A Senior Honors Thesis

Geochemistry of the Municipal Water System and of the Sandusky River at Bucyrus, Ohio

by
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Gunter Faure

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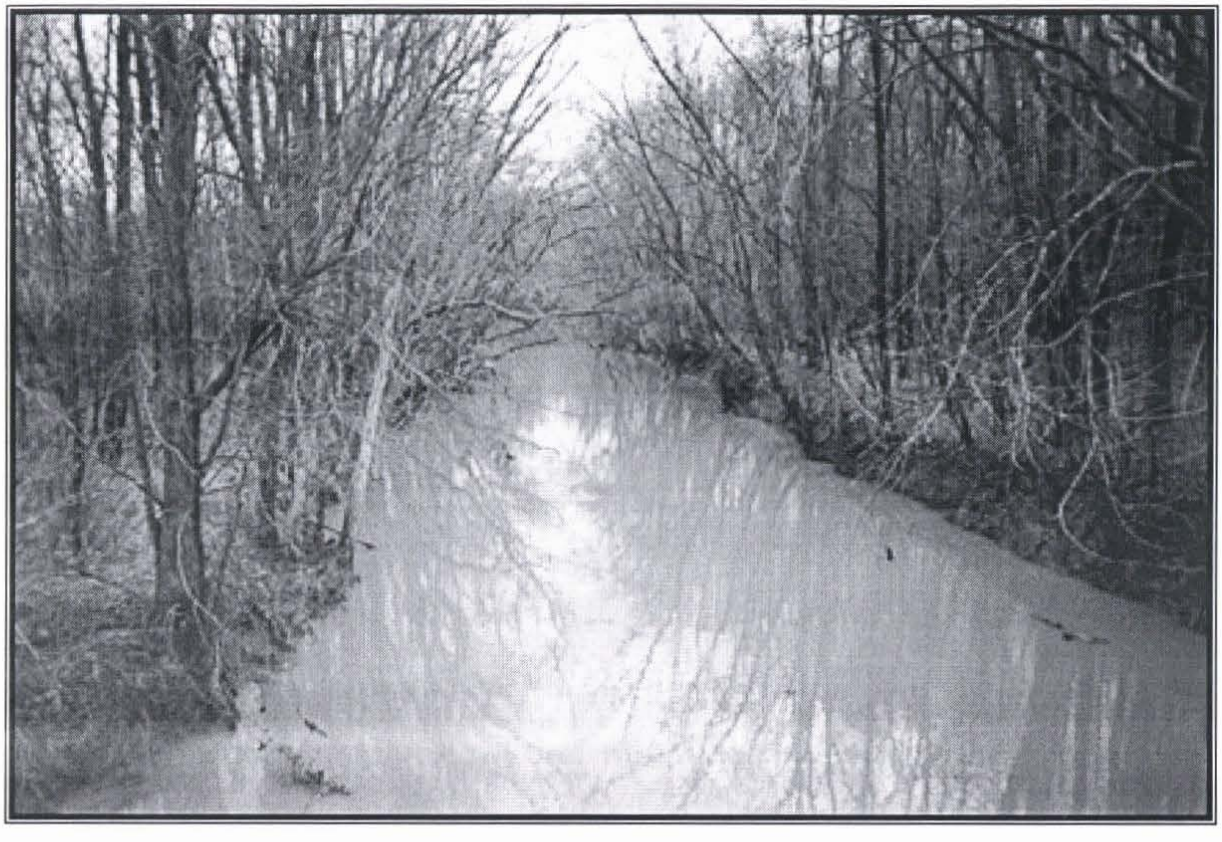
Plate 1. The Sandusky River at Bucyrus, Ohio.



ABSTRACT

The Sandusky River and municipal water at Bucyrus, Ohio were sampled on 15 December 1999. The results of the analysis show that the water has been altered by both anthropogenic and natural geochemical processes. The evolution of municipal water shows increases in concentrations of Mg, Ba, Ca, K, and Na which are caused by anthropogenic processes. Elements Na, Mg, Ca, and Sr demonstrate mixing of the river water with municipal effluent. Elements Al, Fe, Ba, and K demonstrate enrichment in the river water downstream of the effluent discharge point. The enrichment of Al and Fe may be caused by groundwater whose chemical composition is directly related to the presence of a geologic contact between shale and limestone. Barium has an unknown source, but may also originate from the groundwater component. Potassium has an anomalously low concentration in the effluent compared to the river upstream of the discharge point of the effluent. Farther downstream, the K concentration of the river rises because of the apparent introduction of water from a third source of K, which may result from drainage from local farmland.

CHAPTER 1: INTRODUCTION

Rivers provide water for domestic, industrial, and agricultural use. For this reason, Bucyrus, like many other cities, is located adjacent to a river, which in this case is the Sandusky River. The river not only provides the people of Bucyrus with clean water but is also used to discharge the wastewater of the city. Further downstream, cities or towns use the same river water for the same purposes. This cycle continues until the Sandusky River discharges into Lake Erie. The river water is altered by these anthropogenic uses and by changes in composition of the rocks that underlie the Sandusky River Basin. The objectives of this study are to determine:

1.) how the chemical composition of the water is altered by its use in the city of Bucyrus, and

2.) how the chemical composition of the water is altered by the local geology.

COLLECTION OF WATER SAMPLES AND METHODS

The water samples were collected on 15 December 1999 along a 23.6-km section of the Sandusky River. Five additional samples were collected from the municipal water system of Bucyrus. The collecting sites are indicated in Figure 1.

The river samples were collected from the surface at the center of the river by lowering a plastic bucket from bridges. The municipal water samples were collected directly from the Water Treatment Plant of Bucyrus and from city plumbing. The water samples were stored at room temperature in new 250 and 500-mL polyethylene bottles which were rinsed before collection with the water being collected. The river contained an above-average amount of sediment due to a total rainfall of 3.58 cm from December 13 to

