Possible Contamination of the Sandusky River by Wastewater Discharge by Bucyrus, Ohio[1]

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Abstract. **The objective of this study was to determine changes in the chemical composition of water that result from its use by the town of Bucyrus in Crawford County, OH, and to document the effect of the discharge of wastewater on the quality of water in the Sandusky River. The results indicate that the wastewater is enriched in the major elements (Na, K, Mg, Ca, and Sr) compared to tap water in the town of Bucyrus. However, the treated wastewater does not significantly alter the chemical composition of water in the Sandusky River represented by a ten-year average from 1984 to 1994. The concentrations of Mo in raw water and in the wastewater are nearly identical, which means it cannot have an anthropogenic source. The wastewater does not contain P because this element is effectively removed as required by the Great Lakes Water Quality Agreement.**

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INTRODUCTION

Ohio municipalities use water for domestic, commercial, and industrial purposes as well as for consumption by humans and domestic animals. The water required for these purposes is derived from wells, streams, and reservoirs, and is purified before it is released for human consumption. After use, the wastewater is treated again before it is discharged into the environment. The release of wastewater into streams is a potential source for chemical contamination. Previous studies of this phenomenon in streams in Ohio include the work of: Fortner (2000); Heffelfinger (1999, 1995); Mensing and Faure (1998); Piatak (1998); Essenburg (1997); Petz and Faure (1997); Sainey (1997, 1995); and Hicks (1994, 1992).

The purpose of the present study was to track the chemical composition of municipal water in the town of Bucyrus from its source to the discharge of wastewater, and to document the changes that occur in the chemical composition of the Sandusky River downstream of the outfall. The Sandusky River flows north into Lake Erie and therefore is subject to the Great Lakes Water Quality Agreement.

MATERIALS AND METHODS

Study Area

The Sandusky River (Fig. 1) arises from springs located near Crestline north of the local drainage divide. The drainage basin has an area of 3202 km^2 and a downstream length of 210 km. The geology of the basin upstream from Bucyrus consists of the Columbus and Delaware Limestones overlain by the Ohio Shale, all of which are of Devonian age. The rocks dip to the east at low angles and are covered by till of Wisconsinan age, including the Wabash Moraine which was deposited during the recession of the Laurentide ice sheet prior to about 15,000 year before present (Forsyth 1975; Dawson 1992).

The mean monthly discharge of the Sandusky River near Fremont during the 1998/99 water-year ranged from 55.9 m^3/s during high flow in April to 0.849 m^3/s during low flow in September of 1999. Partial chemical analyses, specific conductance, water temperature, pH, and the concentration of suspended sediment in the Sandusky River are recorded annually by the Water Resources Division of the US Geological Survey (Anonymous 2000). The pH of the water of the Sandusky River near Fremont typically ranges from about 7.0 (neutral) to 8.2 (mildly basic). A comprehensive summary

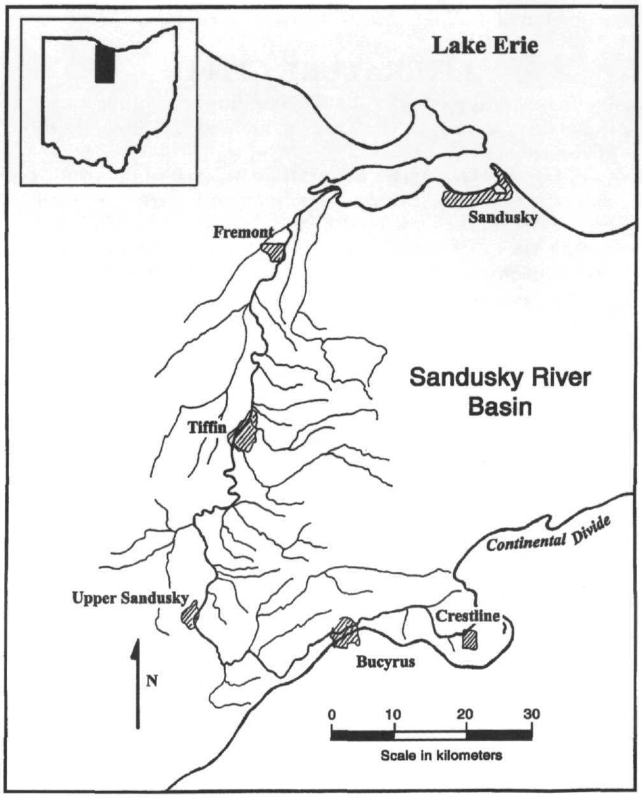

Figure 1. Drainage basin of the Sandusky River in north-central Ohio.

