Students as Scientists: A Study of the Effects of Sewage Plant Effluent

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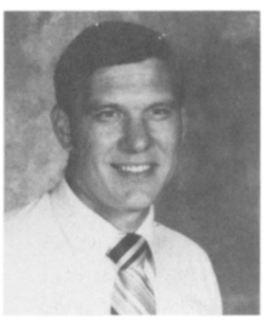

The author is a long-time resident of Ashland, Ohio with a strong commitment to its environment. He received his B.S. in education from Ashland College and his M.S. in zoology from the Ohio State University. Except for a brief stint with the Ohio Environmental Protection Agency as a field zoologist for river studies, he has made teaching (zoology, earth science, biology) his career. He is presently a biology teacher at Ashland Senior High School, Ohio 44805. Mr. Wilkes was named a Jennings Scholar by the Martha Holden Jennings Foundation for 1980-81, Outstanding Science Teacher by the Mohican Science District of the Ohio Academy of Science (1978-79), and Teacher of the Year by the Ashland City School System (1977-78).

Since 1977, six different classes of Ashland High School biology students have been monitoring a local river (the Jerome Fork) for the presence of sewage treatment plant (STP) effluent using procedures and techniques described by Wilkes (1980).

This article reports some of the results of this project so that other science teachers may use the data in their courses. The results may be used by the teacher who finds it impossible to locate a similar situation or to supplement a teacher's data from a similar study.

The physicochemical parameters reported here are dissolved oxygen (D.O.), pH, carbon dioxide, water temperature, and nitrate. A qualitative report of biota collected at the two stations is also included.

Study Area, Materials, and Methods

The Jerome Fork flows southeast through Ashland County, Ohio. The headwaters are 4 km northwest of State Route 58, north of the city of Ashland at the confluence of the Orange and Leidigh Mill Creeks. The Jerome Fork is part of a drainage system that ultimately flows into the Ohio River.

Ten stations have been established along the Jerome Fork, but for the current study two stations are being used: one 0.94 km upstream from the STP (station 2), and one 0.32 km downstream (station 3). The area surrounding each station is farmland and undeveloped forest consisting primarily of beech, maple, and oak trees. At station 2, the Jerome Fork moves slowly through a channel about 10 m wide and 0.4 m deep; the bottom consists of mud over sand. Station 3 is comprised of riffles in a cobble-sand substrate and is 8.0 m wide and 0.4 m deep. Station depth and width vary considerably on a seasonal basis, particularly during the spring flood period.

At each station a portable water analysis kit (Hach Chemical Co., Loveland, CO) is used to measure pH and carbon dioxide. A portable dissolved oxygen meter (Yellow Springs Instrument Co., Yellow Springs, OH) is used to measure dissolved oxygen and water temperature. Water samples are brought back to the school lab from each station and refrigerated to retard

FIGURE 1. Students arrive at river (photo by author).

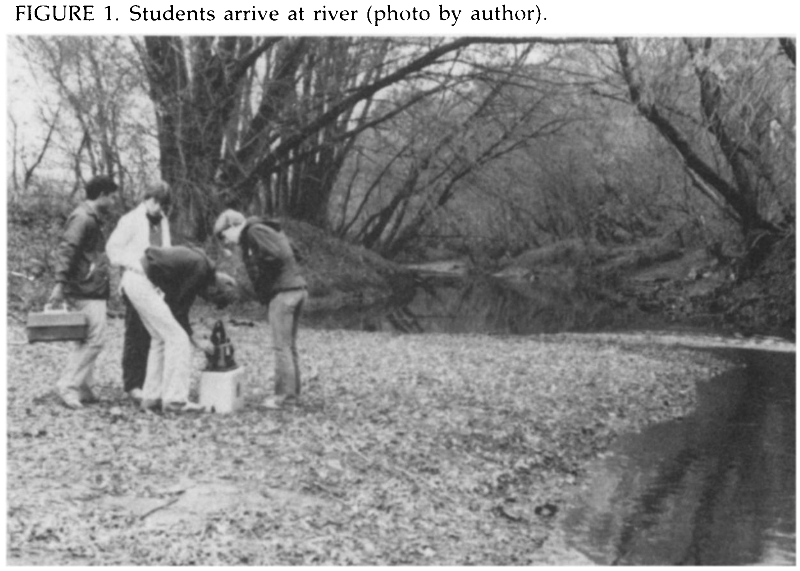

TABLE 1. Physicochemical Water Quality Data for Two Locations Along the Jerome Fork

	Date and Station											
	Summer 1977		*Fall 1977*		*Spring 1978*		*Spring 1979*		*Fall 1979*		*Fall 1980*	
Parameter	*2*	*3*	*2*	*3*	*2*	*3*	*2*	*3*	*2*	*3*	*2*	*3*
D.O. (ppm)	7.0	5.2	11.0	7.3	13.9	11.3	10.0	8.3	8.2	6.3	7.7	4.0
CO_2 (ppm)	17.0	27.0	15.9	23.9	23.0	25.2	11.6	10.9	11.6	13.3	8.0	8.0
pH	8.0	7.6	7.6	7.5	8.4	8.3	8.6	8.2	8.5	8.3	8.6	8.0
NO_3 (ppm)	1.4	3.1	1.1	2.8	1.1	2.8	2.4	3.0	2.8	3.1	2.0	3.4
Temp. (°C)	21.2	21.0	14.4	16.4	10.4	7.4	12.1	14.1	14.9	16.4	16.0	17.3

chemical, physical, and biotic changes in the water. Students analyze the samples for concentrations of nitrate using a spectrophotometer (Bausch & Lomb Co., Rochester, NY). In addition, plants and animals are observed and recorded and/or collected by students (using seines and surber nets) for live observation at school.

