ICR TREATMENT STUDY SUMMARY REPORT

Evaluation of Membrane Technology Using the Pilot/Full Scale Test For Compliance with the Information Collection Rule

Conducted during the period from March 1, 1998 through March 31, 1999.

Prepared by
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In June 1999
For
Palm Beach County, PWSID # FL4501047
2065 Prairie Road
West Palm Beach, FL 33406

Water Treatment Plant No. 3 FCR #310

Attachments: _____ diskettes containing the Data Collection Spreadsheets and Summary Report Spreadsheets QA/QC.

SECTION I - CONCLUSIONS AND RECOMMENDATIONS

During the testing period, our staff had the opportunity to gather an extensive amount of data pertaining to the use of membrane softening technology at a full scale water treatment facility. This plant was designed for the removal precursors found in the ground water source to achieve regulatory compliance with Stage1 and Stage 2 Disinfection/ Disinfection By-Product (D/DBP) requirements.

Based on the collected data, it is concluded that this technology is very effective for the removal of contaminants such as precursors, total organic carbon, chlorinated hydrocarbon compounds, bromide, total hardness and alkalinity by as much as 98%.

The chlorine demand was significantly reduced and the formation of D/DBPs found in the distribution system were consistently maintained at levels that meet future regulation proposed maximum contaminate levels. The SDS samples demonstrated that even with free chlorine residuals regulation MCLs would be achievable.

The only operational problem encountered during the testing was the unusual amount of sand produced by the production wells. This sand was effectively removed with the use of cartridge filters prior to membrane softening treatment.

SECTION II – BACKGROUND INFORMATION

Palm Beach County Water Utilities was approved to conduct the ICR treatment study requirement by using full scale operational data collected from an existing 9.3 MGD membrane softening plant (WTP 3). A summary of the original design and its components is presented in *Table 1*.

Table 1: PROCESS DATA SUMMARY (Original Design)

PROCESS/ PARAMETER	DESCRIPTION
Influent Flow	24 inch venturi flow meter with flow indicator/transmitter.
Pretreatment	Sulfuric Acid Addition: 93% liquid; Dose 135 mg/l; pH adjustment to 5.9 Scale Inhibitor/Antiscalant Addition: 100% as neat liquid; B.F. Goodrich AF600; Dose 2 mg/l Cartridge Filtration: 3 units; 2850 gpm each; 176 elements per unit; polypropylene FDA grade; 40 inches long; 16 gpm per element.
Feed Pumping	Cartridge Filter and Membrane Feed Pumps: 3 pumps; 400 hp; 5.5 mgd each; variable speed; 130 psi TDH; normal operating pressure 115 to 125 psi.
Membrane Softening	Nanofiltration: 4 Trains; 2.33 mgd per train; 2 stages – 36 vessels Stage 1 & 20 vessels Stage 2; 85% Recovery – 65% State 1 & 20% Stage 2; Permeate flux 14.9 gpd/sf; Elements – 7 per vessel, 40 inches long, 8 inch diameter, spiral wound, thin film composite, polyamide active layer cast onto polysulfone support layer, polyester fabric substrate, Fluid Systems model TFC 8929ULP, 400 sf per element.
Concentrate Disposal	Deep Injection Well or bypass to Wastewater Treatment Plant.
Post Treatment	Chlorine Addition: Chlorine gas; Dose 2 mg/l Degasification: 2 Air stripping towers; FRP construction, counter flow; packed tower type; capacity 4.67 mgd each; Air to Water ratio 16.5 cfm air/cfm water; 96% removal of carbon dioxide.

The following schematic diagram represents existing treatment processes (Blending with lime softened water occurs in the clearwell):

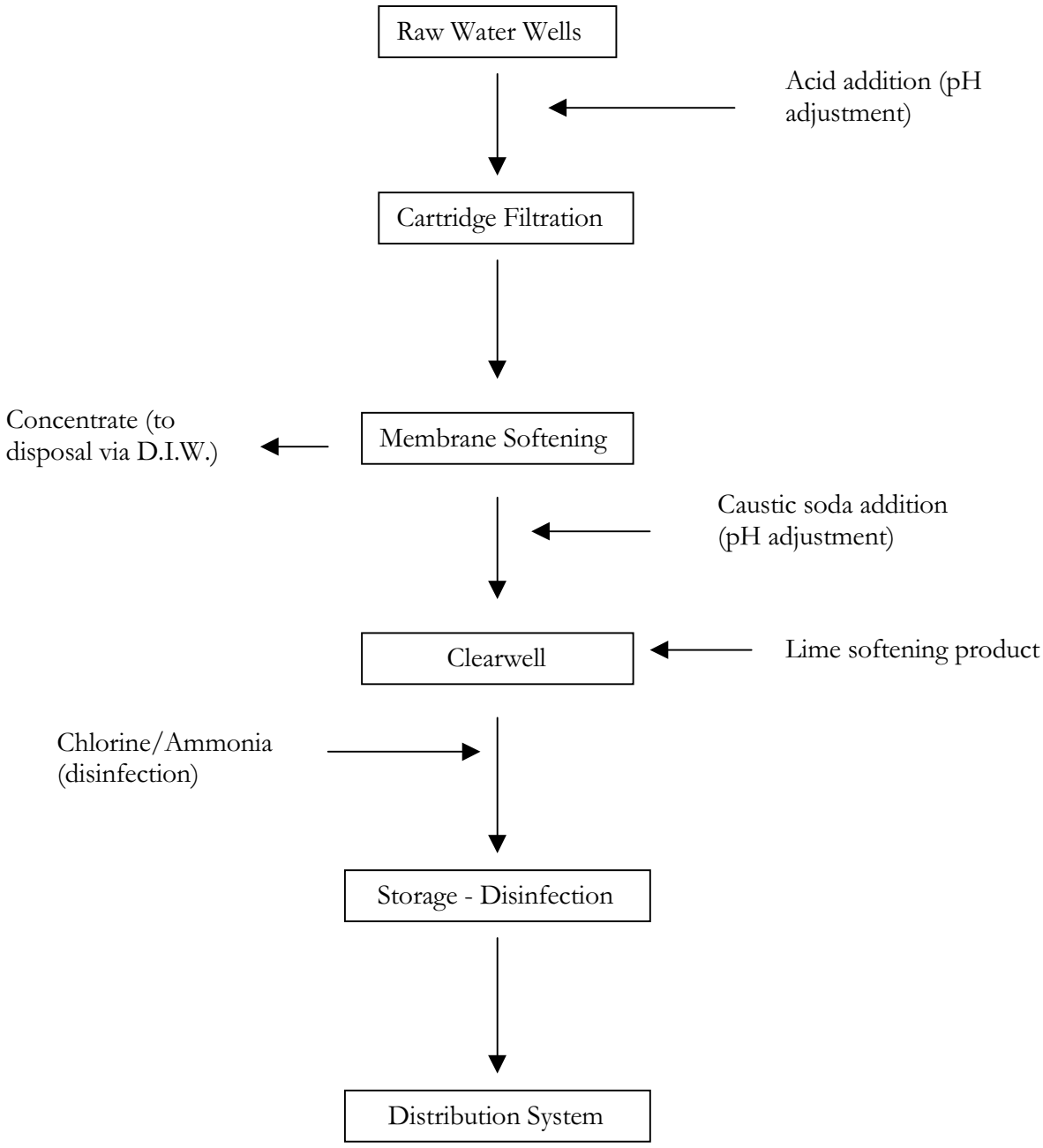

Figure 1: WTP 3 Treatment Process

The following table summarizes some of the source water and finished quality parameters.

Table 2: SOURCE WATER QUALITY PARAMETERS*

PARAMETER	AVERAGE CONCENTRATION	MAXIMUM	MINIMUM
Temperature (°C)	25.0	28.0	20.0
pH	7.2	7.2	6.9
Turbidity (NTU)	0.3	0.5	0.1
Alkalinity (mg/l as CaCo3	65.0	60.0	70.0
Ca Hardness (mg/l as CaC03)	255.0	300.0	225.0
Total Hardness	265.0	285.0	200.0
TOC mg/l	10.7	13.7	8.0
UV 254 (cm –1)	.5	.6	.4
Bromide (ug/l)	162.0	220.0	130.0

*These values remained nearly constant because the source water is groundwater.

Table 3: FINISHED WATER QUALITY PARAMETERS

PARAMETER	AVERAGE CONCENTRATION	MAXIMUM	MINIMUM
Temperature (°C)	25.0	28.0	23.0
pH	9.0	9.5	8.0
Turbidity (NTU)	0.25	0.9	0.1
TOC mg/l	2.6	4.0	1.0
Distribution System (THM 4 ug/l)	39.9	43.3	36.5

During the full testing period (12 months), no cleaning was performed on the membrane system. Under normal conditions, membrane cleaning is performed based on changes in differential pressure parameters established by the membrane manufacturer. During this testing period, the differential pressure across the membrane was below the recommended value for cleaning. The plant was operational for an 85% recovery as designed and remained relatively constant for the duration of the test period.

The following table summarizes the average characteristics of the membrane process performance throughout the testing period.

- Total Feed Flow (gpm) = 1650
- Influent flow to stage #1 (gpm) = 1650
- Permeate flow from stage #1 (gpm) = 908
- Concentrate flow from stage #1 = 742
  (Influent flow to stage #2) (gpm)
- Permeate flow from stage #2 (gpm) = 490
- Concentrate flow from stage #2 (gpm) = 252
- Recovery stage #1= 55%
- Recovery stage #2 = 66%
- Total train recovery = 85%
- Flux gal/ft^2/day = 15

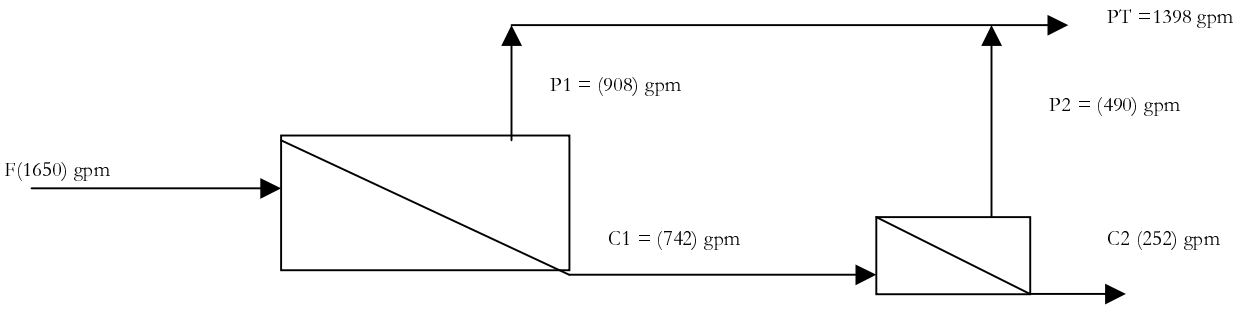

Figure 2: MEMBRANE SOFTENING FLOW DIAGRAM

The following table summarizes the analytical method used during the testing along with the minimum reporting level (MRL) during the study (March 1, 1998 through March 31, 1999).

