WATER QUALITY ASSESSMENT REPORT

TASK 3 – ZAI WATER TREATMENT PLANT PROJECT

USAID Jordan Water Infrastructure

Prepared by CDM International Inc. for United States Agency for International Development under

Global Architect - Engineer Services II IDIQ

USAID Contract No. AID-OAA-I-15-00047

Order: 72027818F00002

The Hashemite Kingdom of Jordan
Ministry of Water and Irrigation
Water Authority of Jordan (WAJ)

Date: 31 October 2018

This publication was produced for review by the United States Agency for International Development. It was prepared by CDM Smith.

Project: USAID Jordan Water Infrastructure

Contract: Global Architect - Engineer Services II IDIQ
USAID Contract No. AID-OAA-I-15-00047
Order: 72027818F00002

Water Quality Assessment Report
Task 3 – Zai Water Treatment Plant Project

Prepared by:	Mark White	Date:	October 2018
Reviewed by:	Al LeBlanc	Date:	October 2018
Approved by:	Rick Minkwitz	Date:	31 October 2018
USAID Approval		Date	5 November 2018

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AJ	*Arabtech Jardaneh*
AWC	*Aqaba Water Company*
BEO	*Bureau Environmental Officer*
BoDR	*Basis of Design Report*
BOT	*Build, Operate and Transfer*
CDM Smith	*CDM International Inc.*
COR	*Contract Officer Representative*
CC	*Consolidated Consultants for Engineering and Environment*
CMS	*Construction Management Services*
DEC	*Development Experience Clearinghouse*
DDL	*USAID's Development Data Library*
DLS	*Department of Land Survey*
DOS	*Department of Statistics*
EA or EIA	*Environmental Assessment or Environmental Impact Assessment*
FARA	*Fixed Amount Reimbursable Agreement*
GIS	*Geographical Information System*
GOJ	*Government of Jordan*
GTD	*Government Tenders Department*
IEE	*Initial Environmental Examination*
IR	*Intermediate Result*
JD or JOD	*Jordanian Dinars*
JISM	*Jordanian Institute for Standards and Metrology*
JDWS	*Jordan Drinking Water Standards*
JWQS	*Jordanian Water Quality Standards*
KAC	*King Abdullah Canal*
KaMP	*USAID/Jordan Knowledge Management Portal*
MCM	*Million Cubic Meters*
MEL	*Monitoring Evaluation and Learning*
MEO	*Mission Environmental Officer*
MF	*Microfiltration*
MoE	*Ministry of Environment*
M&E	*Monitoring & Evaluation*
MoH	*Ministry of Health*
MPWH	*Ministry of Public Works and Housing*
MWI	*Ministry of Water and Irrigation*
N/A	*Not Applicable*
NF	*Nanofiltration*
NRW	*Non-Revenue Water*
O&M	*Operation and Maintenance*
PSP	*Private Sector Participation*

PMU	*Project Management Unit*
QA/QC	*Quality Assurance and Quality Control*
RFTOP	*Request for Task Order Proposal*
RFQ	*Request for Qualification (Prequalification Document)*
RFTOP	*Request for Task Order Proposal*
RO	*Reverse Osmosis*
RSDS	*Red Sea Dead Sea*
SCADA	*Supervisory Control Data Acquisition*
SWRO	*Salt Water Reverse Osmosis*
TOC	*Total Organic Carbon*
TRG	*Training Resources Group*
UF	*Ultrafiltration*
USAID	*United States Agency for International Development*
USD or US$	*United States Dollars*
UV	*Ultraviolet Light*
W&C	*White and Case*
WAJ	*Water Authority of Jordan*
WHO	*World Health Organization*
WTP	*Water Treatment Plant*
WWTP	*Wastewater Treatment Plant*
YWC	*Yarmouk Water Company*

LIST OF UNITS

Bq	*becquerel*
CFU	*colony forming unit*
cm	*centimeter*
CU	*color units*
^{o}C	*degrees Celsius*
d, D	*day*
Dunum	*1,000 square meters*
ha	*hectare (10,000 square meters)*
h, hr	*hour*
JD	*Jordanian Dinar*
kg	*kilogram*
km	*kilometer*
kPa	*kilo Pascal*
kV	*kilovolt*
kVA	*kilovolt ampere*
L, l	*liter*
lpcd	*liters per capita per day*
L/s, l/s	*liter per second*
m	*meter*
m^2	*square meter*
m^3	*cubic meter*
m^3/d	*cubic meter per day*
m^3/h	*cubic meter per hour*
m^3/s	*cubic meter per second*
m/s	*meter per second*
MCM	*million cubic meters*
MCM/y	*million cubic meters per year*
mg	*milligram*
min	*minute*
mL/d	*megaliters per day*
mm	*millimeter*
NTU	*nephelometric turbidity unit*
Pa	*Pascal*
PPB	*parts per billion*
PPM	*parts per million*
s	*second*
TCU	*true color unit*
TON	*threshold odor number*
Y, y	*year*

EXECUTIVE SUMMARY

INTRODUCTION

CDM International Inc. (CDM Smith) was retained by the United States Agency for International Development (USAID) to undertake the USAID Jordan Water Infrastructure (the Project) for the purpose of improving the utilization of limited water resources in Jordan and bring about urgently needed enhancements to the water and wastewater systems.

The major components of the Project are summarized as follows:

- **Task 1** – Preparation of Detailed Design and Providing Services and Support for the Red Sea Dead Sea (RSDS) Conveyance Project – Phase II (Optional)
- **Task 2** – Construction Supervision – Shedeyyeh – Hasa Water Project Phase I
- **Task 3** – Detailed Engineering Design and Tender Documents for Expansion of Zai Water Treatment Plant Project
- **Task 4** – Feasibility Study, Design, and Tender Documents for Expansion of Madaba Wastewater Treatment Plant
- **Task 5** – Feasibility Study, Design, and Tender Documents for Expansion of Ramtha Wastewater Treatment Plant
- **Task 6** – Water and Wastewater Project for Deir Alla
- **Task 7** – Water and Wastewater Project for Bani Kenanah/Irbid Governorate
- **Task 8** – Technical Assistance to Water Utilities (Optional)
- **Task 9** – Assessment of Water/Wastewater Systems, Feasibility Studies, Designs, Tendering Support and Construction Management Services (Optional)

The purpose of this Water Quality Assessment Report is to provide an analysis of the water quality data for the existing Zai Water Treatment Plant (WTP) system, including raw water quality, treated finished water quality, and unit treatment process performance to provide recommendations on treatment process modifications, if required, to improve the ability of the Zai WTP to meet the Government of Jordan (GOJ) standards for drinking water and other key international standards. Results from this analysis will assist with the identification of potential options to upgrade, rehabilitate and provide reliability to the system for the future

RAW WATER QUALITY

The raw source water for the Zai water system is collected from the King Abdullah Canal (KAC) at an intake facility located at Deir Alla in the Jordan Valley. The Ministry of Health (MoH) has classified the KAC as Group 3 source water due to elevated levels of fecal coliform that suggests potential wastewater contamination. A review of KAC water quality data from 2015 to 2017 identified elevated levels of turbidity, total organic carbon (TOC), and fecal coliforms. The water treatment processes currently in use at the Zai WTP meet the requirements of the MoH for systems treating Group 3 source waters and appear capable of producing a finished water that meets current Jordanian Water Quality Standards (JWQS).

Periodically, the KAC experiences events of extreme water quality that are difficult to treat.

To address these events, Miyahuna has developed a series of standard operating procedures to respond to extreme KAC water quality events that include reducing WTP flow rates and/or stopping WTP operations, adjusting chemical feed within the intake pump station and the Zai WTP, and addition of ferric chloride with the KAC upstream of the Deir Alla intake.

A comparison of 2015 – 2017 KAC water quality to historical water quality data from a 2014 report, shows generally higher levels of turbidity and fecal coliforms in the more recent data, suggesting a potential increase in stormwater runoff that may be due to increased development activities within the watershed area.

TREATED WATER QUALITY

Results from periodic sampling of the treated finished water effluent from the Zai WTP for the three-year period from 2015 to 2017 demonstrate compliance with most of the regulated parameters of the JWQS standards for potable water. However, some of the results from the following parameters occasionally exceed the allowable JWQS standard or other industry guidance:

- Turbidity (complies with Jordan Drinking Water Standards (JDWS), but exceeds World Health Organization recommended levels)
- Nematodes
- Chlorine
- Chlorite

A detailed filter evaluation is recommended to identify upgrades to the filters and/or process control systems to lower the finished water turbidity and nematode levels. Upgrades to process controls should also be identified to improve compliance with chlorine and chlorite standards.

A comparison of 2015 – 2017 Zai WTP effluent water quality to historical water quality data from a 2014 report, shows generally higher levels of turbidity in the more recent data, indicating that the performance of the Zai filters has deteriorated in recent years.

SECTION 1 - **INTRODUCTION**

1.1 SUMMARY OF THE USAID JORDAN WATER INFRASTRUCTURE

CDM International Inc. (CDM Smith) was retained by the United States Agency for International Development (USAID) to undertake the USAID Jordan Water Infrastructure (the Project) for the purpose of improving the utilization of limited water resources in Jordan and bring about urgently needed enhancements to the water and wastewater systems.

Water and wastewater infrastructure improvements are needed throughout Jordan to alleviate water supply shortages, public health issues, and impacts on industry and the economy. The Project will serve as an umbrella contract for USAID/Jordan's water, wastewater, and environment sectors and will cover multiple tasks specifically designed to achieve the paired objectives of delivering needed water infrastructure and capacity building to the Water Authority of Jordan (WAJ) and water companies throughout Jordan.

The Project covers engineering infrastructure improvements identified by USAID in cooperation with the Ministry of Water and Irrigation (MWI), the Water Authority of Jordan (WAJ), public sector water companies such as Miyahuna, Yarmouk, and the Aqaba Water Company, the various municipalities, and the Ministry of Environment (MoE). The program provides engineering services to carryout assessments, studies and design and construction management for water, wastewater and environmental projects.

The major components of the Project are summarized as follows:

- **Task 1** - Preparation of Detailed Design and Providing Services and Support for the Red Sea Dead Sea (RSDS) Conveyance Project – Phase II (Optional)
- **Task 2** – Construction Supervision – Shedeyyeh – Hasa Water Project Phase I
- **Task 3** – Detailed Engineering Design and Tender Documents for Expansion of Zai Water Treatment Plant Project
- **Task 4** – Feasibility Study, Design, and Tender Documents for Expansion of Madaba Wastewater Treatment Plant
- **Task 5** - Feasibility Study, Design, and Tender Documents for Expansion of Ramtha Wastewater Treatment Plant
- **Task 6** – Water and Wastewater Project for Deir Alla
- **Task 7** - Water and Wastewater Project for Bani Kenanah/Irbid Governorate
- **Task 8** – Technical Assistance to Water Utilities (Optional)
- **Task 9** – Assessment of Water/Wastewater Systems, Feasibility Studies, Designs, Tendering Support and Construction Management Services (Optional)

1.2 BACKGROUND TO TASK 3 – EXPANSION OF THE ZAI WATER TREATMENT PLANT PROJECT

The purpose of this Water Quality Assessment Report is to provide an analysis of the water quality data for the existing Zai Water Treatment Plant (WTP) system, including raw water quality, treated finished water quality, and unit treatment process performance to provide recommendations on treatment process modifications, if required, to improve the ability of the Zai WTP to meet the GOJ standards for drinking water and other key international standards. Results from this analysis are proposed to be incorporated into the design of

improvements to the Zai WTP that is being conducted under the USAID Jordan Water Infrastructure Project Task 3.

