5-1-1983

Effects of Sewage Pollution in the White River, Arkansas on Benthos and Leaf Detritus Decomposition

Arthur V. Brown
University of Arkansas, Fayetteville

Lawrence D. Willis
University of Arkansas, Fayetteville

Peter P. Brussock
University of Arkansas, Fayetteville

Citation

Brown, Arthur V.; Willis, Lawrence D.; and Brussock, Peter P.. 1983. Effects of Sewage Pollution in the White River, Arkansas on Benthos and Leaf Detritus Decomposition. Arkansas Water Resources Center, Fayetteville, AR. PUB097.
https://scholarworks.uark.edu/awrctr/254

EFFECTS OF SEWAGE POLLUTION IN THE WHITE RIVER, ARKANSAS ON BENTHOS AND LEAF DETRITUS DECOMPOSITION

Arthur V. Brown

Lawrence D. Willis and Peter P. Brussock

Department of Zoology, University of Arkansas
Fayetteville, Arkansas 72701

Publication No. 97

May, 1983

Research Project Technical Completion Report
A-058-ARK

Arkansas Water Resources Research Center
University of Arkansas
Fayetteville, Arkansas 72701

AWRRC

Arkansas Water Resources Research Center

Prepared for
United States Department of the Interior

EFFECTS OF SEWAGE POLLUTION IN THE WHITE RIVER, ARKANSAS ON BENTHOS AND LEAF DETRITUS DECOMPOSITION

Arthur V. Brown, Lawrence D. Willis, and Peter P. Brussock

Department of Zoology, University of Arkansas
Fayetteville, Arkansas 72701

Research Project Technical Completion Report

Project A-058-ARK

The work upon which this report is based was supported in part by federal funds provided by the U. S. Department of the Interior, as authorized under the Water Research and Development Act of 1978, P.L. 95-467, through annual cooperative program agreement number 14-34-0001-2104.

Arkansas Water Resources Research Center
University of Arkansas
223 Ozark Hall
Fayetteville, Arkansas 72701

Publication No. 97

May, 1983

ABSTRACT

EFFECTS OF SEWAGE POLLUTION IN THE WHITE RIVER, ARKANSAS ON BENTHOS AND LEAF DETRITUS DECOMPOSITION

Recently there has been much emphasis placed on the importance of leaf detritus processing to the energetics of stream invertebrates. This study was designed primarily to assess the effects of municipal effluent on the ability of a stream community to utilize leaf detritus, and secondarily to evaluate the extent of the pollution of the White River by the Fayetteville, Arkansas effluent discharge. Physical and chemical water quality, benthos, and fish were sampled periodically at one station upstream and two stations downstream from the discharge, and in the Richland Creek tributary. Processing of leaf detritus was studied at each site using 5 g packs of red oak (*Quercus shumardi*) leaves. Dissolved oxygen was far below recommended levels which resulted in a fish kill. Substantial increases in orthophosphate, ammonia, chlorides, conductivity and turbidity were observed downstream. Only 1 fish species (*Morone chrysops*) was collected downstream as it migrated through. The pattern of benthic species (25 immediately upstream, 8 just downstream, 17 downstream 8 km and 20 in a tributary) indicated heavy pollution. Despite this, leaf detritus processing rates were extremely rapid (K = 0.01-0.03) indicating that leaf decomposition is virtually unaffected by macroinvertebrates.

Arthur V. Brown, Lawrence D. Willis, and Peter P. Brussock

Completion Report to the Office of Water Policy, Department of the Interior, Washington, D.C.   May, 1983.

KEYWORDS-- *stream pollution/*detritus/*decomposition/*benthos/ physiochemical properties/fish/water pollution effects/White River/ Arkansas/city planning.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The work upon which this publication is based was supported by funds provided by the Office of Water Research and Technology, U. S. Department of the Interior, through the Water Resources Research Center at the University of Arkansas under Project A-058-ARK as authorized by the Water Research and Development Act of 1978. We appreciate assistance with field work by Mike Elmore, Greg Hogue, Kevin Lynch and Luncinda Rightnour. Mark Gordon assisted with identification of mollusks.

The following publication has also resulted from this work:

Brown, A. V., L. D. Willis and P. P. Brussock. Effects of sewage pollution in the White River, Arkansas on leaf detritus decomposition. Arkansas Academy of Science Proceedings. Manuscript submitted for publication, April, 1983.

I. INTRODUCTION

Discharge of treated municipal wastewater into a stream always alters the stream's physical, chemical and biological characteristics. The extent of the alteration is governed by the quality and quantity of the effluent and the ability of the receiving stream to assimilate and metabolize the wastes. Degradation of the biological community is recognized to be the most important result of stream pollution. The primary reasons most physical and chemical data are obtained for receiving streams are to enable estimation of the effect of their changes on organisms inhabiting the stream and to determine the quality of the water regarding its various uses by man. Several physiochemical studies of this type have been performed in the upper White River (Eley 1969, Bayliss 1971, Stone 1971, Carahan 1973, Gearhart 1973, Reed 1973, Rowe 1973). The only way to actually assess the effects of an effluent on a stream's living community is by direct biological studies (Hynes 1960, Cairns and Dickson 1971). However, methods used in collecting and analyzing physical and chemical data to assess pollution are fairly well standardized and widely practiced (see United States Environmental Protection Agency 1974, American Public Health Association 1975), while biological procedures for determining water quality are not as standardized despite considerable effort to do so (e.g., Hynes 1960, Wilhm and Dorris 1968, Wilhm 1970, Cairns and Dickson 1971, Weber 1973). Their very ecological nature often precludes rigid standardization or reduction to meaningful mathematical expressions which would be useful to engineers. The difficulties of sampling and analyzing aquatic community structure do not outweigh the need for these data.