Results and Discussion

Dissolved oxygen concentrations have been consistently lower at station 3 than at station 2 (table 1), presumably due to the presence of the STP between the two stations. The surface agitation caused by the presence of riffles at station 3 should have increased the D.O. concentration in comparison to that measured at station 2 (Andrews 1972). However, the organic effluent added to the waters above station 3 is food for aerobic bacteria in the water and the respiratory demand by these bacteria reduces the available oxygen (Wynes and Wissing 1981).

Average carbon dioxide concentrations are generally higher at station 3 than at station 2 (table 1) which, like the decrease in dissolved oxygen, reflects an increase in bacterial respiration downstream of the STP (Hynes 1970; Andrews 1972).

FIGURE 2. Students determining pH using Hack kit (photo by John Dellerba, student).

Stream pH is consistently lower at station 3 (table 1) due to the increased CO_2 concentrations, which led to a lowering of pH through the shifts in the carbonate buffer equilibrium:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + H^+ + CO_3^{--}$$

Organic matter liberates ammonia during decomposition which is oxidized to nitrite which is, in turn, oxidized by nitrifying bacteria to nitrate (Keeton 1980); consequently, nitrate concentration is an excellent indicator of water quality. Table 1 shows that station 3 waters have had a consistently higher nitrate concentration than those at station 2. The effluent from the STP seems to be the only source of organic nitrogen which could be responsible for the observed increase in nitrate concentration.

Ammonia nitrogen concentration has been measured, but the level in the water at station 3 has been greater than the scale used. A new technique has recently been implemented to obtain usable data. The work completed to date on ammonia concentrations reveals a greater concentration of ammonia in waters at station 3 than at station 2 which supports the inference that the STP is a source of organic pollution.

During the six years this project has been conducted, water temperatures were generally higher at station 3 than at station 2 (table 1). During the winters the water at station 3 was never frozen while the water at station 2 often had ice two inches thick. The warmer water was due to passage through the STP (Crego 1981). The increase in water temperature by the STP compounded the loss of D.O. due to a decrease in gas solubility with increasing temperature.

Biota

When the study began in 1977, a qualitative list of organisms collected at each station was begun. There has been no quantitative work. Tables 2 and 3 list the organisms collected at the stations.

The organisms at station 2 are the typical clean-water, pollution-sensitive organisms (Olive and

TABLE 2. Organisms collected at Station 2, Jerome Fork

Common Name	*Lowest Common Taxon*
Insecta	
Mayfly naiads	Ephemeroptera
Stonefly naiads	Plecoptera
Caddisfly larva	Tricoptera
Damselfly naiads	Odonata
Dragonfly naiads	Odonata
Riffle beetle larvae	Psephenidae
Water striders	Gerridae
Water scorpions	Nepidae
Water boatmen	Corixidae
Giant water bugs	Belostomatidae
Crane fly larvae	Tipulidae
Predaceous diving beetles	Dytiscidae
Mosquito larvae	Culicidae
Backswimmers	Notonectidae
Water scavenger beetles	Hydrophilidae
Whirligig beetles	Gyrinidae
Midge fly larvae	Chironomidae
Platyhelminthes	
Planaria	Turbellaria
Mollusca	
Fingernail clams	Sphaeriidae
Clams	Unionidae
Limpets	*Ferrisia* sp.
Snails	*Physa* sp.
Oligochaeta	
Leeches	Hirudinea
Crustacea	
Crayfish	Decapoda
Sideswimmers	Amphipoda
Osteichthyes	
Minnows	Cyprinidae
Bluegills	Centrarchidae
Darters	Percidae
Suckers	Catostomidae

TABLE 3. Organisms collected at Station 3, Jerome Fork

Common Name	*Lowest Common Taxon*
Insecta	
Midge fly larvae	Chironomidae
Rat-tailed maggots	Syrphidae
Mosquito larvae	Culicidae
Oligochaeta	
Sludge worms	Tubificidae
Osteichthyes	
Minnows	Cyprinidae

Dambach 1973). Mayfly and stonefly naiads, water pennies (riffle beetle larvae), and clams have regularly been collected. Numerous individuals of a large number of fish species have been collected. The stream appears to support a complex biological community at station 2.