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of the geology, land use, and water quality in the Sandusky River basin was published by Baker and others (1975).

The Water Treatment Plant of Bucyrus receives raw water from reservoirs fed by tributaries of the Sandusky River upstream of the town. The water passes through a sand filter and is then treated with aluminum sulfate, calcium oxide, potassium permanganate, and activated charcoal. In addition, the water is treated with chlorine gas to reduce bacteria and with hydrofluosilicic acid to fluorinate the water.

The used water and sewage flow to the Wastewater Treatment Facility, which is located along the Sandusky River downstream of Bucyrus (Fig. 2). The solids are collected, the remaining water is aerated, and P is removed by the addition of aluminum potassium sulfate. The treated wastewater is irradiated with ultraviolet radiation before being discharged into the Sandusky River.

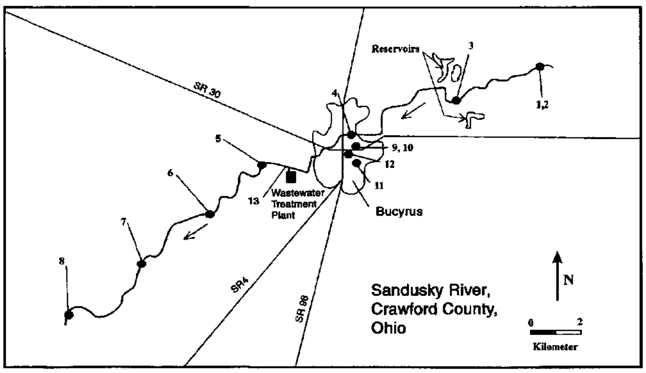

FIGURE 2. Collecting sites of water samples along the channel of the Sandusky River and in Bucyrus, OH.

Samples

Eight samples of Sandusky River water were collected on 15 December 1999, at sites near Bucyrus (Fig. 2). All samples were taken from the center of the river by lowering a plastic bucket from highway bridges and were stored in new polyethylene bottles that were rinsed with the river water at each site. Three additional water samples (9,10,11) were collected before and after purification at the Water Treatment Plant of Bucyrus; one sample (12) of water was taken from a household tap in the town; and one sample of the effluent discharged in the Sandusky River was collected at the Wastewater Treatment Plant on the same date as the river samples (sample 13, Fig. 2).

All samples were filtered through 0.45 μm acetate filters under vacuum as soon as they arrived in the laboratory at The Ohio State University. The filtered samples were then acidified with concentrated reagent-grade nitric acid (HNO_3) prior to analysis by XRAL Laboratory in Toronto, Ontario, using inductively-coupled plasma optical-emission spectrometry (ICP-OES). The (31) elements included in the analysis and their detection limits (μg/L) were: Be(5), Na(50), Mg(50), Al(50), P(50), K(100), Ca(50), Sc(1), Ti(10), V(10), Cr(10), Mn(5), Fe(50), Co(10), Ni(10), Cu(5), Zn(5), As(30), Sr(10), Y(5), Zr(10), Mo(10), Ag(1), Cd(10), Sn(50), Sb(50), Ba(10), La(10), W(50), Pb(30), Bi(50). The following elements were not detected in any of the samples analyzed in this study: Be, Sc, Ti, V, Y, Zr, Cd, Sn, Sb, and La. Three other elements were detected in fewer than five samples: As (2 samples), W (1 sample), and Pb (2 samples).

Two water samples from the Sandusky River (1 and 2) and from the Water Treatment Plant (9 and 10) were analyzed in duplicate as a test of the reproducibility of the analytical results. The data in Table 1 indicate that the differences between duplicate analyses of the major elements (Na, K, Mg, Ca, and Sr) whose concentrations exceed their detection limits by factors of 50 or more, are less than ± 1.0% in all but one case. The reproducibility of duplicate determinations deteriorates as the measured concentrations of certain elements approach their detection limits. For this reason, only those elements were considered in the interpretation whose measured concentrations exceed their detection limits by factors of ten of more. The complete chemical analyses were listed by Fortner (2000), although the sequence of numbering samples was reversed for the present paper.

TABLE 1

Results of duplicate analyses of water collected from the Sandusky River (samples 1 and 2) and from the Water Treatment Plant at Bucyrus, OH (9 and 10), in units of milligrams per liter (mg/L). The samples were analyzed by XRAL Labs, Toronto, Ontario, by ICP-OES.