Biological assessment of water quality, in addition to being a more direct method, has several advantages over physiochemical analyses. Stream organisms act as a continuous monitor of water quality because the water must continually exceed their minimum requirements for them to remain living in a given location (Wilhm 1967). Physiochemical data can only represent the water quality at the specific time the samples were taken. As stream conditions are continuously changing, physiochemical data seldom represent average conditions. As Wilhm (1967) has pointed out, the samples might miss a brief period of particularly bad water quality that would kill many aquatic species or the samples might be collected during temporarily bad conditions that the organisms could endure for a brief period. In either case misinterpretation would result if based only on physiochemical data. Less mobile organisms like benthic macroinvertebrates (especially molluscs) are most useful in this regard. Aquatic species vary considerably in their pollution tolerance. For example, Psychodidae larvae (sewer flies) thrive on trickling filters and some Chironomidae larvae (bloodworms) and Oligochaeta (sludge worms) grow to tremendous populations in streams and ponds receiving raw sewage, while most Trichoptera (caddisflies), Plecoptera (stoneflies), and Ephemeroptera (mayflies) are unable to withstand moderate degradation in water quality (Hynes 1960, Roback 1974, Davis 1975). Similar differences have been recorded for fish (Tsai 1973, Coble 1982), protozoa (Lackey 1938, Mohr 1952) and other groups of organisms. The range of sensitivity allows some discernment of the degree and downstream extent of pollution, but analysis of biological data must transcend simple use of indicator organisms classified as tolerant, intolerant or facultative as often proposed, and involve as complete a community analysis as possible (see Hynes 1970).

Streams receiving treated municipal wastes should be thought of as extensions of their sewage treatment plants because the streams accomplish final purification of the wastes. Therefore, a receiving stream should be carefully monitored and maintained much the same as the mechanical facilities in the sewage treatment plant to optimize its effectiveness. In order to successfully manage such streams we must first understand their ecological structure and how they function.

A general theory concerning the community organization and functional dynamics of lotic ecosystems has recently been developed (see Cummins 1977, McIntire and Colby 1978, Vannote et al. 1980, Minshall et al. 1983). The model is primarily based on the sequential utilization of decomposing organic detritus that enters streams from their watersheds primarily in the form of autumn shed leaves (Minshall 1967, Coffman et al. 1971, Cummins 1974). The rates and mechanisms involved in the processing of leaves by stream invertebrates and decomposers has been rather extensively studied in unperturbed streams (e.g., See Petersen and Cummins 1974, Suberkrop and Klug 1976, Anderson and Sedell 1978, Brown and Ricker 1983), but no studies previous to this one have addressed leaf decomposition in a stream receiving municipal wastes.

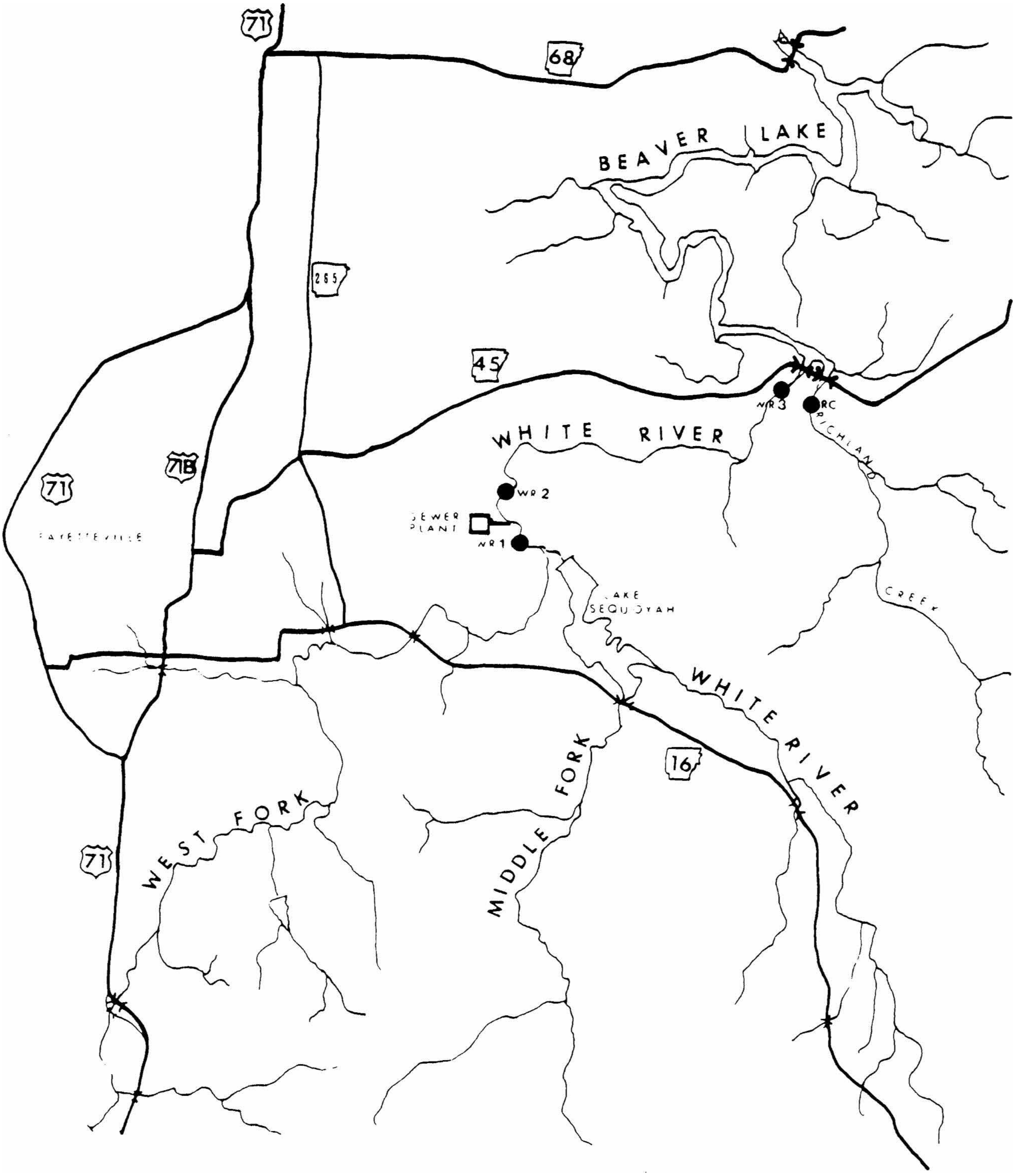
The primary objective of this study was to assess the effects of polluting a stream with treated municipal wastewater on its capacity to process natural allochthonous detritus inputs. This included an assessment of the mechanisms and rates of leaf processing, determination of the benthic macroinvertebrate community structure and analysis of the physiochemical water quality. Additional benthic community samples were taken in the Illinois River, Arkansas (an adjacent drainage basin) for comparison. It was decided to perform a preliminary assessment of the effects of the effluent on the fish community of the White River also.