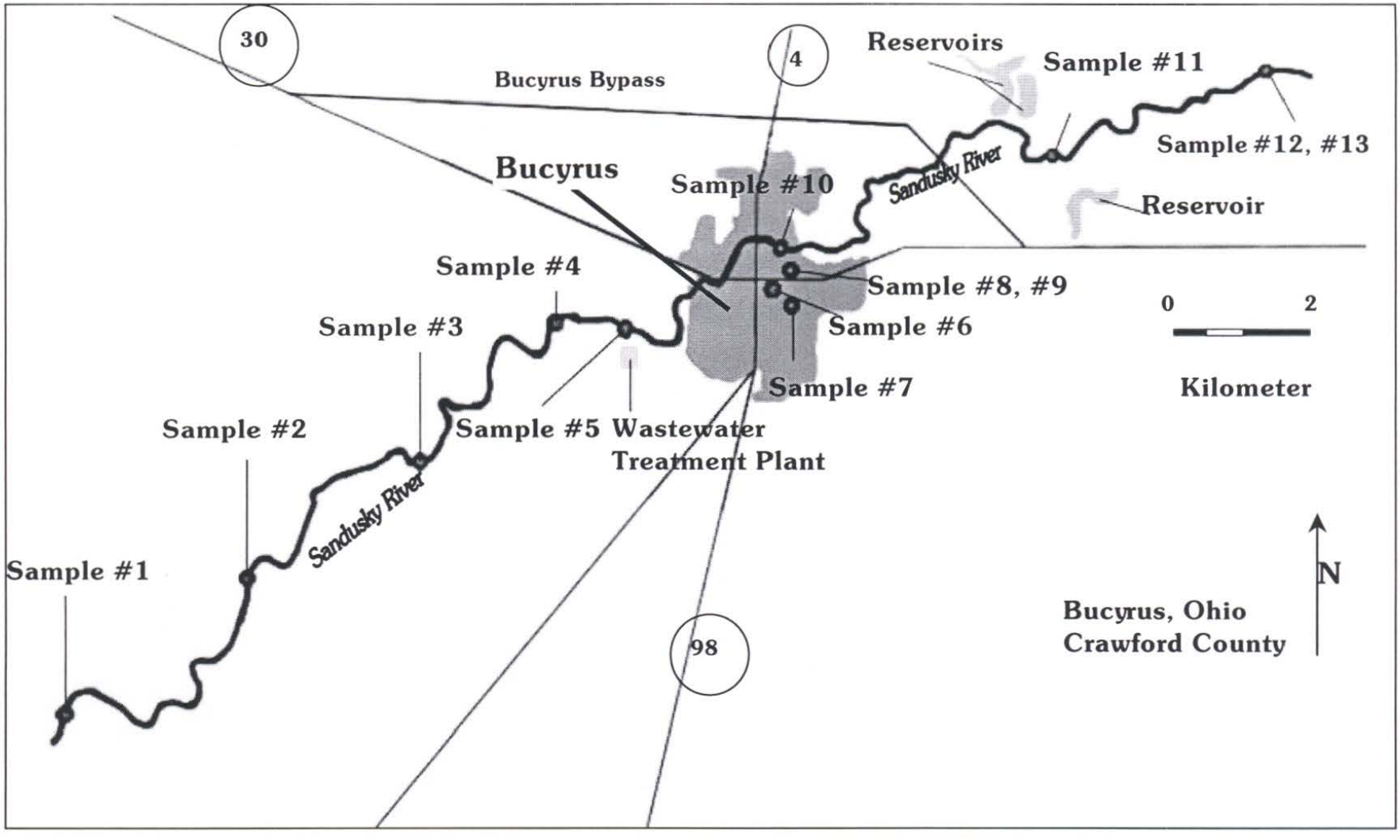


Figure 1. Map of Sandusky River at Bucyrus, Ohio showing location of samples collected on 15 December 1999 (exact site location in appendix).

December 15, 1999. Therefore, the river samples had to be filtered using first preweighed Whatman #1 filters followed by preweighed 0.45-μm acetate filters under vacuum. The municipal water samples were filtered only through 0.45-μm acetate filters. After filtration, the water samples were acidified by adding two drops of concentrated reagent-grade nitric acid to prevent growth of microorganisms. The water samples were analyzed by ICP-OES at XRAL Labs in Toronto, Ontario, Canada. The filters were dried naturally over a two-day period and reweighed to calculate the sediment concentration in mg/L.

GEOLOGY AND HYDROGEOLOGY OF THE SANDUSKY RIVER AT BUCYRUS, OHIO

Geology

The Sandusky River flowing through Bucyrus, Ohio, is located in the Till Plains section of the Central Lowland Province within the glaciated region of Ohio. The topography of the area is a flat till plain composed of clay-loam glacial till left behind by the retreat of the Laurentide ice sheet prior to 15,000 BP (Dawson, 1992). The Sandusky River crosses a contact between shale and shaley limestone from east to west within the city of Bucyrus (Figure 2). Olentangy and Ohio Shale of Devonian age underlie the eastern portion of the river. Columbus and Delaware limestone and shale of Devonian age underlie the western portion of the river (ODNR). The shale in these units contains pyrite and the limestone contains phosphate minerals.

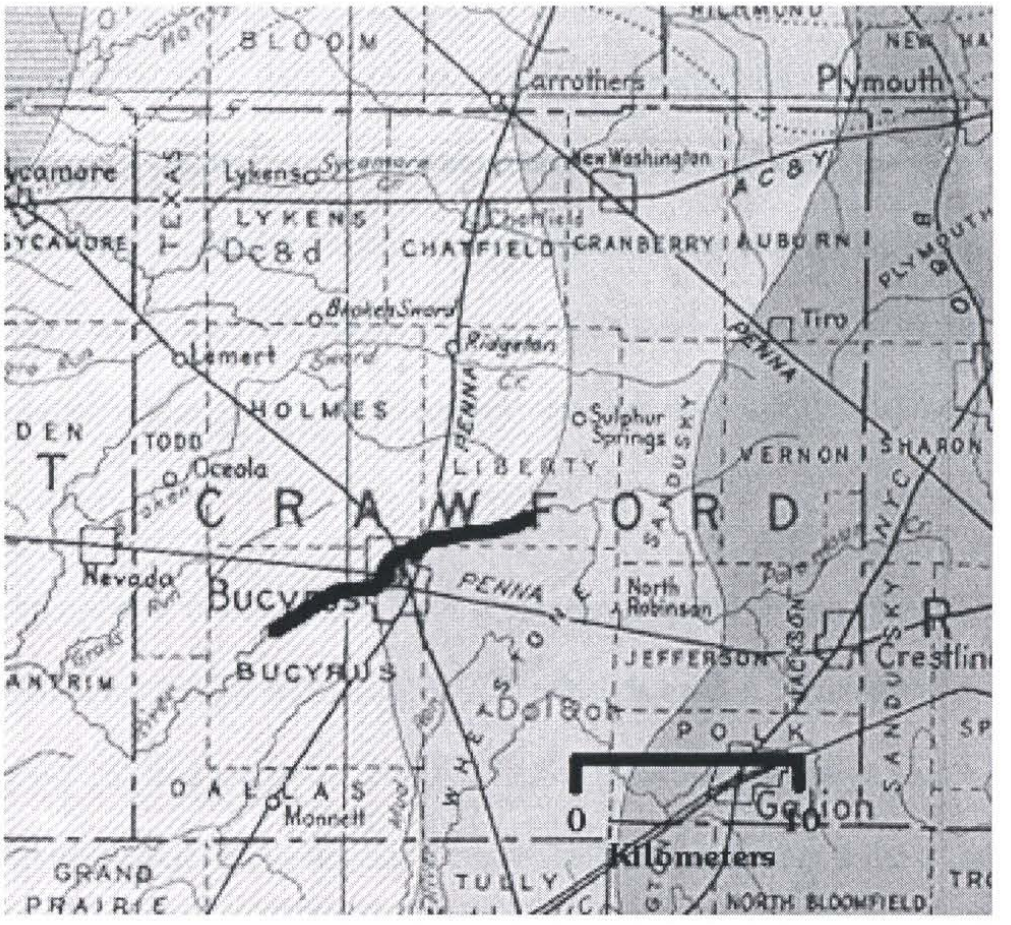


Figure 2. Geologic map of the Sandusky River at Bucyrus, Ohio, showing the study area (Adapted from ODNR).

Hydrogeology

The Sandusky River is part of the St. Lawrence River basin and is located approximately 5 km north of the divide between north-flowing and south-flowing rivers in Ohio. The springs of the river are located about 20 km east of Bucyrus in north-central Ohio. The river flows southwest through Bucyrus and then turns north, into the St. Lawrence River basin. The river discharges into the Sandusky Bay of Lake Erie. The river is 130.2 miles long with a gradient of 4 feet per mile from the source to the mouth (ODNR).

Discharge

The discharge of the Sandusky River is measured by the United States Geologic Survey (USGS) at hydrologic station 04196000, which is located 1.5 miles west of Bucyrus at latitude 40°48'13" and longitude 83°00'21". The measured discharge (cubic feet per second, cfs) at this site during water year October 1997 to September 1998 is used in this report to estimate the mean daily discharge for December 1999. The estimated mean daily discharge of the Sandusky River for December 1999 is shown in Figure 3 with an estimated mean daily discharge for 15 December 1999 of 21 cfs.

Meteoric Precipitation

The average daily meteoric precipitation measured at station 331072 at Bucyrus, Ohio, in December 1999 is shown in Figure 4 with a mean of 2.68 cm per day (NOAA). In the time period from 13 to 15 December 1999 the average precipitation was 1.19 cm per day and the total precipitation for this period is 3.58 cm (complete data table in appendix).