As a result of a coordination meeting on 17 September 2018 with MWI/WAJ and USAID, MWI/WAJ advised that the two additional anticipated water quantities planned to be available in the KAC have not fully materialized to the point where additional water quantities would be available for expanding of the Zai water treatment system. MWI/WAJ advised that additional available water quantities will be used by the Wadi Arab II Project. Therefore, as agreed upon, there are currently no plans under Task 3 to expand the Zai water treatment system.

The plan under Task 3 is to complete the Zai Water Treatment System evaluation and water quality assessment with the intent to identify potential options to upgrade, rehabilitate and provide reliability to the system for the future.

1.2.1 Task 3 – Scope of Work

In addition to this Water quality assessment report, the Task 3 – scope of work will include the following deliverables:

- Existing Conditions and water quantity assessment report
- Options evaluation report to identify those options for potential implementation to upgrade, rehabilitate and provide reliability to the system for the future
- Environmental impact assessment based on the options report
- Based on agreement by USAID and MWI/WAJ to the preferred alternative, preparation of the design report and tender document will begin, geotechnical investigations will commence and confidential cost estimates will be developed.

1.2.2 Water Quality Assessment Activities

The activities carried out as part of the water quality assessment report are described as follows:

- Available water quality data from the KAC has been collected along with additional reports on water quality.
- Available data from the water treatment plant regarding both quantitative and qualitative influent and effluent were collected.
- A site visit by water treatment process staff to gather firsthand information on the facilities, to meet with Miyahuna's management and operation personnel and to gain insight into existing conditions and facility operations.

1.3 ACKNOWLEDGEMENTS

During preparation of this report, CDM received support and assistance from many individuals within MWI/WAJ and Miyahuna. CDM would wish to recognize the Secretary General of WAJ, the project coordinator, Bilal Al Sharif and Miyahuna coordinator, Haitham Kilani, the Zai WTP Manager, the Zai WTP Quality Manager, Majeda Ali Al Zoubi, and their staff for their support and assistance during the preparation of this study.

1.4 REPORT ORGANIZATION

The remainder of this report is organized as follows.

- Section 2 – Jordanian Water Quality Standards
- Section 3 – Raw Water Quality
- Section 4 – Treated Water Quality
- Appendix A - Wadi Arab Water System II – Water Quality Assessment Memorandum (2014)

SECTION 2 - **JORDANIAN WATER QUALITY STANDARDS**

2.1 INTRODUCTION

The governing standards for potable water quality within Jordan are the Jordan Water Quality Standards (JWQS), set forth by the Jordanian Institute for Standards and Metrology (JISM) published in 2008. These standards apply to water used for drinking, household, food industries, and ice making purposes. In addition, the Ministry of Health (MoH) defines minimum potable water treatment requirements for source waters depending upon their quality. The MoH defaults to World Health Organization (WHO) potable water treatment guidelines when the Jordanian standards are silent on a particular water quality item or treatment approach.

CDM met with Dr. Mohamad Al Abhadi of the MoH on 12 August 2018 to discuss the proposed rehabilitation of the Zai WTP, including any concerns that the MoH might have regarding the current operation of the Zai WTP and any pending regulation changes. Dr. Al Abhadi stated that since the ultraviolet light (UV) disinfection system was installed at the Zai WTP, the MoH is satisfied with the Zai WTP operation. The MoH confirmed that no changes were pending for the current regulations in print.

2.2 SOURCE WATER QUALITY CHARACTERIZATION

The MoH defines minimum potable treatment requirements for source waters of various quality. Source water resource areas are classified into four groups depending on the concentration of E. coli, turbidity, and pH. These classifications are summarized in Table 2-1.

The MoH classifications are based primarily on E. coli in raw water. E. coli is an indicator of wastewater contamination in which case, other protozoa such as *Giardia* and *Cryptosporidium* may also be present and pose a more significant health risk. Simple disinfection by chlorination may not be effective for these protozoa and thus filtration and UV disinfection may be appropriate as required by MoH.

Table 2-1 MoH Water Classification and Requirements for Source Waters

Water	Criteria	Treatment Required	Operations
Protected Groundwater			
Group 0	▪ Freeness of E. coli ▪ Turbidity <5 nephelometric turbidity unit (NTU) ▪ pH between 6.5 and 8.5	▪ None, chlorine disinfection and residual only	▪ Shutdown if raw water E. coli exceeds 50/100 megaliters (mL) ▪ Shutdown if 20% of raw water samples exceed 20/100 mL ▪ Shutdown If raw water turbidity > 5 NTU for 3 days of samples ▪ Shutdown if raw water pH outside of range for 3 days of samples
Unprotected Groundwater or Surface Water			
Group 1	▪ E. coli < 20/100 mL for > 20% of raw water samples ▪ No single raw water sample E. coli > 50/100 mL ▪ Turbidity < 5 NTU ▪ pH between 6.5 and 8.5	▪ None, chlorine disinfection and residual only	▪ Shutdown if raw water E. coli exceeds 50/100 mL ▪ Shutdown if 20% of raw water samples exceed 20/100 mL ▪ Shutdown If raw water turbidity > 5 NTU for 3 days of samples ▪ Shutdown if raw water pH outside of range for 3 days of samples
Group 2	▪ E. coli > 20/100 mL for > 20% of raw water samples ▪ pH and Turbidity as required by treatment processes	▪ 4-log (99.99%) Removal of viruses ▪ 3-log (99.9%) removal of *Giardia* and *Cryptosporidium* ▪ Must use rapid filtration, MF, UF, NF, RO or slow sand filtration with coagulation, mixing and sedimentation	▪ Shutdown if raw water E. coli exceeds 5,000/100 mL ▪ Shutdown if more than 20% of raw water samples exceed 2,000/100 mL
Group 3	▪ E. coli > 2,000/100 mL for > 20% of raw water samples ▪ pH and turbidity as required by treatment processes	▪ 5-log (99.999%) Removal of viruses ▪ 4-log (99.99%) removal of *Giardia* and *Cryptosporidium* ▪ Must use rapid filtration, microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), reverse osmosis (RO) or slow sand filtration with coagulation, mixing and sedimentation ▪ Must use UV disinfection	▪ Shutdown if raw water E. coli exceeds 20,000/100 mL

2.3 POTABLE WATER STANDARDS

2.3.1 Physical Characteristics of Drinking Water

Table 2-2 provides a list of Jordanian potable drinking water standards governing the physical characteristics of the treated water.

Table 2-2 JWQS Standards for Physical Characteristics of Drinking Water

Property	Allowable Maximum Level
Color	15 True Color Units (TCU)
Odor	Acceptable
Taste	Agreeable
Turbidity	5 NTU
Temperature	25 degrees C

2.3.2 Biological Characteristics of Drinking Water

Table 2-3 provides a list of Jordanian potable drinking water standards governing the biological characteristics of the treated water.

Table 2-3 JWQS Standards for Biological Characteristics of Drinking Water

Property	Allowable Maximum Level
Fecal Coliform	(See Note 1 below)
Total Coliform	(See Note 1 below)
Nematode	1 count/L (See Note 2 below)

Notes:

1. A 100 mL representative water sample must be free of:
   a. fecal coliform when using the filtration method or any other internationally approved method, and the number of the fecal coliform must be less than 1.1 when using the Most Probable Number (MPN) method.
   b. Heat-resistant fecal coliform rods or E. coli when using the filtration method or any other internationally approved method, and the number of the fecal coliform rods must be less than 1.1 when using the MPN method.
2. For parasites, drinking water must be free of all stages of the pathogenic parasites and infectious intestinal worms. For free living organisms (nematodes), the number of any stage of the free-living organisms (nematodes) should not exceed one living organism per liter.

2.3.3 Inorganic Chemical Substances

Table 2-4 provides a list of Jordanian potable drinking water standards governing the presence of inorganic chemical substances in treated water.

Table 2-4 JWQS Standards for Inorganic Chemical Substances in Drinking Water

Chemical Substance	Symbol	Allowable Maximum Concentration
Antimony	Sb	0.005 ppm
Arsenic	As	0.01 ppm
Barium	Ba	1.0 ppm
Boron	B	1.0 ppm
Cadmium	Cd	0.003 ppm

Chemical Substance	Symbol	Allowable Maximum Concentration
Chromium	Cr	0.05 ppm
Copper	Cu	1.0 ppm
Cyanide	CN	0.07 ppm
Fluoride	F	1.5 ppm
Lead	Pb	0.01 ppm
Manganese	Mn	0.1 ppm
Mercury	Hg	0.001 ppm
Molybdenum	Mo	0.07 ppm
Nickel	Ni	0.07 ppm
Nitrate	NO_3	50 ppm (70 ppm[1])
Nitrite	NO_2	2.0 ppm
Selenium	Se	0.01 ppm
Silver	Ag	0.1 ppm

Notes:

1. Higher level allowed if no other higher quality sources available.

2.3.4 Organic Pollutants and Pesticides

Table 2-5 and Table 2-6 provide lists of Jordanian potable drinking water standards governing the presence of select organic pollutants and pesticides in treated water.

Table 2-5 JWQS Standards for Organic Pollutants in Drinking Water

Chemical Substance	Allowable Maximum Concentration
Benzene	10 parts per billion (ppb)
Tetrachloroethylene (perchlorethylene [PCE])	40 ppb
Trichloroethylene (TCE)	20 ppb
Ethylbenzene	300 ppb
Total Xylene	700 ppb
Toluene	300 ppb

Table 2-6 JWQS Standards for Pesticides in Drinking Water

Chemical Substance	Allowable Maximum Concentration[1]
Endrin	2.0 ppb
Lindane	2.0 ppb
Heptachlor epoxide and Heptachlor	0.03 ppb
Aldrin	0.03 ppb
Dieldrin	0.03 ppb
2,4-D	90 ppb
2-4-5T	9.0 ppb
DDT	2.0 ppb

Notes:

1. Combined total of all listed organic pesticides must not exceed 100 ppb.

2.3.5 Disinfectants and Disinfection Byproducts

Table 2-7 provides a list of Jordanian potable drinking water standards governing the presence of disinfectants and disinfection byproducts in treated water.

Table 2-7 JWQS Standards for Disinfectants and Disinfection Byproducts in Drinking Water[1]

Chemical Substance	Allowable Maximum Concentration
Free Chlorine	When chlorine is used for disinfection, the water in the distribution network must include a free surplus of chlorine which must be no less than 0.2 mg/L at the end of the network. Additionally, it must not exceed 1.5 mg/L after a lapse of no less than 15 minutes from the addition of chlorine to the water. In any case, 15 minutes must elapse after the disinfection operation before the disinfected water reaches the first customer.
Total Trihalomethanes	0.15 ppm[1,2]
Chlorite	0.7 ppm
Chlorine Dioxide	0.4 ppm

Notes:

1. Total trihalomethanes are measured at the finished water and in the distribution system.
2. Total trihalomethanes for distribution system are averaged for the month and then compared to regulation number of 0.15 parts per million (ppm).