II. STUDY SITE DESCRIPTION

The headwaters of the White River flow northward through the Ozark Mountains in northwest Arkansas into Beaver Reservoir (Figure 1). There are three major tributaries with the White River mainstream in the southeastern portion of the water shed and the Middle Fork and West Fork in the remaining portions. The White River and Middle Fork are impounded just above the confluence with West Fork to form Lake Sequoyah, which is owned and managed by the City of Fayetteville. Downstream from the confluence the river if a fifth order stream and remains so downstream to Beaver Reservoir. The river meanders for approximately 15 km below Lake Sequoyah before reaching Beaver Reservoir. The headwater streams flow through the sandstones and shales of the Boston Mountains. Downstream from the lake it flows through cherty limestone of the Springfield Plateau. The different substrata have little influence on the physiochemistry of the river (Horn and Garner 1965). Numerous springs contribute to the river flow along its course.

The White River is used for many purposes in addition to receiving treated wastewaters. These uses include irrigation of farmland, watering livestock and wild game, and as recreation by fishemen, canoeists and swimmers. The most significant aspect of its fishery is the annual white bass (*Morone chrysops*) spawning migration from Beaver Lake each spring. However, there is year around fishing for other species including crappie, various catfish, sunfish, black bass, and walleye. The intake for the municipal water supply for

Figure 1. Map of the headwaters region of the White River, Arkansas with study areas indicated.



Fayetteville and several other communities is located in Beaver Reservoir approximately 42 km downstream from the effluent discharge.

The headwaters downstream to Beaver Reservoir have been placed in use-class A by the Arkansas Department of Pollution Control and Ecology (1975, 1981). This indicates that these streams are classified as suitable for primary contact recreation, propagation of desirable species of fish, wildlife and other aquatic life, raw water source for public water supplies, and other compatible uses. In addition, the stream is classified as a smallmouth bass fishery. The study section of the river downstream from the sewage plant has actually experienced rather extensive fish kills during the summers of 1978, 1979, 1980, and 1982.

Locations of the sampling stations are indicated on Figure 1. Three sites were selected in the White River and one in Richland Creek, a tributary. The first station (WR 1) was chosen to represent the environmental quality of the river before receiving secondary treated effluent from the Fayetteville sewage treatment plant. The Richland Creek site (RC) similarly provided comparative data from a relatively unpolluted tributary. Station WR 2 was about 250 m below the effluent discharge and station WR 3 was about 8 km further downstream.

