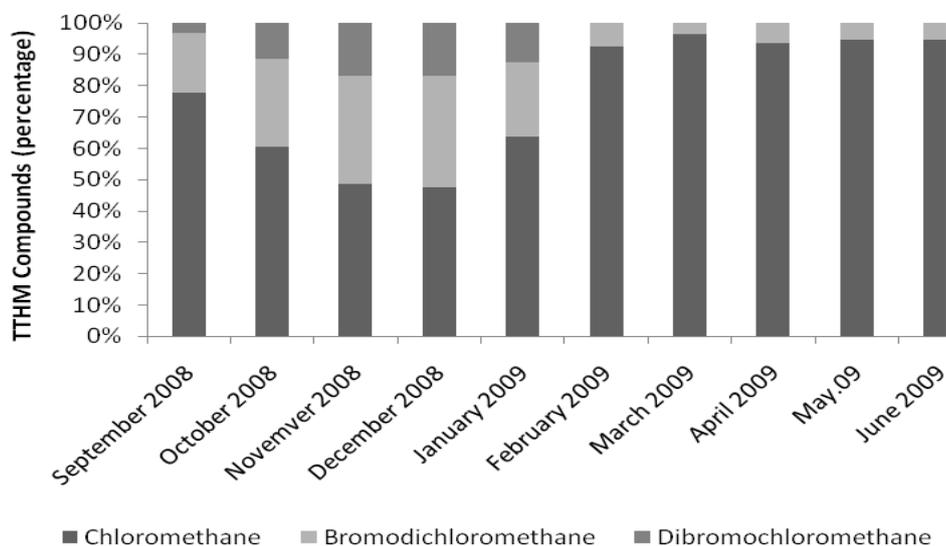


Figure 4-5 “Annual Average TTHM of 24 Districts”

THM was regulated by national and international drinking water quality standards. THM concentration limit (annual average) in drinking water is 80 µg/l in USEPA (Stage I), 100 µg/l in EU Directives, and 150 µg/l in related Turkish Regulation (until 2012). Therefore, annual THM concentration in distribution system satisfies the standards in all districts although the concentrations in some district and in some months exceed the regulated limit values.

While the annual average TTHM in distribution network did not show immense changes in months, it differed in terms of THM compounds between months. Generally, chloromethane was found as the major THM compound in the drinking water samples. Bromodichloromethane was the second compound detected in the samples. Until February, 2009, dibromochloromethane was identified with chloromethane and bromodichloromethane compounds of THM in the drinking water samples of districts. However, dibromochloromethane did not occur in the samples since February, 2009. Figure 4-6 illustrates the change of TTHM compounds in percentage for GOP district within the monitoring period. As seen from the figure, chloromethane and bromodichloromethane were the only compounds forming TTHM in the water sample while dibromochloromethane was detected with chloromethane and bromodichloromethane compounds of THM in the period before

February 2009. The variations in TTHM compounds in months for some selected district are presented in Figure B-12 – Figure B-16 in Appendix.B.

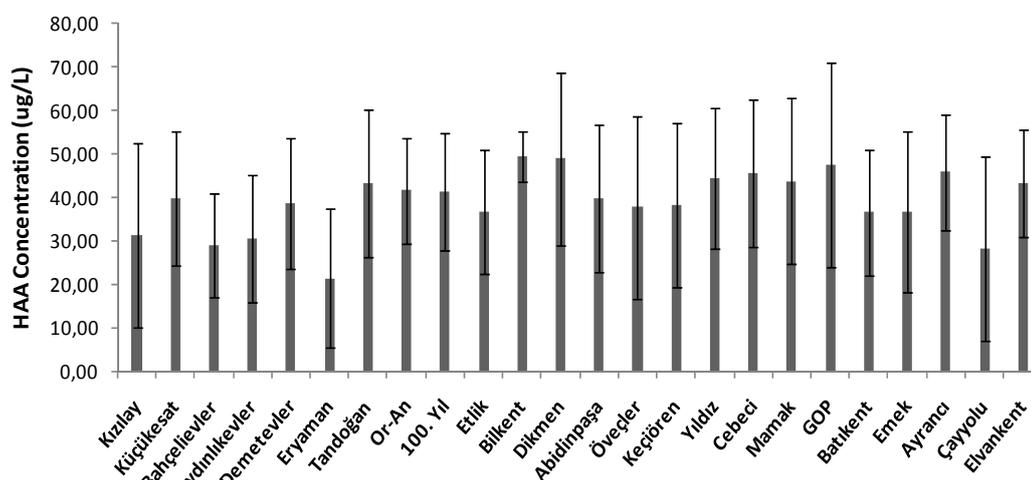


**Figure 4-6 “Percentage of TTHM Compounds of GOP in Months”**

The absence of dibromochloromethane compound in the drinking water samples beginning from February 2009 can be explained with the change of the source water. Since the water from the Kesikköprü line was cut off in February 2009, the source water characteristics have changed. Tokmak et al. [16] studied the occurrence of THM in the distribution system of Ankara in 2004, which is the year that Çamlıdere and Kurtboğazi were using to supply drinking water to Ankara. According to this study, chloroform and bromodichloromethane were the only species detected in the distribution system and it was also found in the study that chloroform constitutes the 90% of the TTHM species. Therefore, the results illustrated in Figure.4.8 are in accordance with the study done in 2004.

### *Haloacetic Acids (HAA)*

HAA measurement in the drinking water samples was started from October 2008 and it was monitored for the months of October 2008, November 2008, December 2008, January 2009, February 2009, April 2009, May 2009 and June 2009. HAA concentrations determined in districts for each monitoring month are shown in the Figures C-1 – C-8 in Appendix C. HAA concentrations in districts were generally higher in fall season (October 2008 and November 2008) as compared to spring and summer seasons. However, the HAA concentration did not show much difference between the fall and winter seasons. The HAA concentration measured in October and November 2008 were comparable to the concentration in December 2008, January and February 2009. In spring, April and May 2009, HAA concentration did not show an obvious decrease except for Kızılay and Çayyolu. HAA concentration measured as very low, around 7-9 µg/l, for Kızılay and Çayyolu in April 2009 may be due to sampling or experimental error. According to the monthly measure results, the annual average HAA concentrations measured in drinking water samples taken from 24 districts of Ankara are calculated and given as a graph in Figure 4-7.



**Figure 4-7 “Annual Average HAA Concentrations in Districts of Ankara”**

As seen from the Figure 4-7, the highest annual average HAA concentrations were observed in the districts of Bilkent and Dikmen, as 50 µg/l and 49 µg/l, respectively.

The HAA concentration is regulated by USEPA (2003). The limit is set for the sum of DCAA, TCAA, DBAA, MCAA and MBAA (denoted as HAA<sub>5</sub>) as the concentration of 60 µg/l on annual average. The annual HAA<sub>5</sub> concentrations in districts are illustrated in Figure 4.8 with the line of showing 60 µg/l limit value. According to the figure, annual HAA<sub>5</sub> concentrations in all districts satisfy the standard. However, only Dikmen and Tandoğan exceeded the limit concentration having 75 µg/l and 64 µg/l, respectively, in February 2009.

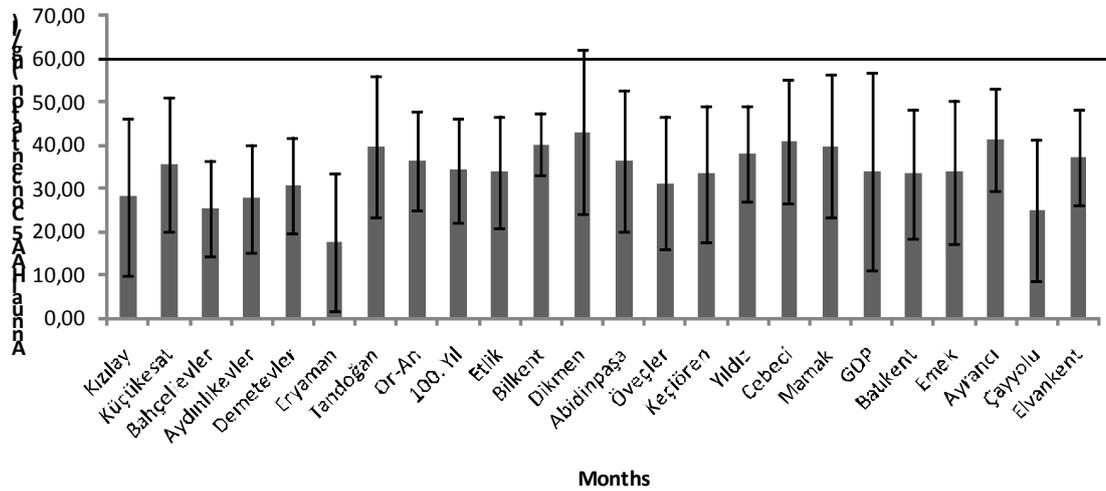


Figure 4-8 “Annual Average HAA<sub>5</sub> Concentrations in Districts of Ankara”

#### 4.2.4. Organic Content Parameters

The concentration and characteristics of NOM is a factor affecting DBPs formation. The NOM content of water is generally characterized by DOC and UVA<sub>254</sub> parameters [26].

### *Dissolved Organic Carbon (DOC)*

During the study, DOC concentrations varied from districts to districts seasonally. DOC concentrations in districts were generally above 3.0 mg/l. The highest DOC concentrations were observed in September 2008 as 4.54 mg/l and November 2008 as 4.20 mg/l for Tandoğan and Or-An, respectively, within the monitoring period until February 2009. In February 2009, a slight increase in DOC concentration was observed. Normally DOC concentration decreases in winter months, and when the average concentrations of DOC in months are considered, the expected decrease was seen in December 2008. This slight increase in February 2009 can be the reason of the change in the source water characteristics as a consequence of ceasing Kesikköprü Reservoir line for water supply to Ankara. Since DOC concentration in Çamlıdere and Kurtboğazi Reservoirs are slightly higher than the concentration in Kesikköprü Reservoir as mentioned in the Section 4.1.4. The DOC measurements for each monitoring month for 24 districts are given in table 4.16 and 4.17. The unexpected high DOC concentrations observed in Ayrancı district in April, 2009 and June, 2009 given in Table 4.17 can be the consequence of contamination since there is not an increase in THM, DOC and AOX concentrations in Ayrancı in April and June, 2009.

**Table 4-16 “DOC Measurements for Districts in Months (July 2008-December 2008)”**

Months Districts	July 2008	September 2008	October 2008	November 2008	December 2008
Kızılay	3.94 ±0.02	2.86 ±0.02	2.64 ±0.03	2.95 ±0.08	2.58 ±0.02
Küçüksat	3.87 ±0.02	3.39 ±0.03	2.27 ±0.02	3.66 ±0.04	2.62 ±0.02
Bahçelievler	3.47 ±0.05	2.99 ±0.06	2.49 ±0.03	3.58 ±0.01	2.59 ±0.01
Aydınlıkevler	3.47 ±0.02		2.48 ±0.03	3.80 ±0.02	2.54 ±0.07
Demetevler	3.47 ±0.02	2.78 ±0.07	2.53 ±0.01	3.22 ±0.02	2.63 ±0.04
Eryaman	3.25 ±0.01	2.89 ±0.04	2.23 ±0.05	1.94 ±0.01	2.52 ±0.01
Tandoğan	3.38 ±0.05	4.54 ±0.05	3.00 ±0.02	3.41 ±0.02	2.32 ±0.01
Or-An	3.20 ±0.06	4.15 ±0.03	2.11 ±0.02	4.20 ±0.02	2.46 ±0.05
100. Yıl	3.51 ±0.02	3.22 ±0.04	2.07 ±0.01	3.63 ±0.04	2.56 ±0.05
Etlik	3.31 ±0.02	3.71 ±0.02	2.41 ±0.02	4.06 ±0.02	2.92 ±0.01
Bilkent	2.65 ±0.03	3.05 ±0.01	1.97 ±0.01	3.28 ±0.02	2.45 ±0.03
Dikmen	2.83 ±0.02	3.30 ±0.01	2.05 ±0.01	2.96 ±0.03	2.74 ±0.03
Abidinpaşa	3.61 ±0.03	3.50 ±0.03	2.28 ±0.02	2.14 ±0.04	2.56 ±0.04
Öveçler	3.58 ±0.06	2.37 ±0.02	2.01 ±0.03	2.34 ±0.02	2.67 ±0.07
Keçiören	3.13 ±0.01	3.57 ±0.04	2.39 ±0.03	3.47 ±0.02	2.70 ±0.03
Yıldız	3.25 ±0.02	3.50 ±0.08	2.15 ±0.02	2.03 ±0.02	2.58 ±0.03
Cebeci	3.10 ±0.02	3.65 ±0.04	2.16 ±0.03	2.16 ±0.03	2.84 ±0.07
Mamak	3.69 ±0.03	0.59 ±0.01	1.98 ±0.01	2.12 ±0.02	2.74 ±0.01
GOP	3.57 ±0.01	3.37 ±0.06	2.18 ±0.01	3.53 ±0.01	2.48 ±0.02
Batıkent	3.77 ±0.01	3.23 ±0.02	2.08 ±0.02	3.42 ±0.02	3.06 ±0.01
Emek	3.95 ±0.02	3.11 ±0.01	2.13 ±0.02	3.55 ±0.01	2.42 ±0.00
Ayrancı	3.65 ±0.03	3.03 ±0.01	2.25 ±0.02	3.46 ±0.02	2.41 ±0.02
Çayyolu	3.04 ±0.03	3.45 ±0.01	2.22 ±0.01	3.36 ±0.01	2.58 ±0.02
Elvankent	3.11 ±0.05	3.36 ±0.02	2.72 ±0.03	3.39 ±0.03	3.01 ±0.06

\*Blank indicate that measurement not done

**Table 4-17 “DOC Measurements for Districts in Months (February 2009-June 2009)”**

Months Districts	February 2009	March 2009	April 2009	May 2009	June 2009
Kızılay	5.01 ±0.02	2.44 ±0.03	2.41	2.98	2.53
Küçükesat	3.22 ±0.26	2.23 ±0.02	2.35	3.77	2.55
Bahçelievler	3.17 ±0.02	2.35 ±0.06	2.16	2.25	2.89
Aydınlıkevler	3.18 ±0.06	2.54 ±0.03	2.39	2.41	2.59
Demetevler	3.17 ±0.03	2.61 ±0.05	2.24	2.39	2.70
Eryaman	2.81 ±0.03	2.54 ±0.02	2.13	2.10	2.48
Tandoğan	3.15 ±0.05	2.44 ±0.02	2.33	2.09	2.61
Or-An		2.28 ±0.03	2.14	3.03	2.55
100. Yıl		2.49 ±0.01	2.25	2.40	2.87
Etlik		2.56 ±0.03	2.36	2.26	2.61
Bilkent	2.22 ±0.03				
Dikmen	2.46 ±0.04	2.42 ±0.03	2.24	2.80	2.71
Abidinpaşa	2.15 ±0.05	2.69 ±0.02	2.67	3.22	2.65
Öveçler	2.60 ±0.03	2.42 ±0.02	2.33	2.24	2.58
Keçiören	2.61 ±0.03	2.56 ±0.03	2.30	2.22	2.93
Yıldız	2.14 ±0.02	2.30 ±0.01	2.52	2.91	3.01
Cebeci	2.51 ±0.02	2.53 ±0.04	2.34	2.45	2.92
Mamak	2.75 ±0.03	2.47 ±0.03	2.26	2.80	3.33
GOP	2.34 ±0.03	2.23 ±0.02	3.01	3.30	2.82
Batıkent	2.23 ±0.01	2.74 ±0.03	2.35	2.26	2.64
Emek	2.41 ±0.03	2.30 ±0.05	2.29	2.09	2.97
Ayrancı	2.68 ±0.03	3.02 ±0.02	5.73	2.25	10.5
Çayyolu	2.18 ±0.04	2.79 ±0.01	2.25	2.26	3.11
Elvankent	2.35 ±0.03	2.96 ±0.02	2.42	2.93	2.88

\*Blank indicate that measurement not done

In order to see the seasonal trend in DOC concentration in drinking water, the average DOC concentrations in months are depicted in Figure 4.9.

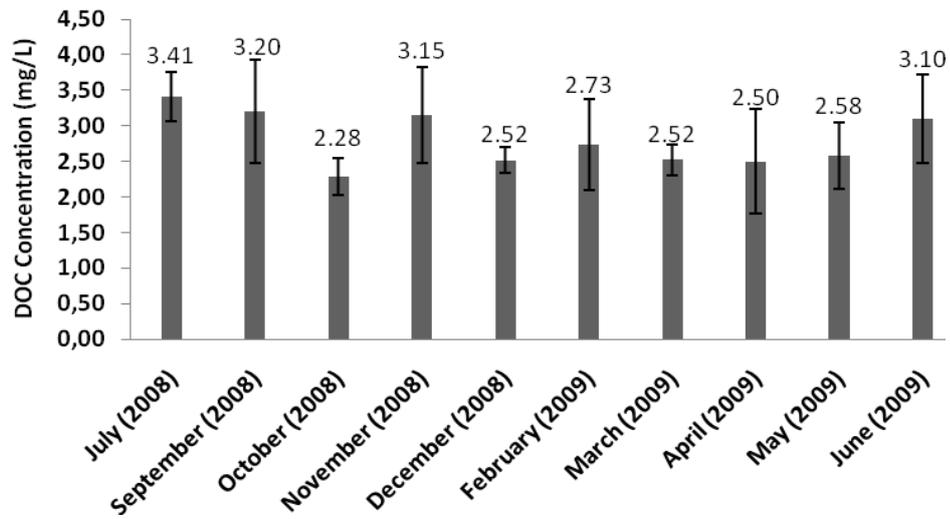


Figure 4-9 “Monthly Average DOC concentration in Drinking Water Samples of Ankara”

According to the DOC concentrations in distribution network given above, an increase in average DOC concentration can be observed in summer and fall seasons (July 2008, June 2009, September 2008, November 2008). This result correlates with the seasonal change in the THM concentration of the districts.