2.3.6 Radionuclides

Table 2-8 provides a list of Jordanian potable drinking water standards governing the presence of radionuclides in treated water.

Table 2-8 JWQS Standards for Radionuclides in Drinking Water

Substance	Allowable Maximum Concentration
Alpha Radionuclides excluding Radon	0.5 Becquerel/L
Beta Radionuclides excluding Tritium and Carbon 14	1 Becquerel/L

Notes:

1. If Alpha and Beta Radionuclides exceed the reference level for radioactive properties, an investigation of the type and source of the radionuclides should be conducted as well as an assessment of the health effects and to measure the level of exposure to radioactive materials so that it does not exceed 0.1 milliseverts/year for Beta radionuclides for each element.

2.3.7 Aesthetic Water Properties

Table 2-9 provides a list of Jordanian potable drinking water standards governing the aesthetic properties of the treated water along with requirements for sampling / monitoring frequencies.

Table 2-9 JWQS Standards for Aesthetic Properties of Drinking Water

Property	Maximum Level
Aluminum (Al)	0.1 ppm
Ammonium (NH_4)	0.2 ppm
Chemical Detergents (MBAS)	0.2 ppm
Chloride (Cl)	500 ppm
Iron (Fe)	1.0 ppm

Property	Maximum Level
pH	6.5 – 8.5
Sodium (Na)	200 ppm (300 ppm[1])
Sulfate (SO_4)	500 ppm
Total Dissolved Solids (TDS)	1000 ppm (1300 ppm[1])
Total Hardness	500 ppm as $CaCO_3$
Zinc (Zn)	4.0 ppm

Notes:

1. Higher level allowed if no other higher quality sources available.

SECTION 3 - **RAW WATER QUALITY**

3.1 INTRODUCTION

The raw source water for the Zai water system is collected from the King Abdullah Canal (KAC) at an intake facility located at Deir Alla in the Jordan Valley. Once collected, the raw source water is screened, treated with chlorine dioxide and/or potassium permanganate, and then conveyed through a series of pump stations, regulating reservoirs, and transmission mains to the Zai Water Treatment Plant.

3.2 RAW WATER QUALITY

The raw source water from the KAC is sampled regularly and analyzed for various water quality parameters. Results from this periodic sampling for the three-year period from 2015 to 2017 was provided by Miyahuna. Table 3-1 provides a summary of this recent historical water quality of the KAC source water. Most of the water quality parameters are within ranges that can be readily treated by conventional water treatment plant methods. However, periodic episodes of poor water quality result in elevated levels of turbidity and total organic carbon (TOC) that can be challenging to address.

3.2.1 Turbidity

Under most conditions, the KAC source water collected at the Deir Alla intake for the Zai water system can be characterized as a high-turbidity source. Figures 3-1 and 3-2 illustrate the reported intake turbidity for the period between 2015 to 2017. Throughout this period, the average turbidity was 74 NTU, and the 95th percentile turbidity was 150 NTU. During an extreme water quality events, the turbidity rose as high as 3000 NTU. These raw water turbidity levels negatively impact the coagulation and settling processes and also lead to increased requirements for sludge processing.

Table 3-1 Recent Water Quality for the KAC Source Water to the Zai WTP

Property	Units	Average	Minimum	Maximum
Physical Characteristics				
Color[1]	CU	<15	<15	39
Odor[1]	TON	12	8	12
Turbidity[2]	NTU	74	10	3000
Temperature[2]	Deg. C	23.7	11.5	33.0
Biological Characteristics				
Algae[3]	Units / mL	536	60	2920
Fecal Coliform[3]	MPN / 100mL	2348	45	9200
Nematodes - Live[3]	No. / L	0.03	None Detected	2
Nematodes - Dead[3]	No. / L	0.01	None Detected	1
Inorganic Chemical Substances				
Antimony[4]	PPB	< 3	< 3	< 3
Arsenic[4]	PPB	< 3	< 3	< 3
Barium[4]	PPM	0.54	0.25	0.94
Boron[4]	PPM	0.21	0.16	0.27
Cadmium[4]	PPB	< 0.2	< 0.2	< 0.25
Chromium[4]	PPB	3.1	< 2	4.1
Cobalt[4]	PPB	< 0.2	< 0.2	< 0.2
Copper[5]	PPM	< 0.15	< 0.15	< 0.15
Cyanide[4]	PPM	< 0.01	< 0.01	< 0.01
Fluoride[6]	PPM	0.47	< 0.2	0.81
Lead[4]	PPB	< 2	< 2	< 2
Manganese[5]	PPM	< 0.05	< 0.05	< 0.05
Mercury[4]	PPM	0.52	< 0.15	1.25
Molybdenum[4]	PPB	4.3	< 2	9.0
Nickel[4]	PPB	2.8	< 2	3.6
Nitrate[7]	PPM	4.9	1.0	14.0
Nitrite[6]	PPM	0.12	< 0.1	0.24
Potassium[4]	PPM	6.4	3.7	7.8
Selenium[4]	PPB	< 5	< 5	< 5
Silver[4]	PPB	< 2	< 1	< 2
Organic Pollutants and Pesticides				
Benzene[4]	PPB	< 8	< 8	< 10
PCE[4]	PPB	< 18	< 11	< 22
TCE[4]	PPB	< 18	< 13	< 38
Ethylbenzene[4]	PPB	< 18	< 8	< 19
Total Xylene[4]	PPB	< 22	< 8	< 38
Toluene[4]	PPB	<18	< 8	< 19
Endrin[8]	PPB	< 0.1	< 0.1	< 0.1
Lindane[8]	PPB	< 0.1	< 0.1	< 0.1
Heptachlor[8]	PPB	< 0.03	< 0.03	< 0.03
Aldrin[8]	PPB	< 0.03	< 0.03	< 0.03
Dieldrin[8]	PPB	< 0.03	< 0.03	< 0.03
2,4-D[8]	PPB	< 0.6	< 0.6	< 0.6

Property	Units	Average	Minimum	Maximum
2-4-5T[8]	PPB	< 0.3	< 0.3	< 0.3
DDT[8]	PPB	< 0.15	< 0.15	< 0.15
Radionuclides				
Alpha[9]	Bq / L	< 0.25	< 0.25	< 0.25
Beta[9]	Bq / L	< 0.5	< 0.5	< 0.5
Aesthetic Water Properties				
Aluminum[5]	PPM	0.03	< 0.01	< 0.1
Ammonium[10]	PPM	0.14	0.06	0.76
Bromide[11]	PPM	0.8	< 0.5	1.2
Chemical Detergents (MBAS)[11]	PPM	< 0.05	< 0.05	< 0.05
Chloride[6]	PPM	174	104	234
Dissolved Oxygen[2]	PPM	7.7	5.2	10.8
Electrical Conductivity[2]	µS / cm	1090	689	1336
Iron[6]	PPM	0.23	< 0.12	2.1
pH[2]		8.2	7.1	8.9
Phosphate[7]	PPM	0.14	0.04	0.38
Sodium[5]	PPM	103	85	115
Sulfate[6]	PPM	103	79	139
Total Alkalinity[12]	PPM as $CaCO_3$	194	156	244
Total Dissolved Solids (TDS)[6]	PPM	631	468	704
Total Hardness[13]	PPM as $CaCO_3$	274	252	307
Total Organic Carbon[3]	PPM	3.0	2.0	4.6
Zinc[5]	PPM	0.11	< 0.06	0.34

Notes:

1. Data Range: Grab samples taken weekly between January 2015 to December 2017
2. Data Range: Grab samples taken every two hours between January 2015 to December 2017
3. Data Range: Grab samples taken daily between January 2017 to December 2017
4. Data Range: Grab samples taken annually between January 2015 to December 2017
5. Data Range: Grab samples taken quarterly between January 2015 to December 2017
6. Data Range: Grab samples taken monthly between January 2015 to December 2017
7. Data Range: Grab samples taken daily between January 2015 to December 2017
8. Data Range: Grab samples taken every two years between January 2015 to December 2017
9. Data Range: Grab samples taken May 2015
10. Data Range: Grab samples taken every six hours between January 2015 to December 2017
11. Data Range: Grab samples taken every six months between January 2015 to December 2017
12. Data Range: Grab samples taken every four hours between January 2017 to December 2017
13. Data Range: Grab samples taken weekly between January 2017 to December 2017

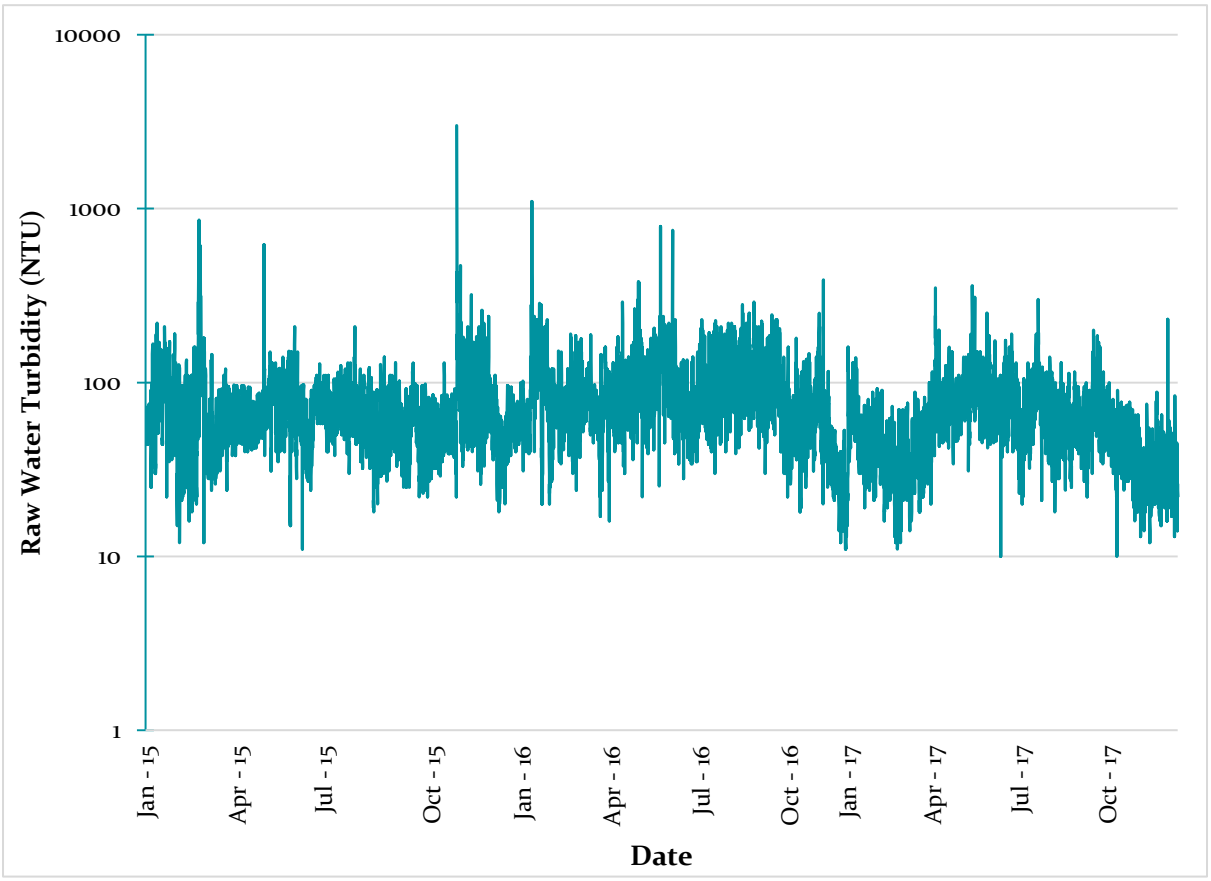

Figure 3-1 Zai WTP Raw Water Turbidity (2015 - 2017)