III. MATERIALS AND METHODS

Leaf packs were prepared, deployed, retrieved and analyzed similarily to the the methods of Petersen and Cummins (1974) at each station. Small (5.0 g) packs of air dry Shumard's Red Oak (*Quercus shumardi*) leaves were sandwiched between small plastic tabs and stapled together. This species does not shed its leaves until spring. The leaves were all collected from one tree during late January 1982 to ensure comparable leaf packs among sites. Instead of lashing the packs to bricks as recommended by Petersen and Cummins (1974) we secured them to the surface of the substrate using a 60d common nail through the center of each. This avoided the nuisance of having our experiments ruined by removal of the packs by curious passers by, as we have experienced during other similar studies. The leaves were placed in areas of similar depth, current and substrate type at each station in an effort to hold these factors constant. Three leaf packs were carefully removed after days 3, 8, 20, and 37 from each station. Invertebrates were removed and preserved, after which the remaining leaf material was dried at moderate temperature (50^0 C), allowed to air dry in the laboratory for several days, and then weighed. Four quantitative substrate samples of benthic macroinvertebrates were collected using a Surber Square foot sampler (250 µm mesh) at each station each month from April 1982 through October 1982. Sites for these samples were chosen to best represent the variety of habitats available at each station. These invertebrate samples were preserved in 75% ethanol and returned to the laboratory where they were hand picked, sorted, identified and counted. Selected physiochemical analyses were performed at each station periodically from April 1982 through March 1983. These tests included flow, dissolved oxygen, turbidity, conductivity, chlorine, nitrate nitrogen, ammonia nitrogen, orthophosphate, and fine particulate organic matter (FPOM). The FPOM was collected by filtration of 500 ml of water on Whatman GFF filters. The other tests were performed according to standard methods (American Public Health Association 1975). Processing rate coefficients (k) for the leaf packs were calculated by the method developed by Petersen and Cummins (1974) using the equation: $-k = \log_e (\%R/100) / t$ where %R is the percent leaf material remaining after the time in days (t) of exposure.

Additional invertebrate samples were collected from a comparable study site in the fifth order reach of the Illinois River (IR), Arkansas during April, July and October. Three samples were taken each date using a 0.05 m^2 vaccuum sampler and the same mesh size (250 µm). The Illinois is quite similar to the White in other respects, but it received less municipal sewage.

Species diversity was calculated by the Shannon-Weaver index: $S.D. = \sum_{i=1}^{n} ni/n (\log_e ni/n)$, where ni/n is the ratio of the number of individuals in the i^{th} species to the total number of organisms in the sample. Fish were sampled by deploying gillnets (2 in. bar mesh, 100 ft. long) at each study site for one night during the period from 12 April 1983 through 23 April 1983. High water made it impossible to successfully seine or electroshock in the study areas. (Analysis of fish populations was not identified as one of the objectives of the study in the proposal. However, this preliminary assessment was attempted late in the study.)

IV. RESULTS AND DISCUSSION

A. Leaf Processing

Apparently weight loss of the leaf packs was dramatically affected by the sewage effluent (see Figure 2). The fastest decomposition rate was observed at the second station (WR 3) downstream from the sewage outfall (k = 0.0346). The slowest rate was at the site immediately below the plant (k = 0.0108) but was not very different from those observed upstream (k = 0.0140) or in Richland Creek (k = 0.0129). The observed differences in leaf processing rates cannot be explained by the numbers of macroinvertebrates which colonized the leaf packs (Figure 3), or by the functional groups (sensu Cummins 1974, Merritt and Cummins 1978) associated with them. Shredders were conspicuously absent from the leaf packs at all sites; only collectors and predators were on them.

Figures 2 and 3. Figure 2. Leaf pack weight loss at four sites in the White River, Arkansas. WR1 = ■, WR2 = ●, WR3 = ○, RC = ▲. See Figure 1 for location of study areas.
Figure 3. Benthic macroinvertebrates which colonized leaf packs (n/pack) at four sites in the White River, Arkansas.

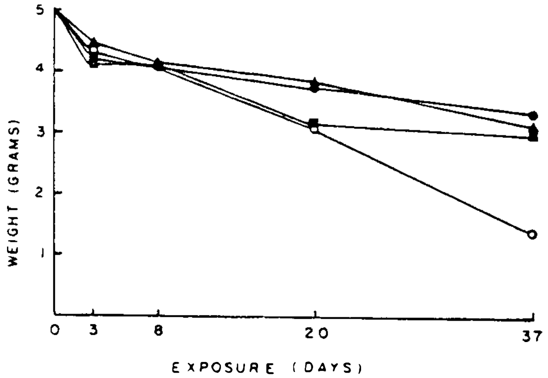


Figure 2

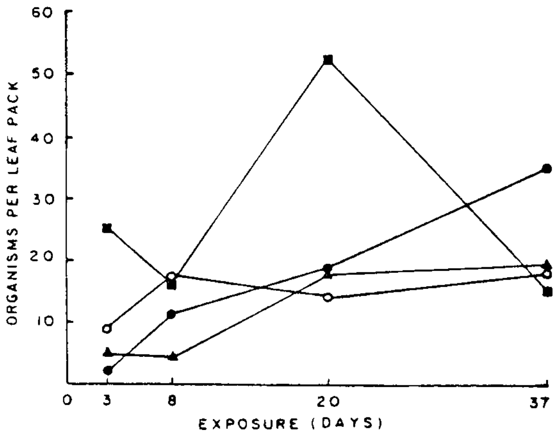


Figure 3

Even the slower leaf processing rates would be classified as fast (i.e., $k > 0.010$) by Petersen and Cummins (1974) even though oak leaves are generally slow (i.e., $k < 0.005$) to decay. The processing rate at station WR 3 was faster than that recorded for the same species in a similar study in the nearby Illinois River ($k = 0.025$, Brown and Ricker 1983). The faster processing rates must be due to a greater density and/or activity of the microbial organisms responsible for decomposition (bacteria and fungi) and perhaps higher stream temperatures experienced during the studies in Arkansas. The highest processing rate reported by Petersen and Cummins (1974) ($k = 0.0305$) was obtained from a study performed during the summer in Michigan. Summer stream temperatures in Michigan may be equivalent to Arkansas spring time temperatures during this study (9-14° C). In any case the leaf processing rates were definitely faster than any previously reported. This fact along with the paucity of invertebrates associated with the leaf packs (< 8 spp) and the absence of shredders indicates that invertebrates have little effect on leaf processing rates. This agrees with the conclusion from a leaf processing study in an Ozark cave stream (Brown and Schram 1983).