#### *Ultraviolet Absorbance (UVA<sub>254</sub>)*

UV Absorbance at 254 nm was measured for drinking water samples of Ankara. UVA<sub>254</sub> is expected to be high in summer and spring months compared to winter and fall months because of higher organic content in water in warm months as compared to cold months. Generally, the monthly average UVA<sub>254</sub> values of drinking water samples were higher in summer and spring (April, May and June 2009) and there was a decline in the values of UVA<sub>254</sub> between the months of September 2008 and November 2008. However, the average UVA<sub>254</sub> in December month was unpredictably very high compared to the other months. This observed increase in December 2009 might be explained by considering the DOC concentrations of drinking water and of Kesikköprü in December 2008 in Table 4-18 and in Figure 4-10, respectively. DOC concentrations in the drinking water samples were generally around 2.5-3.0 mg/l changing from district to district and there was not a huge

difference in DOC concentration between in December 2009 and in other months except for Ayrancı district. Moreover, DOC concentration in Kesikköprü Reservoir water was determined as 3.08 mg/l, which is a normal value for Kesikköprü water when considered DOC concentrations in Kesikköprü Reservoir in general. Turbidity in water can result in an increase in UVA<sub>254</sub> values. The unpredicted high value in UV absorbance in December 2009 may be due to turbidity in water samples. Furthermore, this high UVA<sub>254</sub> value can be an effect of high sulfate concentration in raw water in December, 2008. As can be depicted from Table 4-3, the highest sulfate concentration in Kesikköprü Reservoir water was determined in December, 2008. UVA<sub>254</sub> measurements for each district in each month are given in Table 4-18.

**Table 4-18 “UVA<sub>254</sub> Measurements for Districts in Months”**

Months Districts	September 2008	November 2008	December 2008	April 2009	May 2009	June 2009
Kızılay	0.120	0.018	0.144	0.057	0.049	0.107
Küçükkesat	0.082	0.014	0.161	0.151	0.044	0.110
Bahçelievler	0.041	0.004	0.176	0.168	0.085	0.067
Aydınlıkevler		0.006	0.145	0.055	0.055	0.063
Demetevler	0.048	0.011	0.153	0.094	0.048	0.061
Eryaman		0.006	0.163	0.056	0.127	0.065
Tandoğan	0.033	0.028	0.171	0.074	0.059	0.109
Or-An	0.039	0.023	0.145	0.090	0.055	0.106
100. Yıl	0.062	0.022	0.177	0.048	0.047	0.056
Etlık	0.046	0.018	0.143	0.094	0.049	0.054
Bilkent		0.021	0.151			
Dikmen	0.057	0.017	0.159	0.053	0.061	0.059
Abidinpaşa	0.045	0.020	0.140	0.052	0.033	0.063
Öveçler		0.009	0.140	0.260	0.057	0.072
Keçiören	0.060	0.014	0.145	0.051	0.047	0.058
Yıldız	0.060	0.014	0.151	0.050	0.058	0.055
Cebeci	0.069	0.057	0.148	0.121	0.031	0.105
Mamak	0.032	0.019	0.147	0.187	0.061	0.060
GOP	0.056	0.019	0.137	0.093	0.033	0.100
Batıkent		0.035	0.151	0.056	0.054	0.051
Emek	0.101	0.014	0.160	0.094	0.040	0.066
Ayrancı	0.046	0.034	0.149	0.097	0.038	0.120
Çayyolu	0.047	0.015	0.154	0.096	0.055	0.056
Elvankent	0.045	0.009	0.148	0.049	0.049	0.055

\*Blank indicate that measurement not done

The monthly average UVA<sub>254</sub> values for drinking water samples considering the measurement results above are demonstrated in Figure 4-9.

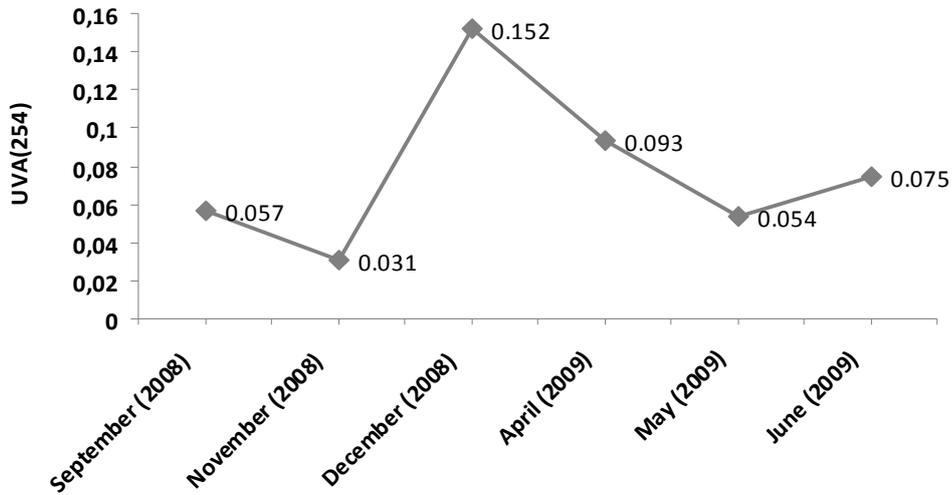


Figure 4-10 “Monthly Average UVA<sub>254</sub> in Distribution Network”

The normalization of measured UV absorbance at a certain wavelength for DOC concentration is defined as Specific UV absorbance (SUVA) [44]. As reported by USEPA (1998b) SUVA value of water is considered as the indicator for DBP precursor removal. Low SUVA value of water is reported low amount of halogenated DBPs formation [45]. SUVA values were determined for average measurements for districts in months. The figure showing the SUVA variation in months with values calculated is presented in Figure 4-11.

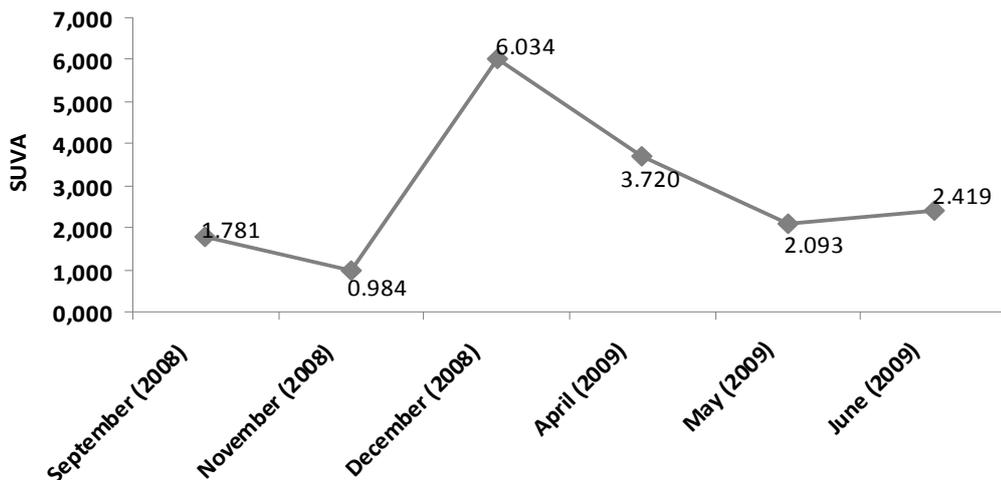


Figure 4-11 “SUVA in distribution network in months”

As observed from Figure 4-11, SUVA values changed between 0.984 to 6.034, from low to high values. SUVA values in December 2008 and April 2009 are high based on the value of 3 L/mg m, which indicates that the water having SUVA value higher than 3 L/mg m contains high amount of humic substances and has high hydrophobicity [51]. Moreover, the water with high SUVA has high formation potential of THM and AOX and it has a higher tendency to form THM and HAA [52, 53]. When THM and AOX concentrations for the districts in December, 2008 (Table 4-13 and Table 4-19, respectively) are considered, high concentration in THM and AOX for the districts in December, 2008 was not observed. Therefore, it can be stated that the unexpectedly high SUVA value in December, 2008 is not due to high amount of humic substances in the water, it can be resulted from turbidity or high sulfate concentration in December, 2008 (Table 4-3).

#### **4.2.5. Adsorbable Organic Halides (AOX)**

AOX concentrations have high values in July 2008, at the beginning of the monitoring study. In October 2008, a decrease was observed in AOX concentrations for the districts except Bilkent, Dikmen and Abidinpaşa. With the following months, it was not observed a general increasing or decreasing trend for the districts until February 2009. Except for Kızılay, AOX concentration increased in all districts in February 2009 as compared to January 2009. Excluding the measurement for Kızılay in December 2009, the highest AOX concentrations were detected in Aydınlikevler as 0.308 mg/l and in Küçükesat as 0.303 mg/l in July 2008. AOX measurements for all districts in months are presented in Table 4-19 and 4-20.

**Table 4-19 “Seasonal AOX Concentrations in Districts”**

<b>Districts</b>	<b>July (2008)</b>	<b>October (2008)</b>	<b>November (2008)</b>	<b>December (2008)</b>	<b>January (2009)</b>
Kızılay	0.275	0.198	0.167	0.343	0.317
Küçükkesat	0.303	0.188	0.193	0.192	0.145
Bahçelievler	0.287	0.220	0.104	0.173	0.179
Aydınlıkevler	0.308	0.167	0.134	0.197	0.188
Demetevler	0.284	0.154	0.182	0.192	0.173
Eryaman	0.261	0.158	0.189	0.132	0.140
Tandoğan	0.254	0.204	0.175	0.101	0.105
Or-An	0.226	0.193	0.180	0.204	0.197
100. Yıl	0.339	0.175	0.160	0.116	0.112
Etlik	0.214	0.181	0.189	0.185	0.174
Bilkent	0.157	0.188	0.124	0.171	0.151
Dikmen	0.184	0.189	0.182	0.172	0.178
Abidinpaşa	0.250	0.435	0.189	0.138	0.133
Öveçler	0.275	0.171	0.155	0.168	0.178
Keçiören	0.254	0.155	0.160	0.175	0.148
Yıldız	0.194	0.174	0.171	0.201	0.187
Cebeci	0.212	0.197	0.149	0.178	0.199
Mamak	0.225	0.195	0.203	0.182	0.197
GOP	0.225	0.193	0.182	0.195	0.188
Batıkent	0.244	0.112	0.138	0.151	0.137
Emek	0.256	0.199	0.167	0.177	0.150
Ayrancı	0.291	0.157	0.389	0.163	0.151
Çayyolu	0.259	0.197	0.201	0.153	0.140
Elvankent	0.246	0.160	0.174	0.153	0.140

**Table 4-20 “Seasonal AOX Concentrations in Districts”**

<b>Districts</b>	<b>February (2009)</b>	<b>March (2009)</b>	<b>April (2009)</b>	<b>May (2009)</b>	<b>June (2009)</b>
Kızılay	0.254	0.263	0.193	0.178	0.195
Küçükesat		0.234	0.211	0.228	0.196
Bahçelievler	0.205	0.241	0.211	0.179	0.133
Aydınlıkevler	0.252	0.262	0.140	0.190	0.186
Demetevler	0.208	0.270	0.191	0.208	0.204
Eryaman	0.180	0.204	0.187	0.184	0.102
Tandoğan	0.231	0.223	0.211	0.197	0.192
Or-An	0.211	0.237	0.220	0.201	0.176
100. Yıl	0.239	0.196	0.218	0.226	0.229
Etlik	0.237	0.234	0.221	0.228	0.187
Bilkent	0.243				
Dikmen	0.245	0.212	0.199	0.201	0.226
Abidinpaşa	0.198	0.201	0.140	0.215	0.223
Öveçler	0.208	0.252	0.191	0.207	0.209
Keçiören	0.219	0.223	0.185	0.201	0.212
Yıldız	0.241	0.259	0.191	0.188	0.199
Cebeci	0.226	0.253	0.174	0.208	0.204
Mamak	0.229	0.278	0.198	0.179	0.196
GOP	0.206	0.221	0.199	0.185	0.190
Batıkent	0.213	0.280	0.170	0.190	0.189
Emek	0.208	0.281	0.192	0.212	0.185
Ayrancı	0.219	0.212	0.225	0.194	0.158
Çayyolu	0.171	0.288	0.182	0.179	0.188
Elvankent	0.218	0.241	0.258	0.175	0.201

\*Blank indicate that measurement not done

When considered the annual averages of AOX concentrations, Kızılay and Ayrancı have the highest concentration in average. Figure 4-12 illustrates the annual AOX concentrations in districts. However, there were not certain differences between the districts in average annual concentrations.

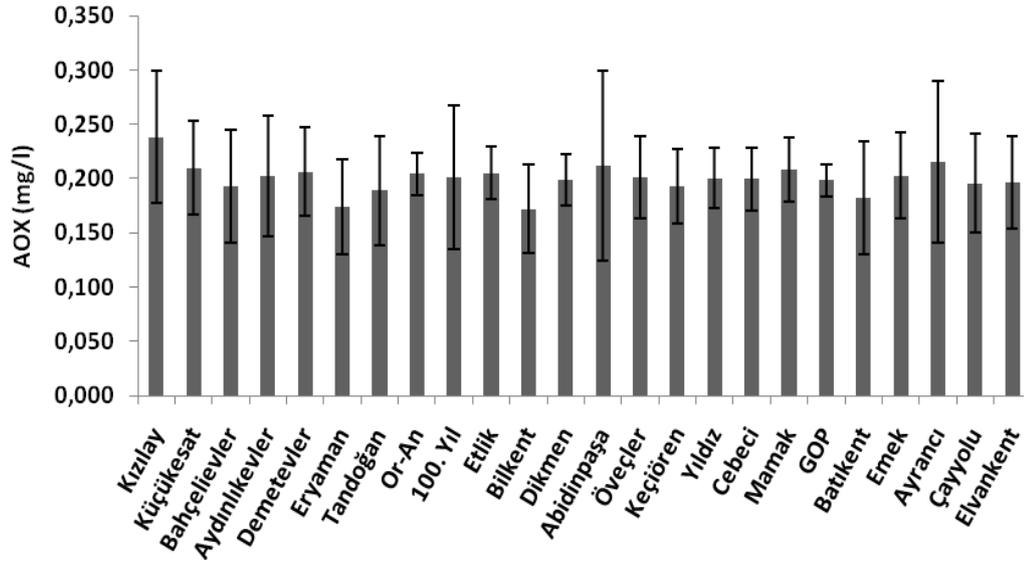


Figure 4-12 “Annual Average AOX concentration in drinking water samples”

AOX is a measurement of chlorinated DBPs including HAA and THM. When compared the THM and HAA concentration in districts for different months, it is distinguished that there are high difference between values of AOX and, THM and HAA. This indicates that the drinking water contain other chlorinated DBPs other than THM and HAA. Moreover, a correlation between AOX, THM and HAA was not observed in monthly variations. In order to see the variation in AOX, THM and HAA<sub>5</sub>, monthly measured concentrations of the three parameters are figured for four selected districts, namely Yıldız, 100. Yıl, Demetevler, Tandoğan, in Figure 4-13, 4-14, 4-15 and 4-16, respectively. As illustrated in the figures, there is not a good correlation between the three parameters. However, it is seen that generally there was an increase in both AOX and HAA<sub>5</sub> concentration in February 2009 though THM concentration decreased for the districts in February 2009 as opposed to AOX and HAA<sub>5</sub> concentration.