	Average Concentrations	
Elements	Sandusky River (#1,2)	Water Treatment Plant (#9,10)
Na	14.13 ± 0.020	27.81 0.010
K	5.62 ± 0.00	3.80 ± 0.160
Mg	16.78 ± 0.025	7.68 ± 0.00
Ca	66.27 ± 0.17	56.55 ± 0.560
Sr	0.35 ± 0.001	0.58 ± 0.001

The reproducibility is expressed as one half of the difference between duplicate determinations and n.d. means "not detected."

RESULTS

Water Treatment Plant

The chemical composition of source water before and after purification was not altered in most cases (Table 2). The concentrations of the major elements remained virtually constant; however, purification removed Mn but added P at a concentration of 0.391 mg/L.

The concentrations of all major elements in the wastewater are significantly higher than those of Bucyrus tap water (Table 2). The concentrations of Al and Mn in the wastewater exceed those of the tap water, but generally remain close to the limit of detection. Molybdenum maintains a near constant concentration from raw water to the wastewater. The concentration of P in the wastewater is below the limit of detection.

TABLE 2

Chemical composition of water before and after purification by the Water Treatment Plant of Bucyrus, OH (mg/L).

Elements	Pretreatment 9 and 10	After Treatment 11	Tap water 12	Wastewater 13
Major Elements				
Na	27.86	27.98	27.92	39.40
K	3.80	3.79	3.72	5.60
Mg	7.68	7.58	7.57	17.45
Ca	56.55	54.32	54.08	89.87
Sr	0.582	0.570	0.564	0.736
Minor Elements				
Al	0.067	0.067	n.d.	0.058
Mn	0.033	n.d.	n.d.	0.019
Mo	0.028	0.026	0.032	0.026
P	n.d.	0.391	0.314	n.d.

n.d. means "not detected."

Sandusky River

The water of the Sandusky River upstream of Bucyrus (samples 1, 2, 3, 4) in Table 3 is characterized by high average concentrations of Ca (63.78 mg/L) with lower concentrations of Mg (16.03 mg/L), Na (13.98 mg/L), and K (5.79 mg/L). These concentrations are consistent with the range of concentration of water in the Sandusky River (Fig. 3) from 1984 to 1994 reported by the Water Resources Division of the US Geological Survey near Fremont, OH (Anonymous 1984-1994). Potassium and Sr have a small range of less than 10 mg/L, whereas Mg, Na, and Ca have larger ranges up to 81 mg/L for Ca (Fig. 3).

After the discharge of the wastewater by the town of Bucyrus (sample 13, Table 2), the concentrations of Na, K, Mg, Ca, and Sr in the Sandusky River all rise (sample 5, Table 3) and then decline downstream in samples 6, 7, and 8. For example, the Na concentration of the Sandusky River increases from 13.98 mg/L upstream of the Wastewater Treatment Plant to 16.03 mg/L immediately downstream (sample 5) and continues to decrease to 13.40 mg/L in sample 8 taken 12.5 km

TABLE 3

Chemical composition of water in the Sandusky River at Bucyrus, OH, on 15 December 1999 (mg/L) (refer to Fig. 2 for sample locations).

Elements	Average Upstream Samples 1+2, 3, and 4	Downstream Samples			
		5	6	7	8
Major Elements					
Na	13.98	16.03	14.43	14.09	13.40
K	5.79	6.48	6.40	6.24	6.17
Mg	16.03	16.04	14.67	14.21	13.48
Ca	63.78	65.66	59.91	58.29	54.97
Sr	0.370	0.414	0.380	0.378	0.368
Minor Elements					
Al	0.103	0.086	0.124	0.140	0.382
Mn	0.013	0.013	0.012	0.013	0.015
Mo	0.024	0.028	0.025	0.033	0.018
P	0.068	n.d.	0.057	0.069	n.d.

n.d. means "not detected."