B. Benthic Macroinvertebrate Community

The most diverse invertebrate fauna was found above the effluent discharge with a total of 25 species (see Table 1). Twenty species were present in Richland Creek, 17 species were collected at WR 3 about 8 km downstream and only 8 species could be found 250 m below

Table 1. Benthic macroinvertebrate distribution and abundance (N/M^2) in the White River, Arkansas upstream and downstream from the Fayetteville sewage discharge and at a comparable site in the Illinois River, Arkansas. See Figure 1 and the text for station locations.

TAXA	WR 1	WR 2	WR 3	RC	IR
Insecta					
Ephemeroptera					
Baetis	9.99		14.60	50.34	2384.40
Caenis			0.38		182.19
Choroterpes					2.20
Ephemera					68.90
Ephemerella					35.57
Ephoron					6.67
Hexagenia					3.73
Isonychia bicolor	5.38		3.46	1.15	217.80
Leptophlebia					8.67
Paraleptophlebia					2.20
Potamanthus					1035.67
Rhithrogena	1.15			4.23	20.20
Stenonema sp.					886.67
S. bipunctatum					164.40
S. pullchellum	6.15		14.60	24.59	144.40
S. terminatum	1.54				91.09
S. tripunctatum	1.92		1.54	0.77	86.67
S. femoratum					8.67
S. nepotellum	0.38			6.15	
Tricorythodes attratus	1.92		8.84	4.99	55.53
Stenacron interpunctatum				0.77	120.00
Tricoptera					
Chimarra	5.38	0.77	0.38	98.76	1602.22
Cheumatopsyche	8.07		2.31	19.98	3273.31
Hydropsyche	13.83	3.07	6.92	17.68	2.20
Marilia					2.20
Potamyia					2.20
Diptera					
Chironimidae	22.67	64.18	80.70	27.67	1511.11
Simuliidae	9.22	14.22	80.70	32.28	
Pupae					68.96
Atherix					4.44
Tipula	1.54		0.38	0.77	

Table 1. Continued

TAXA	WR 1	WR 2	WR 3	RC	IR
Plecoptera					
Acroneuria	13.45	0.77	0.77	4.99	102.20
Allocapnia					4.43
Neoperla clymene	6.15			0.77	260.00
Phasganophora					22.21
Megaloptera					
Corydalus cornutus	11.91	7.69	30.70	2.31	19.97
Sialis					2.20
Coleoptera					
Ectopria					6.67
Psephenis				0.38	695.53
Stenelmis larvae	3.46	1.15	4.99	0.77	1073.33
Stenelmis adults					46.66
Hemiptera					
Gerris remigis				6.53	
Odonata					
Argia emma					6.60
Crustacea					
Decapoda					
Orconectes nana	0.38				8.93
Isopoda					
Lirceus	1.15	1.15	0.38		471.07
Caecidotea					6.60
Unidentified sp.					6.70
Amphipoda					
Stygobromus					33.31
Arachnida					
Acarina					
Acarina					33.55
Mollusca					
Gastropoda					
Corbicula fluminea	443.08				
Tritogonia verrucosa	0.38				
Lampsilis ventricosa	0.38				

Table 1. Continued.

TAXA	WR 1	WR 2	WR 3	RC	IR
Mollusca					
Gastropoda (continued)					
Anodonta grandis	0.38				
Physa gyrina			0.77		
Ferrissia rivularus					2.20
Sphaerium striatinum					4.47
Annelida					
Hirudinea					2.20
Oligochaeta	1.15		0.77		26.67
Platyhelminthes					
Turbellaria					15.56
Nematomorpha					6.60
Nematoda					26.67
TOTALS	561.79	93.00	253.19	305.83	15,093.83
Species Diversity	1.10	1.05	1.60	2.05	2.49

the outfall. May flies and molluscs were fairly abundant upstream but were conspicuously absent immediately below the sewer plant. Gordon (1976, 1982) in studies of the Mollusca of the White River reported 47 species from the headwaters and noted the complete extirpation of species from below the Fayetteville sewage outfall to the headwaters of Beaver Reservoir. When he collected in this area the Asiatic clam, *Corbicula*, was in Beaver but not above it in the headwaters. It was very abundant during this study upstream from the sewage plant (WR 1) but was absent from the other sampling stations (Table 1). Perhaps fishermen who use them for bait have unintentionally introduced them at this site.

The macroinvertebrate fauna was not very rich in species or numbers at any of the sampling stations which indicates a generally depauperate situation within this reach of the stream. This observation is supported by the low species diversity indices given in Table 1. Wilhm and Dorris (1968) considered streams with a diversity index between 1 and 3 to be moderately polluted. Considering the other facts for this stream, including the absence of Mayflies and molluscs below the sewage outfall and the recurrent fish kills, we would suggest that it is heavily polluted at the other sites. The Richland Creek site was primarily bedrock with little suitable habitat for benthos or it may have had a higher diversity. The Shannon-Weaver index is quite responsive to evenness (Wilhm 1967) so the large number of *Corbicula* at the upstream site depressed the value there.