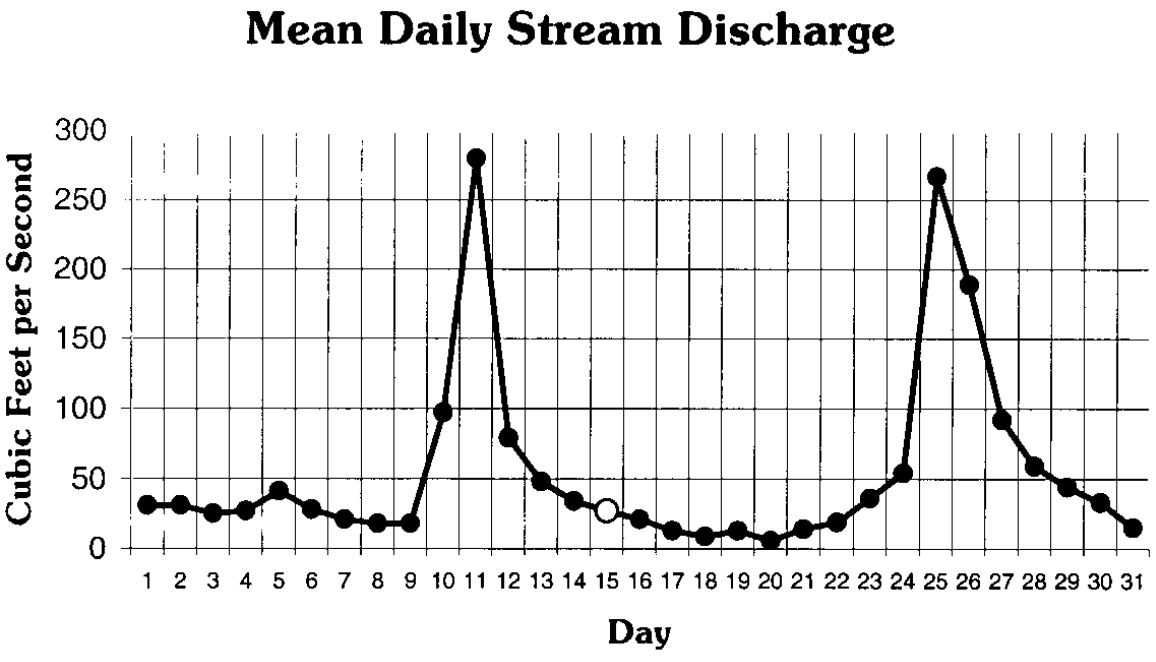


Figure 3. Mean daily discharge (cfs) for December 1997 used to estimate the mean daily discharge for December 1999 (USGS).

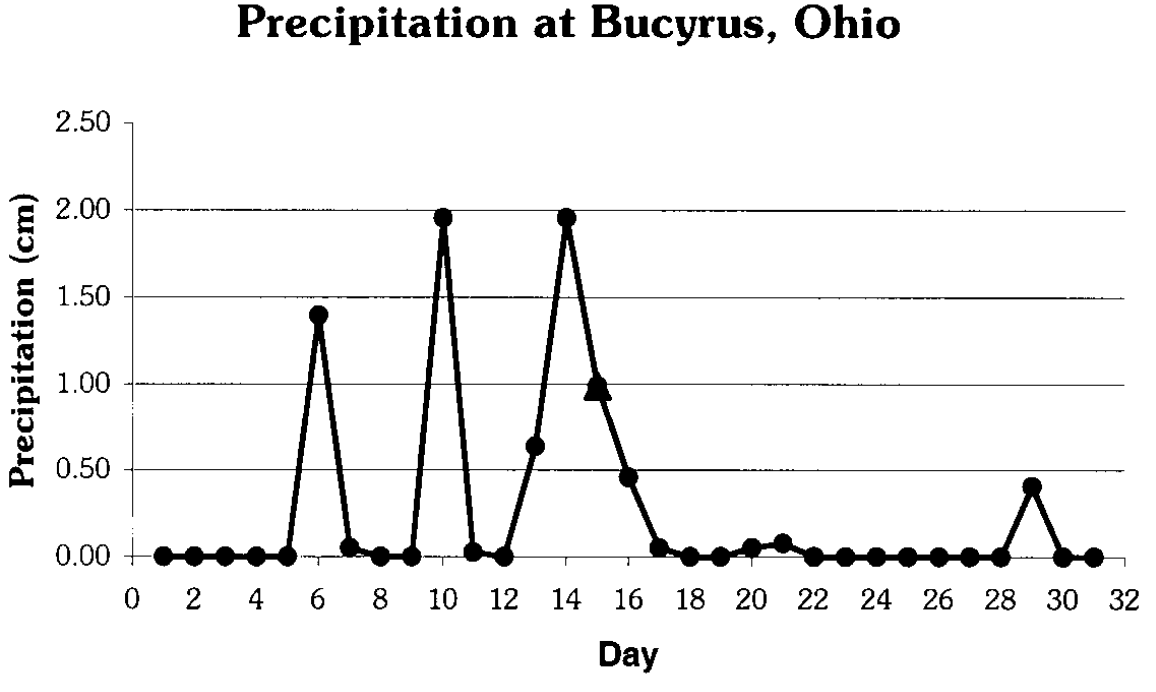


Figure 4. Daily precipitation (cm) for December, 1999 (NOAA).

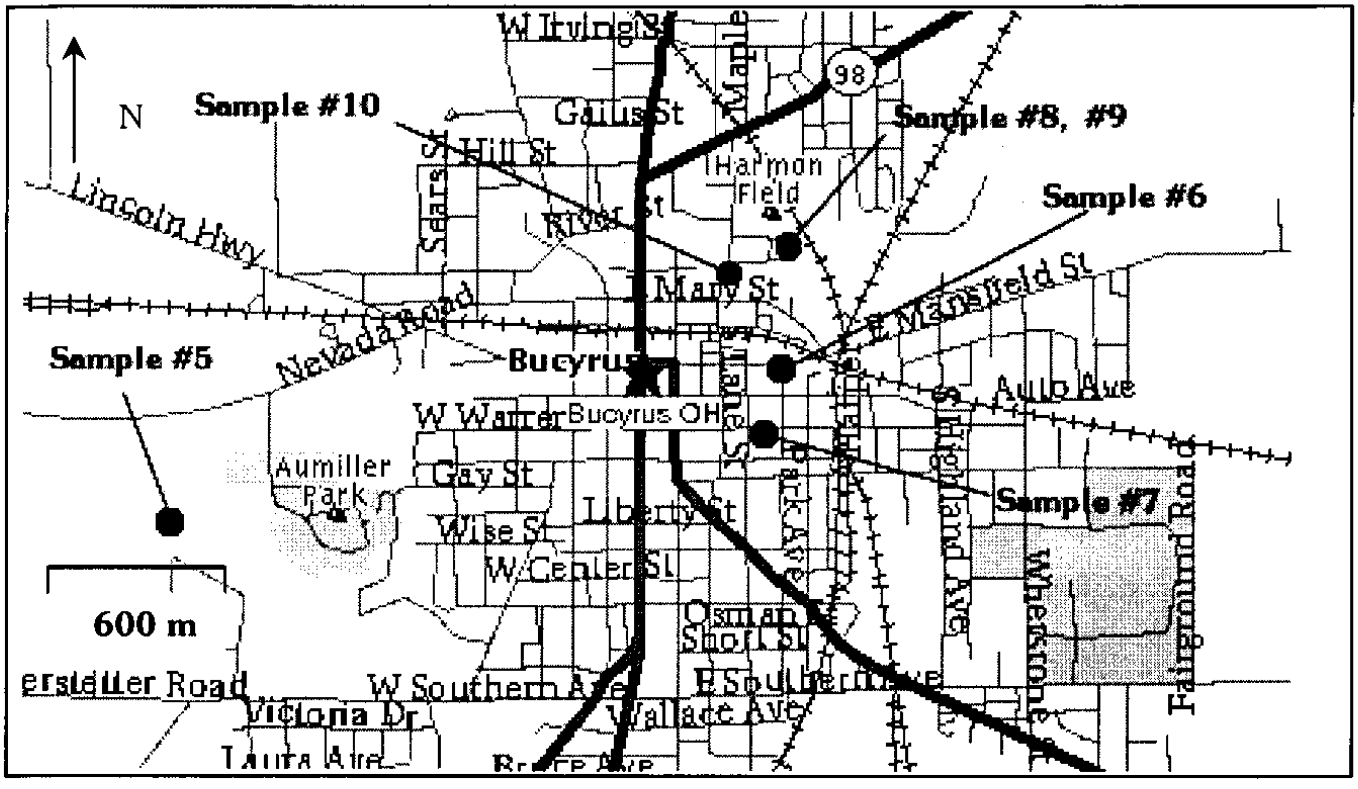
The precipitation for December 1999 is 1.02 cm above normal for the north-central portion of Ohio which encompasses the Sandusky River (ODNR).