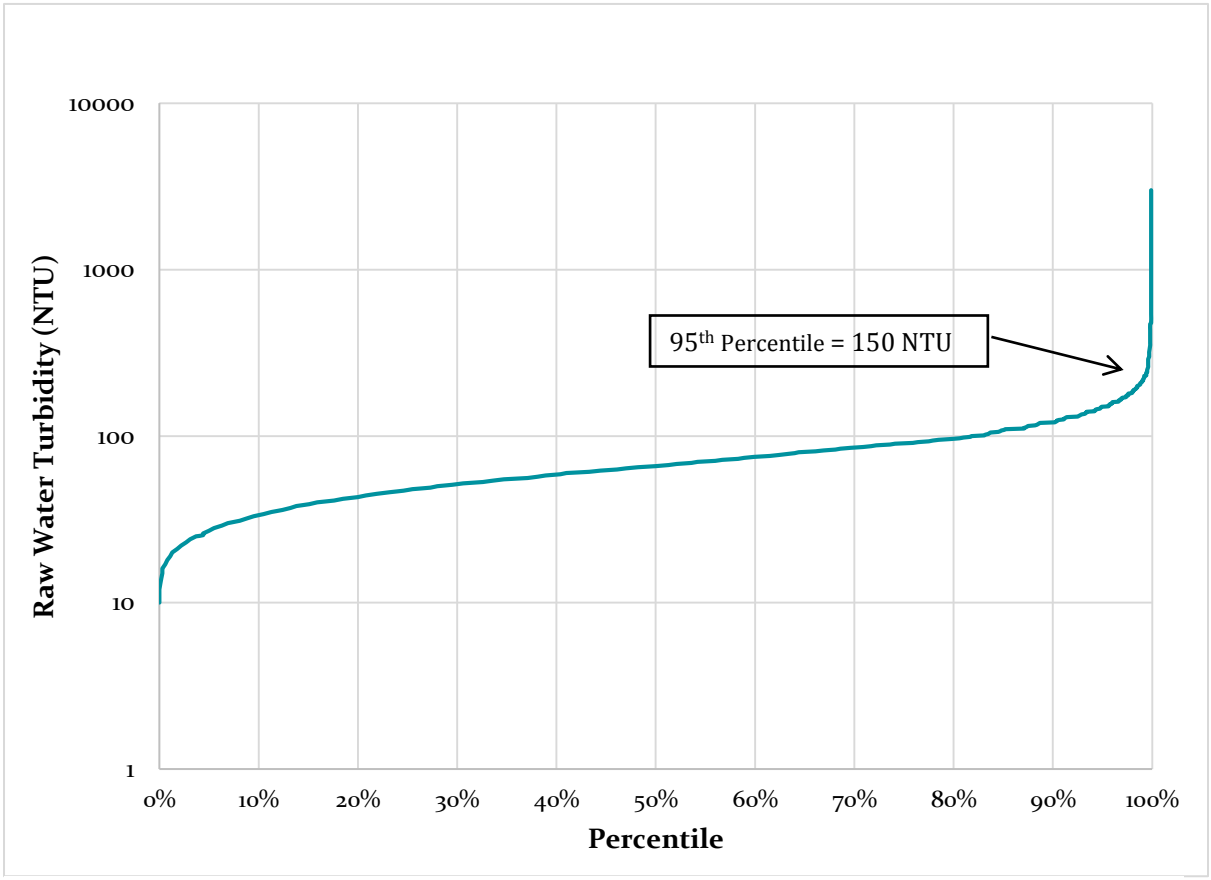

Figure 3-2 Zai WTP Raw Water Turbidity Percentile (2015 - 2017)

3.2.2 Total Organic Carbon

Under most conditions, the KAC source water can be characterized as having moderate levels of organic carbon. Figures 3-3 and 3-4 illustrate the reported raw water TOC levels for 2017. The raw water TOC ranged from 2.0 to 4.6 ppm in 2017, with an average level of 3.0 ppm. High levels of TOC can reduce the effectiveness of the coagulation process and can lead to the formation of excessive amounts of disinfection byproducts when chlorine is added for disinfection.

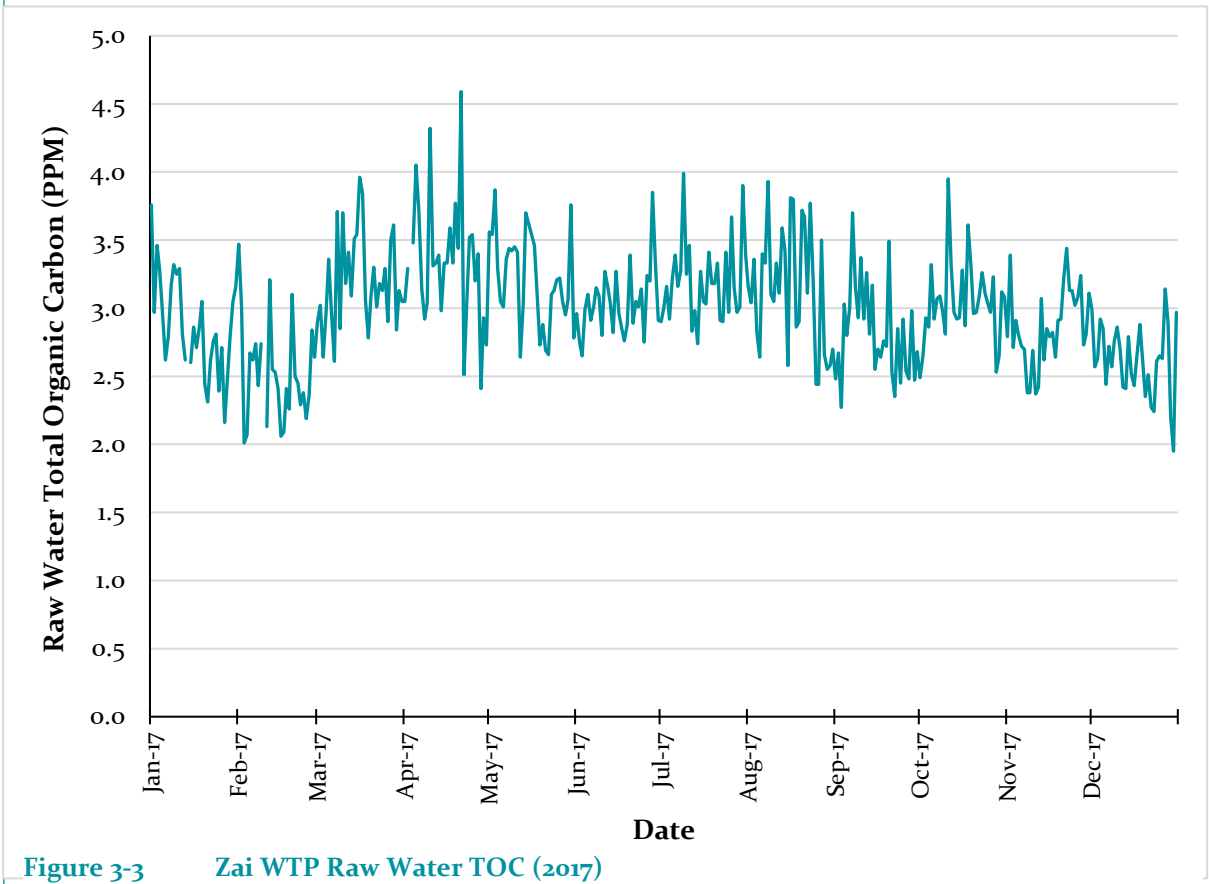

Figure 3-3 Zai WTP Raw Water TOC (2017)

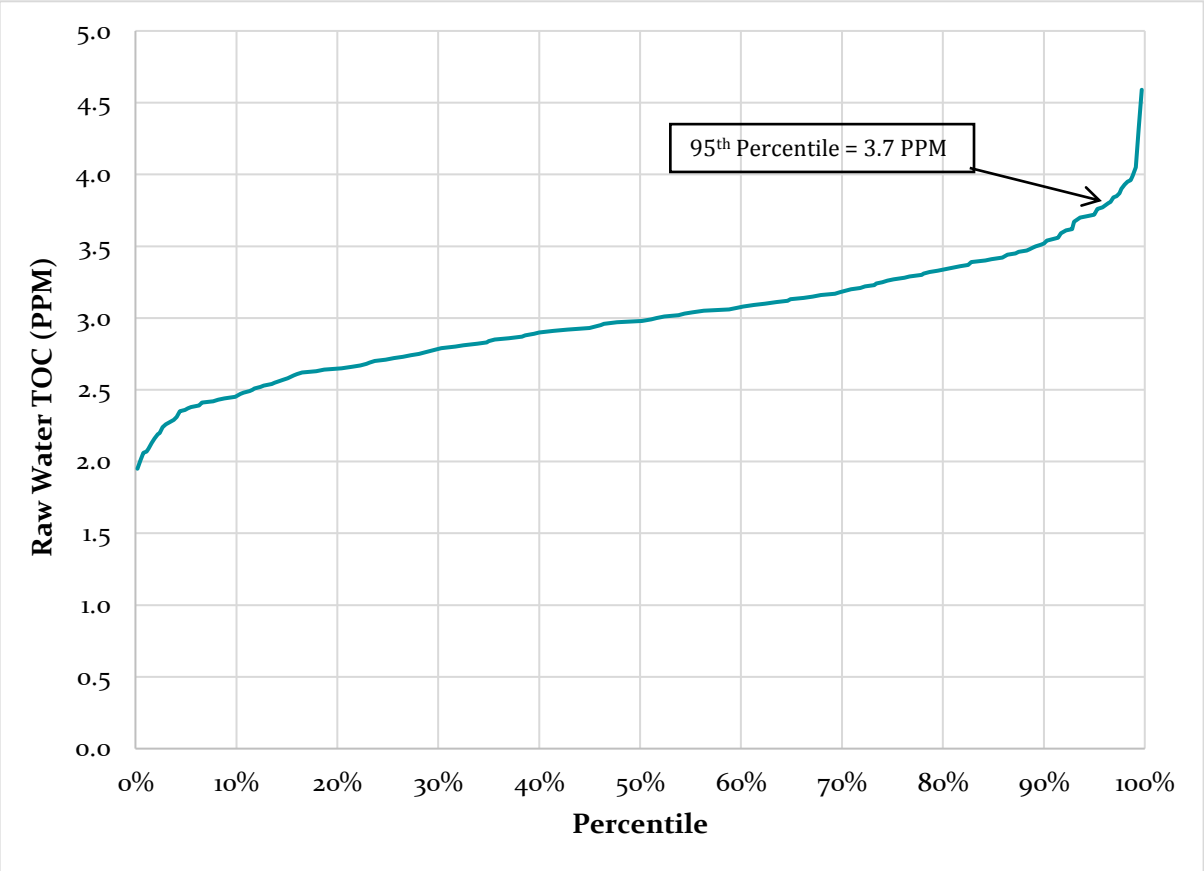

Figure 3-4 Zai WTP Raw Water TOC Percentile (2017)

3.2.3 Coliforms and MoH Source Water Classification

The MoH has classified the KAC as Group 3 source water since more than 20 percent of the raw water samples show fecal coliform numbers greater than 2000 per 100 mL. Figures 3-5 and 3-6 illustrate the reported raw water fecal coliform values for 2017. The high levels of coliforms are likely due to stormwater runoff from livestock grazing or from leaking cesspools or similar in the communities adjacent to the KAC.