A comparable site on the Illinois River had 53 species and a species diversity index of 2.49 despite the fact that only 9 samples were represented compared with 28 at each site from the White (see Table 1). The abundance of mayflies (Ephemeroptera) attests to the relatively unpolluted status of the Illinois. The rivers have very similar watersheds regarding their topography, geology and the agricultural practices within them.

C. Physical and Chemical Water Quality

The physical and chemical analyses defintely indicate that the effluent from Fayetteville's sewer plant is degrading the water quality of the White River and exceeding the standards set by the Arkansas Department of Pollution Control and Ecology (1981) (see Table 2). The abuses are especially severe during times of normal or low flow conditions. Substantial increases in orthophosphates, ammonia nitrogen, chlorides, conductivity and turbidity were observed downstream from the plant. Dissolved oxygen (DO) was considerably below recommended levels for this stream at the second station downstream during the August and September samples. The first station downstream may have been too near the outfall (250 m) to have been maximally effected regarding DO levels. During normal flow, oxygen depletion was just beginning as the water passed this station and was always lower at the second station except in April 1982 when the flow was above average. During the week of 12 September the DO consistently ranged from less than 1 to a maximum of 3 mg/ℓ for

Table 2. Physical and chemical characteristics of the White River, Arkansas upstream and downstream from the Fayetteville sewage plant effluent discharge from April 1982 through March 1983. See text for station locations (WR 1, 2, 3, and RC).

	April 23				June 8				June 29			
	WR 1	WR 2	WR 3	RC	WR 1	WR 2	WR 3	RC	WR 1	WR 2	WR 3	RC
DO (mg/ℓ)	9.9	9.5	9.6	11.4	8.2	8.1	7.8	9.3	7.6	6.8	6.6	8.4
Conductivity (μmho/cm)	60	95	65	110	82	122	82	112	60	140	140	150
Turbidity (NTU)	24	26	29	8	30	32	33	19	38	36	42	22
Temperature (°C)	13	14	14	14	23	28	23	23	23	23	23	21
O-Phosphate (mg/ℓ)	.05	.05	-	<.05	<.05	<.05	<.05	<.05	.30	.30	.68	.39
NH_3 (mg/ℓ)	0	0	0	0	0	0	0	0	.35	.52	.58	.20
NO_3 (mg/ℓ)	.60	.60	.50	2.2	.80	<.05	.20	0	.60	3.6	8.3	.40
Cl^- (mg/ℓ)	25	38	25	25	25	25	25	25	25	25	25	25
FPOM (mg/ℓ)	.0064	.0084	.0091	.0027	.0111	.0109	.0119	.0053	.0217	.0319	.0110	.0025

Table 2. Continued.

	July 20				August 24				September 21			
	WR 1	WR 2	WR 3	RC	WR 1	WR 2	WR 3	RC	WR 1	WR 2	WR 3	RC
DO (mg/ℓ)	6.9	6.6	6.0	9.0	6.7	6.3	4.3	7.7	6.6	6.2	3.9	6.9
Conductivity (µmho/cm)	192	183	300	200	8.3	233	210	197	60	260	180	195
Turbidity (NTU)	17	16	20	11	21	22	24	12	22	23	28	14
Temperature (°C)	21	29	28	25	29	29	26	26	28	28	25	26
O-Phosphate (mg/ℓ)	.32	.37	.30	.40	.22	.73	.47	.41	.24	.25	.38	.50
NH_3 (mg/ℓ)	.22	.10	.50	.05	.10	.50	.50	.10	.22	2.0	3.5	.10
NO_3 (mg/ℓ)	.40	.40	.60	.40	.60	.30	.50	.80	2.9	5.2	4.1	2.0
CL^- (mg/ℓ)	25	25	63	25	.25	.85	.62	.72	25	88	75	25
FPOM (mg/ℓ)	.0076	.0070	.0087	.0014	-	-	-	-	.0069	.0072	.0083	.0031

Table 2. Continued.

	October 21				January 5				March 26			
	WR 1	WR 2	WR 3	RC	WR 1	WR 2	WR 3	RC	WR 1	WR 2	WR 3	RC
DO (mg/ℓ)	9.1	7.3	6.5	8.8	11.4	11.4	11.1	11.8	12.5	12.3	11.6	13.6
Conductivity (μmho/cm)	120	260	460	241	72	58	63	71	60	92	90	76
Turbidity (NTU)	14	14	16	7	17	16	19	15	20	18	17	5
Temperature (°C)	-	-	-	-	12	13	12	12	10	11	11	11
O-Phosphate (mg/ℓ)	.40	5.5	.70	.70	0	.12	.15	0	.12	.20	.17	.03
NH_3 (mg/ℓ)	0	2.0	2.0	0	.05	.08	.10	.06	.22	.47	.32	.32
NO_3 (mg/ℓ)	-	-	-	-	.30	.40	.40	.30	.14	.19	.17	.13
Cl^- (mg/ℓ)	25	75	125	38	25	25	25	25	25	25	25	25
FPOM (mg/ℓ)	.0096	.0102	.0109	.0041	.0075	.0081	.0097	.0038	.0072	.0068	.0084	.0036

several kilometers below the outfall and resulted in a fish kill. We observed that most of the fish killed were carp (*Cyprinus carpio*) and green sunfish (*Lepomis cyanellus*) which are pollution tolerant species, although other less tolerant species were included. This could indicate that the reach of river no longer produces many game fish, or that the poor water quality developed gradually and the more sensitive species left before the conditions became lethal.