CHAPTER 2: MUNICIPAL WATER

The municipal water for the city of Bucyrus is tracked in Figure 5 with sample locations indicated. The Sandusky River supplies water to the Bucyrus Water Treatment Plant from where the treated water is pumped to the water tower. The water flows through extensive plumbing systems before it reaches a household tap. After use, the city water is drained into the sewer system, which flows into the Wastewater Treatment Plant. After treatment of the wastewater, the effluent is discharged into the river. The reason for studying the municipal water system is to show that anthropogenic and industrial processes affect the chemical composition of the water.

Water Treatment Plant of Bucyrus

The Water Treatment Plant is located at 407 Water Street in Bucyrus, Ohio (Figure 5, sample #8 and #9). The plant was built in 1977 to provide an amount of water adequate to support the needs of the current and future population of the city. The plant uses the methods listed in Table 1 to purify water for domestic use. The water originates from the Sandusky River and from three reservoirs. The purified water is pumped into a 500,000-gallon water tower located at the corner of East Street and Warren Street (sample #7).



Sample #5: Effluent from wastewater treatment plant.
Sample #6: Tap from 411 E. Mansfield Street.
Sample #7: Water tower at the corner of East Street and Warren Street.
Sample #8, #9: Pre-filtrated water from water treatment plant.
Sample #10: River sample before discharge of the effluent.
Figure 5. Map of Bucyrus, Ohio, showing locations of the municipal water samples.

Table 1. Methods of purifying drinking water and preventing tooth decay used at the Water Treatment Plant at Bucyrus, Ohio.

Aluminum Sulfate	Reacts with water to form aluminum oxides that attract fine sediment.
Calcium Oxide	Reacts with water to form calcium hydroxides, which is insoluble and precipitates.
Activated Carbon	Absorbs ions to remove odor.
Chlorine	Added to water in gas form to eliminate all harmful bacteria.
Hydrofluosilicic Acid	Added to water to help prevent tooth decay.
Potassium Permanganate	Reacts with water by oxidation to remove odors.
Sodium Hexametaphosphate	Reacts with iron and calcium released by municipal plumbing system.

Wastewater Treatment Plant of Bucyrus

The Wastewater Treatment Plant of Bucyrus is located at 1500 West Southern Avenue in Bucyrus, Ohio (Figure 5, sample #5). The plant receives wastewater from the city of Bucyrus which has an approximate population of 16,000 and from various industries. The two major industries located in Bucyrus are the Timken Company and Dayco Swan Rubber Company. The Wastewater Treatment Plant uses the methods in Table 2 to treat the wastewater before it is discharged into the Sandusky River.

Table 2. Methods of treating wastewater at the Wastewater Treatment Plant, Bucyrus, Ohio.

Screening	Removes solid material greater than 2.5 cm.
Aerating	Replenishes anoxic water with oxygen.
Removing Sludge	Wastewater enters sedimentation tanks where organic sludge settles from water.
Removing Scum	Slow-moving rakes skim the scum off the surface of the wastewater in sedimentation tanks.
Ultraviolet Radiation	Kills harmful bacteria in the wastewater.
Alum	Addition of 18% alum to precipitate phosphorus compounds.

RESULTS

Purification of water prior to its use increases the concentrations of Na, indicated in Figure 6, and other elements. The data in Figure 7 indicate that the effluent discharged by the Wastewater Treatment Plant is enriched in Mg (56%), Ba (47%), Ca (37%), K (32%), and Na (30%). The concentration of Fe does not rise as the water passes through the city

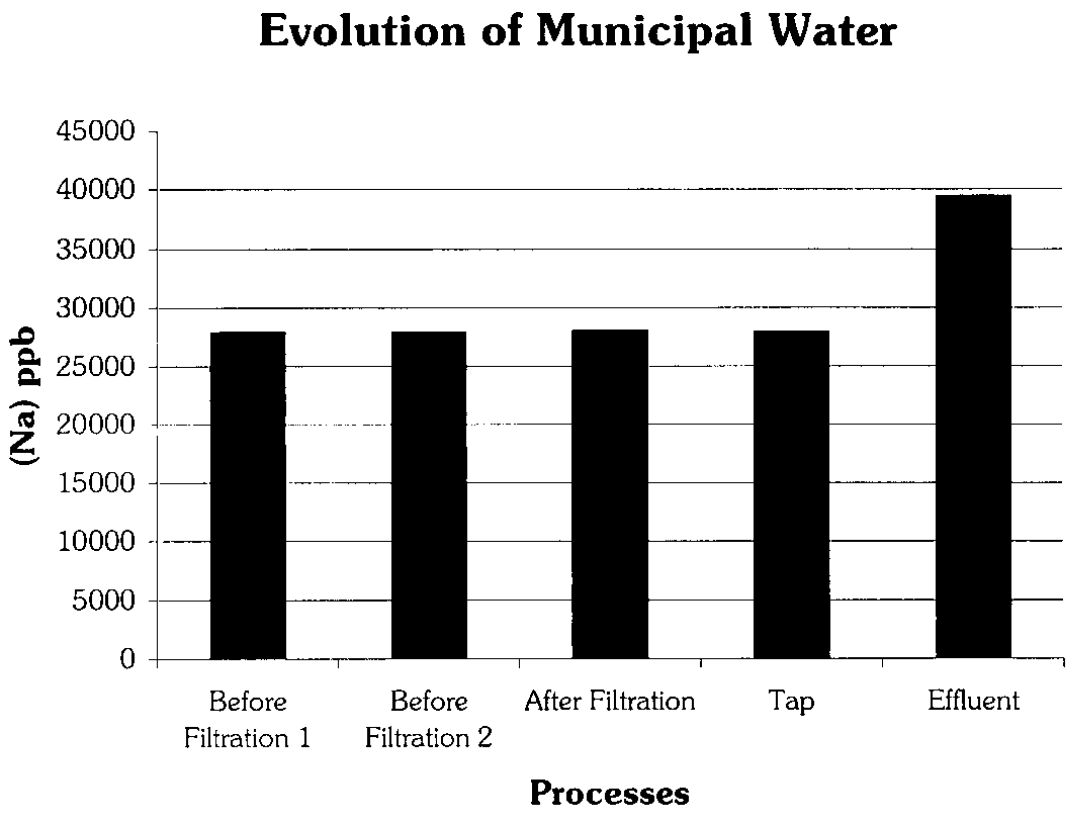


Figure 6. Sodium concentration (ppb) during evolution through municipal processes.