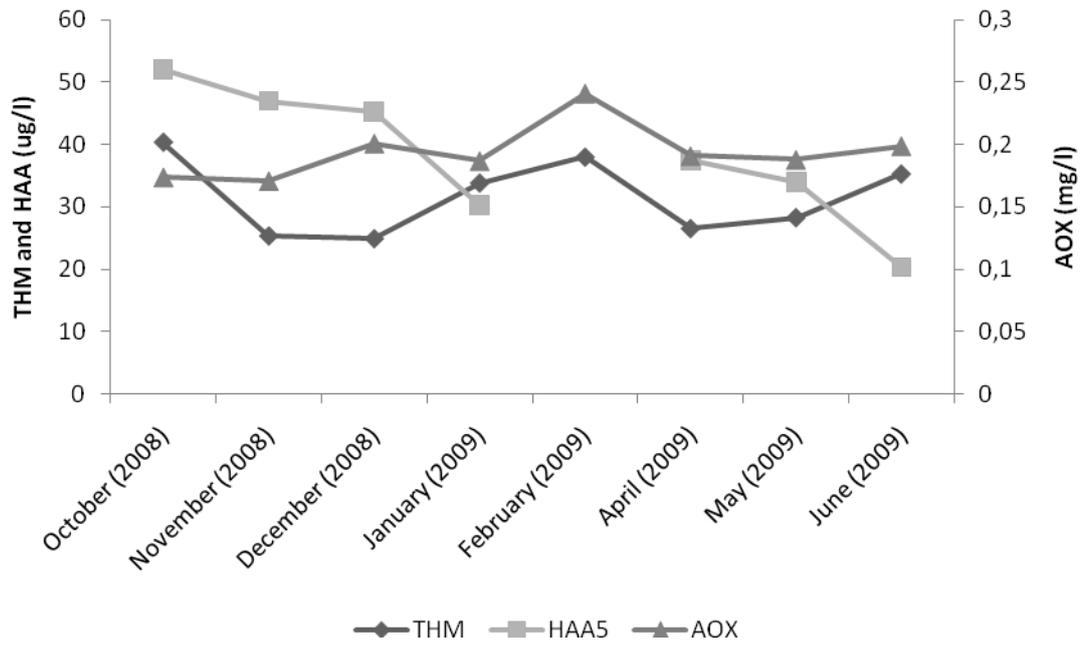


Figure 4-13 “HAA5, THM and AOX for Yıldız”

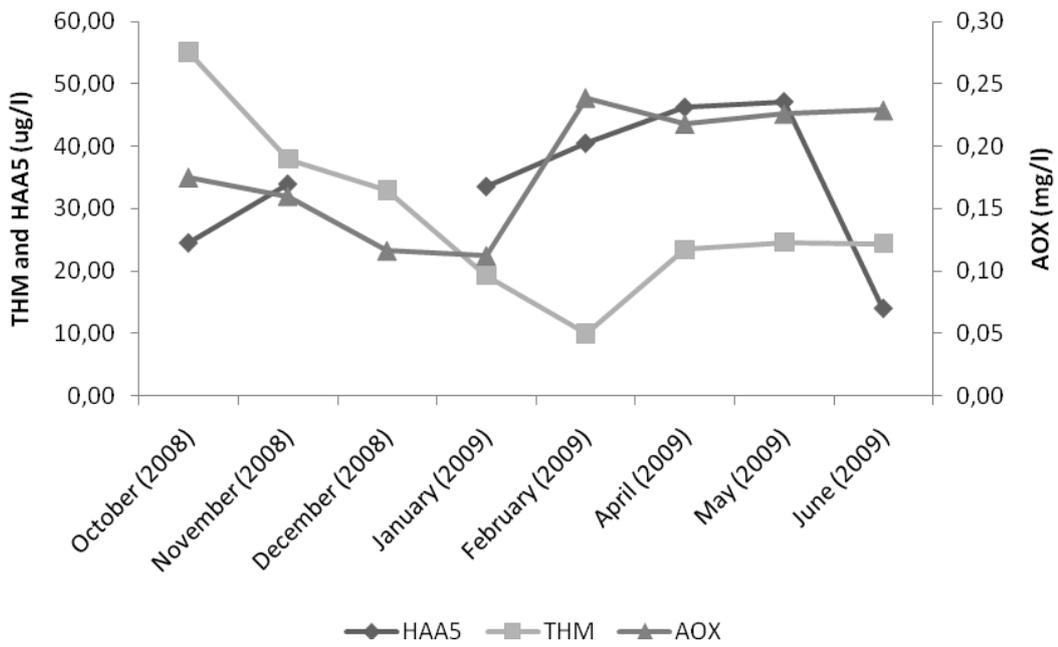


Figure 4-14 “HAA5, THM and AOX for 100. Yil”

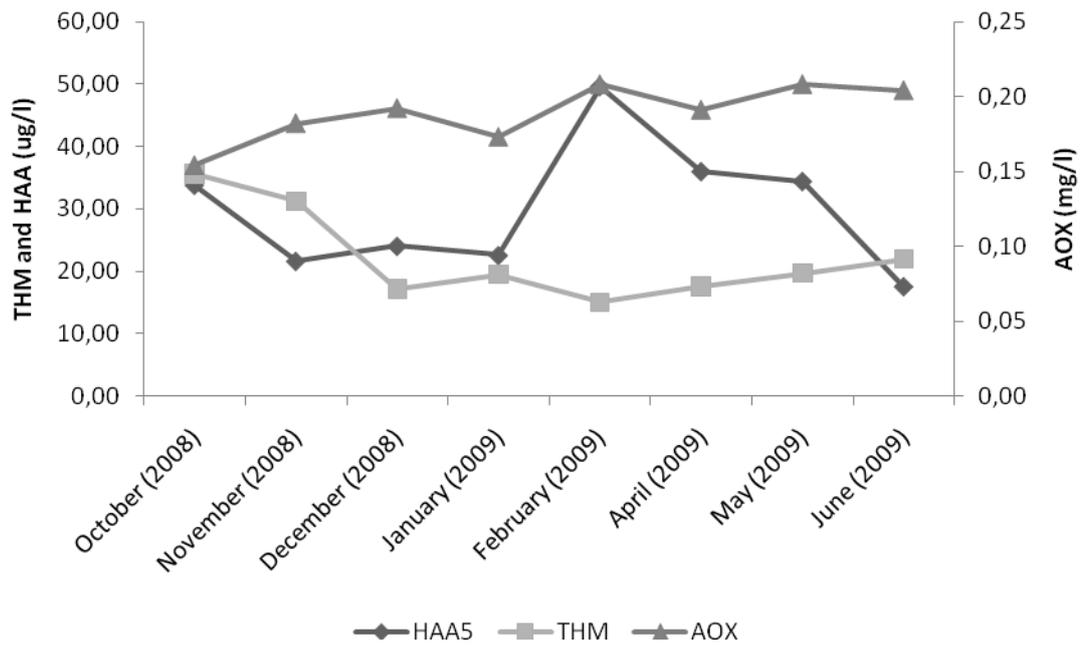


Figure 4-15 “HAA5, THM and AOX for Demetevler”

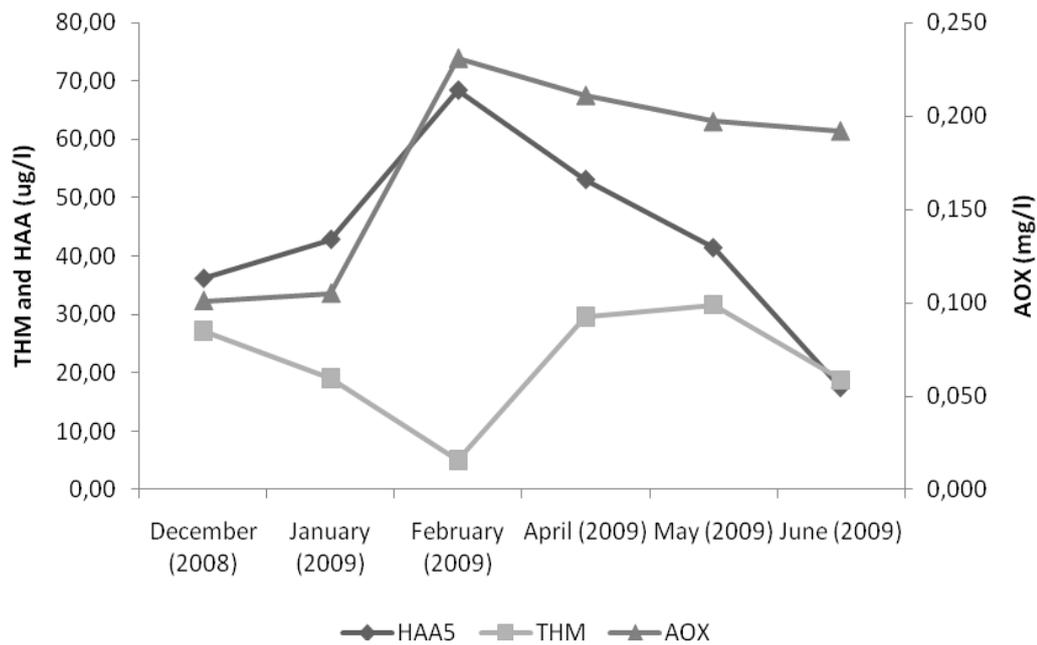


Figure 4-16 “HAA5, THM and AOX for Tandoğan”

#### **4.2.6. Microbiological Parameters**

Microbiological parameters are important in terms of water quality control and public health because they are the indicator for water-borne diseases. However, it is not practical to detect all types of organism deteriorating microbial quality of water. Coliform organisms are used as a good microbial indicator of drinking water quality because detection and enumeration of them in water are simple. Therefore, coliform test is generally applied for the monitoring of microbial quality in water supplies. Coliform bacteria should not be detectable in drinking water samples in terms of safe water supply [1]. Consequently, total coliform and fecal coliform bacteria were analyzed in the distribution network samples to determine the microbial quality in water supply.

##### *Total Coliform/Fecal Coliform*

At the beginning of the monitoring study, for the first months starting from July 2008, total coliform and fecal coliform were detected in the drinking water samples for most of the districts. The number of total coliform and fecal coliform detected in the drinking water samples of some districts decreased with months. In January 2009 coliform bacteria were detected in the drinking water samples from only two of the districts, namely Batikent and Ayrancı. After January 2009, any coliform bacteria were not observed in any of the water samples of the districts. The results of total/fecal coliform analyses for July 2008, January 2009 and April 2009 are given in Table 4-21, 4-22 and 4-23 as an example in order to observe the change in coliform bacteria seasonally. All coliform analyses results for all monitoring months are shown in Tables E-1 – E-9 in Appendix.E.

Table 4-21 "Coliform Analyses in July 2008"

Districts	Total Coliform/100 ml	Fecal Coliform/100 ml
Kızılay	Dense Growth	-
K.Esat	Dense Growth	-
Bahçelievler	-	-
Aydınlıkevler	-	-
Demetevler	-	-
Eryaman	20	-
Tandoğan	5	-
Oran Sitesi	24	-
100. Yıl	9	-
Etlik	Dense Growth	-
Bilkent	48	-
Dikmen	-	-
Abidinpaşa	4	-
Öveçler	32	-
Yıldız	5	-
Cebeci	6	-
Mamak	Dense Growth	-
GOP	Dense Growth	5
Keçiören	Dense Growth	5
Emek	-	-
Ayrancı	2	-
Çayyolu	4	-
Elvankent	18	-

Table 4-22 “Coliform Analyses in January 2009”

<b>Districts</b>	<b>Total Coliform/100 ml</b>	<b>Fecal Coliform/100 ml</b>
Kızılay	-	-
K.Esat	-	-
Bahçelievler	-	-
Aydınlıkevler	-	-
Demetevler	-	-
Eryaman	-	-
Tandoğan	-	-
Oran Sitesi	-	-
100. Yıl	-	-
Etlik	-	-
Bilkent	-	-
Dikmen	-	-
Abidinpaşa	-	-
Öveçler	-	-
Keçiören	-	-
Yıldız	-	-
Cebeci	-	-
Mamak	-	-
GOP	-	-
Batıkent	6	2
Emek	-	-
Ayrancı	3	2
Çayyolu	-	-
Elvankent	-	-

Table 4-23 “Coliform Analyses in April 2009”

Districts	Total Coliform/100 ml	Fecal Coliform/100 ml
Kızılay	-	-
K.Esat	-	-
Bahçelievler	-	-
Aydınlıkevler	-	-
Demetevler	-	-
Eryaman	-	-
Tandoğan	-	-
Oran Sitesi	-	-
100. Yıl	-	-
Etlik	-	-
Bilkent	NS*	NS
Dikmen	-	-
Abidinpaşa	-	-
Öveçler	-	-
Keçiören	-	-
Yıldız	-	-
Cebeci	-	-
Mamak	-	-
GOP	-	-
Batıkent	-	-
Emek	-	-
Ayrancı	-	-
Çayyolu	-	-
Elvankent	-	-

NS\*: Sample not taken

Within the scope of this study, in July 2008, water sample was taken from the outlet of the IWTP after chlorination. Any total or fecal coliform bacteria were not detected in that water sample. In order to investigate and understand the reason of the presence of coliform bacteria in the distribution system of Ankara, residual chlorine was also monitored monthly during the study. In IWTP, chlorination is applied for disinfection purposes as well as to prevent bacteriological regrowth through the distribution system maintaining residual chlorine at certain levels. Therefore, residual chlorine is a critical parameter because it has to be maintained at a certain level in order not to lead to bacteriological growth or to DBPs formation, which results adverse effects on public health. Free residual chlorine in the drinking water samples

for selected months, September 2008, October 2008, December 2008, February 2009, March 2009 and May 2009, are presented in Table 4-24.

**Table 4-24 “Monthly Free Residual Chlorine (mg/l) in Drinking Water Samples”**

<b>Districts</b>	<b>September 2008</b>	<b>October 2008</b>	<b>December 2008</b>	<b>February 2009</b>	<b>March 2009</b>	<b>May 2009</b>
Kızılay	0.02	0.13	0.72	0.80	0.38	0.88
K.Esat	0.05	0.37	0.23	NM	0.68	0.96
Bahçelievler	0.17	0.01	0.82	0.67	0.41	0.96
Aydınlıkevler	NM*	0.15	0.39	NM	0.52	1.28
Demetevler	0.39	1.18	0.97	0.40	0.87	1.05
Eryaman	0.04	0.11	0.01	NM	0.06	0.19
Tandoğan	0.02	0.11	0.01	0.26	0.23	0.96
Oran Sitesi	0.09	0.56	1.01	0.37	0.71	1.23
100. Yıl	0.05	0.05	NM	NM	0.50	1.19
Etlik	0.03	0.72	0.62	0.55	0.54	1.12
Bilkent	0.03	0.12	0.32	0.50	NS**	NS
Dikmen	0.02	1.01	0.26	0.48	0.50	1.24
Abidinpaşa	0.03	0.24	0.32	0.15	0.29	0.84
Öveçler	NM	0.73	1.18	0.32	0.44	0.44
Keçiören	0.03	0.22	0.33	NM	0.56	0.74
Yıldız	0.13	0.55	1.04	0.78	0.61	1.14
Cebeci	0.07	0.09	0.43	0.78	0.46	0.83
Mamak	1.21	0.63	0.31	NM	0.41	0.26
GOP	0.06	0.36	0.77	0.35	0.60	1.17
Batıkent	< 0.01	0.02	0.33	0.16	0.17	0.49
Emek	0.05	0.57	0.8	0.37	0.51	1.17
Ayrancı	0.21	0.64	0.97	0.10	0.42	1.06
Çayyolu	0.01	0.50	0.31	NM	0.33	0.96
Elvankent	0.18	0.90	0.72	0.51	0.41	1.07

\*NM: Sample not measured

\*\*NS: Sample not taken

As can be observed from the table, at the beginning of the monitoring period, residual chlorine values were generally at low levels in districts. Indeed, any residual chlorine was not observed in some districts' water samples. However, an increase in the residual chlorine concentration was noticed with following months.

When compared results of coliform bacteria analyses with residual chlorine measurement results for the districts in months, the results correlate well. As can be seen from the Table 4-25, the dense growth of coliform bacteria was observed when

residual chlorine concentrations were detected at very low values. With the increase in the residual chlorine concentration in the distribution network, coliform bacteria started to disappear in the samples. As shown in Table 4-26, any coliform bacteria were detected in the distribution network with the increasing residual chlorine. However, an increase in the amount of residual chlorine for some district was observed, which is due to the fact that interval chlorination after post-chlorination at the IWTP via the intermediate chlorine pumping stations is applied to drinking water for supplying additional residual chlorine in the system.