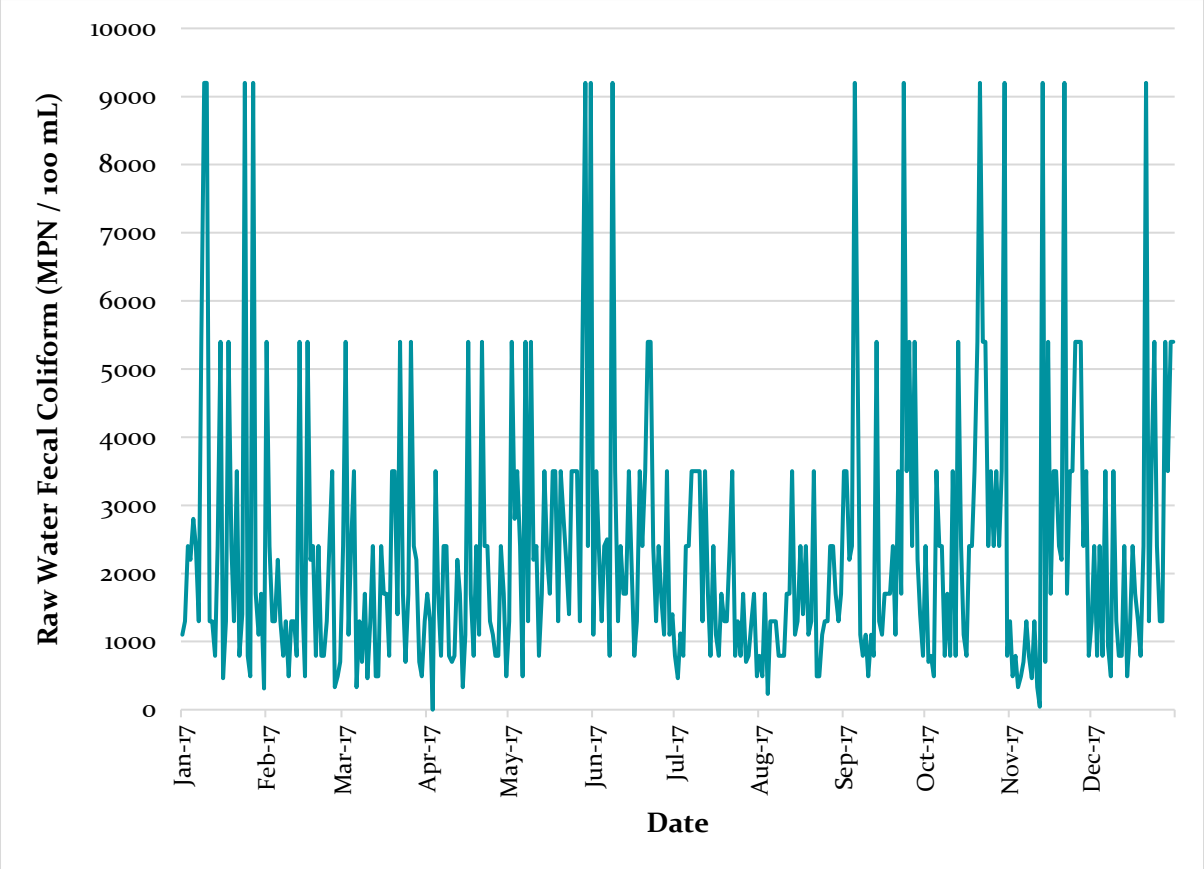

Figure 3-5 Zai WTP Raw Water Fecal Coliform Levels (2017)

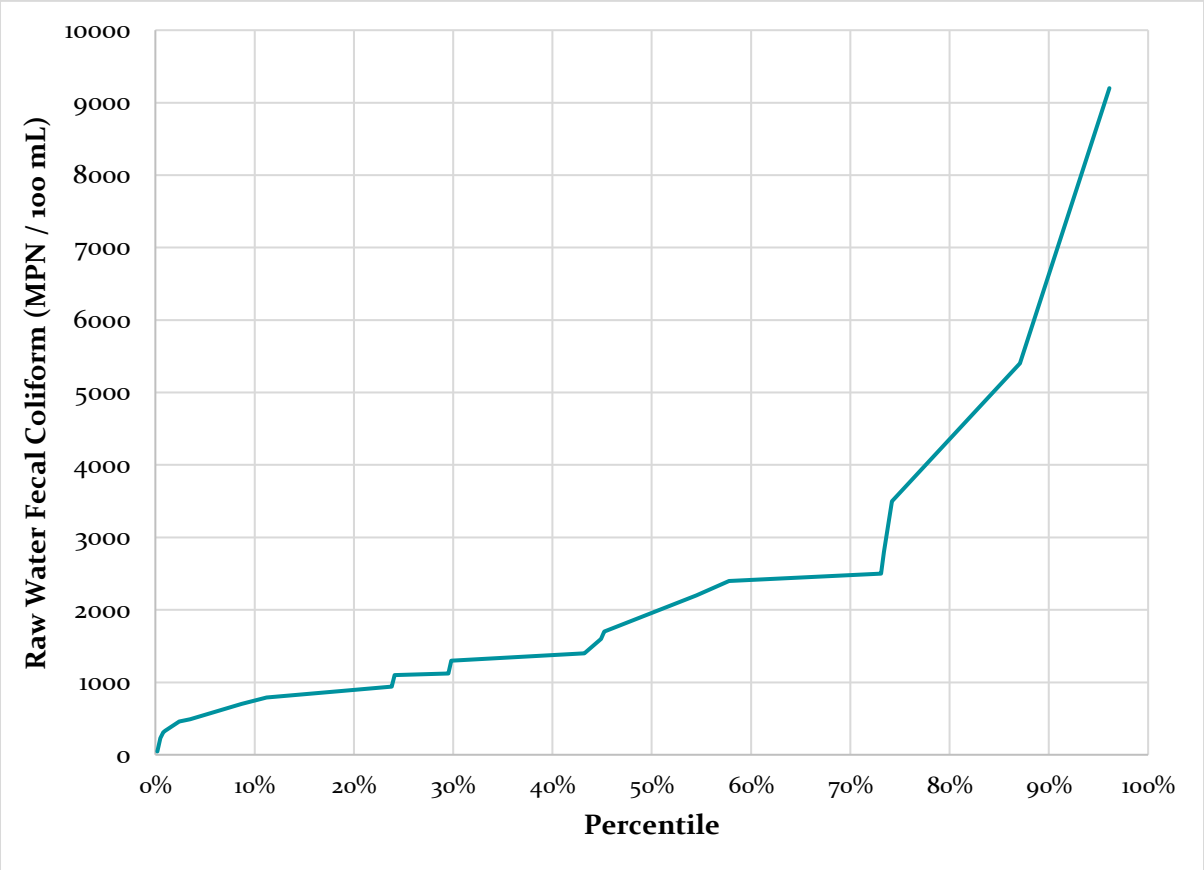

Figure 3-6 Zai WTP Raw Water Fecal Coliform Percentile (2017)

3.2.4 Applicable Water Treatment Processes

Under MoH requirements, potable water treatment systems that utilize a Group 3 source are required to provide the following minimum treatment requirements:

- 5-log (99.999%) removal of viruses
- 4-log (99.99%) removal of *Giardia* and *Cryptosporidium*
- Must use rapid filtration, MF, UF, NF, RO or slow sand filtration with coagulation, mixing and sedimentation
- Must use UV disinfection

The Zai water treatment plant utilizes coagulation, mixing, sedimentation, rapid media filtration, UV disinfection, and chlorine disinfection, and thus appears capable of meeting minimum treatment requirements dictated by the MoH. In addition, none of the KAC raw water quality data summarized in Table 3-1 indicates water quality parameters of concern at levels that would require different or additional water treatment processes to be used at the Zai WTP to comply with the JWQS standards.

3.2.5 Extreme Water Quality Events

Historically, the KAC has been susceptible to extreme water quality events, resulting from stormwater runoff and/or flushing of upstream water supply channels, that include very high raw water turbidity levels and TOC concentrations that make the raw water difficult to treat. In a 2005 report by CDM Smith exploring alternative treatment technologies for the KAC, a maximum turbidity of 32,775 NTU was reported as was a maximum TOC of 42 mg/L. Miyahuna has developed a series of standard operating procedures (SOP) to respond to extreme KAC water quality events, such as high levels of raw water turbidity, algae, phosphate, nematodes, or ammonia. Measures that may be taken to respond to extreme water quality events include: reducing WTP flow rates and/or stopping WTP operations, adjusting chemical feed within the intake pump station and the Zai WTP, and addition of ferric chloride with the KAC upstream of the Dier Alla intake.

During the years 2015 – 2017, operation of the Zai water system was impacted by several episodes of extreme raw water quality, as shown in Table 3-2.

Table 3-2 Impact of KAC Extreme Water Quality Events on the Zai Water System

Dates	KAC Water Quality	Zai Water System Response
21-22 February 2015	Reported maximum raw water turbidity of 860 NTU.	Pumping rate to Zai WTP reduced.
26-28 October 2015	Reported maximum raw water turbidity of 3000 NTU.	Pumping rate to Zai WTP reduced.
10-12 January 2016	Reported maximum raw water turbidity of 1100 NTU.	Pumping rate to Zai WTP reduced.
3 April 2017	Reported maximum raw water turbidity of 350 NTU.	Pumping rate to Zai WTP reduced.