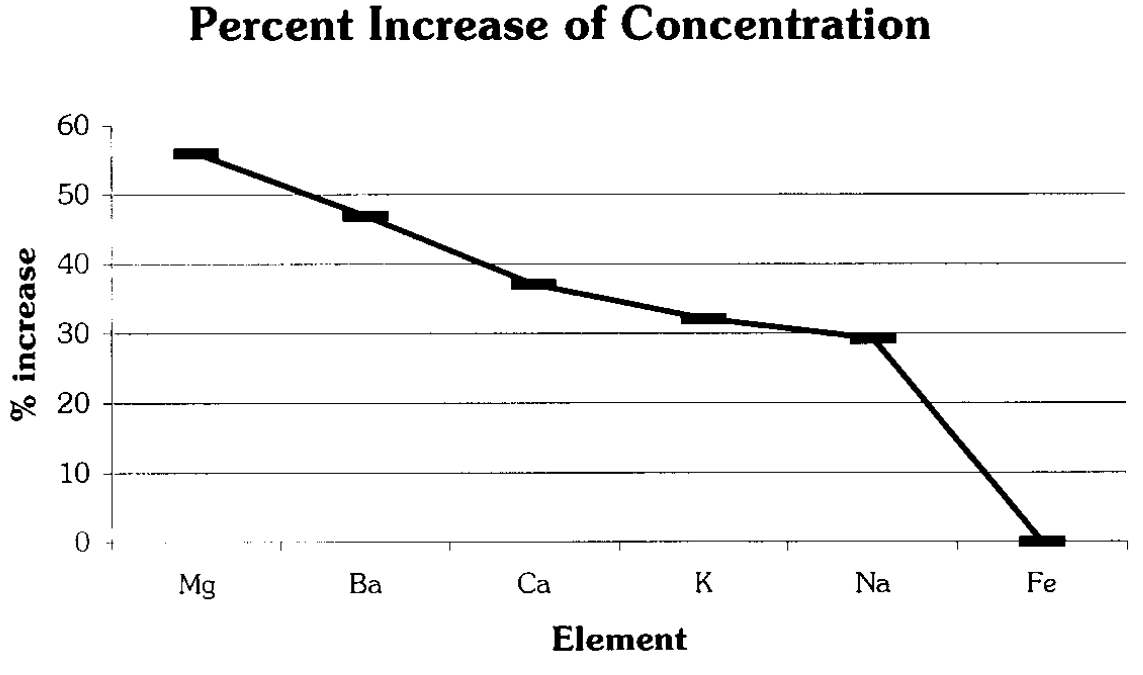


Figure 7. Percent increase of concentration (ppb) from before filtration to effluent of elements in decending order.

of Bucyrus. The concentration of Zn also increases (not shown in Figure 7). In addition, the concentration of P is 0 ppb before filtration, 391 ppb after filtration, 314 ppb in the tap water, and 0 ppb in the effluent because it is removed from the wastewater by the addition of alum. In addition, the concentration of Al not shown in Figure 7 decreases by 14% and that of Mn decreases by 43%.

DISCUSSION

The increases in concentrations of Mg, Ba, Ca, K, and Na may be attributable to certain chemical, anthropogenic, and industrial processes to which the water was subjected during its progress through the system. The wastewater is distinguished by high concentrations of Na and P. The Na originates from table salt and water softeners. The P is removed from the wastewater by treating the water with alum at the Wastewater Treatment Plant of Bucyrus. The increases in concentrations of Mg, Ba, Ca, and K may be from industrial wastewater entering the city's sewer system. The increase of Zn may be from meteoric runoff of galvanized steel sheets used for roofing and siding of buildings.

The decreases of the concentrations of Al and Mn may result from chemical precipitation in the pipes of the plumbing systems.

CONCLUSION

The chemical evolution of municipal water is characterized by increases in the concentrations of Mg, Ba, Ca, K, Na, and Zn. Phosphorus is removed from the municipal

wastewater according to EPA regulations. The decreases in the concentrations of Al and Mn may be caused by the formation of chemical precipitates in the plumbing of the city of Bucyrus.

CHAPTER 3: RESULTS AND DISCUSSION, SANDUSKY RIVER

The locations of the river samples and the discharge of the effluent are shown in Figure 1. Samples #13 to #10 are upstream from the discharge of the effluent, sample #5 is the effluent, and samples #4 to #1 are downstream from the effluent. The results for the sediment concentration and the concentration of inorganic elements are listed in Table 3. Sample #12 and #13 are duplicates taken at the same location at the bridge on McCurdy Road at the intersection of Stetzer Road. The deviations of the concentrations determined by the duplicate samples are indicated in Table 3. Elements that are omitted due to large deviations or have limits below the detection level are included in a comprehensive table in the appendix.

The results of the chemical analysis of the river are separated into two groups according to the trends in chemical concentration in a downstream direction. Group 1 elements have trends of decreasing in concentration continuously after the discharge of the effluent. Group 2 elements have trends of increasing concentration downstream of the effluent.

Table 3. Sediment concentration (mg/L) and chemical concentration (ppb) at sample locations (km).

SEDIMENT AND CHEMICAL CONCENTRATION IN RIVER AND EFFLUENT

Distance Upstream to Downstream

Sample		0	0	3.7	9.1	12.6	13	16.6	20.1	24.5	
		13	12	11	10	5	4	3	2	1	σ
Sediment Concentration		8.6	6.78	8.85	10.78	6.2	12.95	14.78	15.12	18.22	±0.92
Group	**Element**										
1	Na	14110	14150	13540	14270	39400	16030	14430	14090	13400	± 20
	Mg	16750	16800	15850	15460	17450	16040	14670	14210	13480	± 25
	Ca	66100	66440	62900	62160	89870	65660	59910	58290	54970	± 170
	Sr	351	353	368	391	736	414	380	378	368	± 1
2	Al	99	134	112	80	58	86	124	140	382	± 17.5
	Fe	85	131	99	92	0	92	118	177	447	± 23
	Ba	62	56	60	58	49	82	106	108	120	± 3
	K	5620	5620	6000	5750	5600	6480	6400	6240	6170	± 0

RESULTS

Sediment Concentration

The sediment concentrations (mg/L) of the Sandusky River segment under study in a downstream direction are plotted as a function of distance in Figure 8. The sediment

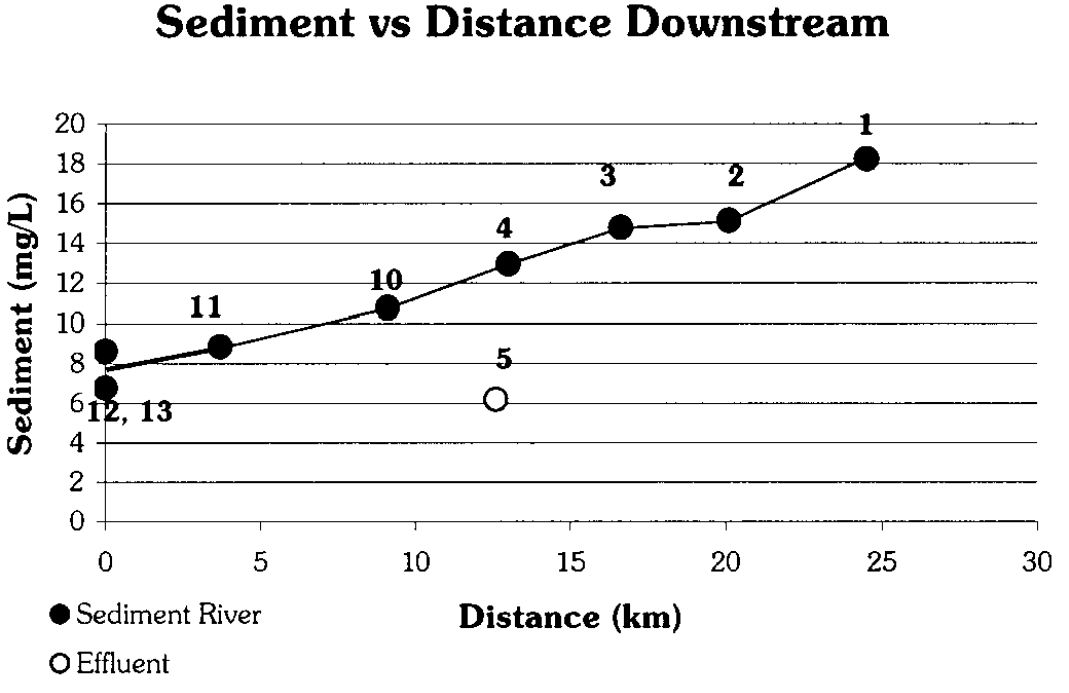


Figure 8. Sediment concentration (mg/L) in Sandusky River as a function of distance (km).

concentration increases steadily by 137%. The sediment concentration of the effluent (6.2 mg/L) is lower than that of the river sample #10 (10.8 mg/L) upstream of the discharge of the effluent, and sample #4 (12.9 mg/L) downstream of the effluent. Evidently, the discharge of the effluent did not significantly alter the sediment load of the Sandusky River.