Station 3 organisms, however, are pollution-tolerant and can withstand low D.O., increased suspended solids, and bottom sludge. The most conspicuous observation at station 3 is the tremendous numbers of the few species present. During the late summer months, the tubifex worms become so numerous that the river bottom appears as a red wiggling carpet from shore to shore. Such a simplified ecosystem is indicative of a severe environmental disturbance (Bartsch and Ingram 1967). The changes in pH, D.O., organic pollution, and temperature caused by the STP (and documented in this study) have made the stream at station 3 incapable of supporting a diverse and productive ecosystem like that of station 2.

Summary

The results of the research show a serious pollution problem in a major drainage system. The city's STP effluent is causing an ecosystem to change from a healthy, clean river to one poor in species and offensive to sight and smell.

FIGURE 3. Student using the dissolved oxygen meter (photo by author).

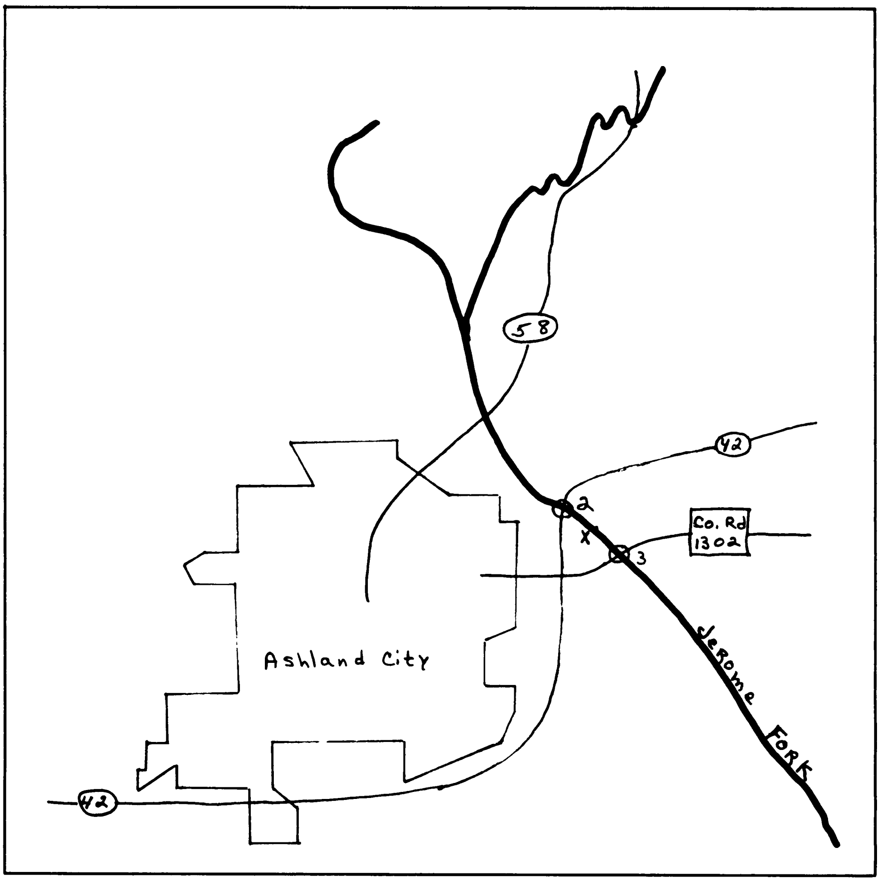

FIGURE 4. Stations along Jerome Fork, Ashland, Ohio.

KEY
2 = Station 2
3 = Station 3
X = Ashland City sewage treatment plant

All samples are collected and analyzed by high school juniors and seniors. The involvement of students in this project has created an awareness of a local problem which, otherwise, might have gone unnoticed by them. The city is in the midst of building a new STP, and future classes will be able to monitor its effect on water quality. The fact that the study is an ongoing project impresses students because they know their peers have been involved and now they are contributing to the final results. As potential voting citizens of the city, they will be better prepared to question, understand, and express opinions on a topic that affects all the members of any city.

FIGURE 5. Students determining nitrate and ammonia using the spectronic 20 (photo by John Dellerba, student).

Students learn to use equipment which they may use in college or on the job and to collect, organize, and present data. They can see for themselves the difference between the classic textbook healthy ecosystem and the organically polluted ecosystem. Students also recognize that the stream community is dependent upon the physicochemical factors of the stream.

Hynes (1970) states that man's activity has profoundly affected rivers and streams and it is difficult if not impossible to find an unaltered river. The present study indicates to students how man's activities can have such an adverse effect upon a local river. Students can actually see these effects by comparing the data collected at the control station (upstream) to the data collected at the affected station (downstream). Students do not have to travel to foreign countries or "big cities" in order to find pollution. A pollution problem has existed in their own city for several years and will continue for several more. In studying their own results rather than those of others, students realize firsthand the problems and rewards of research.

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supplemental source of income. Both the demands on their time and the lack of facilities and funds limited their research activities. The few who did engage in research utilized students for research assistants or collaborated with colleagues. As a group, these experienced teachers were professionally influential at both departmental and school levels. We found our members ambitious, successful, and secure in their professional activities, associations, and contributions.

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