**Table 4-25 “Analyses Results of Coliform Bacteria and Residual Chlorine in the Distribution Network”**

Districts	August 2008			September 2008		
	T. Coliform (/100 ml)	F. Coliform (/100 ml)	Residual Chlorine (mg/L)	T. Coliform (/100 ml)	F. Coliform (/100 ml)	Residual Chlorine (mg/L)
Kızılay	1	-	0.01	1	-	0.13
Küçükesat	1	-	<0.01	-	-	0.37
Bahçelievler	1	-	<0.01	-	-	0.01
Aydınlıkevler	-	-	0.01	-	-	0.15
Demetevler	2	-	0.84	-	-	1.18
Eryaman	1	-	0.01	-	-	0.11
Tandoğan	1	-	0.45	1	-	0.11
Or-An	D*	-	<0.01	-	-	0.56
100. Yıl	-	-	0.62	-	-	0.05
Etlık	-	-	0.33	-	-	0.72
Bilkent	1	-	<0.01	24	-	0.12
Dikmen	-	-	0.48	-	-	1.01
Abidinpaşa	-	-	0.23	8	-	0.24
Öveçler	3	-	0.25	-	-	0.73
Keçiören	-	-	0.26	-	-	0.22
Yıldız	1	-	0.47	5	-	0.55
Cebeci	-	-	0.12	-	-	0.09
Mamak	D	1	0.43	-	-	0.63
GOP	-	-	0.02	8	-	0.36
Batıkent	-	-	0.19	-	-	0.02
Emek	-	-	0.14	-	-	0.57
Ayrançı	D	1	0.01	-	-	0.64
Çayyolu	-	-	<0.01	-	-	0.50
Elvankent	-	-	0.01	-	-	0.90

\* D: Dense growth (Not counted)

**Table 4-26 “Analyses Results of Coliform Bacteria and Residual Chlorine in the Distribution Network”**

Districts	January 2009			April 2009		
	T. Coliform (/100 ml)	F. Coliform (/100 ml)	Residual Chlorine (mg/L)	T. Coliform (/100 ml)	F. Coliform (/100 ml)	Residual Chlorine (mg/L)
Kızılay	-	-	0.56	-	-	0.58
Küçükesat	-	-	NM*	-	-	1.04
Bahçelievler	-	-	0.61	-	-	0.74
Aydınlıkevler	-	-	NM	-	-	0.87
Demetevler	-	-	NM	-	-	1.09
Eryaman	-	-	NM	-	-	0.00
Tandoğan	-	-	0.16	-	-	0.35
Or-An	-	-	0.88	-	-	1.00
100. Yıl	-	-	NM	-	-	0.87
Etlık	-	-	NM	-	-	0.88
Bilkent	-	-	NM	-	-	
Dikmen	-	-	0.60	-	-	0.65
Abidinpaşa	-	-	0.35	-	-	0.34
Öveçler	-	-	0.85	-	-	0.48
Keçiören	-	-	NM	-	-	0.49
Yıldız	-	-	0.83	-	-	0.95
Cebeci	-	-	NM	-	-	0.64
Mamak	-	-	0.46	-	-	0.14
GOP	-	-	0.70	-	-	0.91
Batıkent	6	2	NM	-	-	0.31
Emek	-	-	NM	-	-	0.67
Ayrancı	3	2	0.26	-	-	0.45
Çayyolu	-	-	NM	-	-	0.69
Elvankent	-	-	NM	-	-	0.82

NM: Not Measure

The deficiency in residual chlorine in distribution system can be attributed to the high sulfate concentration. Sulfate can react with free chlorine and result in decrease in the free residual chlorine in distribution system combining the chlorine [47]. In order to observe the relation between sulfate and residual chlorine in distribution system analyses results for some months, August 2008, November 2008, February 2009 and May 2009, are tabulated in Table 4-27. It can be generally stated that there was an increase in residual chlorine concentration in the water samples from all districts for the months of February 2009 and May 2009. Any residual chlorine

deficiency was not detected in the samples of the districts in February 2009 and May 2009. As can be seen from the table, sulfate concentration changed between 20-40 mg/l and was much lower than the concentration in August 2008 and November 2008.

**Table 4-27 “Relation between Residual Chlorine and Sulfate Concentration in Drinking Water Samples”**

Districts	August 2008		November 2008		February 2009		May 2009	
	SO <sub>4</sub> <sup>2-</sup> (mg/L)	Residual Chlorine (mg/L)	SO <sub>4</sub> <sup>2-</sup> (mg/L)	Residual Chlorine (mg/L)	SO <sub>4</sub> <sup>2-</sup> (mg/L)	Residual Chlorine (mg/L)	SO <sub>4</sub> <sup>2-</sup> (mg/L)	Residual Chlorine (mg/L)
Kızılay	78	0.01	335	0.13	20	0.80	35	0.88
Küçükesat	30	<0.01	270	0.37	25		35	0.96
Bahçelievler	80	<0.01	320	0.01	30	0.67	36	0.96
Aydınlıkevl er	48	0.01	285	0.15	20		36	1.28
Demetevler	120	0.84	285	1.18	15	0.40	36	1.05
Eryaman	21	0.01	285	0.11	25		45	0.19
Tandoğan	89	0.45	335	0.11	5	0.26	37	0.96
Or-An	84	<0.01	330	0.56	20	0.37	36	1.23
100. Yıl	38	0.62	330	0.05	10		34	1.19
Etlik	76	0.33	345	0.72	5	0.55	36	1.12
Bilkent	93	<0.01	290	0.12	35	0.5		
Dikmen	23	0.48	290	1.01	35	0.48	38	1.24
Abidinpaşa	56	0.23	340	0.24	35	0.15	34	0.84
Öveçler	89	0.25	315	0.73	35	0.32	33	0.44
Keçiören	20	0.26	370	0.22	33		34	0.74
Yıldız	80	0.47	335	0.55	38	0.78	36	1.14
Cebeci	21	0.12	330	0.09	36	0.78	35	0.83
Mamak	72	0.43	310	0.63	35		37	0.26
GOP	80	0.02	355	0.36	35	0.35	35	1.17
Batıkent	66	0.19	285	0.02	34	0.16	43	0.49
Emek	113	0.14	340	0.57	31	0.37	36	1.17
Ayrancı	47	0.01	335	0.64	33	0.10	36	1.06
Çayyolu	69	<0.01	300	0.50	38		34	0.96
Elvankent	118	0.01	310	0.90	31	0.51	35	1.07

\*Blank indicate that measurement not done

### **4.3 Effect of Kesikköprü reservoir water on the drinking water quality of Ankara**

In this study, it is investigated that the quality of Kesikköprü Reservoir water and its effect on drinking water quality of Ankara by monitoring both reservoir water and water in distribution system in terms of selected water quality parameters for a one-year of period. Moreover, at the beginning of the monitoring study, in July 2008, Çamlıdere and Kurtboğazi Reservoir waters were analyzed with Kesikköprü Reservoir water in terms of several quality parameters in order to obtain a general view of the characteristics of the three reservoir waters. For this purpose, water samples were collected from the inlet points of Kesikköprü, Çamlıdere and Kurtboğazi Reservoir waters to IWTP. Additionally, water samples were taken from the mixing point of the water collecting from the three reservoirs lines at IWTP and from the outlet point of IWTP. The five different water samples collected from different points of IWTP were analyzed for the various quality parameters. The results of the analyses are summarized in a tabular form in Table 4-28.

**Table 4-28 “Summary- Results of Source Water of Ivedik Water Treatment Plant (July 2008)”**

Parameters	Unit	Kesikköprü Reservoir Water	Çamlıdere Reservoir Water	Kurtboğazi Reservoir Water	Mixing point of the three reservoir waters at IWTP	Outlet of IWTP
Alkalinity	mg/l CaCO <sub>3</sub>	152	124	136	144	120
Arsenic	µg/l	10.39	22.76	5.86	10.8	2.18
Cu	µg/l	2.07	-	-	2.63	3.36
Cr	µg/l	<2	-	-	<2	<2
Ni	µg/l	<2	-	-	<2	<2
Cd	µg/l	<2	-	-	<2	<2
Zn	µg/l	<5	-	-	<5	115.93
Fe	µg/l	<5	-	-	146.62	<5
NH <sub>3</sub> -N	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2
AOX	mg/l	0.014	<0.008	<0.008	0.008	0.278
B	mg/l	0.2	<0.1	<0.1	0.1	0.1
Turbidity	NTU	3.42	16.6	1.72	4.85	0.23
F <sup>-</sup>	mg/l	0.34	0.1	0.1	0.25	0.25
Conductivity	µmho/cm	1720	210	220	830	950
Cl <sup>-</sup>	mg/l	255.47	7.99	2.14	97.25	109.61
NO <sub>3</sub> <sup>-</sup> N	mg/l	<0.06	0.18	0.34	<0.06	<0.06
NO <sub>2</sub> <sup>-</sup> N	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01
PO <sub>4</sub> -P	mg/l	<0.05	<0.05	0.18	<0.05	<0.05
Hardness	mg/l CaCO <sub>3</sub>	428	108	120	236	260
Sulfate (SO <sub>4</sub> <sup>2-</sup> )	mg/l	327.6	21.8	20	127.3	154.7
THMFP	µg/l	67	138	117	128	67
Fecal Coliform	/100 ml	-	-	-	-	-
Total Coliform	/100 ml	-	-	-	-	-

According to the results in Table 4-28, Kesikköprü Reservoir water primarily affects sulfate concentration in distribution network. As seen from Table 4-28, sulfate concentration was measured 155 mg/l at the outlet from IWTP. When compared the sulfate values of Kesikköprü, Çamlıdere and Kurtboğazi Reservoir waters, it can be

reached the result that the high sulfate concentration at the outlet from IWTP was the consequence of the water supplied from Kesikköprü Reservoir. This result supported with the monitoring results of the analyses conducted for both Kesikköprü Reservoir and distribution network from July 2007 to June 2008. In the study, the average sulfate concentration in the distribution network increased starting from July 2008 to February 2009. Especially for the months between September 2008 and January 2009 (including) sulfate concentration in the distribution system was above the limit value of 250 mg/l set by international (WHO, EPA, USEPA) and national (TS266, WIHCR) regulations.

The study showed that Kesikköprü Reservoir water secondarily affected the microbiological quality in distribution network negatively. As seen from Table 4-28, total and fecal coliform did not appear in the water taken from outlet of IWTP, before giving to the distribution system in July 2008. However, according to the results of the monitoring study, in July 2008 microbiological contamination was observed in distribution system. As being accordance with this result, residual chlorine concentration was low, 0.01 mg/l or lower for some districts, in distribution network. In pursuing months, total/fecal coliform stated to disappear in drinking water samples with the increasing chlorine amount. Thus, microbiological contamination was considered as a result of insufficient residual chlorine in distribution network. Additionally, the deficiency observed in residual free chlorine concentration correlated well with sulfate concentration in the system. Generally, lower chlorine concentration was observed when higher sulfate concentration was detected. After February 2009, there was not any detection of total/fecal coliform in distribution network as a result of lower sulfate concentration due to not usage of Kesikköprü Reservoir water as water source for Ankara after February 2009.

The conductivity value in Kesikköprü Reservoir water is comparably high as depicted from Table 4-28 and from the monitoring results during the study. It was determined as around 1600  $\mu\text{mho/cm}$  in general. As indicated in the Table 4-28, the high conductivity in Kesikköprü water led to increase in outlet water from the

treatment plant. According to analyses result done by ASKİ in September 2010 when only Çamlıdere and Kurtboğazı Reservoir waters are in service for water supply of Ankara, the conductivity was measured as 25.5  $\mu\text{mho/cm}$  at outlet from IWTP.

When the reservoir waters were assessed in terms of formation potential of DBPs, THMFP in Kesikköprü Reservoir water was higher than Çamlıdere and Kurtboğazı Reservoirs. However, the annual average concentrations for THM and HAA in distribution network did not exceed the standards for THM (80  $\mu\text{g/l}$  USEPA) and HAA<sub>5</sub> (60  $\mu\text{g/l}$  USEPA). Therefore, it can be stated that Kesikköprü Reservoir water does not result in a problem in distribution network in terms of DBPs formation. Contrarily, as seen from the Table 4-28, it was found out that Kesikköprü Reservoir water affected drinking water quality in a positive way, since it has lower formation potential of THM as compared to Çamlıdere and Kurtboğazı Reservoirs.

According to the monitoring results, Kesikköprü reservoir water leads to change in the value of quality parameters. However, the monitored parameters satisfied the regulated limits (both international and national given in Table 2-2 and 2-3) except for sulfate and coliform bacteria.

## CHAPTER 5

### SUMMARY AND CONCLUSION

The results of one year monitoring study conducted on Kesikköprü Raw water and Ankara Distribution system to assess the water quality in Ankara can be summarized as follows:

- Sulfate concentration in Kesikköprü Reservoir water was between 300-500 mg/l throughout the year. High sulfate concentration in raw water affected the drinking water of the city and sulfate concentration in distribution system was between 200-300 mg/l when Kesikköprü was in service as water supply to Ankara. The sulfate concentration in distribution system decreased to 20-30 mg/l after cutting off the water supply from Kesikköprü Reservoir to Ankara.
- When the three reservoir waters of Kesikköprü, Çamlıdere and Kurtboğazi are evaluated in terms of chlorine, sulfate, arsenic and conductivity parameters, according to the relevant standards defined in WPCR (2004), Kesikköprü raw water can be classified as Class II inland source water because chlorine, sulfate and conductivity values in Kesikköprü Reservoir water do not comply with the limits required to be classified as Class-I inland water based on the WPCR.
- The results of total and fecal coliform bacteria analysis in the distribution network showed a compatible trend with the results of residual chlorine and

sulfate concentration. When the high sulfate concentration and low residual chlorine concentration were measured in the distribution system, coliform bacteria were detected. Sulfate reacts with the free chlorine compounds combining them and affects the disinfection resulting lower level of residual chlorine. Therefore, the coliform bacteria appear in the absence of chlorine.

- Arsenic concentration in Kesikköprü Reservoir water was generally between 9-11  $\mu\text{g/l}$ . This result is contrary to the debates on the arsenic concentration of Kesikköprü water. Since Kesikköprü has lower arsenic concentration than Çamlıdere water, it leads to a dilution in the total arsenic concentration at the outlet of the treatment plant. However, a sharp decrease in arsenic concentration in distribution system was observed after February 2009. Until February 2009, the average arsenic concentration in distribution network was 2.5  $\mu\text{g/l}$ , whereas arsenic concentration dropped to 0.5  $\mu\text{g/l}$  on average with February 2009.
- THMFP of Kesikköprü Reservoir water was 50  $\mu\text{g/l}$  on average in a year showing the highest concentrations in summer and fall months.
- THM concentration in distribution system varied in districts and in months. The THM concentrations were higher in summer and fall seasons as compared to winter and spring seasons. The highest THM concentration was measured in July 2008 as 109  $\mu\text{g/l}$  in Küçükesat. The annual average THM concentrations in all districts were below the USEPA THM limit of 80  $\mu\text{g/l}$ , even though THM concentration did not satisfy the standard for some districts in July 2008. Besides, THM compounds differed for all districts after February 2009. Until February 2009, CM, BDCM and DBCM were detected in the drinking water samples from the districts. However, DBCM did not occur in any of the districts with the month of February 2009.

- The highest HAA concentrations in districts were observed in fall and winter months and HAA concentration did not show obvious variations in general throughout the monitoring period except for June 2009. Nonetheless, a slight increase in the HAA concentration in districts was observed in February 2009 compared to in January 2009. The annual average HAA<sub>5</sub> concentration for each district complied with the USEPA (2003) standard of 60 µg/l. The limit concentration exceeded only in February 2009 for Dikmen and Tandoğan.
- As a conclusion, Kesikköprü Reservoir water leads to change in distribution network of Ankara in terms of monitored parameters. However, the parameters monitored in drinking water during the study satisfy the standards (set by WHO, EPA, EU, and the relevant Turkish Regulations) except for sulfate and microbiological quality.

## **CHAPTER 6**

### **RECOMMENDED FUTURE WORK**

- Arsenic compounds and treatability should be investigated in Kesikköprü and Çamlidere Reservoir Waters.
- Bromide concentration should be also monitored in both Kesikköprü and Çamlidere Reservoir waters during the monitoring period.

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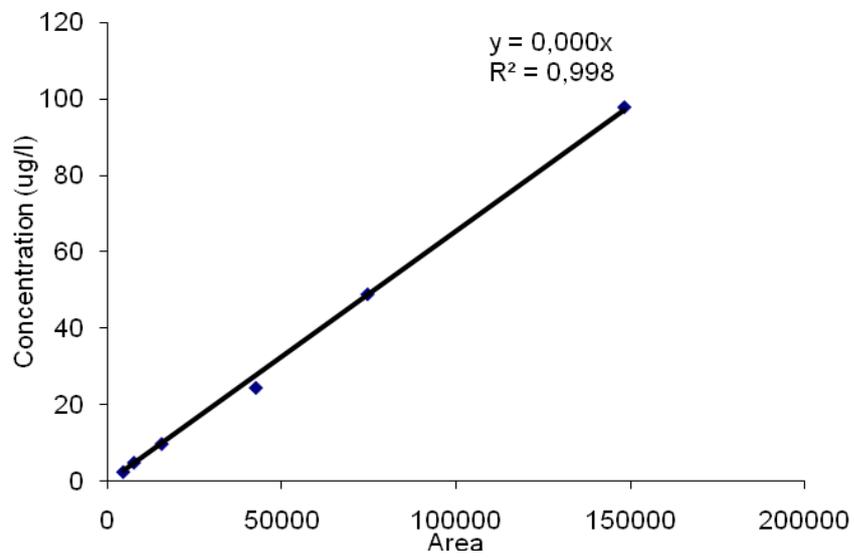
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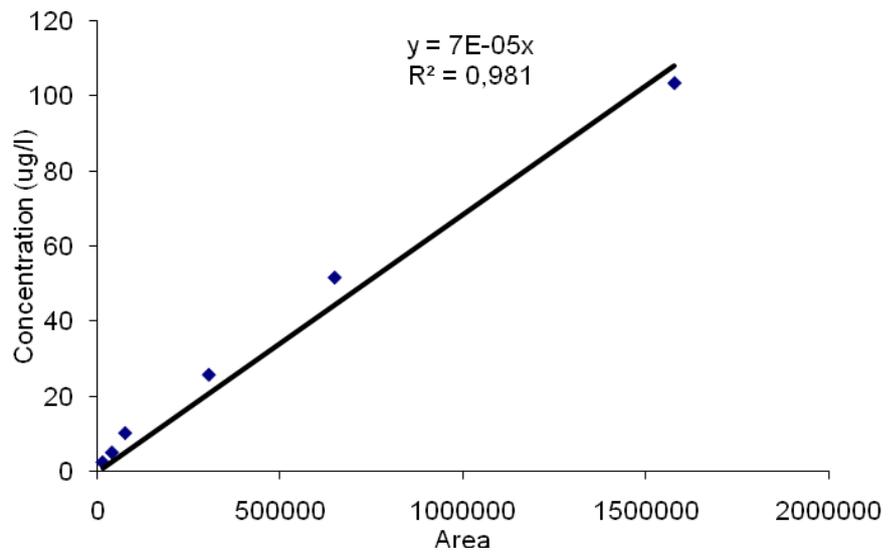
## APPENDIX A