3.2.6 Comparison to Historical KAC Water Quality

In preparation for the Wadi Arab II WTP, CDM prepared a Water Quality Assessment and Treatment Process Technical Memorandum (June 2014) that presented summaries of KAC raw

water quality from May 2011 through April 2014. Excerpts from this technical memorandum are included in Appendix A. Many of the water quality parameters of this historical data are similar to the current data (e.g., pH, total alkalinity, TDS, total hardness). The range of TOC levels reported for the KAC in 2017 are slightly lower than the levels reported in 2011 to 2014. However, the turbidity and fecal coliform levels in the recent data are higher than was reported in the Wadi Arab II WTP report. This suggests that the KAC may be more susceptible to stormwater runoff, possibly due to increased development activities within the watershed area.

SECTION 4 - **TREATED WATER QUALITY**

4.1 INTRODUCTION

The Zai WTP is a conventional treatment process that was originally commissioned in 1985 and has been expanded and upgraded several times since then. The following major water treatment processes are currently utilized at the Zai WTP:

- Raw water screening
- Pre-oxidation with chlorine dioxide and/or potassium permanganate
- Pre-sedimentation grit removal
- Powdered activated carbon adsorption
- Chlorite control using ferrous sulfate (reductant)
- Coagulation with ferric sulfate and cationic polymer
- Rapid mixing, flocculation, sedimentation
- Rapid dual-media filtration
- UV disinfection
- Chlorine disinfection

4.2 TREATED WATER QUALITY

The treated finished water from the Zai WTP is regularly sampled and analyzed for various water quality parameters. Results from this periodic sampling for the three-year period from 2015 to 2017 was provided by Miyahuna. Table 4-1 provides a summary of recent historical water quality of the Zai WTP effluent.

Table 4-1 Recent Treated Water Quality of the Zai WTP Effluent

Property	Units	Average	Minimum	Maximum	JWQS Standard
Physical Properties					
Color[1]	TCU	< 15	< 15	< 15	15
Odor[1]	TON	NO	NO	NO	N/A
Turbidity[2]	NTU	0.26	0.10	0.84	5
Biological Properties					
Total Coliform[3]	CFU / 100mL	< 1	< 1	< 1	<1.1
Nematodes - Live[4]	No. / L	0.1	None Detected	**6**	1
Nematodes - Dead[4]	No. / L	0.6	None Detected	21	N/A
Cryptosporidium[6]	No. / L	None Detected	None Detected	None Detected	None Detected
Giardia[6]	No. / L	None Detected	None Detected	None Detected	None Detected

Property	Units	Average	Minimum	Maximum	JWQS Standard
Inorganic Chemical Substances					
Antimony[5]	PPB	< 3	< 3	< 3	5
Arsenic[5]	PPB	< 3	< 3	< 3	10
Barium[5]	PPM	0.18	0.15	0.21	1.0
Boron[5]	PPM	0.19	0.15	0.22	1
Cadmium[5]	PPB	< 0.2	< 0.2	< 0.25	3
Chromium[5]	PPB	< 2	< 2	< 2	50
Cobalt[5]	PPB	< 0.2	< 0.2	< 0.2	N/A
Copper[6]	PPM	< 0.15	< 0.15	< 0.15	1.0
Cyanide[5]	PPM	< 0.01	< 0.01	< 0.05	0.07
Fluoride[7]	PPM	0.46	0.24	0.74	1.5
Lead[5]	PPB	< 2	< 2	< 2	10
Manganese[6]	PPM	< 0.05	< 0.05	< 0.05	0.10
Mercury[5]	PPB	0.19	<0.15	0.27	1
Molybdenum[5]	PPB	6.6	3.6	8.5	70
Nickel[5]	PPB	4.0	< 2	8.0	70
Nitrate[2]	PPM	5.8	1.8	12.8	50
Nitrite[7]	PPM	< 0.1	< 0.1	0.11	2.0
Potassium[5]	PPM	6.7	3.8	8.4	N/A
Selenium[5]	PPB	< 5	< 5	< 5	10
Silver[5]	PPB	< 1	< 1	< 2	100
Organic Pollutants and Pesticides					
Benzene[5]	PPB	< 8	< 8	< 10	10
PCE[5]	PPB	< 18	< 11	< 22	40
TCE[5]	PPB	< 18	< 13	< 38	20
Ethylbenzene[5]	PPB	< 18	< 8	< 19	300
Total Xylene[5]	PPB	< 22	< 8	< 38	700
Toluene[5]	PPB	<18	< 8	< 19	300
Endrin[8]	PPB	< 0.1	< 0.1	< 0.1	2
Lindane[8]	PPB	< 0.1	< 0.1	< 0.1	2
Heptachlor[8]	PPB	< 0.03	< 0.03	< 0.03	0.03
Aldrin[8]	PPB	< 0.03	< 0.03	< 0.03	0.03
Dieldrin[8]	PPB	< 0.03	< 0.03	< 0.03	0.03
2,4-D[8]	PPB	< 0.6	< 0.6	< 0.6	90
2-4-5T[8]	PPB	< 0.3	< 0.3	< 0.3	9.0
DDT[8]	PPB	< 0.15	< 0.15	< 0.15	2
Disinfectants and Disinfection Byproducts					
Free Chlorine[2]	PPM	1.47	1.34	**1.58**	1.5
THMs[4]	PPB	50	19	103	150
Chlorite[9]	PPM	0.59	0.13	**0.98**	0.7
Radionuclides					
Alpha[10]	Bq / L	< 0.25	< 0.25	< 0.25	0.5
Beta[10]	Bq / L	< 0.61	< 0.61	< 0.61	1.0
Aesthetic Water Properties					
Aluminum[6]	PPM	< 0.01	< 0.01	< 0.01	0.1

Property	Units	Average	Minimum	Maximum	JWQS Standard
Ammonium[1]	PPM	< 0.1	< 0.1	< 0.1	0.2
Bromide[11]	PPM	0.53	< 0.25	0.92	N/A
Chemical Detergents (MBAS)[11]	PPM	< 0.05	< 0.05	< 0.05	0.2
Chloride[7]	PPM	177	113	226	500
Dissolved Oxygen[12]	PPM	6.9	5.0	10.1	N/A
Iron[7]	PPM	< 0.15	< 0.15	< 0.15	1
pH[12]		7.4	6.7	8.0	6.5 – 8.5
Phosphate[1]	PPM	< 0.1	< 0.1	< 0.1	N/A
Sodium[6]	PPM	108	87	123	200
Sulfate[7]	PPM	177	113	226	500
Total Alkalinity[12]	PPM as $CaCO_3$	162	131	207	N/A
Total Dissolved Solids[7]	PPM	632	511	729	1000
Total Hardness[2]	PPM as $CaCO_3$	280	250	308	500
TOC[4]	PPM	1.7	1.1	2.2	N/A
TOC Removal	Percent	44%	15%	62%	N/A
Zinc[6]	PPM	< 0.06	< 0.06	< 0.06	4

Notes:

1. Data Range: Grab samples taken daily between January 2015 to December 2017
2. Data Range: Grab samples taken daily between January 2017 to December 2017
3. Data Range: Grab samples taken every six hours between January 2015 to December 2017
4. Data Range: Grab samples taken twice daily between January 2017 to December 2017
5. Data Range: Grab samples taken annually between January 2015 to December 2017
6. Data Range: Grab samples taken quarterly between January 2015 to December 2017
7. Data Range: Grab samples taken monthly between January 2015 to December 2017
8. Data Range: Grab samples taken every two years between January 2015 to December 2017
9. Data Range: Grab samples taken every six hours between January 2017 to December 2017
10. Data Range: Grab samples taken May 2015
11. Data Range: Grab samples taken every six months between January 2015 to December 2017
12. Data Range: Grab samples taken every four hours between January 2017 to December 2017

4.3 WATER TREATMENT PLANT PERFORMANCE

The water quality data in Table 4-1 shows the Zai WTP complies with most of the regulated parameters. However, a few of the parameters appear to occasionally exceed the maximum allowable standard or other industry guidance. These are discussed further below.

4.3.1 Turbidity

While the effluent filter turbidity levels (daily averages) are less than the maximum allowable value of 5 NTU, they do not comply with World Health Organization (WHO) recommendations or current industry best practice guidelines. The Zai WTP effluent finished water turbidity levels (average daily) from 2017 are shown in Figure 4-1. The WHO recommends filter effluent turbidity levels to be less than 0.3 NTU 95 % of the time. The 95th percentile effluent turbidity level for the Zai WTP in 2017 was 0.44 NTU which is 46% above the WHO recommendations, as shown in Figure 4-2. It is recommended that a detailed filter evaluation be conducted to identify the cause of the less than optimal filter performance. It is also recommended that the Zai WTP resume the use of filter-aid-polymer to improve filter performance.

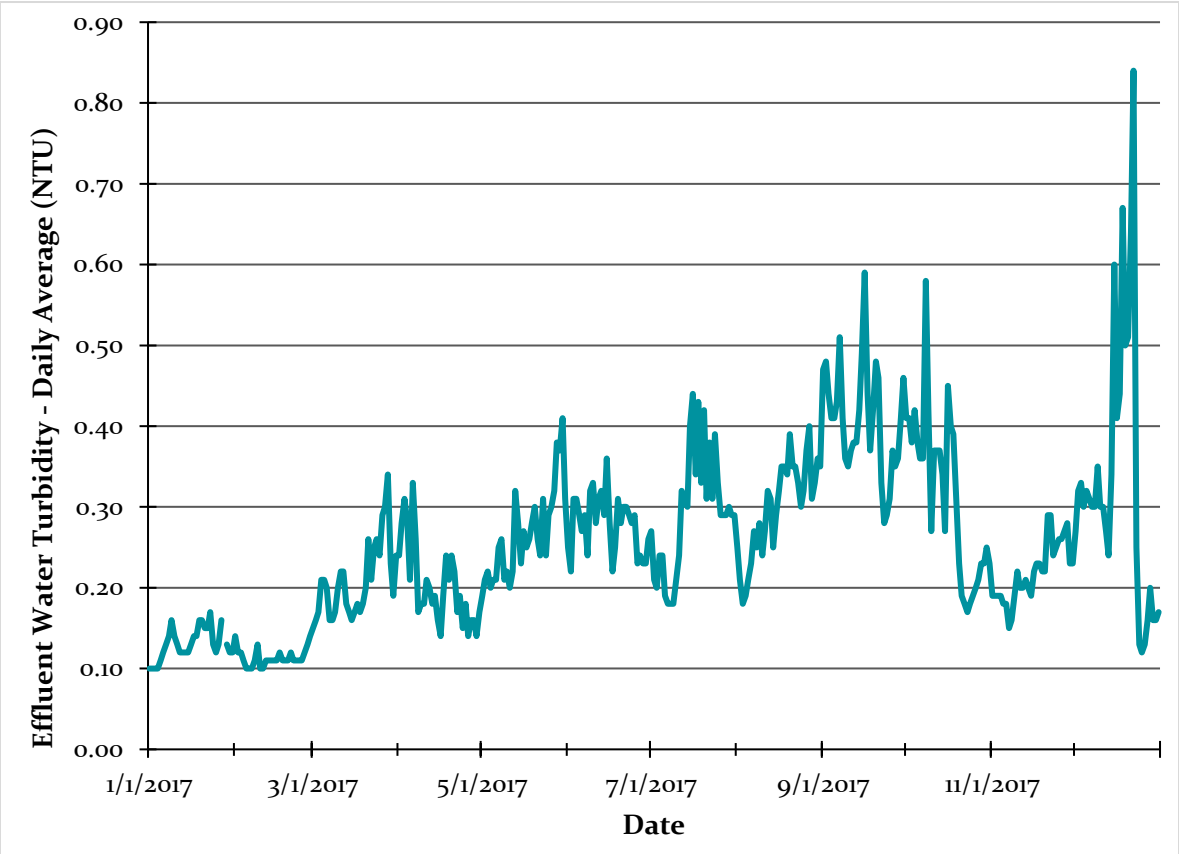

Figure 4-1 Zai WTP Average Daily Effluent Water Turbidity (2017)