Table 4: ANALYTES EVALUATED DURING THE TEST

ANALYTE	UNITS	METHOD	MRL	LABORATORY
Ca Hardness	mg/l	SM 3500-CaD	0.5	PBC Water Utilities
Cl^2 Demand			0.05	PBC Water Utilities
Contact Time	Min.	SM 2350-B	1	PBC Water Utilities
Cl^2 Dose	mg/l	SM 2350-B	0.05	PBC Water Utilities
Cl^2 Demand			0.05	PBC Water Utilities
Free Residual	mg/l	SM 4500-CLG	0.05	PBC Water Utilities
Cl^2 Demand pH		EPA 150.1	0.1	PBC Water Utilities
Cl^2 Demand Temp	°C	SM 2550-B	0.1	PBC Water Utilities
Cl^2 Demand Total			0.05	PBC Water Utilities
Residual Chlorine	mg/l	SM 4500-CL-G	0.05	PBC Water Utilities
Total Alkalinity	mg/l	SM 2320-B	0.8	PBC Water Utilities
Total Hardness	mg/l	EPA 130.2	0.5	PBC Water Utilities
TOC	mg/l	SM 5310-D	0.5	PBC Water Utilities
Turbidity	NTU	SM 2130-B	0.09	PBC Water Utilities
UV 254	cm-1	SM 5910-B	0.009	PBC Water Utilities
Bromide	mg/l	ML/EPA.300	.02	Montgomery Watson
Total Organic Halogen	mg/l	ML/9020/SM 5320	625.0	Montgomery Watson
BCAA	mg/l	ML/S6251B	1.0	Montgomery Watson
DCBAA	mg/l	ML/S6251B	10.0	Montgomery Watson
CDBAA	mg/l	ML/S6251B	2.0	Montgomery Watson
DBAA	mg/l	ML/S6251B	1.0	Montgomery Watson
DCAA	mg/l	ML/S6251B	10.0	Montgomery Watson
MBAA	mg/l	ML/S6251B	1.0	Montgomery Watson
MCAA	mg/l	ML/S6251B	2.0	Montgomery Watson
TBAA	mg/l	ML/S6251B	4.0	Montgomery Watson
TCAA	mg/l	ML/56251B	10.0	Montgomery Watson
CH Br 3	mg/l	ML/EPA 551	0.5	Montgomery Watson
$CH\ Cl_3$	mg/l	ML/EPA 551	5.0	Montgomery Watson
DBCM	mg/l	ML/EPA 551	0.5	Montgomery Watson
BDCM	mg/l	ML/EPA 551	5.0	Montgomery Watson

The mailing address and contact person for each laboratory is as follows:

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SECTION IV – RESULTS AND DISCUSSION

After completion of the 12 months of testing, the collected data showed a consistent performance for the parameters under monitoring. No cleaning was performed during the testing period. Pressure drop and flux decline were below the manufacturer's recommended values to schedule cleaning.

Table 5 shows the average values of the parameters for the 50 weeks testing based on 10 week periods. These values are graphically shown in figures 3 through15.

Table 5: WATER QUALITY PARAMETERS – EVERY TEN WEEKS

	FEED WATER						PERMEATE				
Parameter	**10wk**	**20wk**	**30wk**	**40wk**	**50wk**		**10wk**	**20wk**	**30wk**	**40wk**	**50wk**
TDS,mg/l	310	299	301	299	296		59	60	62	59.4	61.8
Tot. Hdns,mg/l CaCO3	270	267	272	271	271		36	46	32	35	40
Turbidity,NTU	0.08	0.1	0.09	0.08	0.06		0.02	0.06	0.02	0.02	0.09
TOC,mg/l	12	12.4	13	12.7	12.8		0.52	1	0.5	0.5	1.6
UV254,cm-1	0.47	0.48	0.48	0.49	0.48		0.034	0.05	0.03	0.045	0.07
Bromide,ug/l	188	210	191	226	222		57.4	55.6	71.8	69.4	75.6
SDS Cl2 dem.,mg/l	7.5	9.7	8.8	10.3	10.1		3	3.9	2.4	4.4	3.6
SDS TOX,ug/l	1340	1594	1806	1704	1632		10	41	18	51	80
SDS THM4,ug/l	259	375	305	306	290		5.4	11.5	8.3	10.9	35.5
SDS HAA5,ug/l	279	357	411	377	359		4	9.7	4.7	7.4	15.7
SDS HAA6,ug/l	293	376	429	394	378		4.6	10.9	5.7	9	18.3
Alkalinity,mg/l	62.2	78.5	72.2	57.1	68.1		33.2	38.2	35	34.3	35.6