Group 1

The elements in Group 1 are Na, Mg, Ca, and Sr. The concentration of Na (ppb) in Figure 9 is variable upstream of the discharge of the effluent and subsequently decreases

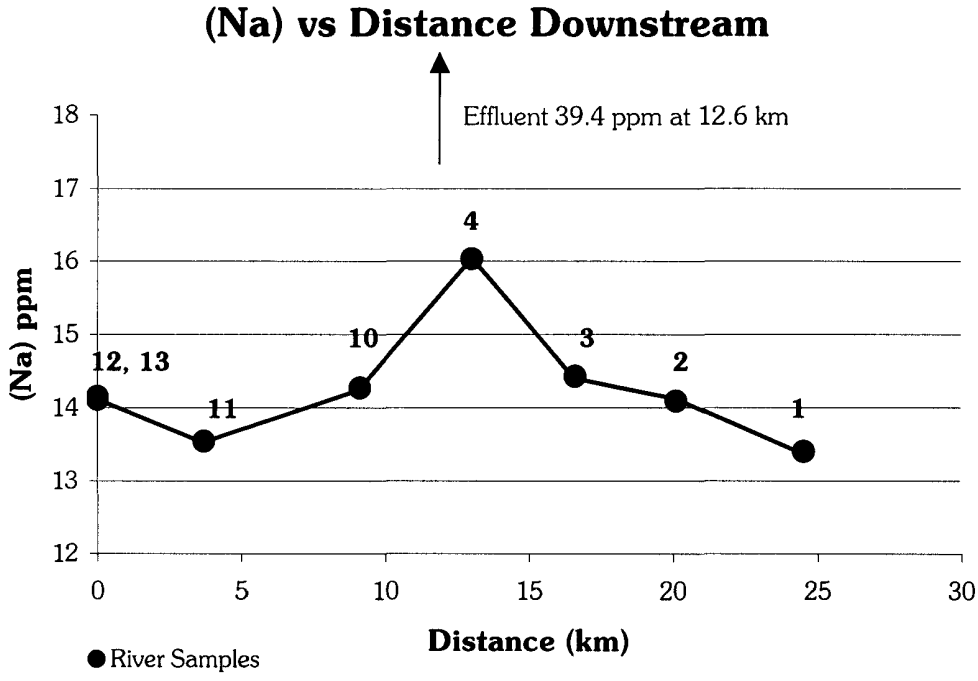


Figure 9. Sodium concentration plotted as a function of distance downstream.

downstream. The Na concentration in the effluent is 39.4 ppm, causing the Na concentration of the river to increase by 12.3% from sample #10 to sample #4. Further downstream from samples #3 to #1, there is a continuous decrease in the Na concentration. Calcium, Mg, and Sr all have trends similar to Na.

Group 2

The elements in Group 2 are Al, Fe, Ba, and K. The concentration of Al (Figure 10)

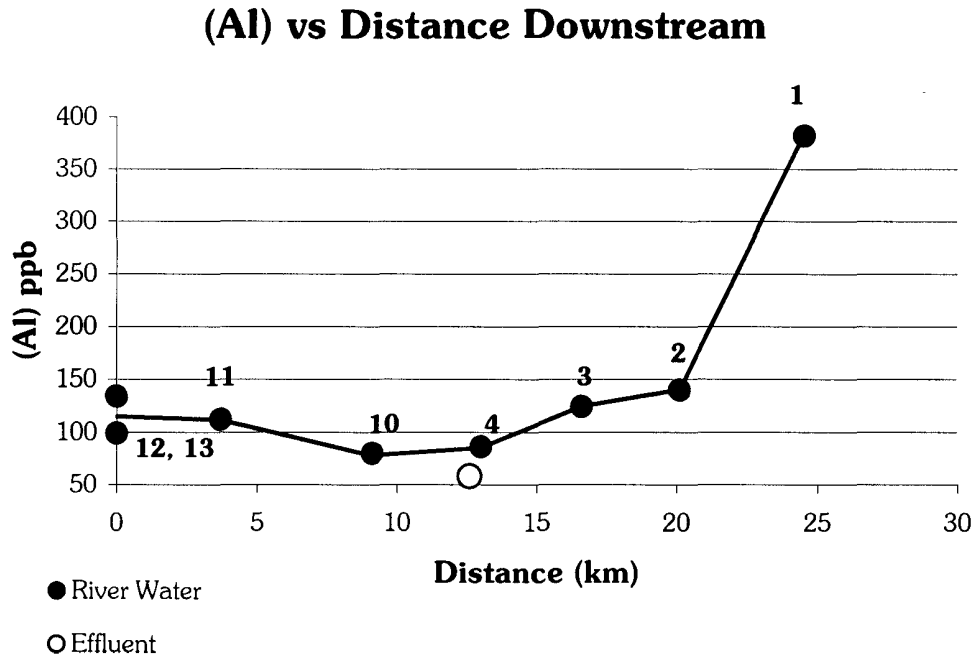


Figure 10. Aluminum concentration as a function of distance downstream.

increases downstream even though the effluent has a lower Al concentration than the river. The Al concentration in the effluent is 80 ppb, whereas sample #10 contains 112 ppb. The concentrations of Fe and Ba have trends similar to Al; however, the K concentration proceeds differently further downstream. Potassium has continuously decreasing concentration after the release of the effluent, like the elements in Group 1; however, the K concentration of the effluent is only 5600 ppb compared to 5750 ppb in sample #10.

DISCUSSION

The elements of Groups 1 and 2 have different concentration trends in a downstream direction. The concentrations of the elements in Group 1 decrease downstream of the wastewater discharge point whereas those of Group 2 increase.

Group 1

The elements in Group 1 have decreasing trends in concentration in a downstream direction indicating that the wastewater is being diluted. Therefore, the natural logarithm of the Na concentration (ppb) in the river in Figure 11 deceases as a function of distance (km) downstream and forms a straight line. The equation of the line through the data points was determined by least-squares regression (Figure 11). The concentrations of Mg, Ca, and Sr

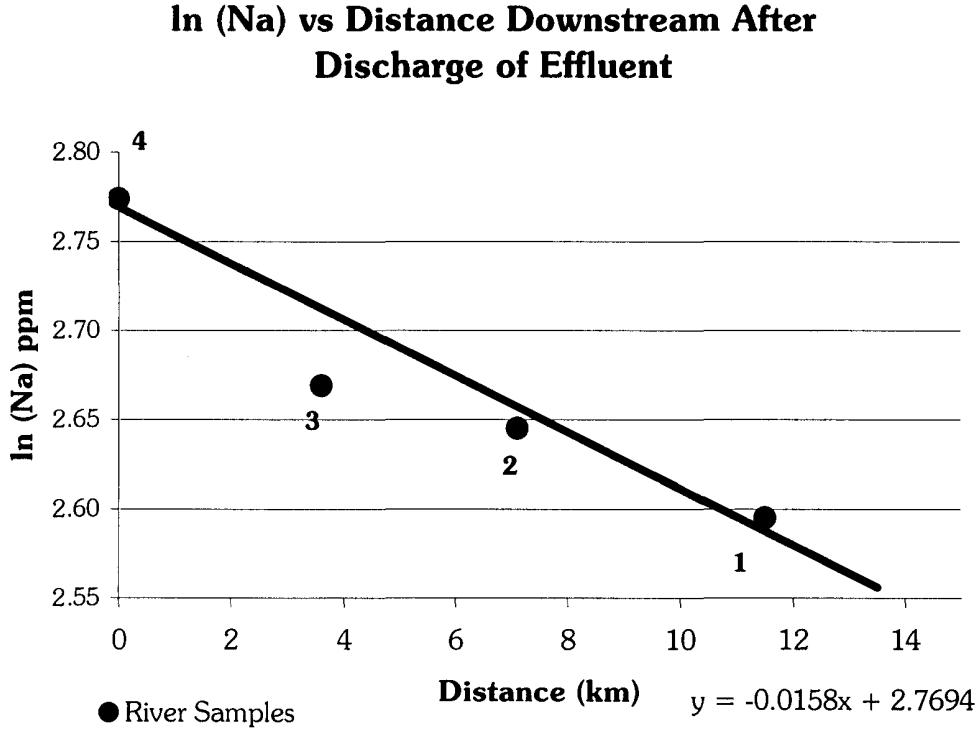


Figure 11. Natural logarithm of the Na concentration as a function of distance downstream after the effluent.