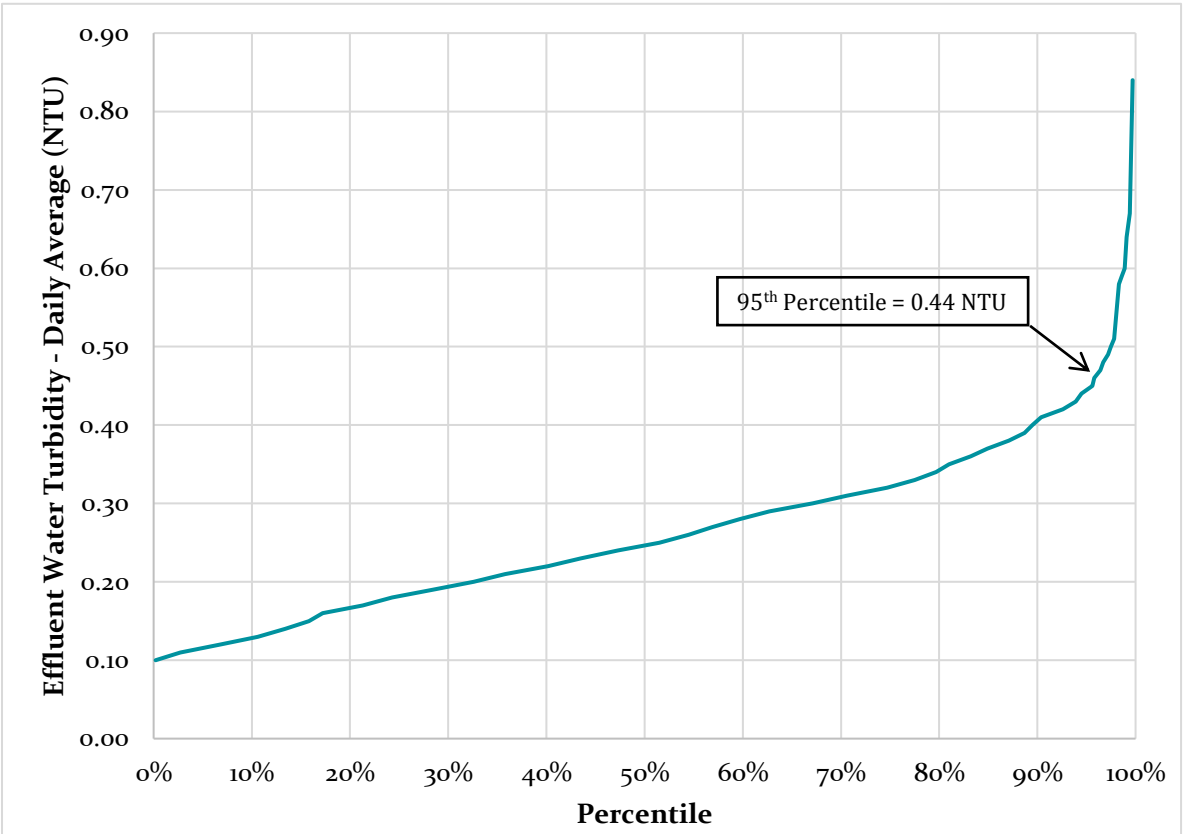

Figure 4-2 Zai WTP Average Daily Effluent Water Turbidity Percentile (2017)

4.3.2 Nematodes

Levels of live nematodes that exceed the Jordanian standard (greater than 1 per L) were reported in the effluent water on several dates in 2017. Since many times the number of live nematodes reported within the effluent water exceed those reported in the raw water, it appears that there may be colonies of nematodes reproducing within the Zai WTP basins. More frequent basin cleaning is recommended. In addition, improvements to the filtration process, described above, may also be effective at improving the control of nematode levels in the effluent water.

4.3.3 Chlorine

Free chlorine is used as a primary disinfectant in the Zai WTP as well as a residual disinfectant within the finished water transmission and distribution piping. Finished water chlorine levels are fairly consistent, ranging from a minimum of 1.34 ppm to a maximum of 1.58 ppm. The maximum residual chlorine levels are a little greater than the maximum JWQS standard of 1.5 ppm, although this is below the WHO health-based maximum guideline of 5 ppm. Chlorine levels must be controlled by reducing the chlorine feed rate for the plant.

4.3.4 Chlorite

Chlorite is a byproduct of the application of chlorine dioxide as a pre-oxidant at the intake pump station in Deir Alla. Chlorite levels can be reduced by reducing the dose of chlorine dioxide or by increasing the dose of ferrous sulfate reductant. Table 4-2 illustrates that the

Zai WTP is capable of controlling the chlorine concentration in the effluent water and was effective at keeping the level below the regulatory limit of 0.7 ppm for most of the time.

Table 4-2 Chlorite Concentrations in the Zai Water System (2017)

	Chlorite Concentration	
	Influent to Zai WTP (leaving Raw Water Pipeline)	Effluent from Zai WTP
Average	1.10 PPM	0.59 PPM
Maximum	1.65 PPM	0.98 PPM
95th Percentile	1.32 PPM	0.69 PPM
Minimum	0.34 PPM	0.13 PPM

4.3.5 Total Organic Carbon

The treatment processes used in the Zai WTP are effective at achieving a significant reduction of TOC from the source water. The TOC in the effluent water averaged 1.7 ppm in 2017, constituting an average TOC removal of 44 %. Figure 4-3 shows the effluent water TOC levels for 2017. Figure 4-4 shows the percent TOC removal percentile achieved by the Zai WTP in 2017.

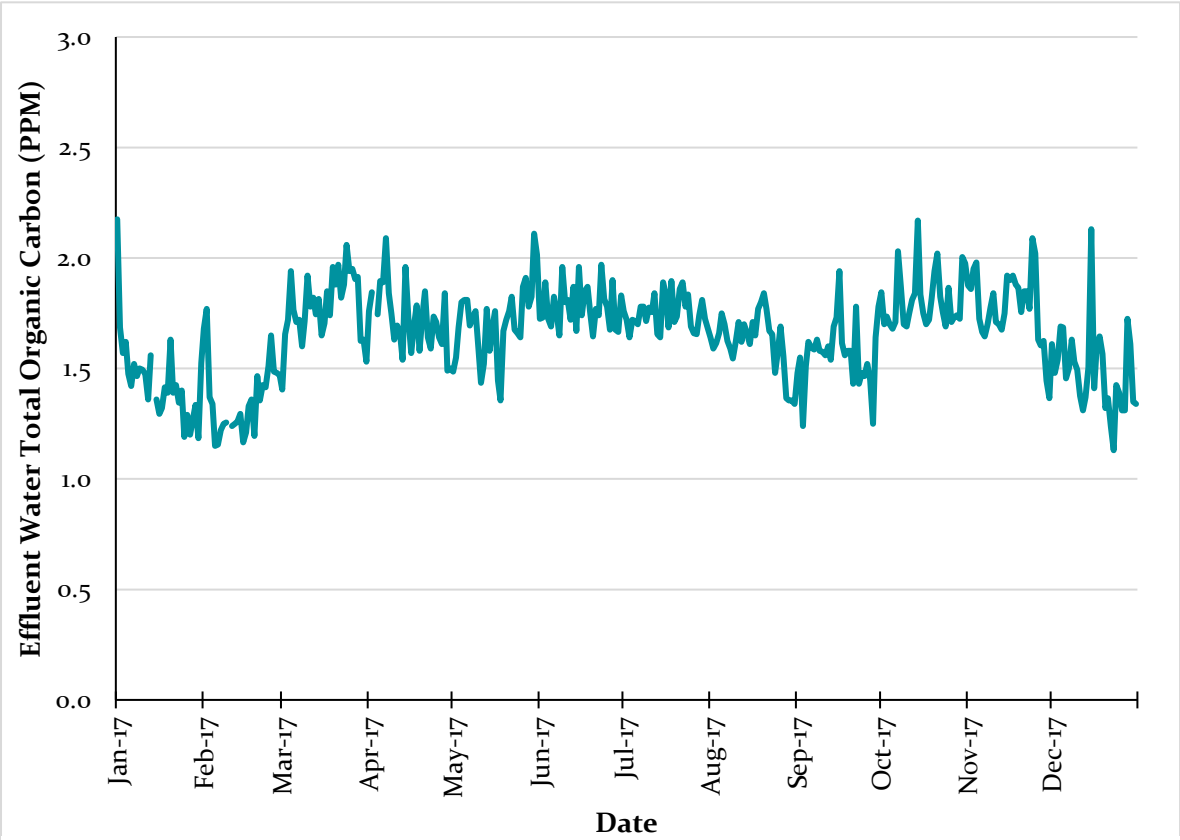

Figure 4-3 Zai WTP Effluent Water TOC (2017)