Figure 3: **TDS FEED WATER**

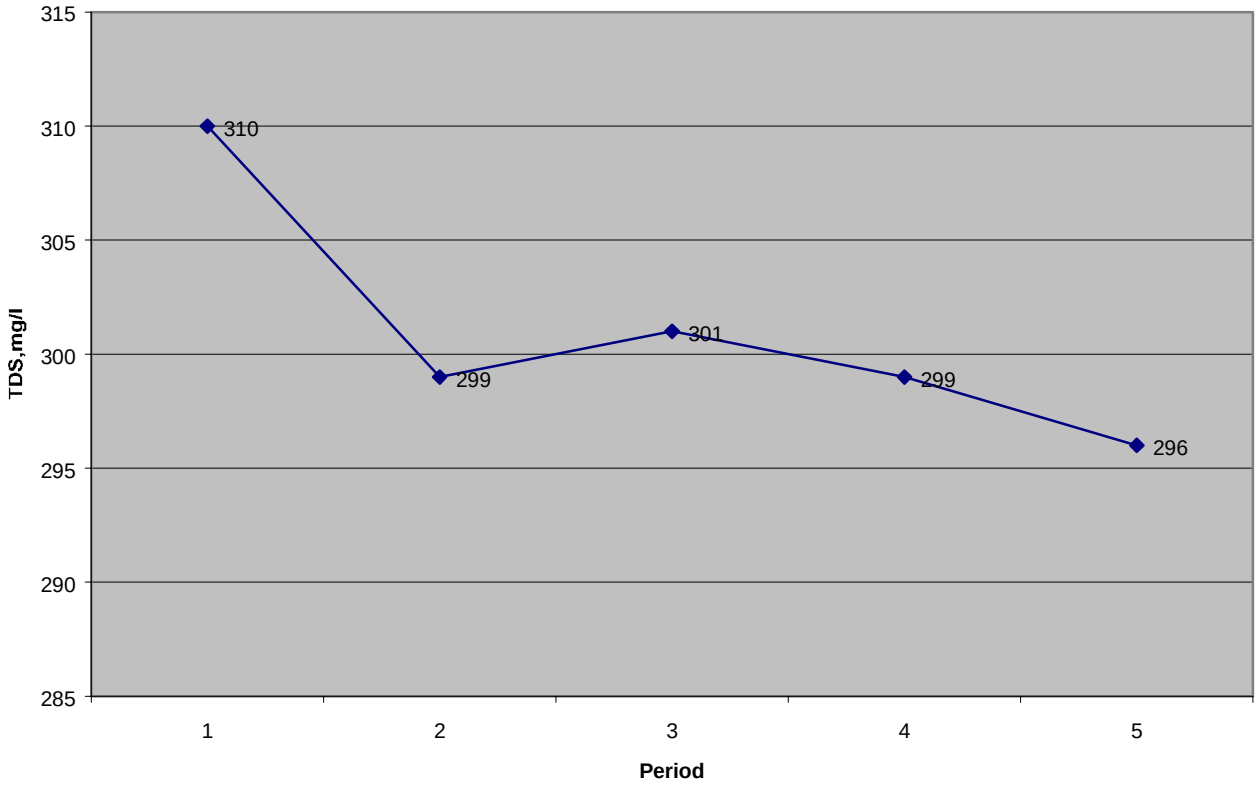


Figure 4**: TDS PERMEATE**

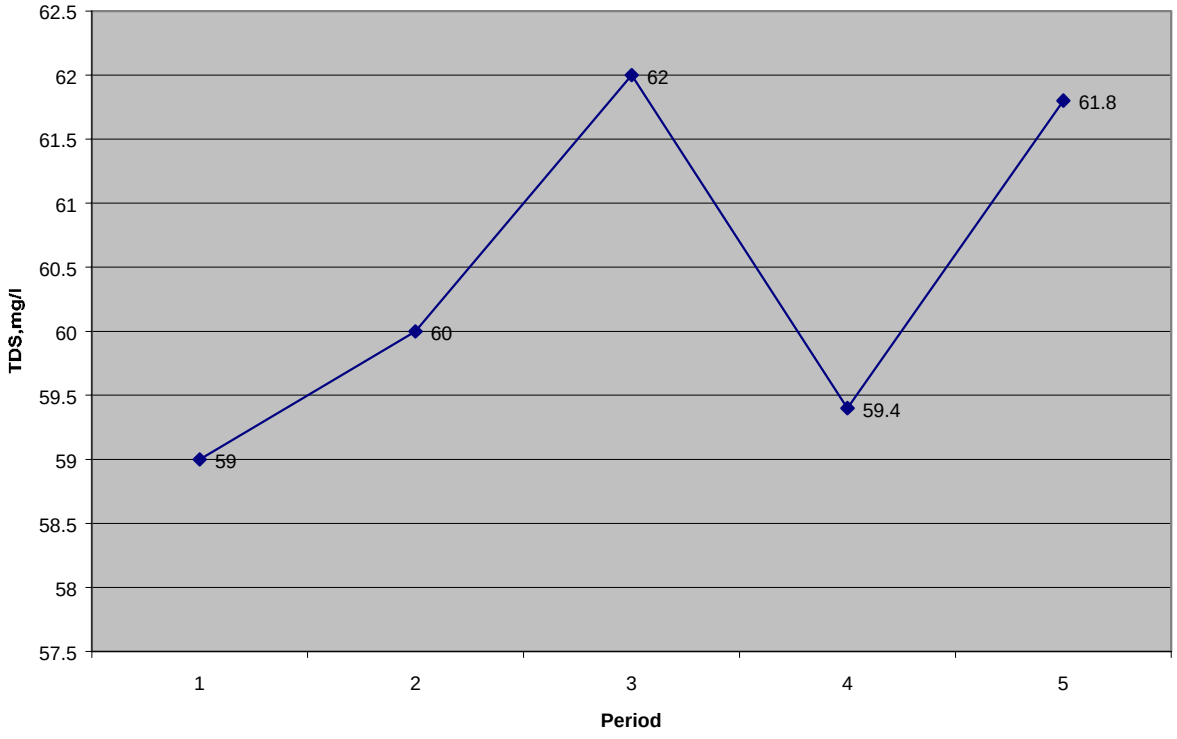


Figure 5: **Total Hdns. Feed Water**

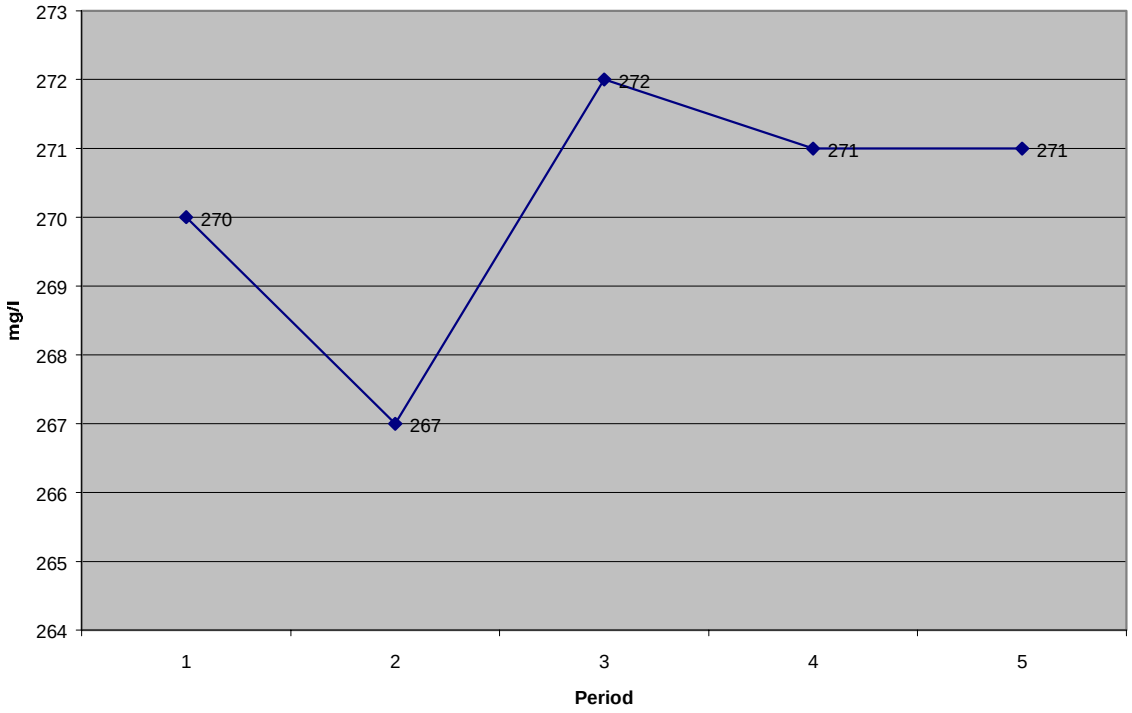


Figure 6: **Total Hdns. Permeate**

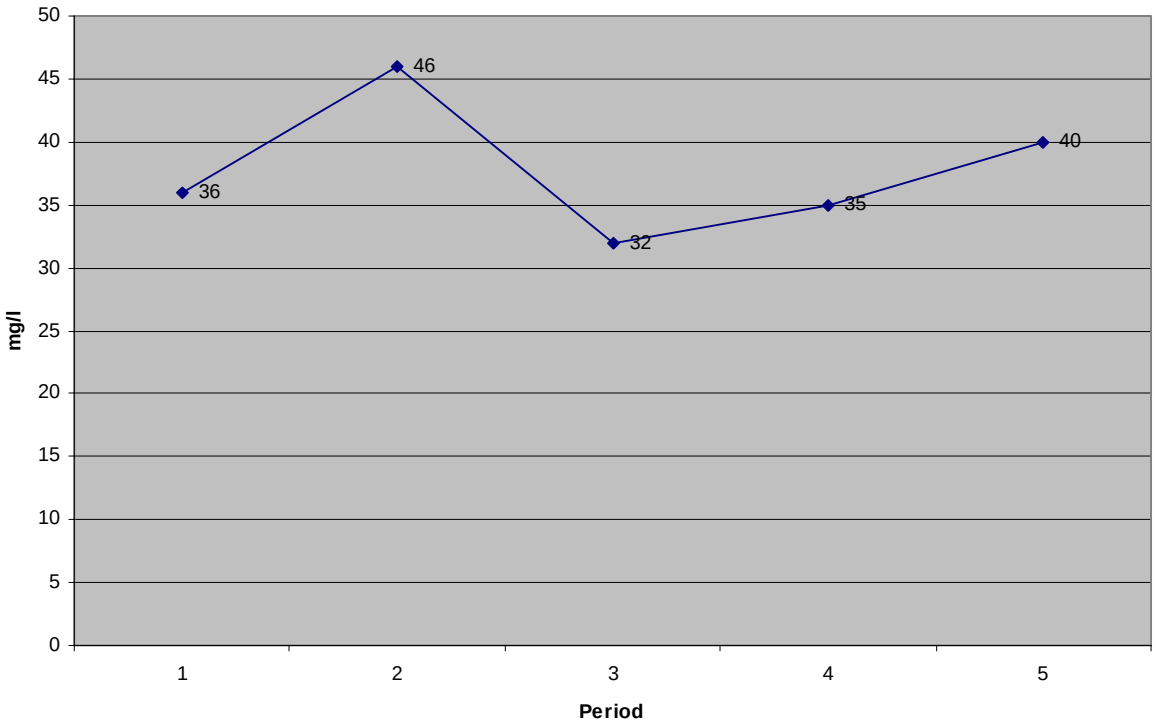


Figure 7: **Turbidity Feed Water**

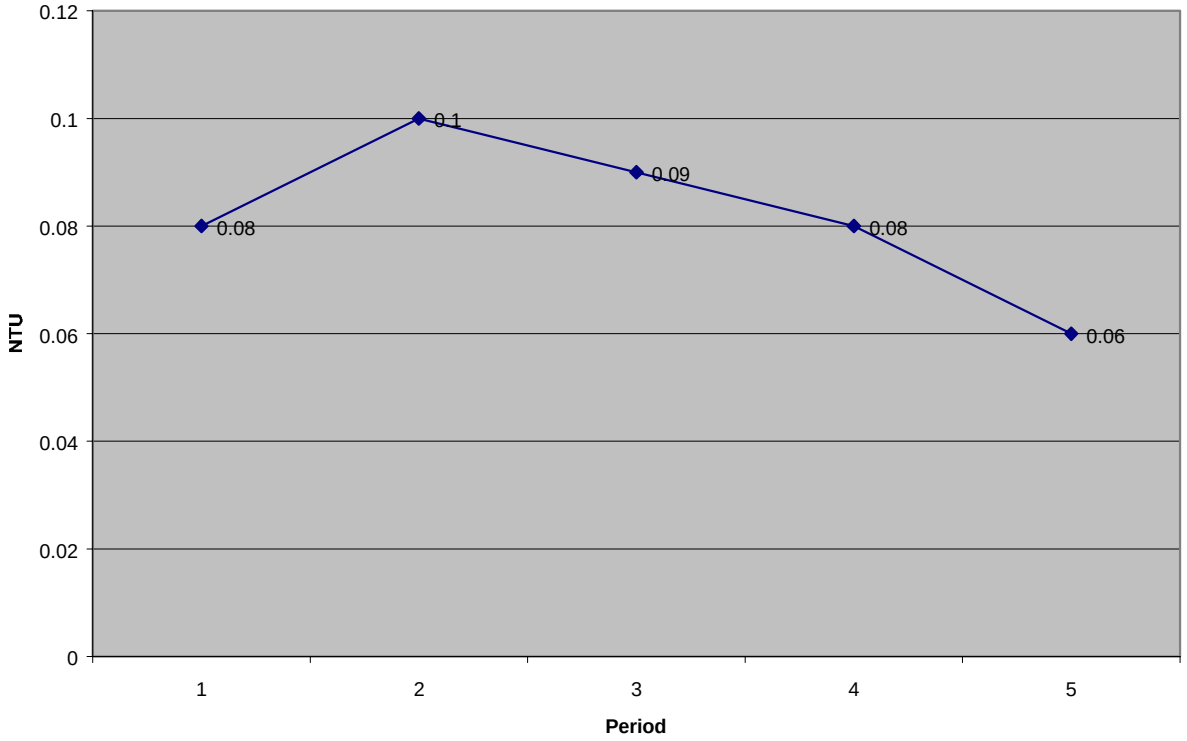


Figure 8: **Turbidity Permeate**

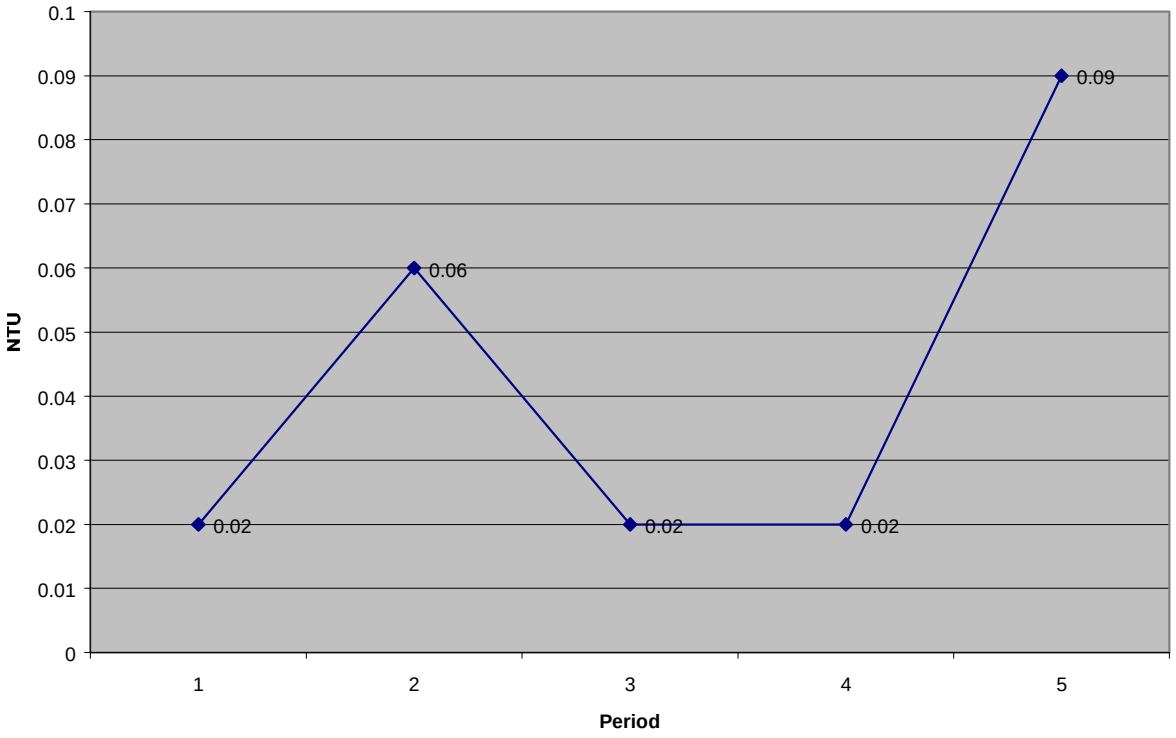


Figure 9: **TOC Feed Water**

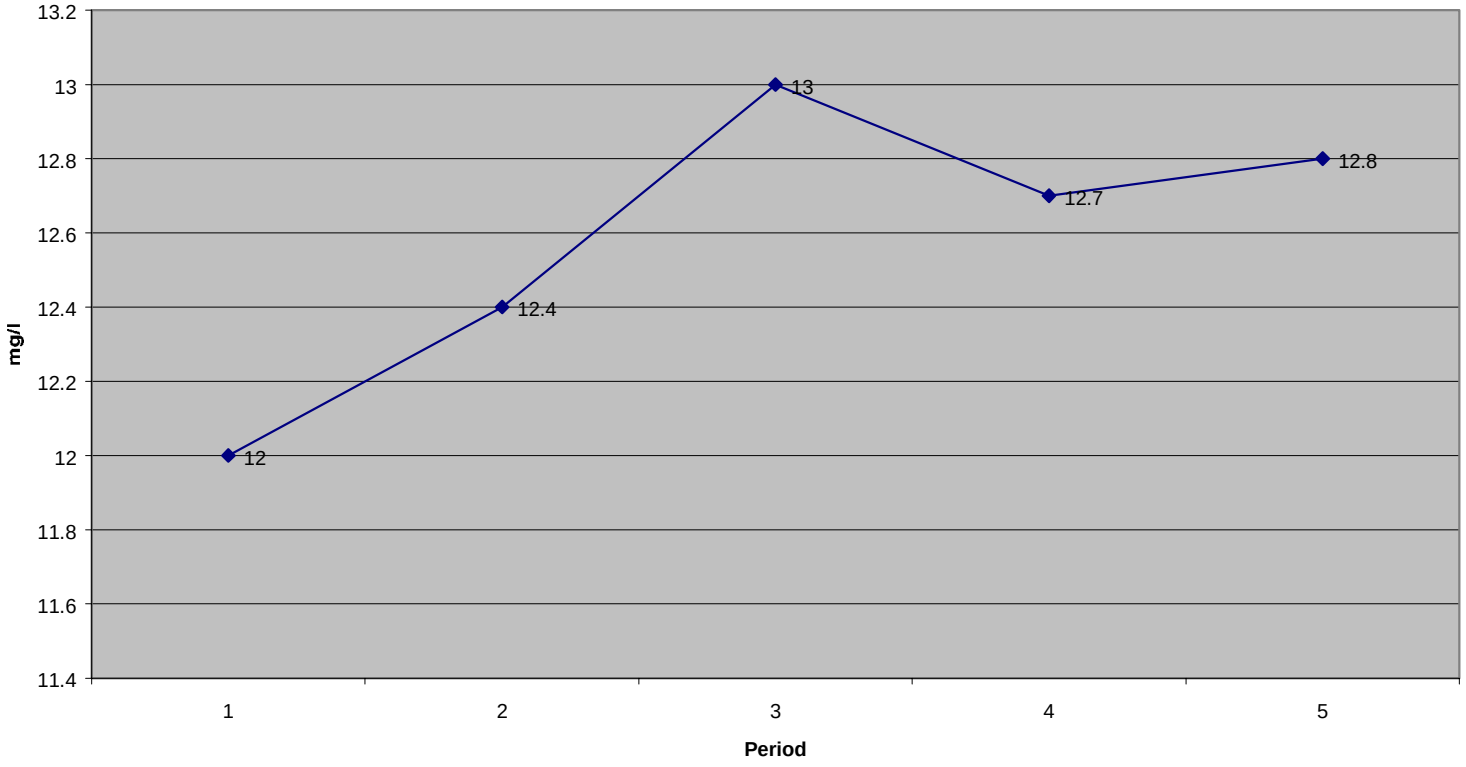