D. Fish Community Structure

The sparse data which we were able to obtain during this study definitely indicate that the sewage pollution from the City of Fayetteville is harming the fish community of the White River (see Table 3). Six species of fish including pollution tolerant species such as smallmouth bass (*Micropterus dolomieui*) and black and river redhorse (*Moxostoma duquesnei* and *M. carinatum* respectively) were collected about 1 km upstream from the sewage discharge. Only one species, white bass (*Morone chrysops*) was collected approximately 1 km downstream from the effluent dishcarge. These fish were probably moving through the area on their annual spawning migration to upstream areas. With the exception of 2 channel catfish (*Ictalurus punctatus*), white bass were the only fish collected at the station 8 km downstream.

Table 3. Fish distribution and relative abundance in the White River, Arkansas upstream and downstream from the Fayetteville sewage discharge. See Figure 1 and the text for station locations.

TAXA	WR 1	WR 2	WR 3	RC
Morone chrysops	8	28	165	18
Lepisosteus osseus	4			
Micropteras dolomieui	2			
Moxostoma duquesnei	2			
Moxostoma carinatum	2			
Ictalurus punctatus	1		2	

V. SUMMARY AND CONCLUSIONS

Results of this study indicate that the headwaters portion of the White River in the vicinity of the Fayetteville, Arkansas sewage treatment facility has rather poor water quality and supports very few species of benthic macroinvertebrates compared with an adjacent stream, the Illinois River. Effluent from the sewage treatment plant further degrades the stream at least as far as the upper reaches of Beaver Reservoir. Oxygen depletion caused by the effluent resulted in a fish kill in September 1983 and similar conditions probably caused the fish kills in previous years in this stream.

The depauperate condition of the aquatic invertebrate fauna upstream from the effluent discharge could be the result of nonpoint source agricultural pollution, faulty septic tanks and run off from small towns in the watershed. However, the fauna upstream could have been depleted by the harsh conditions downstream. Aquatic invertebrates drift downstream in large numbers (see Waters 1967, 1972; Müller 1974) and the adults of aquatic insects then fly upstream to complete what Müller (1954, 1981) has called their recolonization cycle. If they are killed as they disperse downstream they can not subsequently recolonize upstream locations.

The benthic macroinvertebrate community structure and fish species collected distinctly indicated the water quality conditions at each station. Despite the poor water quality and the depauperate benthic fauna, the leaf detritus decomposition rates were very high, in fact there was some indication that the decomposition (processing) rate was enhanced by the effluent. This result was unexpected because benthic macroinvertebrates, especially shredders, are generally thought to strongly influence leaf decomposition rates (see Cummins 1974, 1977; Vannote et al. 1980; and Minshall et al. 1983).

It was feared that leaf decomposition rates would be depressed by sewage pollution of streams and result in an accumulation of allochthonous leaf detritus. This would aggravate the situation concerning organic loading of receiving streams. This study indicated that while there was some suppression of decay rates immediately downstream, they were accelerated further downstream. Except in cases of severe pollution, depression of leaf processing rates will probably not be a problem.

VI. LITERATURE CITED

American Public Health Association. 1976. Standard methods for the examination of water and wastewater. 14th ed. APHA. New York.

Anderson, N. H. and J. R. Sedell. 1979. Detritus processing by macroinvertebrates in stream ecosystems. Ann. Rev. Entomol. 24:351-377.

Arkansas Department of Pollution Control and Ecology. 1981. Regulation extablishing water quality standards for surface waters of the state of Arkansas. 49 pp.

Bayliss, R. B. 1971. Kinetics of nutrient concentrations in a receiving stream. Masters Thesis, Civil Engineering Department, University of Arkansas, Fayetteville, Arkansas.

Brown, A. V. and J. P. Ricker. 1983. Macroinvertebrate utilization of leaf detritus in a riffle of the Illinois River, Arkansas. Arkansas Acad. Sci. Proc. 36:10-13.

Brown, A. V. and M. D. Schram. 1983. Leaf detritus processing in an Ozark cave stream. Arkansas Acad. Sci. Proc. 36:14-16.

Cairns, J., Jr. and K. L. Kickson. 1971. A simple method for the biological assessment of the effects of waste discharges on aquatic bottom-dwelling organisms. Jour. Water Poll. Control Fed. 43(5): 755-772.

Carahan, G. 1973. Eutrophic potential of Beaver Reservoir influents. Special Problem, Civil Engineering Department, University of Arkansas, Fayetteville, Arkansas.

Coble, D. W. 1982. Fish populations in relation to dissolved oxygen in the Wisconsin River. Trans. Am. Fish. Soc. 111:612-623.

Coffman, W. P., K. W. Cummins, and J. C. Wuycheck. 1971. Energy flow in a woodland stream ecosystem. 1. Tissue support trophic structure of the autumnal community. Arch. Hydrobiol. 68:232-276.