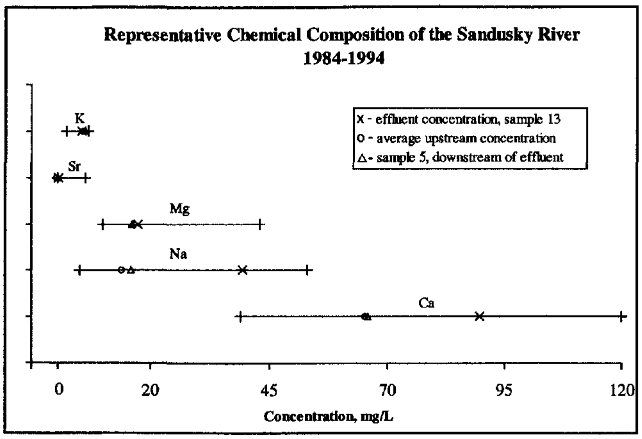

FIGURE 3. Ten year representative chemical composition of the Sandusky River from 1984 to 1994 with compositions of average upstream samples, sample 13, and sample 5 from 15 December 1999.

downstream. Concentrations of Al, Mn, and Mo are virtually unaffected by the discharge of the wastewater.

DISCUSSION

The data demonstrate that the wastewater discharged by Bucyrus is enriched in several major elements (Na, K, Mg, Ca, and Sr) relative to tap water in the town. The effect of the municipal contamination, from raw water (samples 9, 10) to wastewater (sample 13), is demonstrated by increases in the concentrations of Na (41% increase) and Ca (59% increase). A two-component mixing model between the raw water and the wastewater establishes a linear relationship between these elements (Fig. 4). The Na and Ca concentrations of the wastewater lie on the extension of the mixing line that joins the raw water and the hypothetical municipal contaminant (Fig. 4). The rectangular box in Fig. 4 is intended as a symbol of the process by which the Na and Ca concentrations of the water rise as it passes through the municipal plumbing system. The high Na and Ca concentrations are attributable to anthropologic sources.

The wastewater then mixes with the upstream water of the Sandusky River (samples 1+2, 3, 4) and causes the concentrations of Na and Ca in the river to rise. Mixtures of the upstream water and the effluent plot along the mixing line between wastewater and the upstream water in Fig. 4. For example, sample 5 collected downstream of the wastewater discharge-point is enriched in Na by 15% and in Ca by 3.0%. Application of the lever rule (Faure 1998) in Fig. 4 indicates that sample 5 contains about 8% wastewater.

The concentrations of Mo in the raw water (samples 9, 10) and in the wastewater (sample 13) are identical within analytical errors. Therefore, Mo is not an anthropogenic contaminant. The absence of P in the wastewater shows that the town of Bucyrus is in compliance with the Great Lakes Water Quality Agreement of 1972 by removing P by the addition of aluminum potassium sulfate.

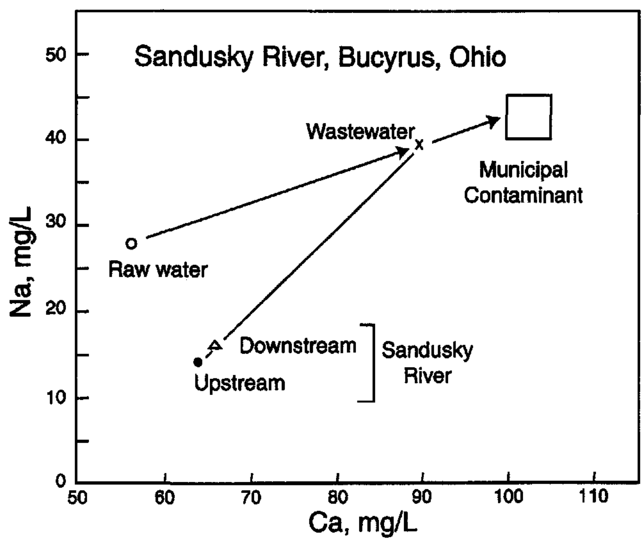

FIGURE 4. Two component mixing diagram illustrating alteration of the Na and Ca concentrations in the water by its use in the town of Bucyrus and the effect of wastewater on the Sandusky River.

CONCLUSIONS

The purification of raw water by the Water Treatment plant of Bucyrus does not alter its chemical composition significantly (Table 2). However, the wastewater discharged into the Sandusky River is enriched in all major elements (Na, K, Mg, Ca, and Sr) compared to domestic tap water in the town, whereas P is effectively removed and is not detectable in the wastewater of Bucyrus. Molybdenum has a near constant concentration throughout the purification and wastewater treatment processes and therefore is not attributable to anthropologic sources.

The wastewater of Bucyrus is characterized by a high Ca concentration; however, the concentrations of all major elements (Na, K, Mg, Ca, and Sr) are within the range of the ten-year representative chemical composition of the Sandusky River from 1984 to 1994. Therefore, the Sandusky River is not significantly altered by the discharge of wastewater by the town of Bucyrus.

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