Figure 10: **TOC Permeate**

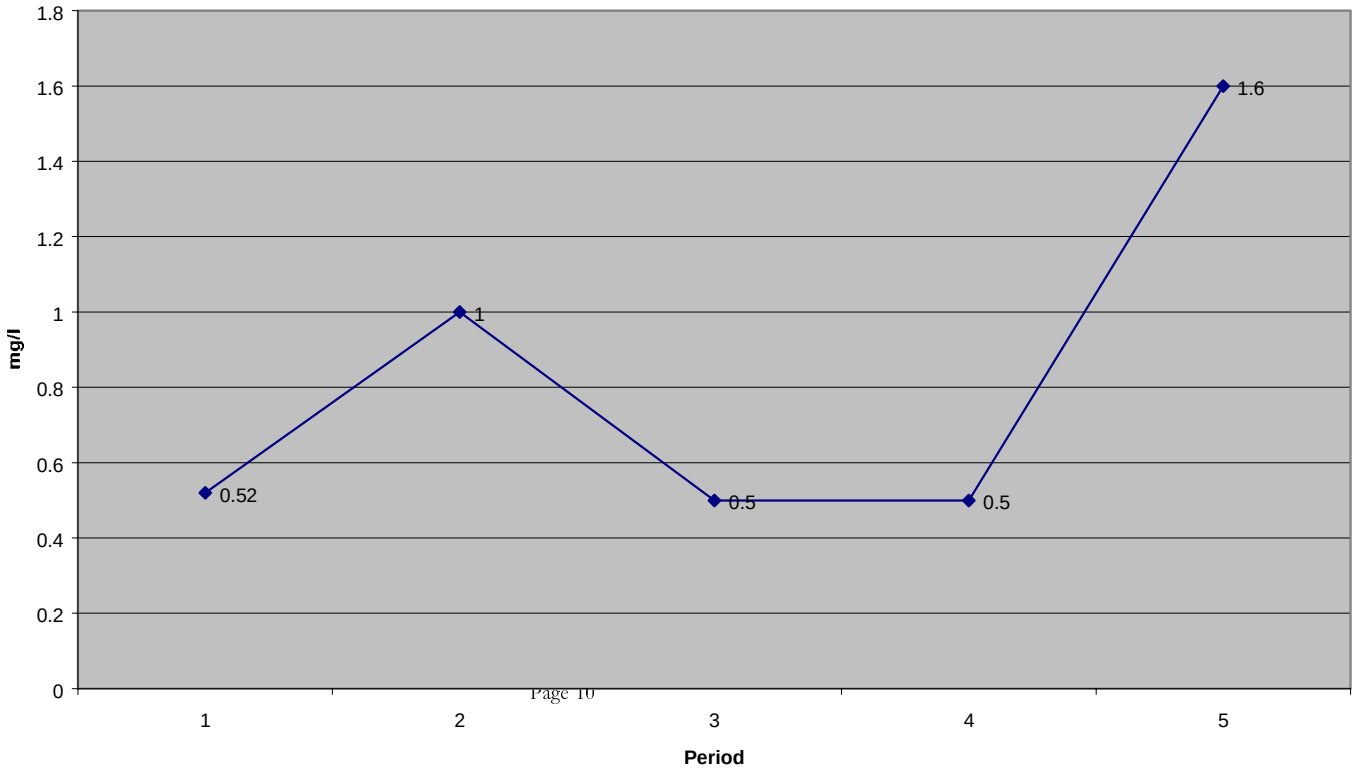


Figure 11: **UV254 Feed Water**

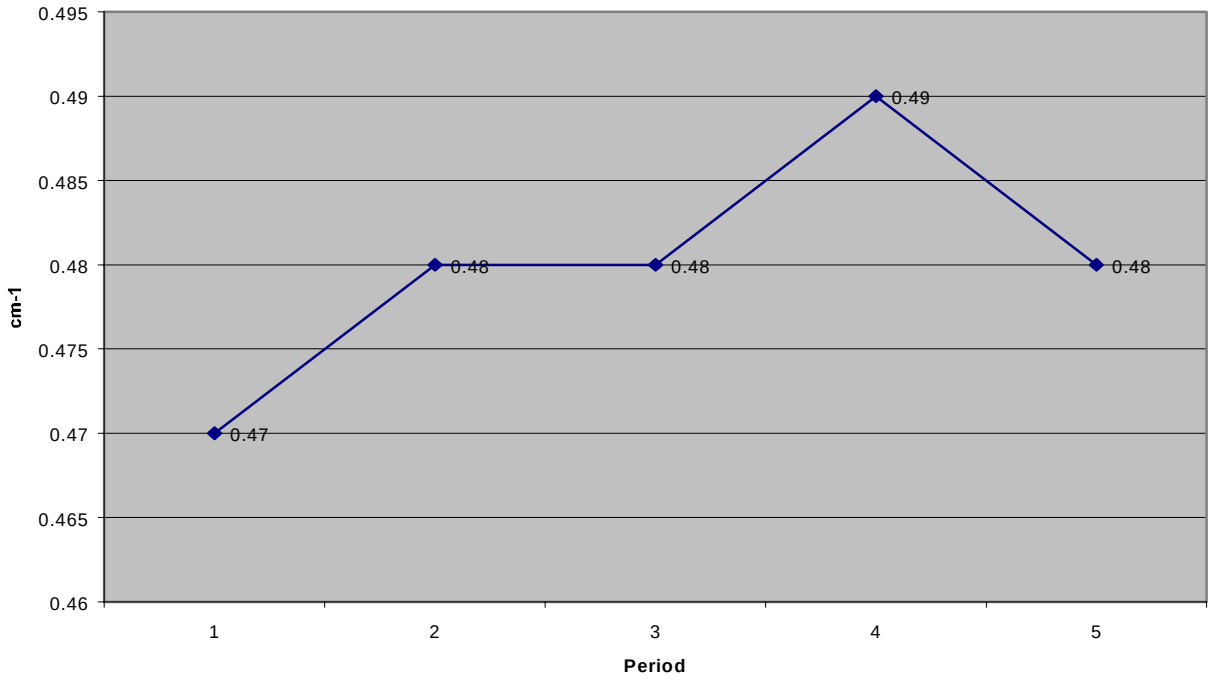


Figure 12: **UV254 Permeate**

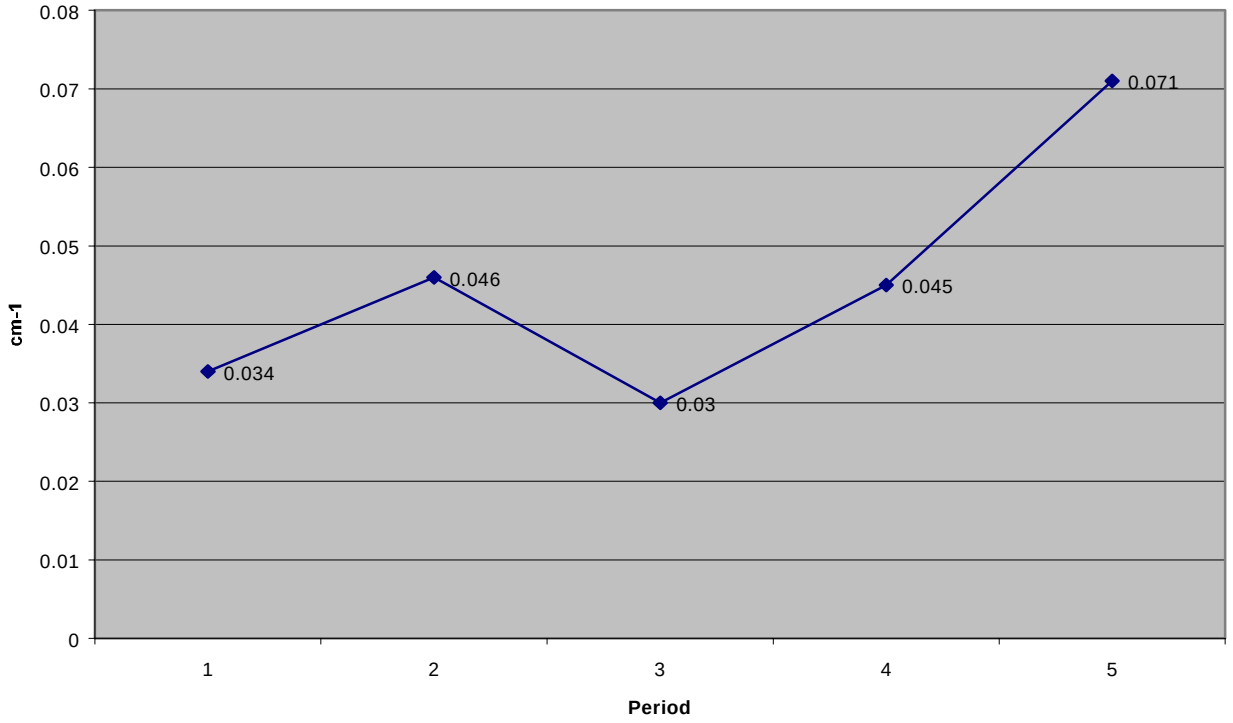


Figure 13: **Bromide Feed Water**

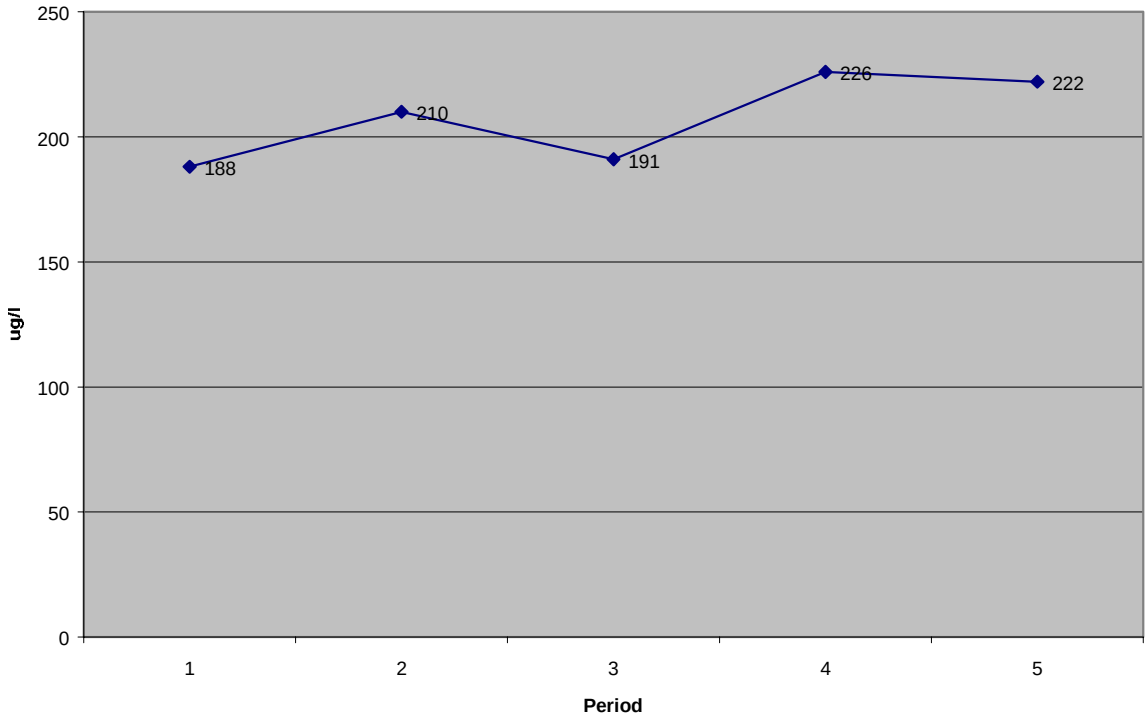


Figure 14: **Bromide Permeate**

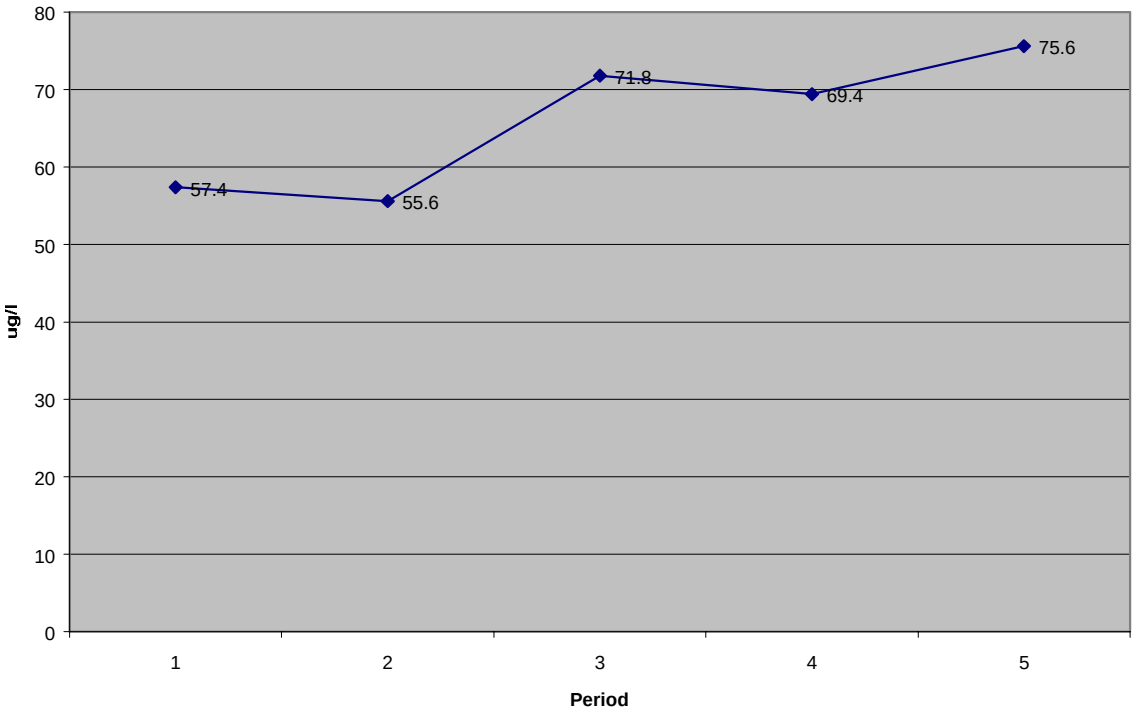


Figure 15: **SDS Cl2 Demand, Feed Water**

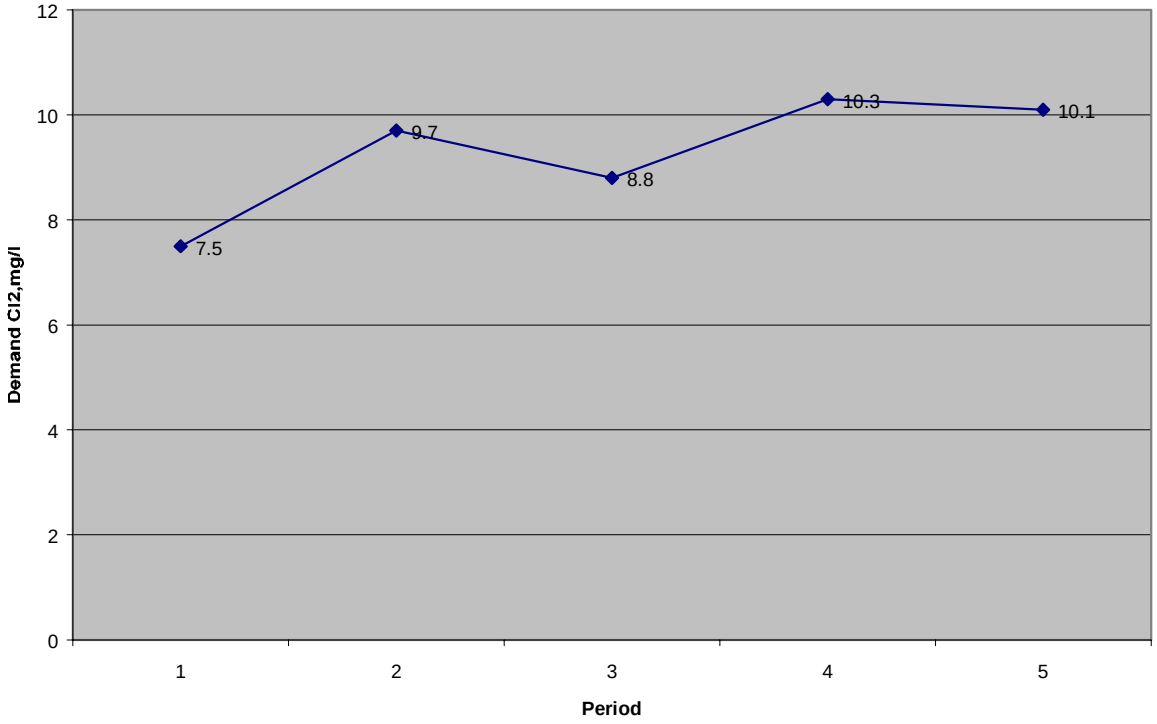


Figure 16: **SDS Cl2 Demand Permeate**

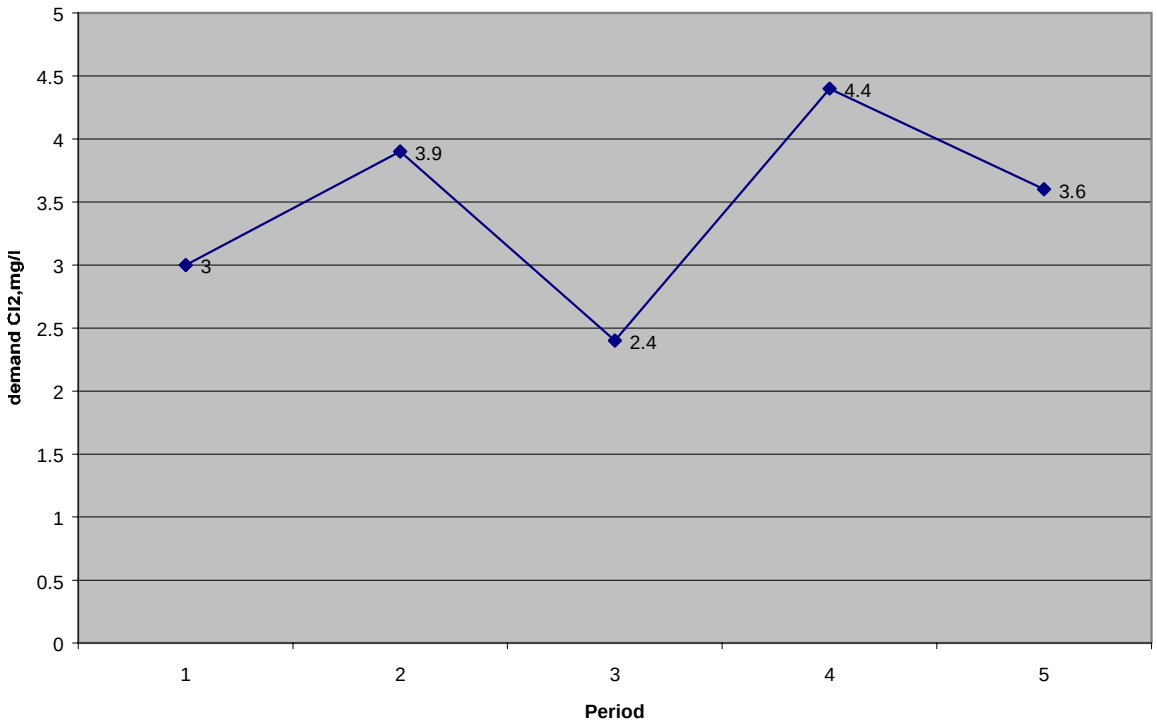