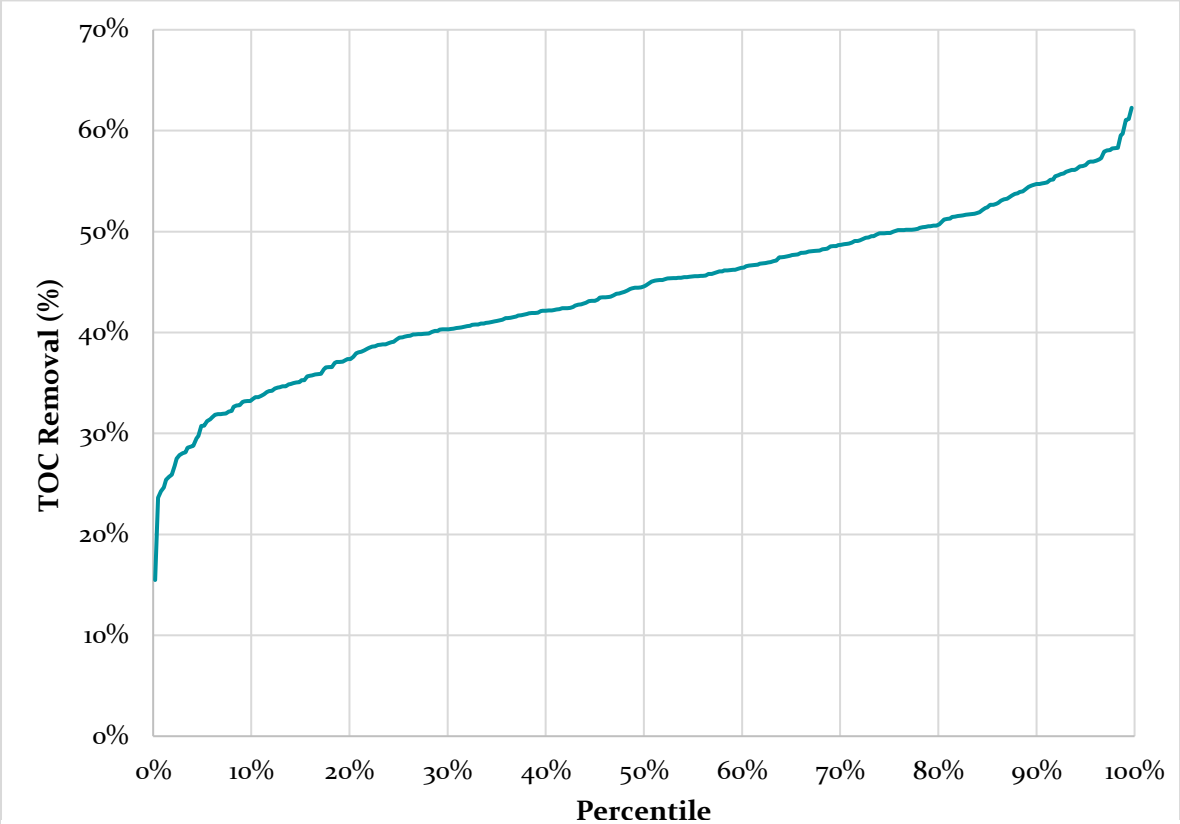

Figure 4-4 Zai WTP TOC Removal Percentile (2017)

4.3.6 Trihalomethanes

The TOC removal achieved in the Zai WTP provides an important mechanism to control the formation of disinfection byproducts, such as trihalomethanes (THMs). THMs are produced through the interaction of chlorine with TOC in water. THMs form within the water treatment process and also continue to form in the water conveyance and distribution system. Figure 4-5 shows the trihalomethane levels in the effluent water for 2017. There is a strong seasonal trend in the formation of the THMs which can be mostly attributed to water temperature which has a major impact on the rate of THM formation. The highest THM levels are seen in the summer when the water is the warmest.

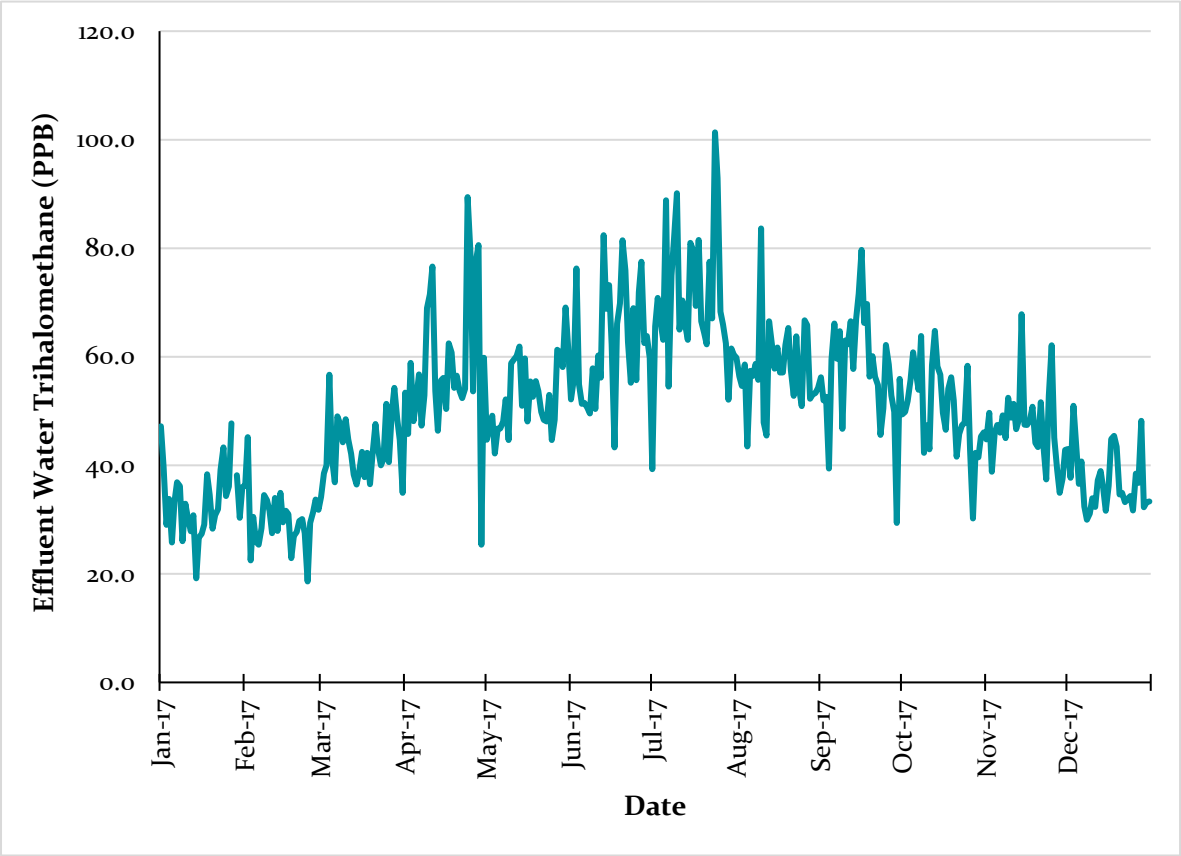

Figure 4-5 Zai WTP Effluent Water Trihalomethane Levels (2017)

4.3.7 Applicable Water Treatment Processes

The treated finished water quality of the Zai WTP complies with most JWQS standards and industry guidance. A detailed filter evaluation is recommended to identify upgrades to the filters and/or process control systems to lower the finished water turbidity and nematode levels. Upgrades to process controls should also be identified to improve compliance with chlorine and chlorite standards.

4.3.8 Comparison to Historical Zai WTP Water Quality

In preparation for the Wadi Arab II WTP, CDM Smith prepared a Water Quality Assessment and Treatment Process Technical Memorandum (June 2014) that presented summaries of Zai WTP effluent water quality from May 2011 through April 2014. Excerpts from this technical memorandum are included in Appendix A. Many of the water quality parameters of this historical data are similar to the current data, however, the effluent turbidity levels in the recent data are higher than this earlier data, indicating that the performance of the Zai filters has deteriorated in recent years.

APPENDIX A

WADI ARAB WATER SYSTEM II – WATER QUALITY ASSESSMENT MEMORANDUM (2014)

APPENDIX A - WADI ARAB WATER SYSTEM II – WATER QUALITY ASSESSMENT MEMORANDUM (2014)

The Wadi Arab Water System II – Water Quality Assessment and Treatment Process Selection Technical Memorandum (June 2014) presented summaries of KAC raw water quality and Zai WTP effluent water quality from May 2011 through April 2014. The following are excerpts of data from this technical memorandum.

A.1 DEIR ALLA RAW WATER QUALITY

Table A-1 KAC Raw Water Statistics at Deir Alla from May 2011 through April 2014

Property	Units	Average	Minimum	Maximum
Physical Characteristics				
Odor	TON	12	8	17
Turbidity	NTU	42	10	1224
Temperature	Deg. C	22	14	28
Biological Characteristics				
Fecal Coliform	MPN / 100mL	1865	23	24196
Nematodes – Live	No. / L	N/A	None Detected	22
Nematodes – Dead	No. / L	N/A	None Detected	9
Inorganic Chemical Substances				
Nitrate	PPM	4.5	0.5	17.1
Nitrite	PPM	0.08	0.03	0.12
Aesthetic Water Properties				
Aluminum	PPM	0.067	0.020	0.289
Bromide	PPM	0.71	0.25	1.14
pH		8.19	7.71	8.5
Total Alkalinity	PPM as $CaCO_3$	191	139	275
Total Dissolved Solids (TDS)	PPM	632	302	716
Total Hardness	PPM as $CaCO_3$	277	156	358
Total Organic Carbon	PPM	3.18	1.48	6.24

A.2 ZAI EFFLUENT WATER QUALITY

Table A-2 Zai WTP Finished Water Quality Statistics from May 2011 through April 2014

Property	Units	Average	Minimum	Maximum	JWQS Standard
Physical Properties					
Color	TCU	< 15	< 15	< 15	15
Odor	TON	0.01	No Odor	12	N/A
Temperature	Deg. C	25	13	33	25
Turbidity	NTU	0.16	0.06	0.44	5
Biological Properties					
Total Coliform	CFU / 100mL	< 1	< 1	< 1	<1.1
Nematodes - Live	No. / L	N/A	None Detected	4	1

Property	Units	Average	Minimum	Maximum	JWQS Standard
Nematodes - Dead	No. / L	N/A	None Detected	8	N/A
Cryptosporidium	No. / L	None Detected	None Detected	None Detected	None Detected
Giardia	No. / L	None Detected	None Detected	None Detected	None Detected
Inorganic Chemical Substances					
Nitrate	PPM	4.1	1	13	50
Nitrite	PPM	0.08	0.03	0.1	2.0
Organic Pollutants and Pesticides					
Benzene	PPB	< 8	< 8	< 8	10
PCE	PPB	< 22	< 22	< 22	40
TCE	PPB	< 18	< 18	< 18	20
Ethylbenzene	PPB	< 18	< 18	< 18	300
Total Xylene	PPB	< 38	< 38	< 38	700
Toluene	PPB	< 19	< 19	< 19	300
Endrin	PPB	< 0.1	< 0.1	< 0.1	2
Lindane	PPB	< 0.1	< 0.1	< 0.1	2
Heptachlor	PPB	< 0.03	< 0.03	< 0.03	0.03
Aldrin	PPB	< 0.03	< 0.03	< 0.03	0.03
Dieldrin	PPB	< 0.03	< 0.03	< 0.03	0.03
DDT	PPB	< 0.15	< 0.15	< 0.15	2
Disinfectants and Disinfection Byproducts					
Free Chlorine	PPM	1.5	1	1.8	1.5
THMs	PPB	31	8	92	150
Chlorite	PPM	0.61	0.36	1.07	0.7
Radionuclides					
Alpha	Bq / L	< 0.25	< 0.25	< 0.25	0.5
Beta	Bq / L	< 0.59	< 0.59	< 0.59	1.0
Aesthetic Water Properties					
Aluminum	PPM	0.0036	< 0.00001	0.0177	0.1
Ammonium	PPM	0.05	0.04	0.06	0.2
Chemical Detergents (MBAS)	PPM	< 0.05	< 0.05	< 0.05	0.2
Chloride	PPM	170	58	227	500
Iron	PPM	< 0.12	< 0.12	< 0.12	1
pH		7.3	7.0	7.7	6.5 – 8.5
Sulfate	PPM	96	52	145	500
Total Dissolved Solids	PPM	613	350	726	1000
Total Hardness	PPM as $CaCO_3$	277	166	342	500
TOC	PPM	1.88	0.27	3.51	N/A