### THM CALIBRATION CURVES FOR JULY 2008

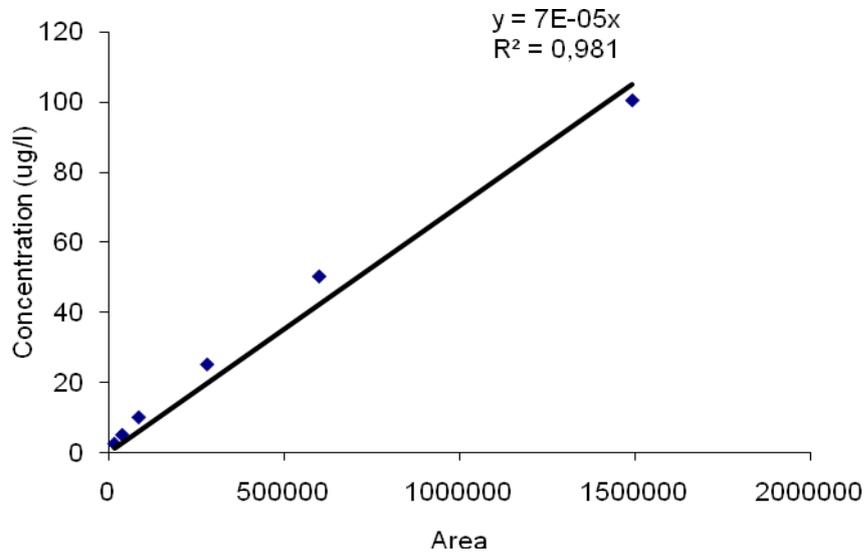
#### Chloroform



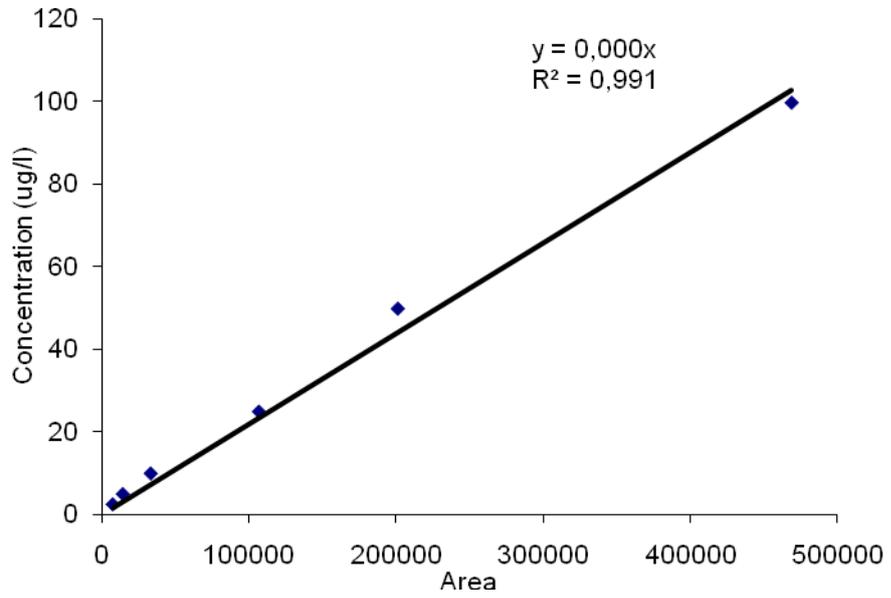
#### Bromodichloromethane



### Dibromochloromethane

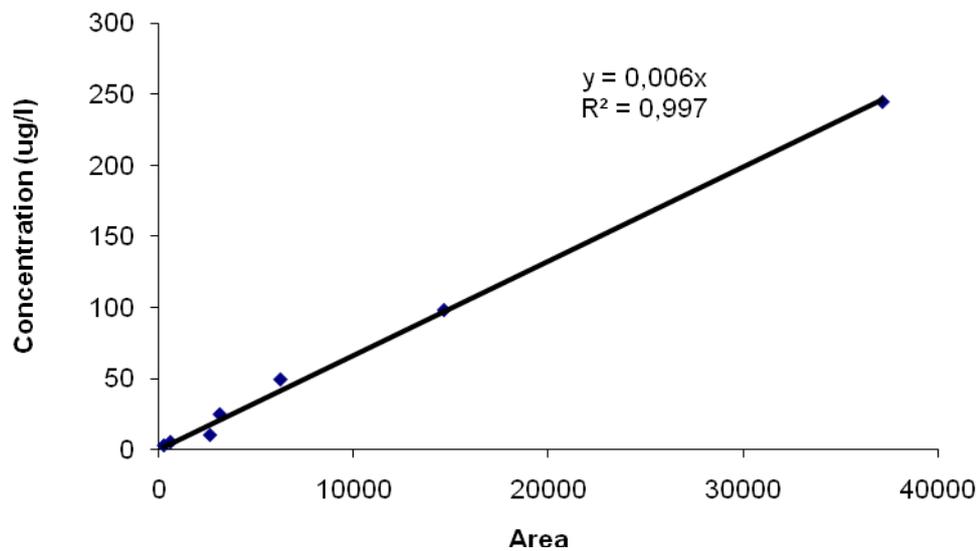


### Bromoform

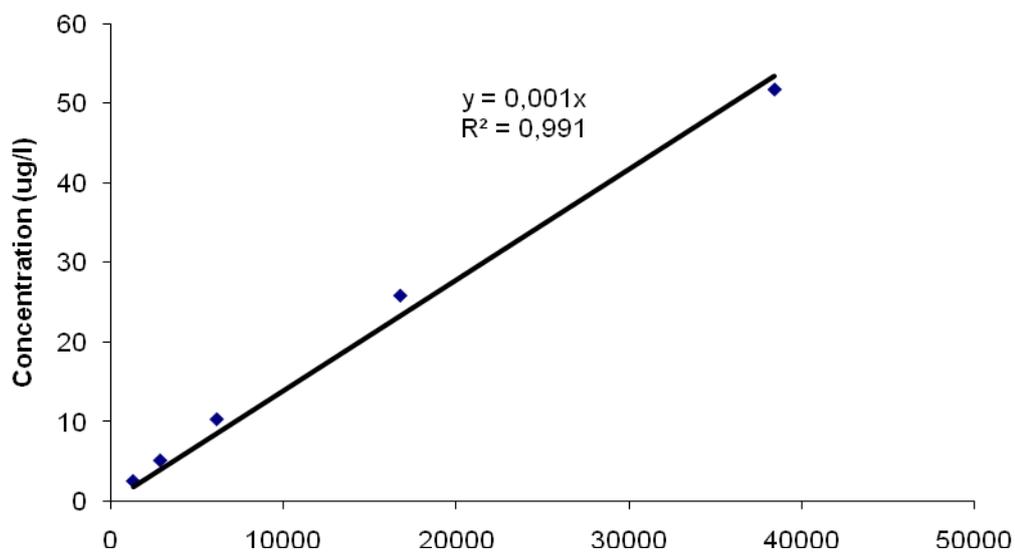


## THM CALIBRATION CURVES FOR NOVEMBER 2008

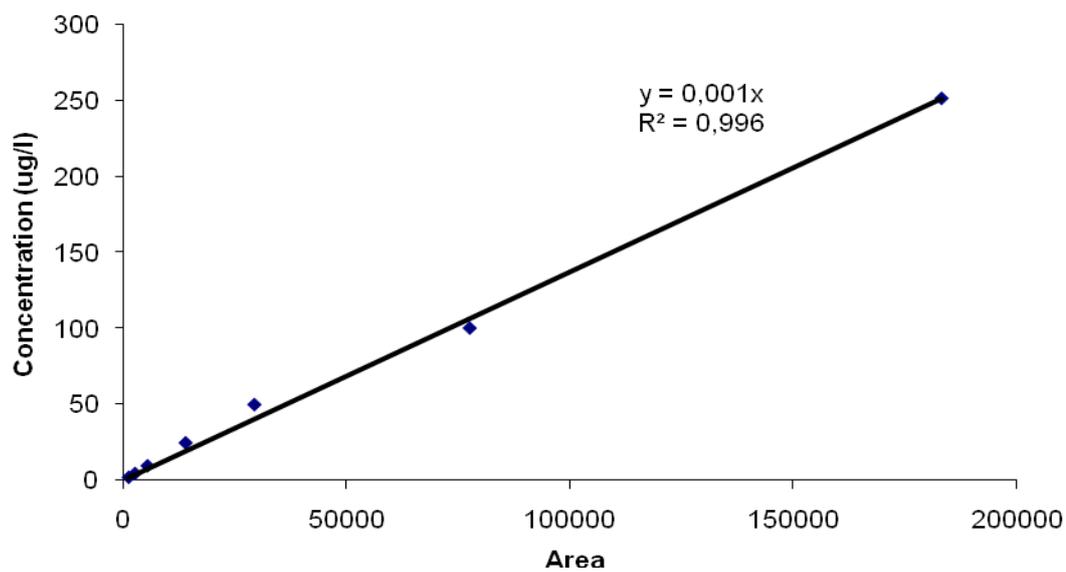
### Chloroform



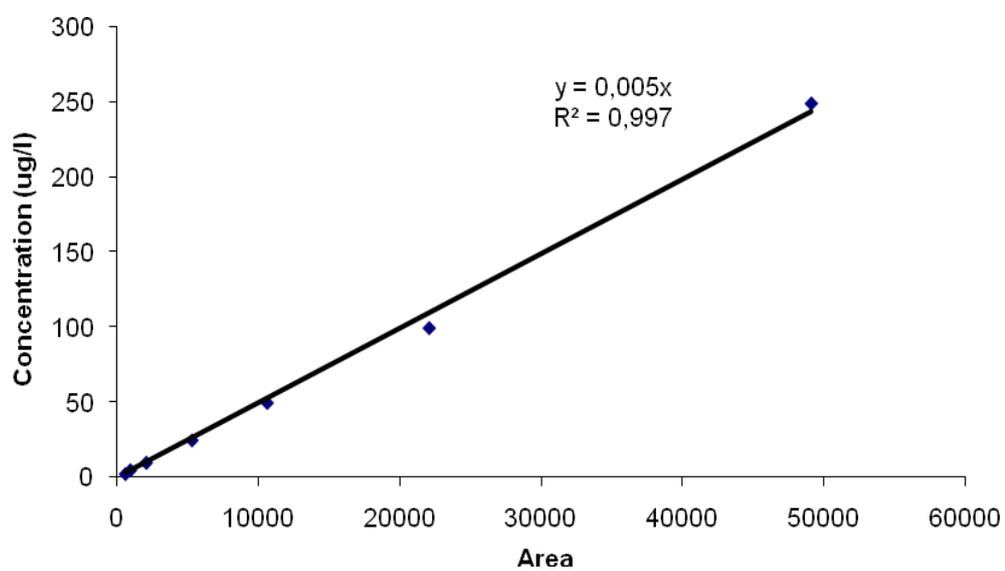
### Bromodichloromethane



### Dibromochloromethane



### Bromoform



## APPENDIX B

### TTHM CONCENTRATIONS IN DISTRICTS IN MONTHS

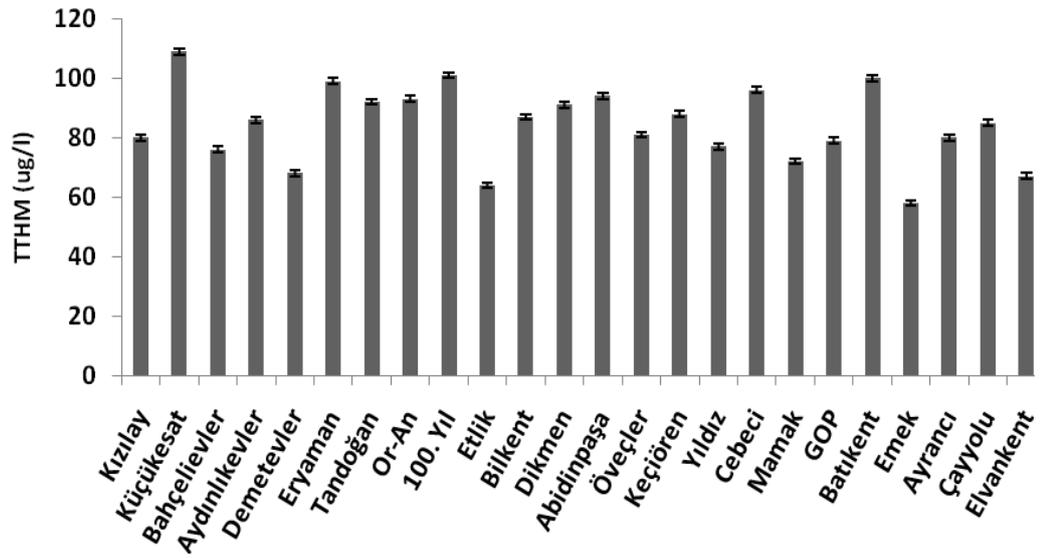


Figure B-1 "TTHM Concentration for districts in July 2008"

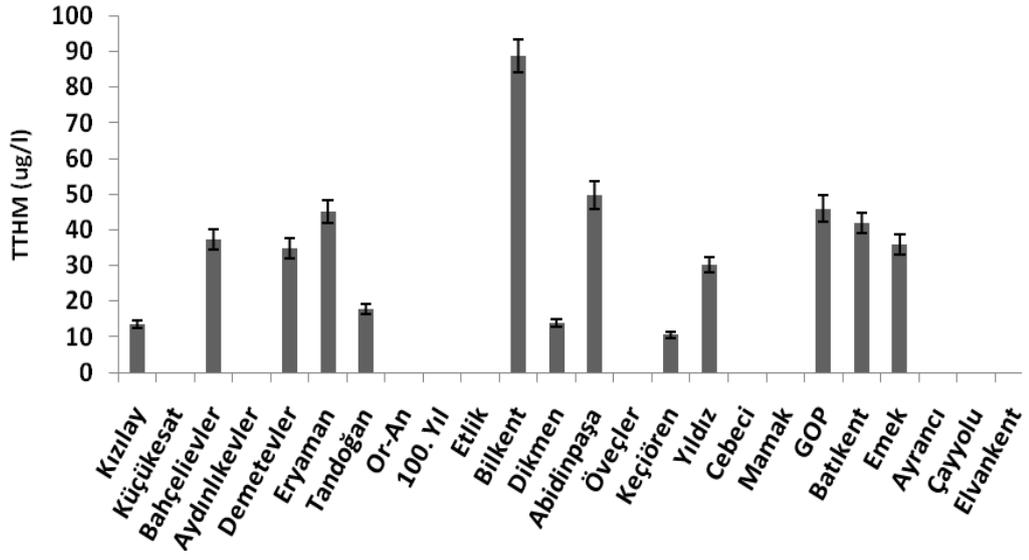


Figure B-2 "TTHM Concentration for districts in September 2008"

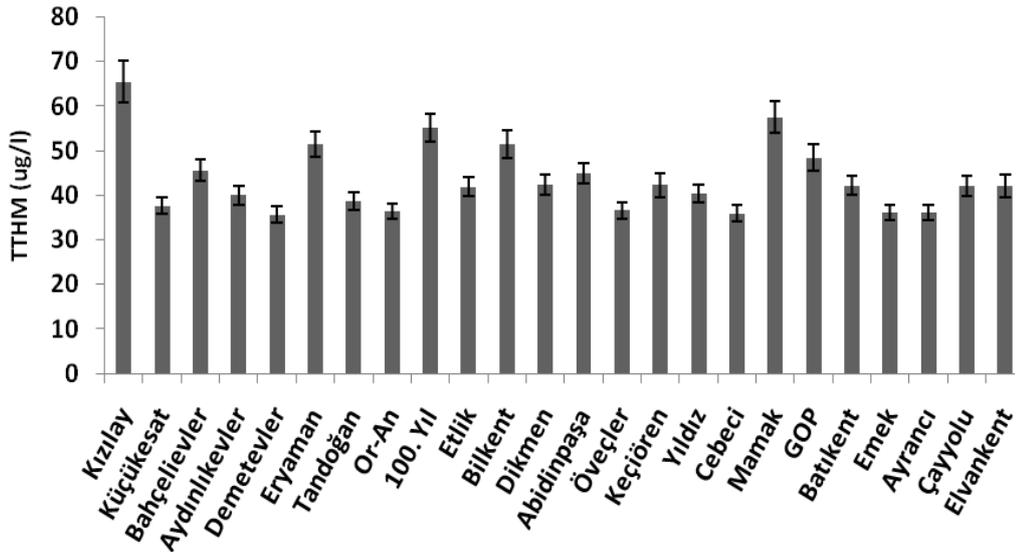


Figure B-3 "TTHM Concentration for districts in October 2008"