Figure 17: **SDS TOX, Feed Water**

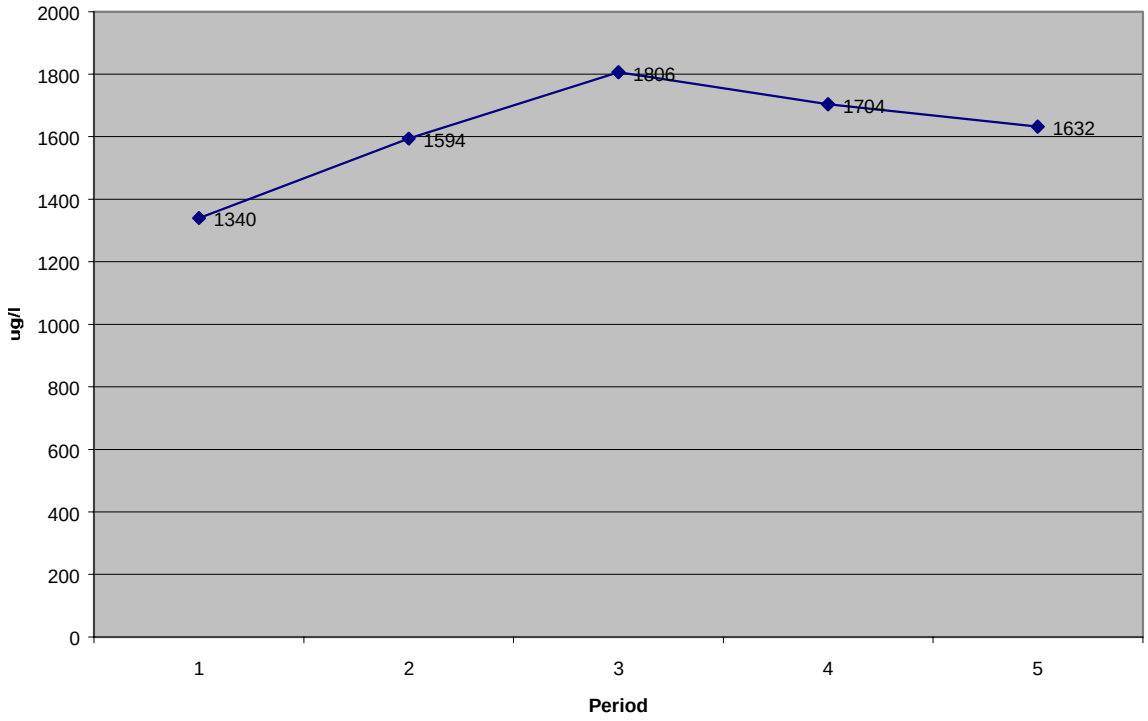


Figure 18: **SDS TOX,Permeate**

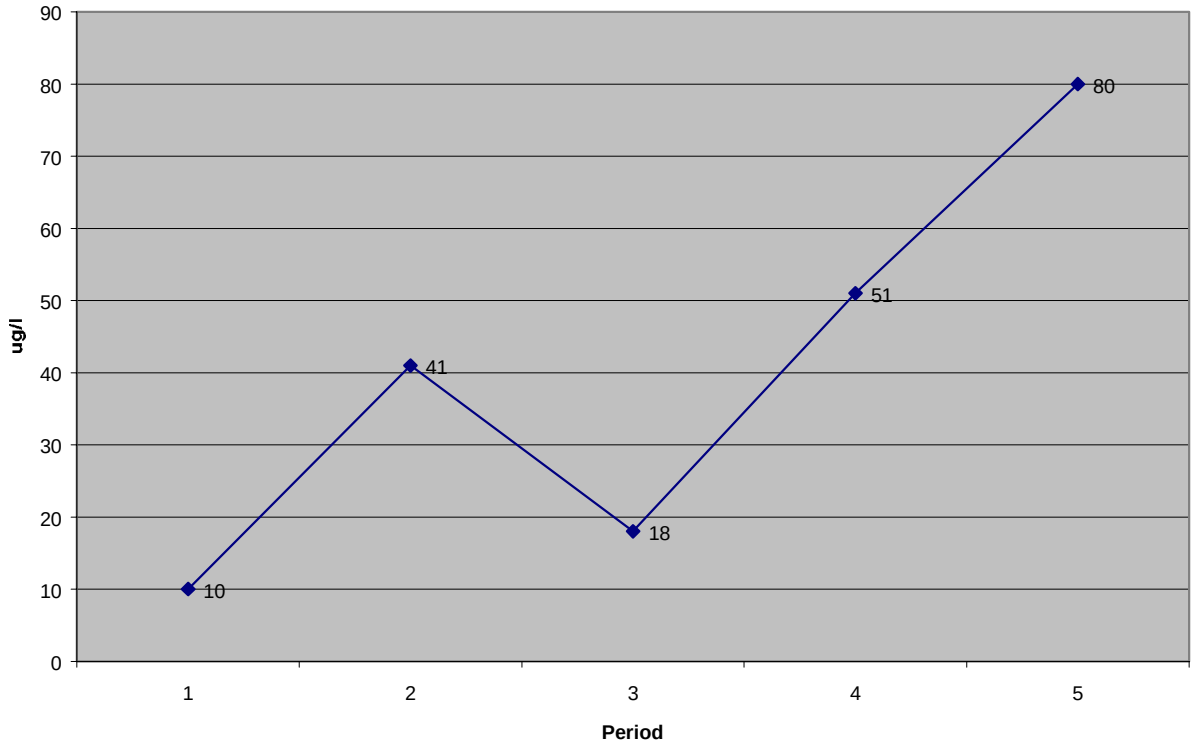


Figure 19: **THM4 Feed Water**

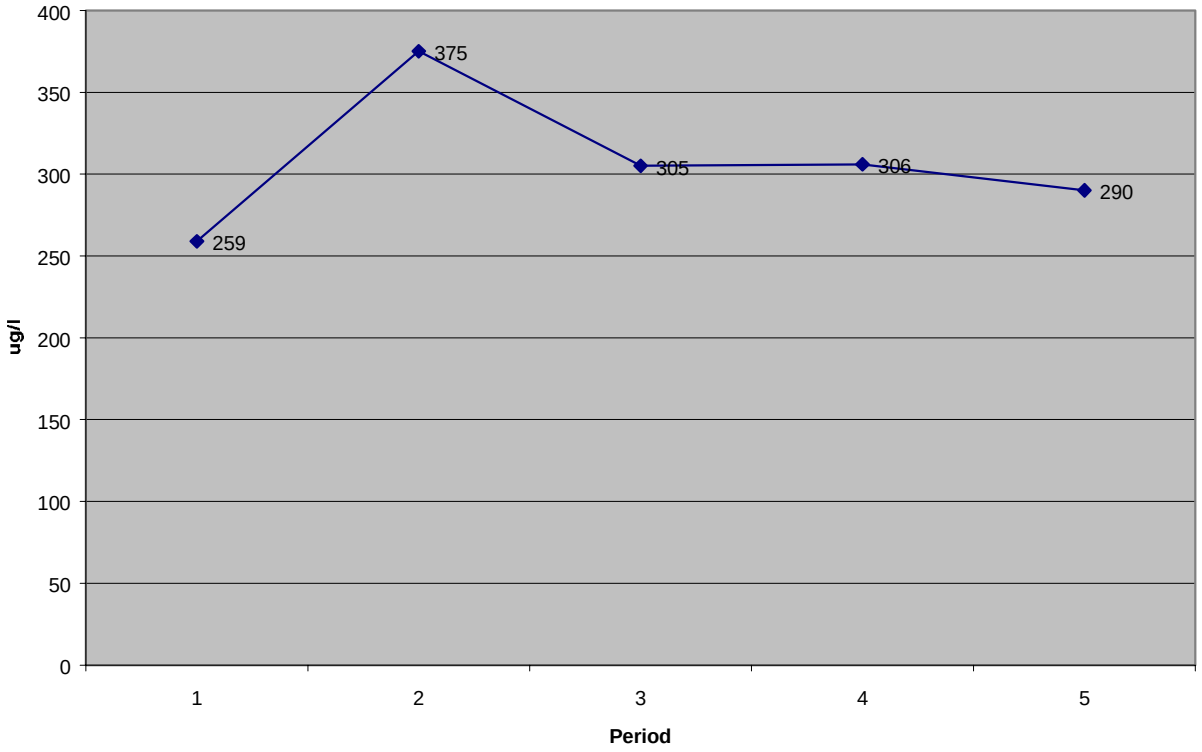


Figure 20: **THM4 Permeate**

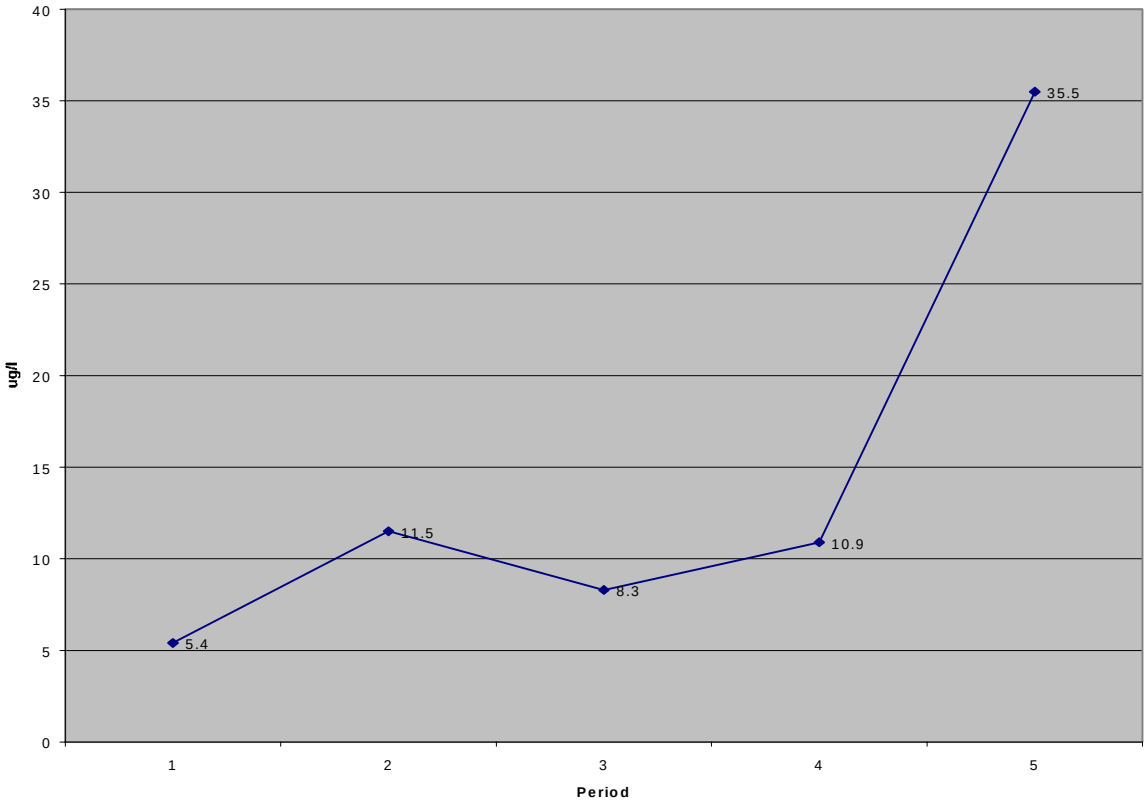


Figure 21: **SDS HAA5 Feed Water**

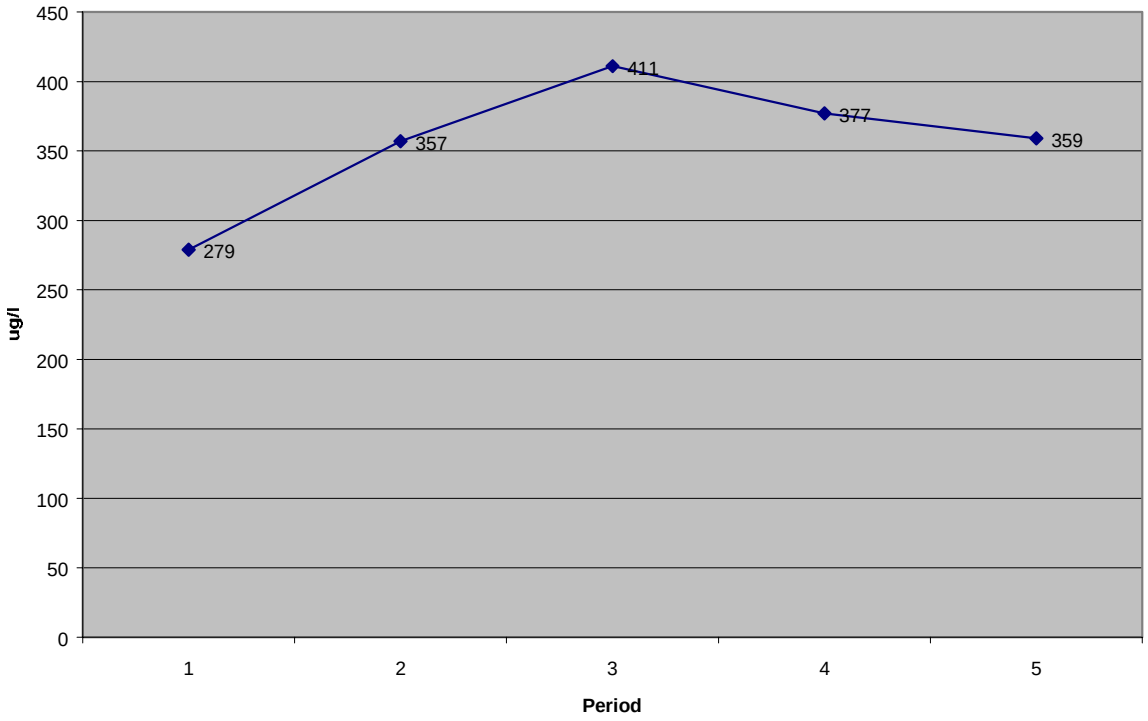


Figure 22: **SDS HAA5 Permeate**

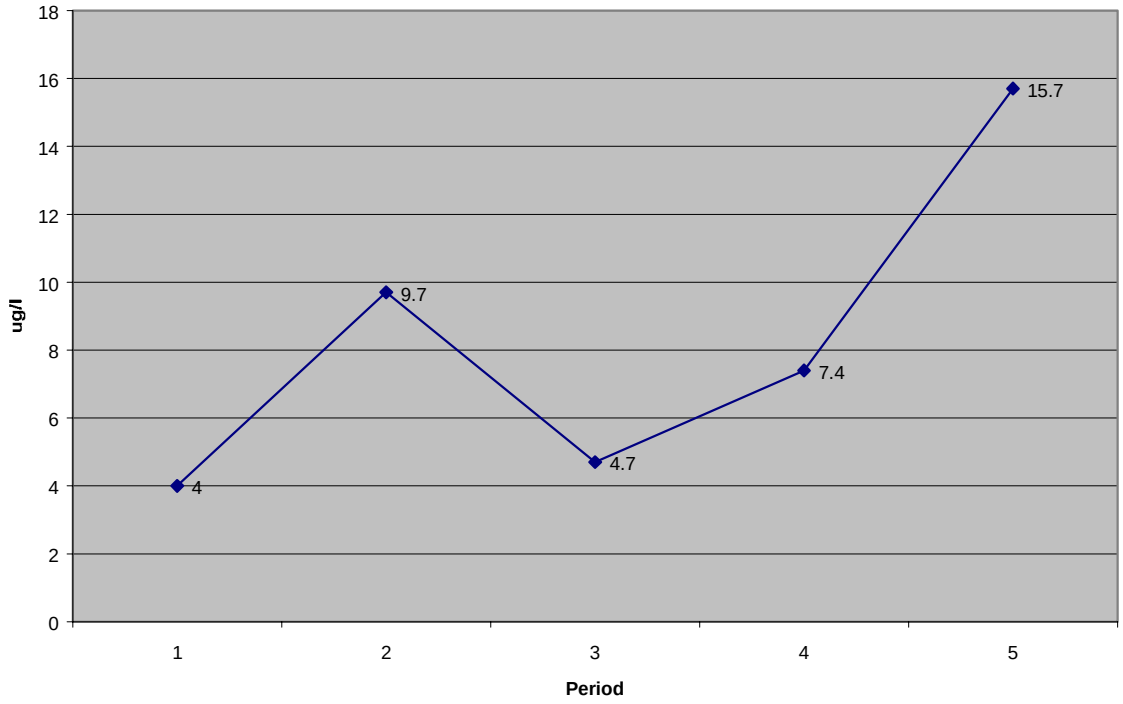


Figure 23: **SDS HAA6 Feed Water**

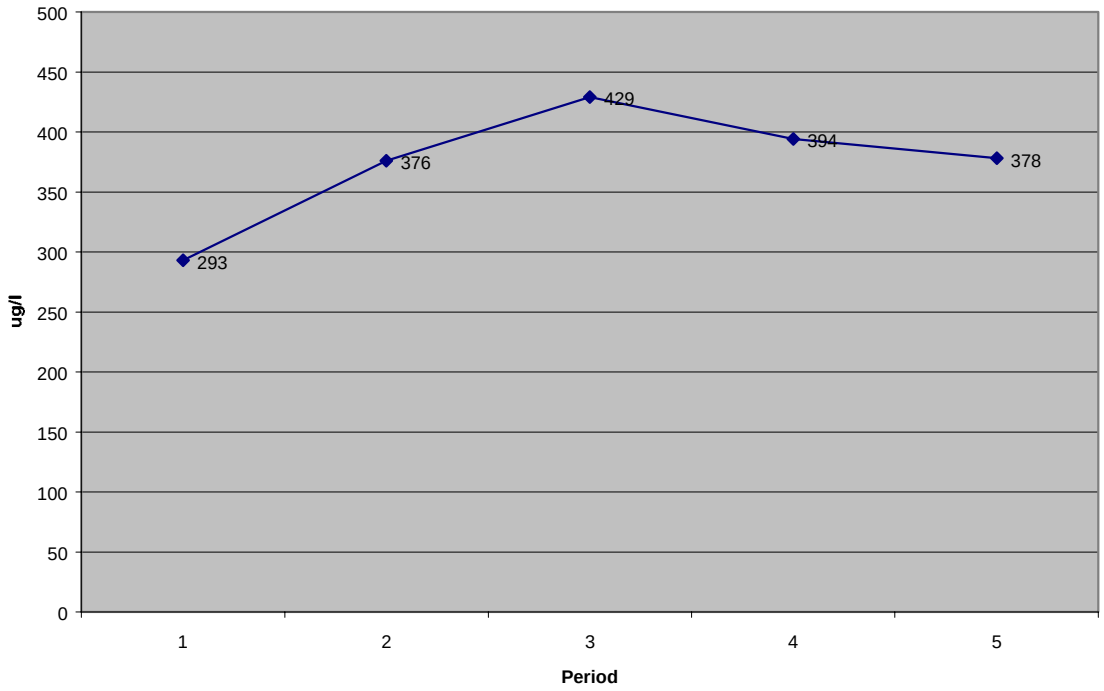


Figure24: **SDS HAA6 Permeate**