Cummins, K. W. 1974. Structure and function of stream ecosystems. BioScience 24:631-641.

Cummins, K. W. 1977. From headwater streams to rivers. Am. Biol. Teacher 39:305-312.

Davis, J. C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species. A. Review J. Fish. Res. Bd. Can. 32(12):2295-2332.

Eley, B. W. 1969. First interim progress report - a eutrophication model of the White River basin above Beaver Reservoir in Northwest Arkansas. Arkansas Water Resources Research Center, University of Arkansas, Fayetteville, Arkansas.

Gearhart, R. A. 1973. A eutrophication model of the White River basin above Beaver Reservoir in Northwestern Arkansas. Publ. No. 15. Water Resources Research Center, University of Arkansas, Fayetteville.

Gordon, M. E. 1976. Freshwater mollusca of the Elk River, White River above Beaver Reservoir, and Frog Bayou drainages of the Southwestern Ozarks. Masters Thesis, Department of Zoology, University of Arkansas, Fayetteville, Arkansas. 351 pp.

Gordon, M. E. 1982. Mollusca of the White River, Arkansas and Missouri. The Southwestern Naturalist 27(3):347-352.

Horn, M. E. and D. E. Garner. 1965. Characterization of soils and water in the Beaver Reservoir area: Pre-impoundment studies of chemical properties. Bull. 702. Agricultural Experiment Station, University of Arkansas, Fayetteville, Arkansas. 57 pp.

Hynes, H. B. N. 1970. The ecology of running waters. Liverpool University Press, Liverpool, England. 202 pp.

Lackey, J. B. 1938. Protozoan plankton as indicators of pollution in a flowing stream. Publ. Hlth. Rept. Wash. 53:2037-2058.

McIntire, C. D. and J. A. Colby. 1978. A hierarchical model of lotic ecosystems. Ecol. Monogr. 48:167-190.

Merritt, R. W. and K. W. Cummins. 1978. An introduction to the aquatic insects of North America. Kendall-Hunt, Dubuque, Iowa. 441 pp.

Minshall, G. W. 1967. Role of allochthonous detritus in the trophic structure of a woodland springbrook community. Ecol. 48:139-149.

Minshall, G. W., R. C. Petersen, K. W. Cummins, T. L. Bott, J. R. Sedell, C. E. Cushing, and R. L. Vannote. 1983. Interbiome comparison of stream ecosystem dynamics. Ecol. Monogr. 53:1-25.

Mohr, J. L. 1952. Protozoa as indicators of pollution. Sci. Mon. 74:7-9.

Müller, K. 1954. Investigations on the organic drift in North Swedish streams. Rep. Inst. Freshwater Res. Drottningholm 35:133-148.

Müller, K. 1974. Stream drift as a chronobiological phenomenon in running water ecosystems. Ann. Rev. Ecol. and Systematics 5: 309-323.

Müller, K. 1982. The colonization cycle of freshwater insects. Oecologia 52:202-207.

Peterson, R. C. and K. W. Cummins. 1974. Leaf processing in a woodland stream. Freshwater Viol. 4:343-368.

Reed, G. D. 1973. A wastewater treatment analysis for Northwest Arkansas. Northwest Arkansas Regional Planning Commission, Springdale, Arkansas. 151 pp.

Roback, S. S. 1974. Insects (Arthropoda: Insecta) *In*: C. W. Hart, Jr., and S. L. H. Fuller, Eds. Pollution Ecology of Freshwater IEvertebrates. Academic Press, New York. pp. 313-376.

Rowe, V. D. 1973. Determination of the reaeration ond deoxygenation rates of the White River. Special Report, University of Arkansas, Fayetteville, Arkansas.

Stone, L. J. 1971. Water quality development of the upper reaches of White River and War Eagle Creek. Masters Thesis, Civil Engineering Department, University of Arkansas, Fayetteville, Arkansas.

Suberkrop, K. and M. J. Klug. 1976. Fungi and bacteria associated with leaves during processing in a woodland stream. Ecology 57: 707-719.

Tsai, C. 1973. Water quality and fish life below sewage outfalls. Trans. Amer. Fish. Soc. 102(2):281-292.

U. S. Environmental Protection Agency (EPA). 1974. Methods for chemical analysis of water and wastes. National Environmental Research Center, Cincinnati, Ohio. 298 pp.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Can. J. Fish. Aquat. Sci. 37:130-137.

Waters, T. F. 1967. Interpretation of invertebrate drift in streams. Ecology 46:327-334.

Waters. T. F. 1972. The drift of stream insects. Ann. Rev. Entomol. 17:253-272.

Weber, E. I., ed. 1973. Biological field and laboratory methods for measuring the quality of surface water and effluents. U. S. Environmental Protection Agency, Cincinnatti, Ohio. 178 pp.

Wilhm, J. L. 1967. Comparison of some diversity indices applied to populations of benthic macroinvertebrates in a stream receiving organic wastes. J. Water Poll. Control Fed. 39(10):1673-1683.

Wilhm, J. L. 1970. Range of diversity index in benthic macroinvertebrate populations. J. Water Poll. Control Fed. 42(3):221-224.

Wilhm, J. L. and T. C. Dorris. 1968. Biological parameters for water quality criteria. BioScience 18(6):477-481.