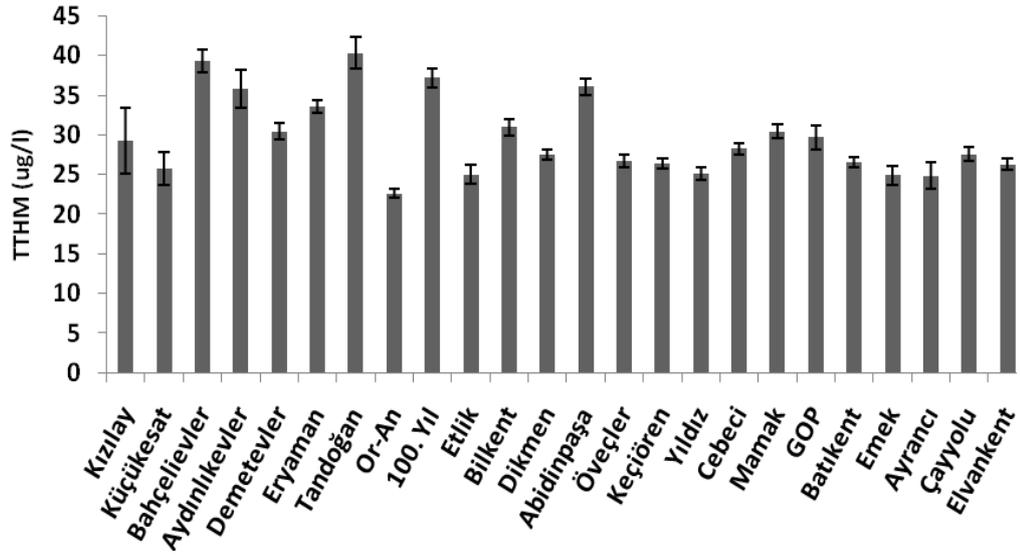


Figure B-4 “TTHM Concentration for districts in November 2008”

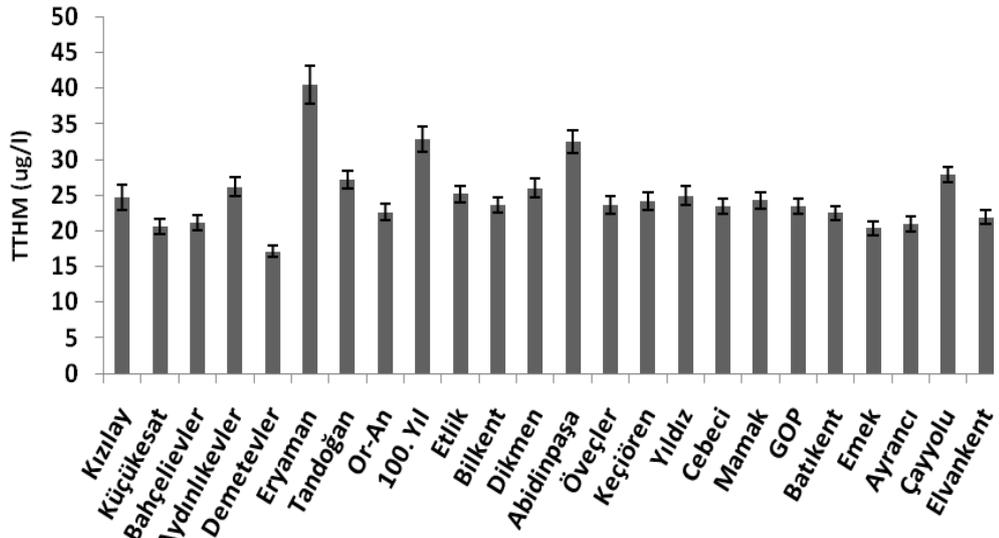


Figure B-5 “TTHM Concentration for districts in December 2008”

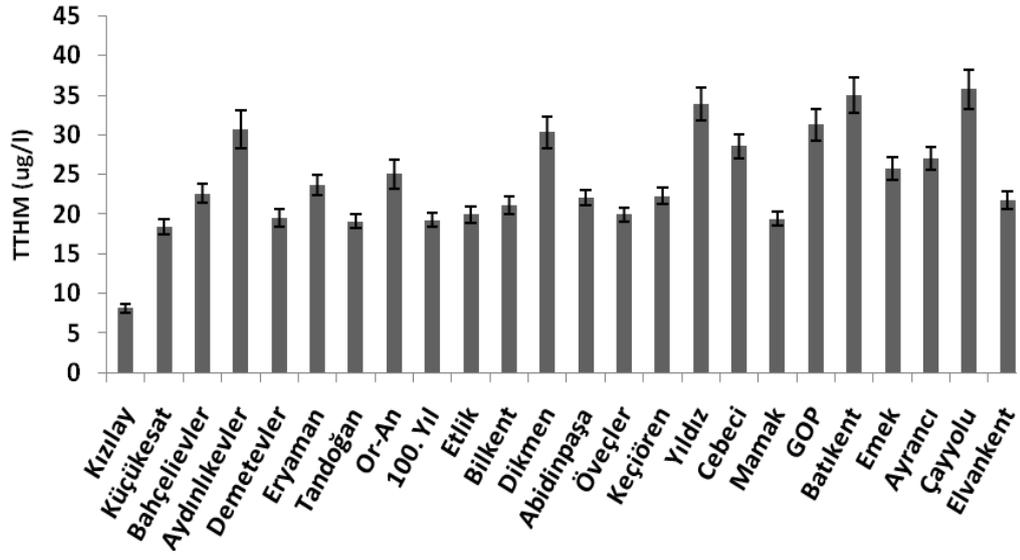


Figure B-6 “TTHM Concentration for districts in January 2009”

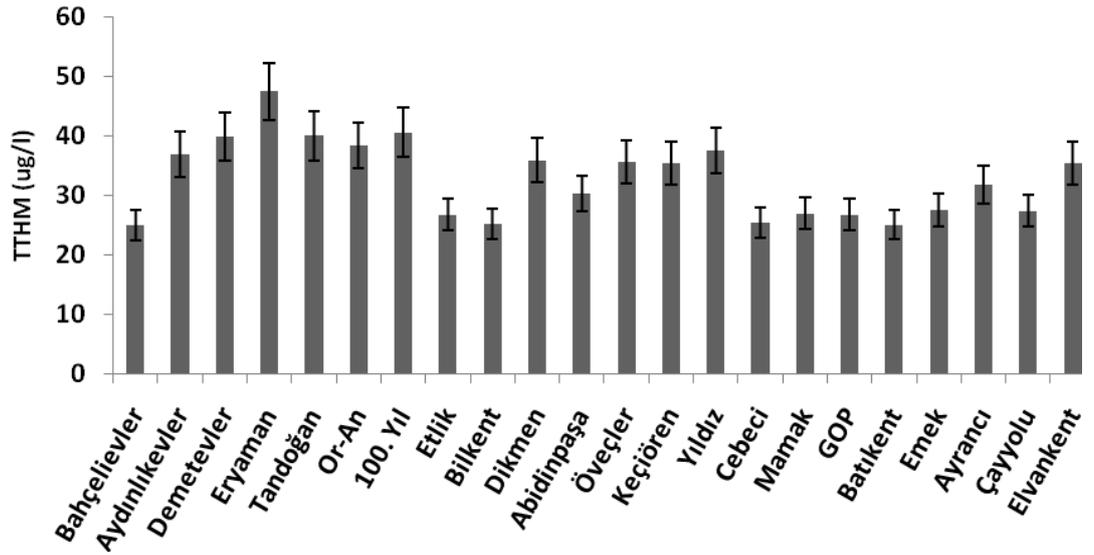


Figure B-7 “TTHM Concentration for districts in February 2009”

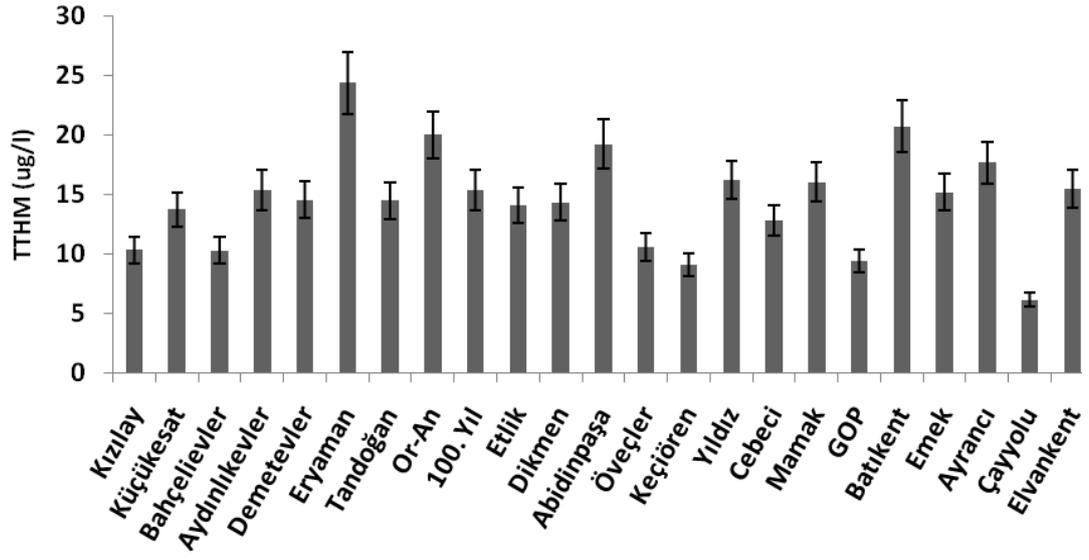


Figure B-8 “TTHM Concentration for districts in March 2009”

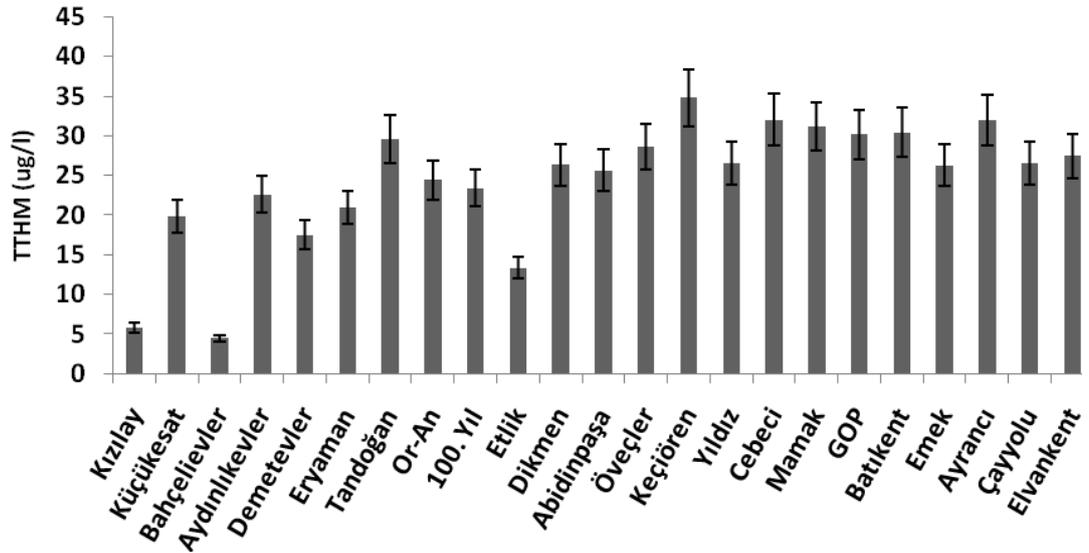


Figure B-9 “TTHM Concentration for districts in April 2009”

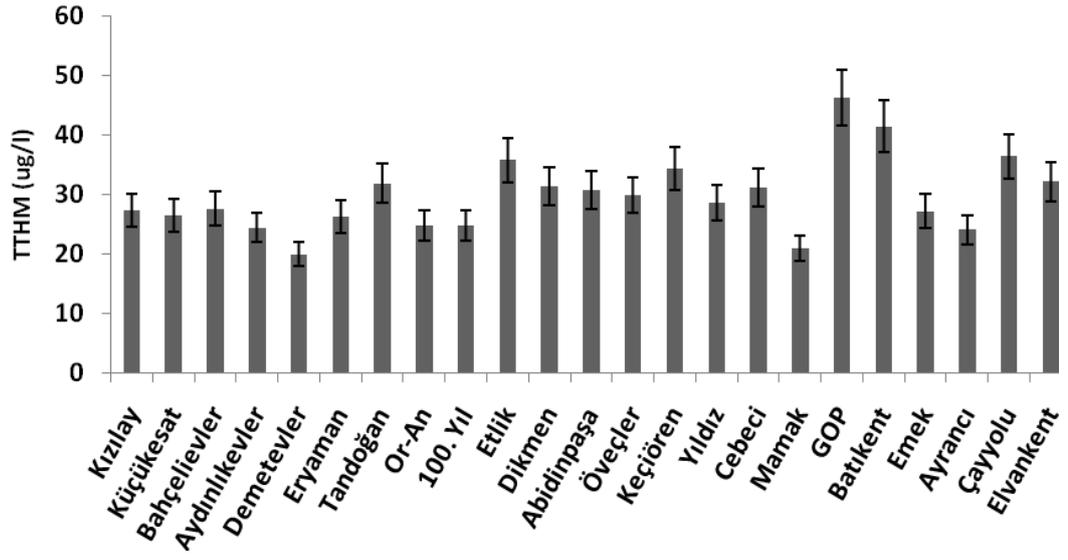


Figure B-10 “TTHM Concentration for districts in May 2009”

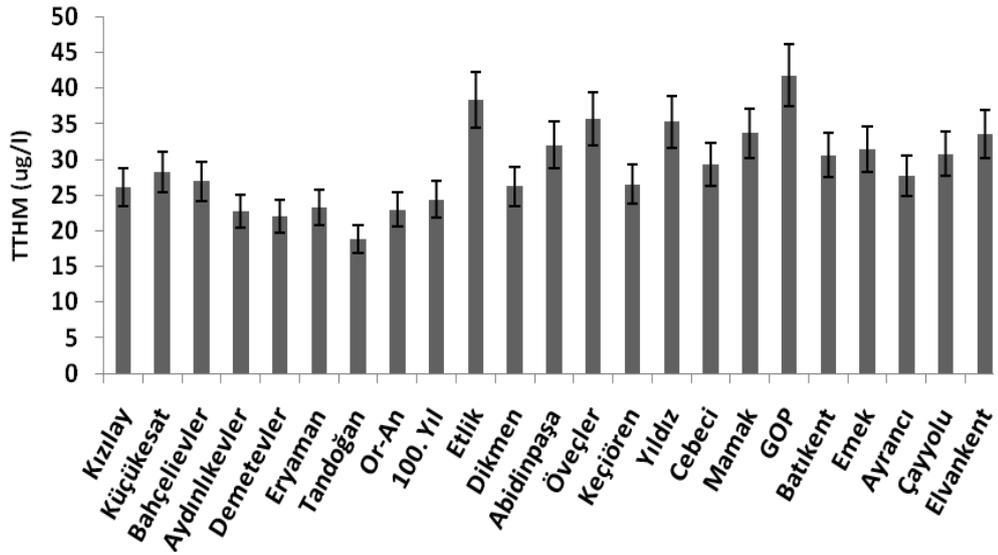


Figure B-11 “TTHM Concentration for districts in June 2009”

### TTHM COMPOUNDS PERCENTAGES

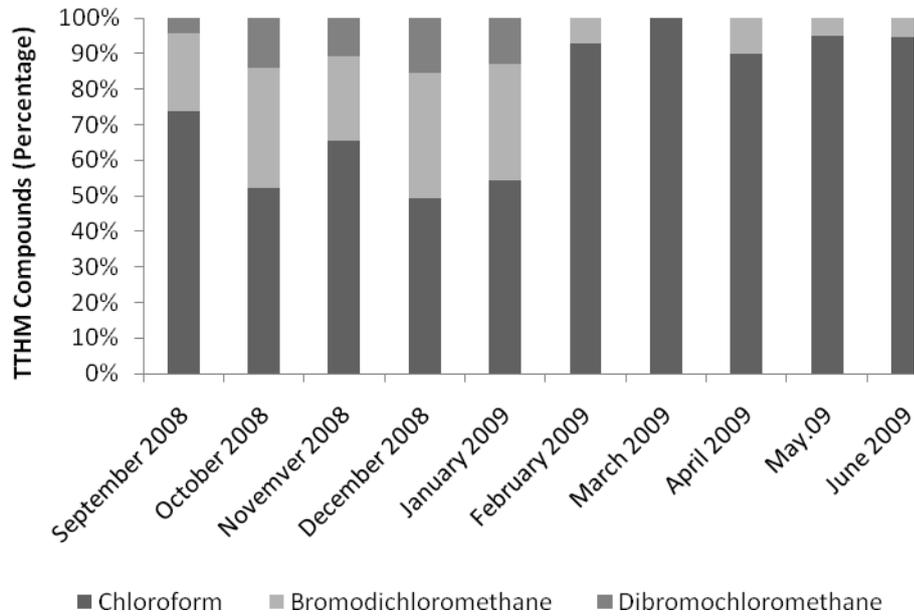


Figure B-12 “Percentage of TTHM Compounds of Bahçelievler in Months”