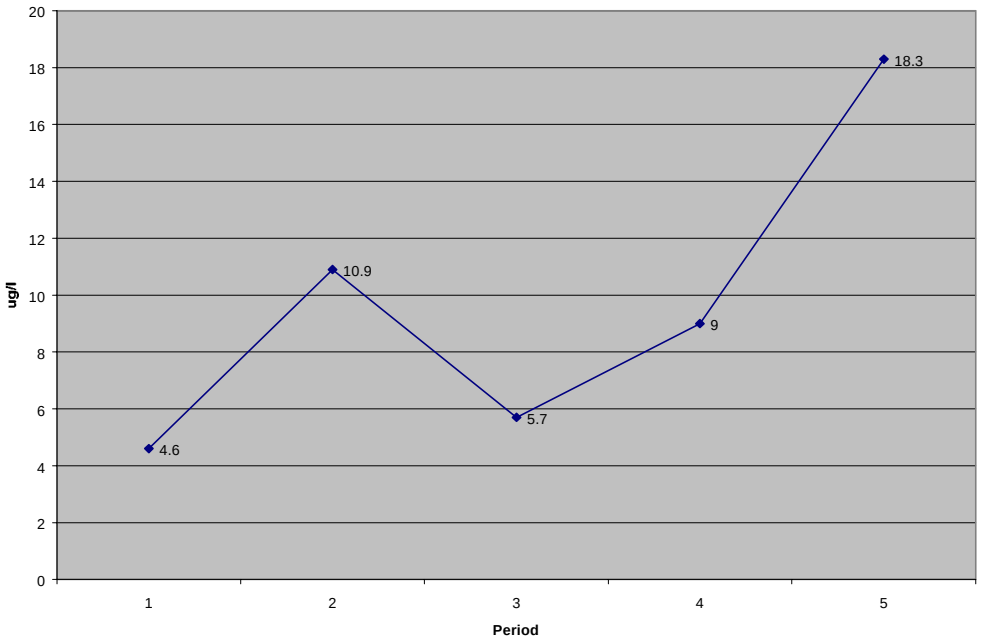


Figure 25: **Alkalinity Feed Water**

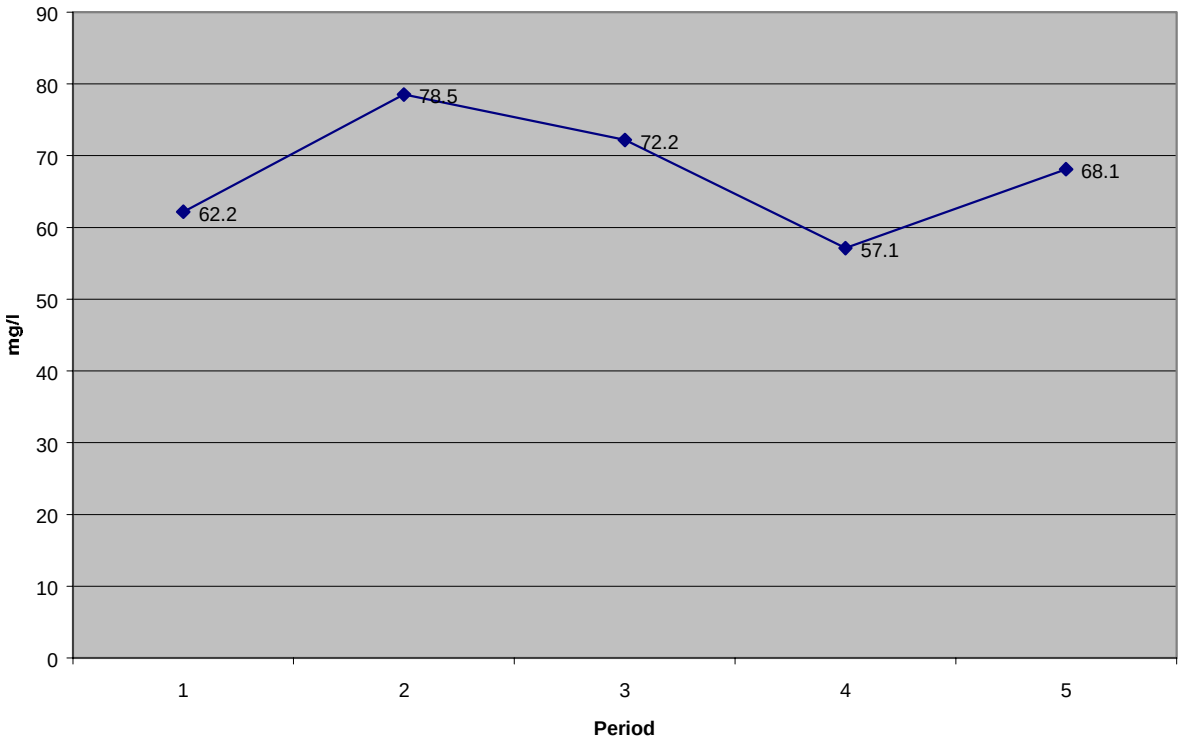
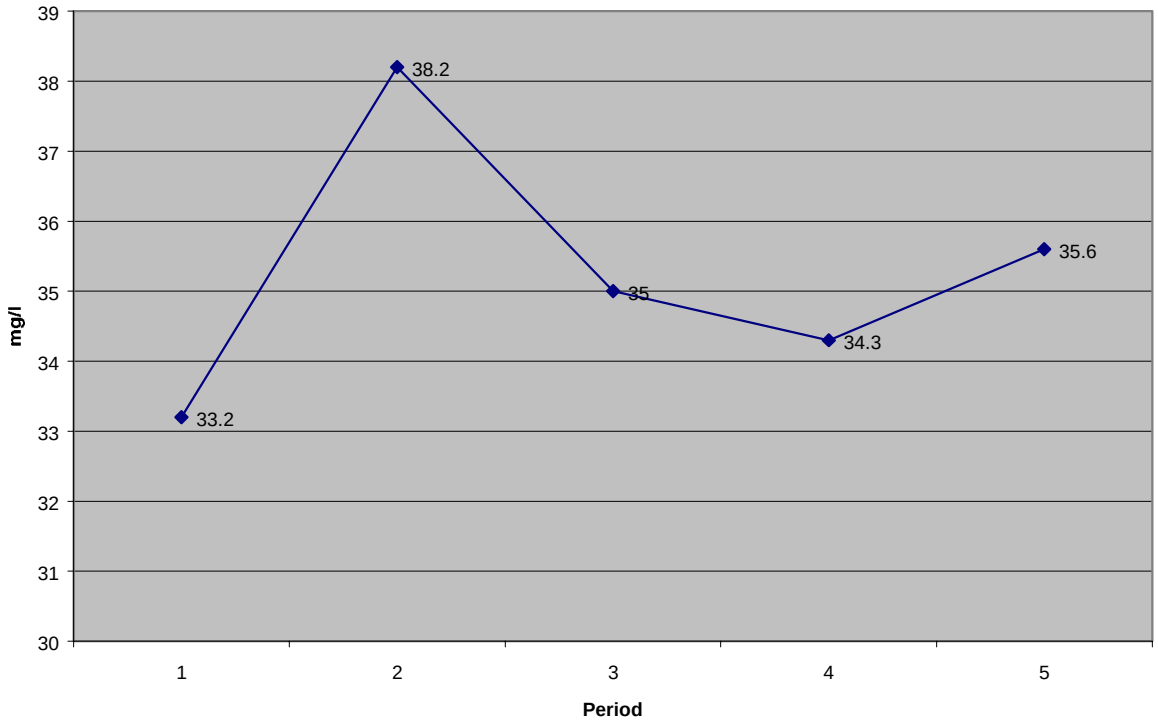


Figure 26: **Alkalinity Permeate**



A summary of the typical values obtained during the testing period is shown in *Table 6*. As noted previously, these parameters remained nearly constant during the testing period. *Table 7* values of the mass transfer coefficient at average temperature during the testing period.

Table 6 – TYPICAL WATER QUALITY PARAMETERS FOR WTP 3