all form similar patterns to Na. The three most abundant elements (Na -0.0146, Mg – 0.0145, Ca –0.0147) have similar mixing coefficients, which supports the interpretation of progressive dissolution of the Group 1 elements in the river water.

The data for Na and Ca in Figure 12 demonstrate that the concentrations of these elements are attributable to mixing of the effluent and the river water (sample #10). If the two end members are the only sources contributing Na and Ca to the river, then samples #4 to #1 should lie on the mixing line connecting the two end members. In fact, samples #4 to #1 do lie close to the mixing line in Figure 12. This demonstrates that the concentrations of Na and Ca are attributable to mixing of the river water and the effluent.

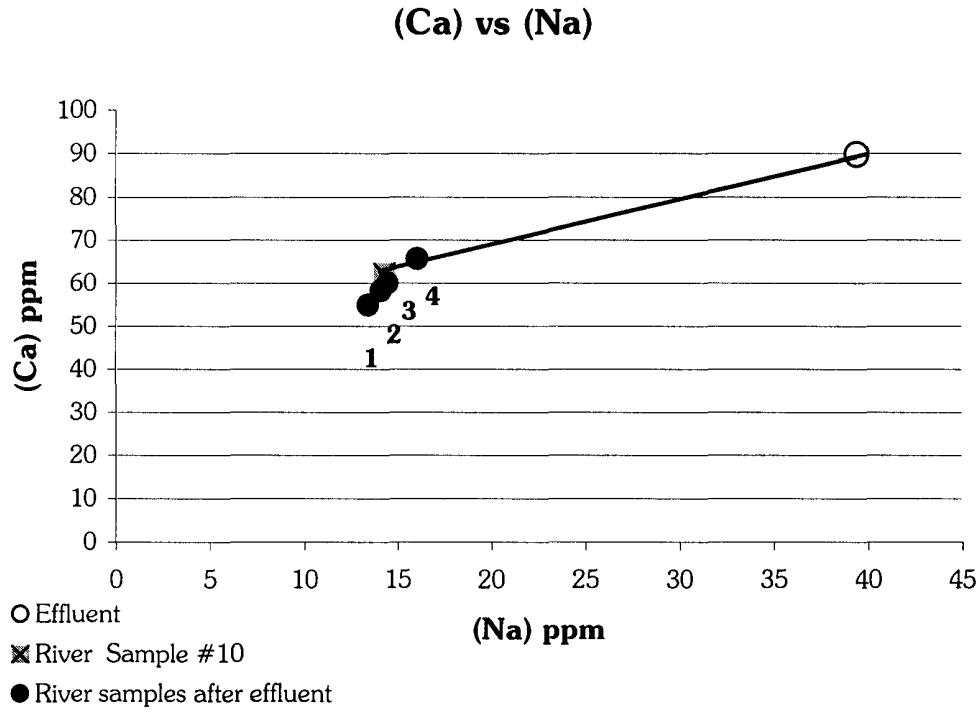


Figure 12. Mixing diagram of Ca (ppm) vs Na (ppm).

Group 2

The elements in Group 2, including Al, Fe, and Ba have increasing concentrations in a downstream direction after the effluent enters the river, which requires the existence of a source that is continuously adding these elements to the river. The increase of the concentration of K requires a source that is not continuous, since K demonstrates mixing after the introduction of a third source at sample #4. The Al concentration of samples #4 to #1 increase downstream and deviate progressively from the mixing line in Figure 13 between the effluent and the river water. Therefore, Al is being added to the river by a third component. Both Fe and Ba also show this exact pattern in mixing diagrams generated with Na.

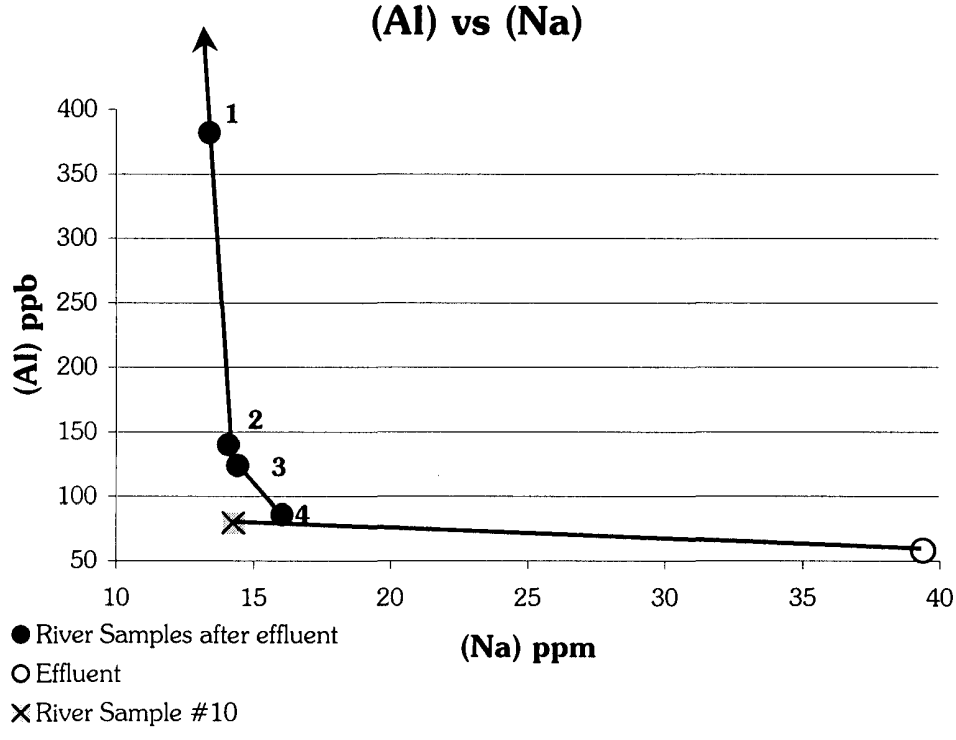


Figure 13. Mixing diagram of Al (ppb) vs Na (ppm).

This third source may be the groundwater whose chemical composition reflects the existence of a geologic contact from shale to limestone, which occurs within the city of Bucyrus. Samples #13 to #10 were collected upstream of the contact and are underlain by shale; whereas samples #4 to #1 are located downstream and are underlain by limestone. The chemical composition of the groundwater entering the river as it flows through Bucyrus changes at or close to the geologic contact and causes the observed increases in the concentration of Al, Fe, Ba, and K. The Al enrichment of the river may arise because the groundwater is in contact with clay minerals in the shale, whereas the Fe enrichment may result from the oxidation of pyrite crystals in the shale. The source of Ba may be the limestone, although barite ($BaSO_4$) is insoluble. Alternatively, Ba^{2+} may be sorbed to clay minerals in the shale of the local bedrock. Without further study of the area by testing the groundwater, the source of Ba remains unknown. Potassium has a high concentration in sample #4 after the effluent enters the river suggesting that there is another source of K immediately after the effluent discharge. This may be caused by drainage from local farmland because sample #4 is located west of the city in a farming area. The K concentrations in samples #3 to #1 show mixing of the river water with the other source of K.