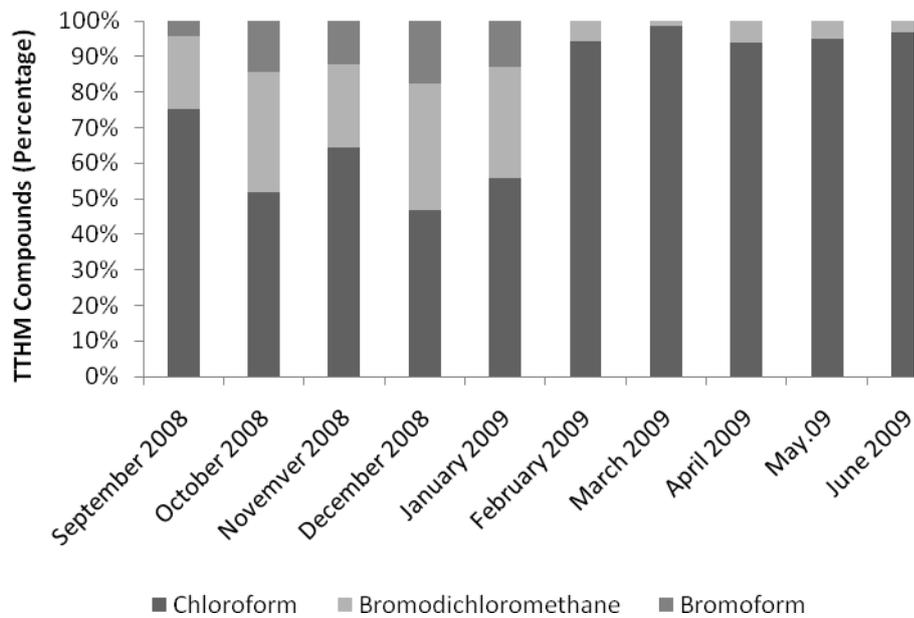
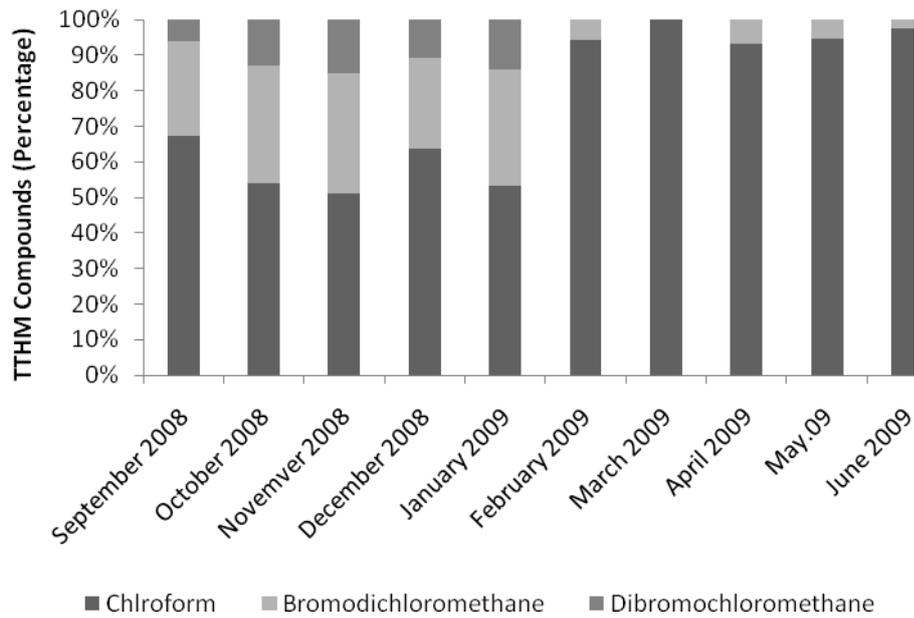
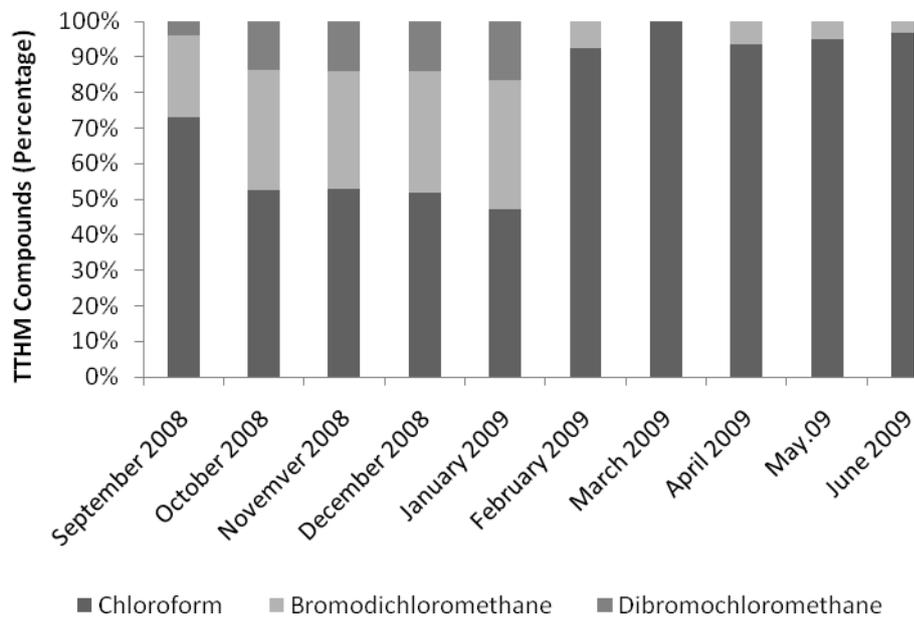


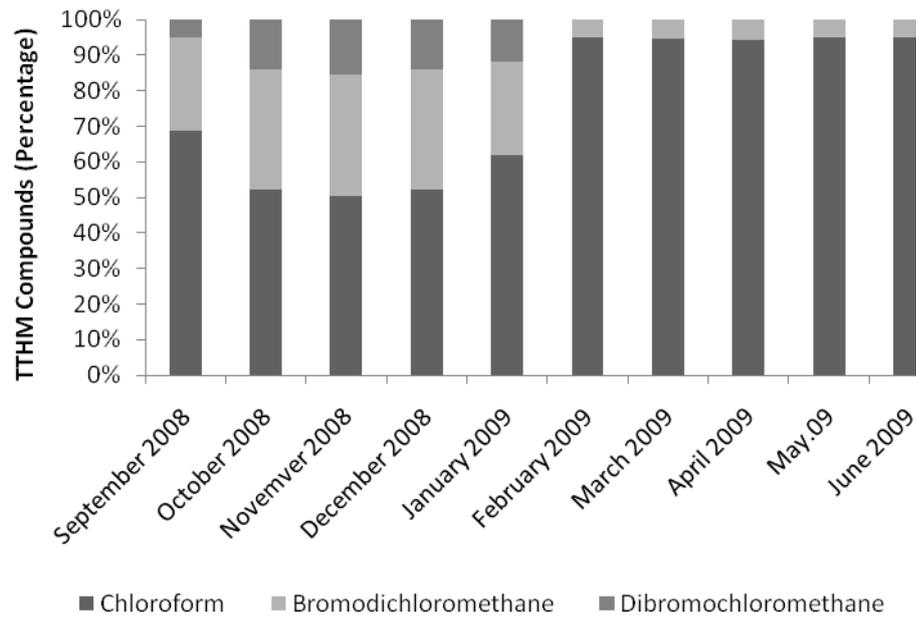
Figure B-13 “Percentage of TTHM Compounds of Demetevler in Months”



**Figure B-14 “Percentage of TTHM Compounds of Eryaman in Months”**



**Figure B-15 “Percentage of TTHM Compounds of Abidinpaşa in Months”**



**Figure B-16 “Percentage of TTHM Compounds of Yıldız in Months”**

## APPENDIX C

### HAA<sub>5</sub> CONCENTRATIONS FOR 24 DISTRICTS IN MONTHS (OCTOBER 2008 – JUNE 2009)

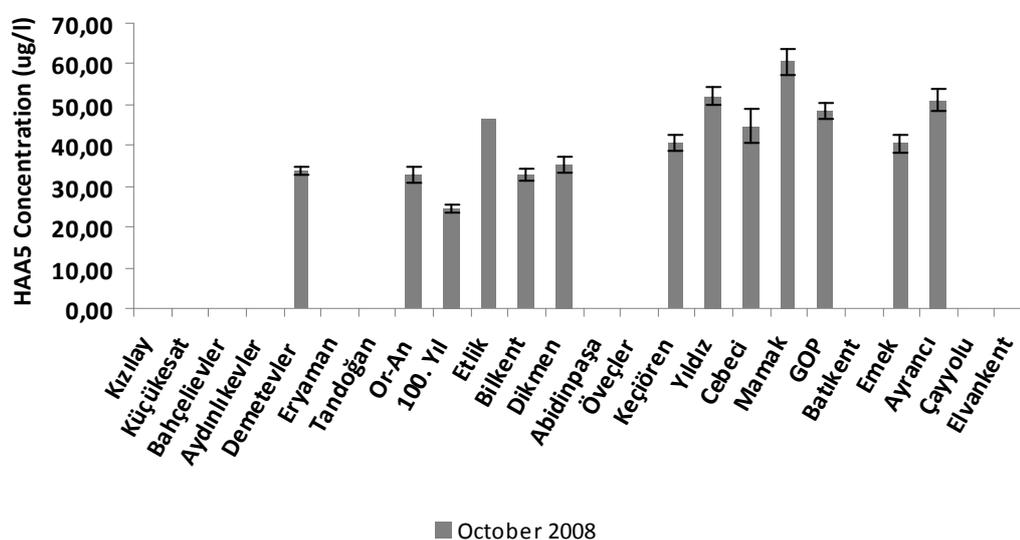


Figure C-1 “HAA<sub>5</sub> Concentration for districts in October 2008”

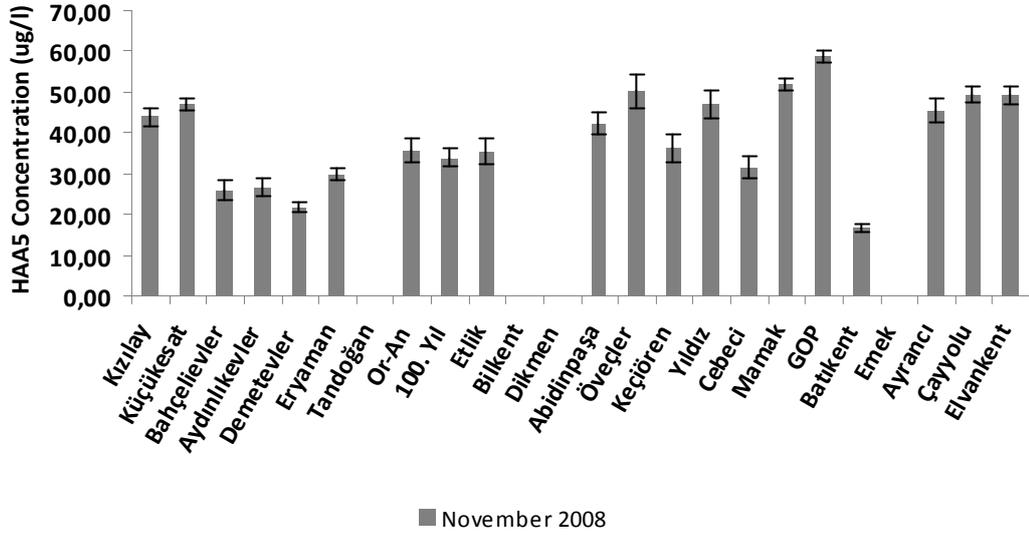


Figure C-2 “HAA<sub>5</sub> Concentration for districts in November 2008”

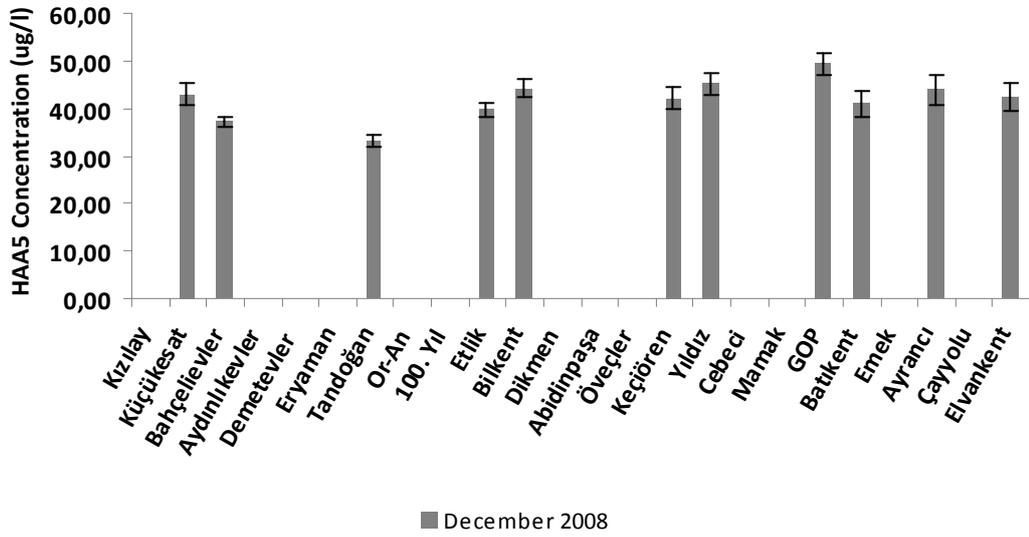


Figure C-3 “HAA<sub>5</sub> Concentration for districts in December 2008”

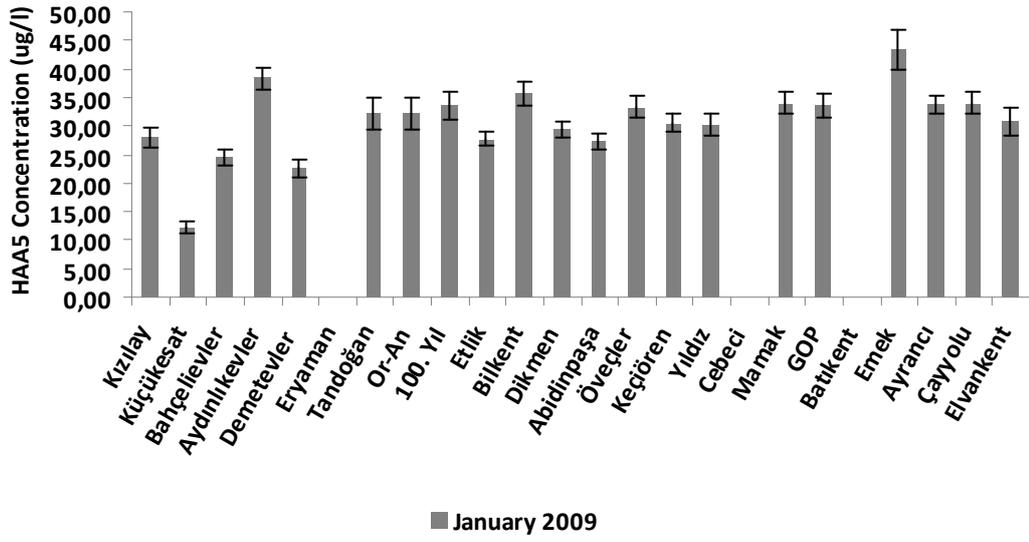


Figure C-4 “HAA<sub>5</sub> Concentration for districts in January 2009”

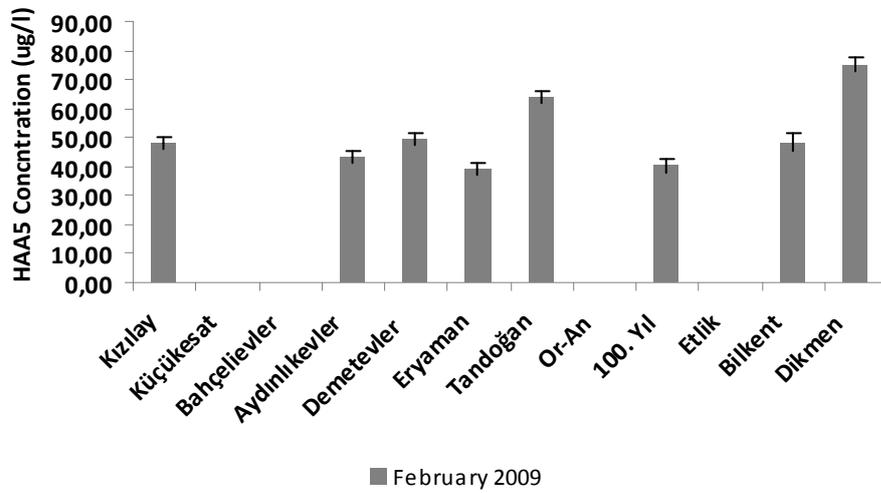


Figure C-5 “HAA<sub>5</sub> Concentration for districts in February 2009”