WATER QUALITY PARAMETER	FEED	INFLUENT	PERMEATE	CONCENTRATE
Temperature (°C)	25.0	24.7	25.0	26.0
pH	7.2	5.9	5.4	6.4
Turbidity (ntu)	0.10	0.08	0.01	0.4
Alkalinity (mg/l as $CaCO_3$)	65.0	60.0	30.0	300.0
Calcium Hardness (mg/l as $CaCO_3$)	245.0	240.0	30	1400.0
Total Hardness (mg/l as $CaCO_3$)	270.0	265.0	35.0	1580.0
Bromide (ug/l)	190.0	190.0	60.0	--
TOC (mg/l)	12.0	12.0	0.5	70.0
UV254 (cm-1)	0.5	0.5	0.03	3.0
SDS-THM4 (ug/l)	300.0	--	10.0	--
SDS-HAA5 (ug/l)	300.0	--	10.0	--
SDS-HAA6 (ug/l)	350.0	--	15.0	--
SDS-TOX (ug Cl/l	1600.0	--	30.0	--
SDS-Chlorine Demand (mg/l)	8.7	--	3.0	--

Table 7 – AVERAGE VALUE FOR TEN WEEK PERIODS

MASS TRANSFER COEFICIENT ,AVERAGE TEMPERATURE					
MTCw @ T avg gal/s.f./d/psi	Period				
	10wk	20wk	30wk	40wk	50wk
	0.2043	0.2008	0.1912	0.1952	0.1904

These values are shown graphically in *Figure 27*.

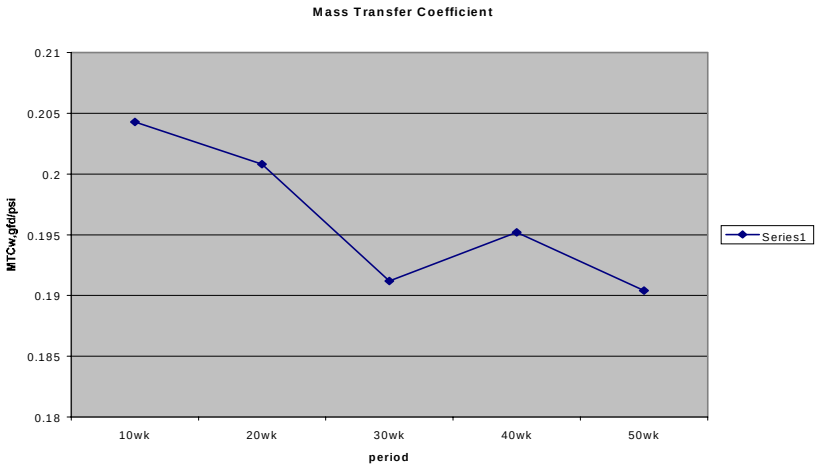


Figure 27

The use of the membrane softening process had proved to be a very effective method for removal/reduction of parameters such as TDS, TOC, Bromide, THM precursor, and hydrogenated compounds.