CONCLUSION

The progressively increasing concentrations of Al, Fe, Ba, and K in the Sandusky River after it crosses a geologic contact within the city limits of Bucyrus are caused by a change in chemical composition of the groundwater that enters the river downstream of the contact.

SUMMARY OF CONCLUSIONS

The municipal water used by the city of Bucyrus is contaminated by Mg, Ba, Ca, K, Na, and Zn. Phosphorus added to the river by detergents and organic waste is removed in the Wastewater Treatment Plant. The concentrations of Al and Mn of the municipal water actually decrease because of chemical precipitation in the water pipes as scale.

The effluent discharged into the Sandusky River does not alter the chemical concentration of the river water significantly. However, the presence of a geologic contact within the city limits of Bucyrus probably explains why the concentrations of Al, Fe, Ba, and K of the river increase downstream.

The results of this study have shown two different aspects of water evolution; one is the way people alter the chemical composition of the water they use and the other is that natural processes alter the water more significantly than the people.

ACKNOWLEDGEMENTS

I would like to thank the Wastewater Treatment Plant and The Water Treatment Plant of Bucyrus for supplying me with information for this report. I would like to thank XRAL Labs in Toronto, Canada for the analysis.

I would also like to express my deepest gratitude to Dr. Gunter Faure who recommended and advised this project. His guidance and patience have taught me about the geochemistry of rivers and our conversations were both enlightening and enjoyable.

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APPENDIX

Table 1A. Meteoric precipitation data (NOAA).

Day	Precipitation (in)	Precipitation (cm)
1	0	0.0000
2	0	0.0000
3	0	0.0000
4	0.01	0.0000
5	0	0.0000
6	0.55	1.3970
7	0.02	0.0508
8	0	0.0000
9	0	0.0000
10	0.77	1.9558
11	0.01	0.0254
12	0	0.0000
13	0.25	0.6350
14	0.77	1.9558
15	0.39	0.9906
16	0.18	0.4572
17	0.02	0.0508
18	0	0.0000
19	0	0.0000
20	0.02	0.0508
21	0.03	0.0762
22	0	0.0000
23	0	0.0000
24	0	0.0000
25	0	0.0000
26	0	0.0000
27	0	0.0000
28	0	0.0000
29	0.16	0.4064
30	0	0.0000
31	0	0.0000

Table 2A. Chemical analysis results performed by XRAL Labs Toronto, Canada.

Sample Identificaton	Be	Na	Mg	Al	P	K	Ca	Sc
System	ICP200	ICP200	ICP200	ICP200	ICP200	ICP200	ICP200	ICP200
Analysis Unit	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
Detection Limit	5	50	50	50	50	100	50	1
1	-5	13400	13480	382	-50	6170	54970	-1
2	-5	14090	14210	140	69	6240	58290	-1
3	-5	14430	14670	124	57	6400	59910	-1
4	-5	16030	16040	86	-50	6480	65660	-1
5	-5	39400	17450	58	50	5600	89870	1
6	-5	27920	7570	-50	314	3720	54080	-1
7	-5	27980	7580	67	391	3790	54320	-1
8	-5	27850	7680	61	-50	3640	55990	-1
9	-5	27870	7680	74	-50	3960	57110	-1
10	-5	14270	15460	80	67	5750	62160	-1
11	-5	13540	15850	112	67	6000	62900	-1
12	-5	14150	16800	134	59	5620	66440	-1
13	-5	14110	16750	99	78	5620	66100	1
Duplicate for 1	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000
Duplicate for 13	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000

Sample Identificaton	Ti	V	Cr	Mn	Fe	Co	Ni	Cu
System	ICP200	ICP200	ICP200	ICP200	ICP200	ICP200	ICP200	ICP200
Analysis Unit	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
Detection Limit	10	10	10	5	50	10	10	5
1	-10	-10	36	15	447	-10	19	12
2	-10	-10	-10	13	177	16	-10	10
3	-10	-10	21	12	118	0	11	5
4	-10	-10	-10	13	92	19	13	13
5	-10	-10	12	19	-50	17	-10	8
6	-10	-10	-10	-5	-50	-10	-10	-5
7	-10	-10	-10	-5	-50	10	13	6
8	-10	-10	-10	32	-50	11	23	-5
9	-10	-10	17	35	-50	-10	-10	6
10	-10	-10	-10	11	92	14	-10	6
11	-10	-10	15	14	99	-10	-10	7
12	-10	-10	24	16	131	33	0	-5
13	-10	-10	-10	10	85	-10	-10	-5
Duplicate for 1	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000
Duplicate for 13	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000

Continuation of **Table 2A:**

Sample Identificaton	Zn	As	Sr	Y	Zr	Mo	Ag	Cd
System	ICP200	ICP200	ICP200	ICP200	ICP200	ICP200	ICP200	ICP200
Analysis Unit	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
Detection Limit	5	30	1	5	10	10	1	10
1	7	32	368	-5	-10	18	-1	-10
2	-5	-30	378	-5	-10	33	3	-10
3	5	-30	380	-5	-10	25	-1	-10
4	8	-30	414	-5	-10	28	-1	-10
5	25	-30	736	-5	-10	26	2	-10
6	-5	37	564	-5	-10	32	2	-10
7	-5	-30	570	-5	-10	26	3	-10
8	-5	-30	580	-5	-10	26	-1	-10
9	-5	-30	583	-5	-10	30	5	-10
10	6	-30	391	-5	-10	27	-1	-10
11	13	-30	368	-5	-10	23	1	-10
12	8	-30	353	-5	-10	15	-1	-10
13	6	0	351	-5	-10	30	-1	-10
Duplicate for 1	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000
Duplicate for 13	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000

Sample Identificaton	Sn	Sb	Ba	La	W	Pb	Bi
System	ICP200	ICP200	ICP200	ICP200	ICP200	ICP200	ICP200
Analysis Unit	ppb	ppb	ppb	ppb	ppb	ppb	ppb
Detection Limit	50	50	10	10	50	30	50
1	-50	-50	120	-10	-50	-30	-50
2	-50	-50	108	-10	51	-30	-50
3	-50	-50	106	-10	-50	-30	85
4	-50	-50	82	-10	0	-30	67
5	-50	-50	49	-10	-50	0	109
6	-50	-50	43	-10	-50	-30	178
7	-50	-50	30	-10	-50	42	88
8	-50	-50	26	-10	-50	-30	100
9	-50	-50	26	-10	-50	-30	-50
10	-50	-50	58	-10	-50	-30	76
11	-50	-50	60	-10	-50	-30	64
12	-50	-50	56	-10	-50	64	-50
13	-50	-50	62	-10	-50	-30	-50
Duplicate for 1	-3000	-3000	-3000	-3000	-3000	-3000	-3000
Duplicate for 13	-3000	-3000	-3000	-3000	-3000	-3000	-3000

Table 3A. Sample number and site sample was collected.

Samples	Locations
1	Bridge on Rex Road at Knauss Road
2	Bridge on Shupp Road at Mount Zion Road
3	Bridge on Denzer Road at River Road
4	Bridge on Kerstetter Road at River Road
5	Wastewater Treatment Plant, 1500 West Sourthern Avernue
6	Tap water at 411 East Mansfield Street
7	Water Tower at the corner of East Street and Corner Street
8	Water Treatment Plant, 407 Water Street
9	Water Treatment Plant, 407 Water Street
10	Bridge on Lane avenue at Water Street
11	Bridge on Keiss Road at Stezter Road
12	Bridge on McCurdy Road at Stezter Road
13	Bridge on McCurdy Road at Stezter Road