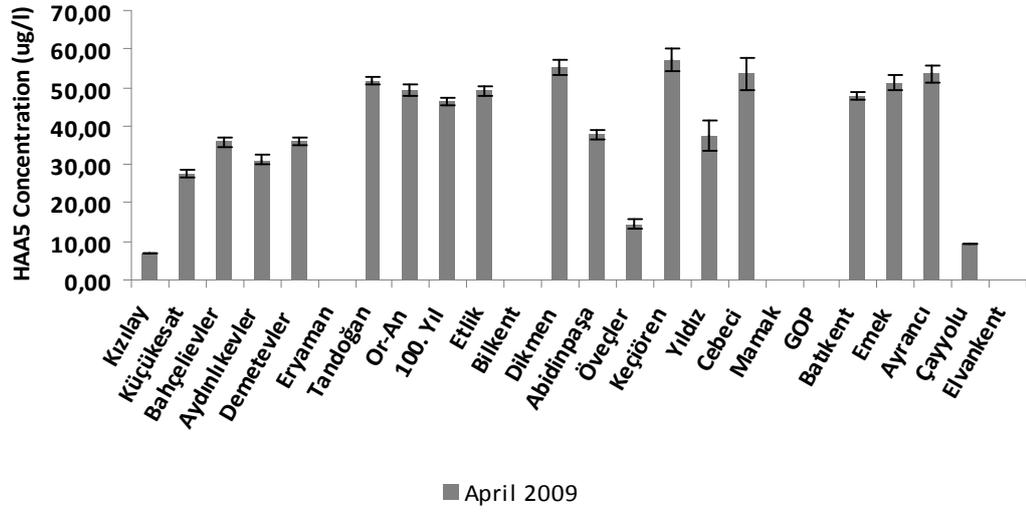


Figure C-6 “HAA<sub>5</sub> Concentration for districts in April 2009”

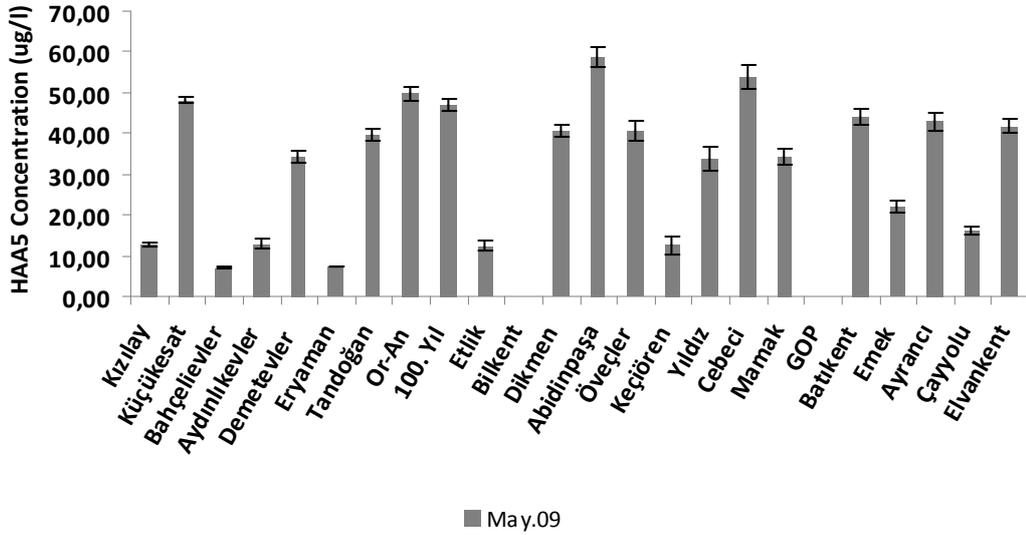


Figure C-7 “HAA<sub>5</sub> Concentration for districts in May 2009”

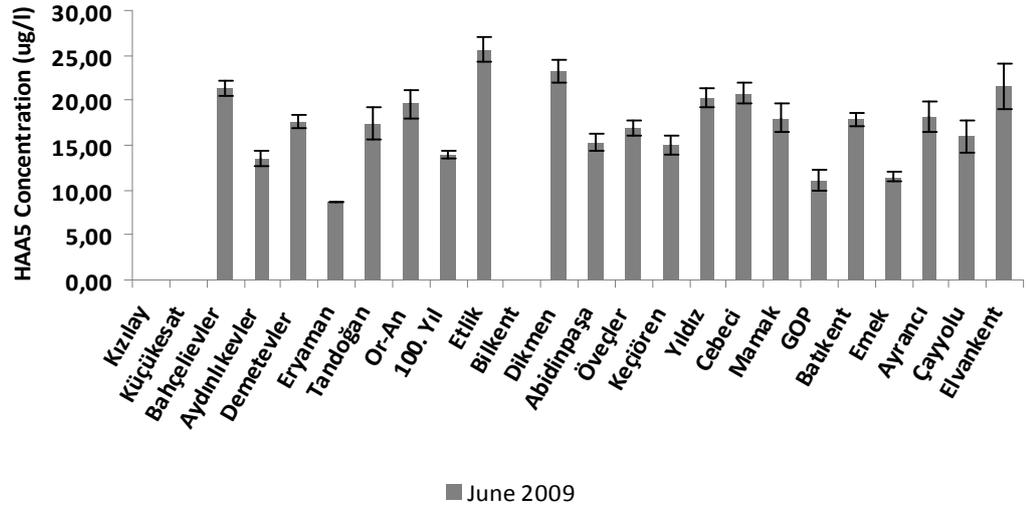


Figure C-8 "HAA<sub>5</sub> Concentration for districts in June 2009"

## APPENDIX D

**Table D-1 Quality Parameters of Inland Water Sources based on Classes**

Quality Parameters	Water Quality Classes			
	I	II	III	IV
<b>A) Physical and inorganic- chemical Parameters</b>				
1) Temperature (°C)	25	25	30	> 30
2) pH	6.5-8.5	6.5-8.5	6.0-9.0	Out of 6.0-9.0
3) Dissolved oxygen (mg O <sub>2</sub> /L) <sup>a</sup>	8	6	3	< 3
4) Oxygen saturation (%) <sup>a</sup>	90	70	40	< 40
5) Chloride (mg Cl <sup>-</sup> /L)	25	200	400 <sup>b</sup>	> 400
6) Sulfate (mg SO <sub>4</sub> <sup>=</sup> /L)	200	200	400	> 400
7) Amonium (mg NH <sub>4</sub> <sup>+</sup> -N/L)	0.2 <sup>c</sup>	1 <sup>c</sup>	2 <sup>c</sup>	> 2
8) Nitrite (mg NO <sub>2</sub> <sup>-</sup> -N/L)	0.002	0.01	0.05	> 0.05
9) Nitrate (mg NO <sub>3</sub> <sup>-</sup> -N/L)	5	10	20	> 20
10) Total phosphate (mg P/L)	0.02	0.16	0.65	> 0.65
11) Total dissolved solids (mg/L)	500	1500	5000	> 5000
12) Color (Pt-Co birimi)	5	50	300	> 300
13) Sodium (mg Na <sup>+</sup> /L)	125	125	250	> 250
<b>B) Organic parameters</b>				
1) Chemical oxygen demand (COD) (mg/L)	25	50	70	> 70
2) Biological oxygen demand (BOD) (mg/L)	4	8	20	> 20
3) Total organic carbon (mg/L)	5	8	12	> 12
4) Total kjeldahl-nitrogen (mg/L)	0.5	1.5	5	> 5
5) Oil and grass (mg/L)	0.02	0.3	0.5	> 0.5
6) MBAS (mg/L)	0.05	0.2	1	> 1.5
7) Fenolic solids (volatile) (mg/L)	0.002	0.01	0.1	> 0.1
8) Minarel oil (mg/L)	0.02	0.1	0.5	> 0.5
9) Total pesticide (mg/L)	0.001	0.01	0.1	> 0.1
<b>C) Inorganic pollutant parameters<sup>d</sup></b>				
1) Mercury (µg Hg/L)	0.1	0.5	2	> 2
2) Cadmium (µg Cd/L)	3	5	10	> 10
3) Lead (µg Pb/L)	10	20	50	> 50
4) Arsenic (µg As/L)	20	50	100	> 100
5) Copper (µg Cu/L)	20	50	200	> 200
6) Chromium (total) (µg Cr/L)	20	50	200	> 200
7) Chromium (µg Cr <sup>+6</sup> /L)	Not detectable	20	50	> 50
8) Cobalt (µg Co/L)	10	20	200	> 200
9) Nickel (µg Ni/L)	20	50	200	> 200
10) Zinc (µg Zn/L)	200	500	2000	> 2000
11) Cyanide (total) (µg CN/L)	10	50	100	> 100
12) Fluoride (µg F <sup>-</sup> /L)	1000	1500	2000	> 2000
13) Free chlorine (µg Cl <sub>2</sub> /L)	10	10	50	> 50
14) Sulphur (µg S <sup>-</sup> /L)	2	2	10	> 10

**Table D-1 Quality Parameters of Inland Water Sources based on Classes**

Quality Parameters	Water Quality Classes			
	I	II	III	IV
15) Iron ( $\mu\text{g Fe/L}$ )	300	1000	5000	> 5000
16) Manganese ( $\mu\text{g Mn/L}$ )	100	500	3000	> 3000
17) Boron ( $\mu\text{g B/L}$ )	1000 <sup>e</sup>	1000 <sup>e</sup>	1000 <sup>e</sup>	> 1000
18) Selenium ( $\mu\text{g Se/L}$ )	10	10	20	> 20
19) Barium ( $\mu\text{g Ba/L}$ )	1000	2000	2000	> 2000
20) Aluminum ( $\text{mg Al/L}$ )	0.3	0.3	1	> 1
21) Radioactivity ( $\text{Bq/L}$ )				
Alfa-activity	0,5	5	5	> 5
beta-activity	1	10	10	> 10
D) Bacteriological parameters				
1) Fecal coliform( $\text{EMS}/100 \text{ mL}$ )	10	200	2000	> 2000
2) Total coliform ( $\text{EMS}/100 \text{ mL}$ )	100	20000	100000	> 100000

## APPENDIX E

### TOTAL/FECAL COLIFORM ANALYSIS RESULTS IN DISTRICTS FOR MONTHS

Table E-1 “Coliform measurement in August 2008”

Districts	Total Coliform (/100 ml)	Fecal Coliform (/100 ml)
Kızılay	-	1
Küçükesat	-	-
Bahçelievler	1	-
Aydınlıkevler	3	-
Demetevler	1	-
Eryaman	-	-
Tandoğan	-	-
Or-An	1	-
100. Yıl	-	-
Etlik	-	-
Bilkent	-	-
Dikmen	1	-
Abidinpaşa	1	-
Öveçler	-	-
Keçiören	-	-
Yıldız	Dense Growth	-
Cebeci	1	-
Mamak	19	-
GOP	-	-
Batıkent	2	-
Emek	Dense Growth	1
Ayrancı	1	-
Çayyolu	-	-
Elvankent	Dense Growth	1

Table E-2 “Coliform measurement in September 2008”

<b>Districts</b>	<b>Total Coliform (/100 ml)</b>	<b>Fecal Coliform (/100 ml)</b>
Kızılay	1	-
Küçükesat	-	-
Bahçelievler	-	-
Aydınlıkevler		
Demetevler	-	-
Eryaman		-
Tandoğan	1	-
Or-An	-	-
100. Yıl	-	-
Etlik	-	-
Bilkent	24	-
Dikmen	-	-
Abidinpaşa	8	-
Öveçler		
Keçiören	-	-
Yıldız	5	-
Cebeci	-	-
Mamak	-	-
GOP	8	-
Batıkent		
Emek	-	-
Ayrancı	-	-
Çayyolu	-	-
Elvankent	-	-

Table E-3 "Coliform measurement in October 2008"

<b>Districts</b>	<b>Total Coliform (/100 ml)</b>	<b>Fecal Coliform (/100 ml)</b>
Kızılay	-	-
Küçükesat	-	-
Bahçelievler	-	-
Aydınlıkevler	12	5
Demetevler	-	-
Eryaman	31	25
Tandoğan	-	-
Or-An	-	-
100. Yıl	-	-
Etlik	-	-
Bilkent	-	-
Dikmen	10	-
Abidinpaşa	-	-
Öveçler	-	-
Keçiören	24	-
Yıldız	-	-
Cebeci	2	-
Mamak	-	-
GOP	-	-
Batıkent	11	-
Emek	-	-
Ayrancı	-	-
Çayyolu	-	-
Elvankent	-	-

Table E-4 “Coliform measurement in November 2008”

<b>Districts</b>	<b>Total Coliform (/100 ml)</b>	<b>Fecal Coliform (/100 ml)</b>
Kızılay	-	-
Küçükesat	-	-
Bahçelievler	-	-
Aydınlıkevler	-	-
Demetevler	-	-
Eryaman	-	-
Tandoğan	-	-
Or-An	-	-
100. Yıl	10	-
Etlik	2	-
Bilkent	-	-
Dikmen	-	-
Abidinpaşa	-	-
Öveçler	-	-
Keçiören	-	-
Yıldız	-	-
Cebeci	-	-
Mamak	-	-
GOP	-	-
Batıkent	-	-
Emek	-	-
Ayrancı	-	-
Çayyolu	-	-
Elvankent	-	-

Table E-5 "Coliform measurement in December 2008"

<b>Districts</b>	<b>Total Coliform (/100 ml)</b>	<b>Fecal Coliform (/100 ml)</b>
Kızılay	-	-
Küçükesat	-	-
Bahçelievler	-	-
Aydınlıkevler	-	-
Demetevler	-	-
Eryaman	-	-
Tandoğan	-	-
Or-An	-	-
100. Yıl	-	-
Etlik	-	-
Bilkent	-	-
Dikmen	-	-
Abidinpaşa	-	-
Öveçler	-	-
Keçiören	-	-
Yıldız	-	-
Cebeci	-	-
Mamak	-	-
GOP	-	-
Batıkent	160	-
Emek	-	-
Ayrancı	-	-
Çayyolu	-	-
Elvankent	-	-

Table E-6 “Coliform measurement in February 2009”

<b>Districts</b>	<b>Total Coliform (/100 ml)</b>	<b>Fecal Coliform (/100 ml)</b>
Kızılay	-	-
Küçükesat	-	-
Bahçelievler	-	-
Aydınlıkevler	-	-
Demetevler	-	-
Eryaman	-	-
Tandoğan	-	-
Or-An	-	-
100. Yıl	-	-
Etlik	-	-
Bilkent	-	-
Dikmen	-	-
Abidinpaşa	-	-
Öveçler	-	-
Keçiören	-	-
Yıldız	-	-
Cebeci	-	-
Mamak	-	-
GOP	-	-
Batıkent	-	-
Emek	-	-
Ayrancı	-	-
Çayyolu	-	-
Elvankent	-	-

Table E-7 "Coliform measurement in March 2009"

<b>Districts</b>	<b>Total Coliform (/100 ml)</b>	<b>Fecal Coliform (/100 ml)</b>
Kızılay	-	-
Küçükesat	-	-
Bahçelievler	-	-
Aydınlıkevler	-	-
Demetevler	-	-
Eryaman	-	-
Tandoğan	-	-
Or-An	-	-
100. Yıl	-	-
Etlik	-	-
Bilkent	-	-
Dikmen	-	-
Abidinpaşa	-	-
Öveçler	-	-
Keçiören	-	-
Yıldız	-	-
Cebeci	-	-
Mamak	17	2
GOP	-	-
Batıkent	-	-
Emek	-	-
Ayrancı	-	-
Çayyolu	-	-
Elvankent	-	-

Table E-8 "Coliform measurement in May 2009"

<b>Districts</b>	<b>Total Coliform (/100 ml)</b>	<b>Fecal Coliform (/100 ml)</b>
Kızılay	-	-
Küçükçekircek	-	-
Bahçelievler	-	-
Aydınlıkevler	-	-
Demetevler	-	-
Eryaman	-	-
Tandoğan	-	-
Or-An	-	-
100. Yıl	-	-
Etlik	-	-
Dikmen	-	-
Abidinpaşa	-	-
Öveçler	-	-
Keçiören	-	-
Yıldız	-	-
Cebeci	-	-
Mamak	-	-
GOP	-	-
Batıkent	-	-
Emek	-	-
Ayrancı	-	-
Çayyolu	-	-
Elvankent	-	-

Table E-9 "Coliform measurement in June 2009"

Districts	Total Coliform (/100 ml)	Fecal Coliform (/100 ml)
Kızılay	-	-
Küçükçekircek	-	-
Bahçelievler	-	-
Aydınlıkevler	-	-
Demetevler	-	-
Eryaman	-	-
Tandoğan	-	-
Or-An	-	-
100. Yıl	-	-
Etlik	-	-
Dikmen	-	-
Abidinpaşa	-	-
Öveçler	-	-
Keçiören	-	-
Yıldız	-	-
Cebeci	-	-
Mamak	-	-
GOP	-	-
Batıkent	-	-
Emek	-	-
Ayrancı	-	-
Çayyolu	-	-
Elvankent	-	-

## APPENDIX F

Table F-1 “pH measurements in Kesikköprü Reservoir Water”

	pH
July 2008	
August 2008	8.3±0.0
September 2008	8.2±0.2
October 2008	8.1±0.1
November 2008	8.4±0.2
December 2008	8.5±0.2
January 2009	8.3±0.2
February 2009	8.4±0.3
March 2009	8.6±0.3
April 2009	8.4±0.2
May 2009	8.4±0.1
June 2009	8.3±0.2