Verh. internat. Ver. Limnol.	XIII	603—610	Stuttgart, Februar 1958

The effects of sulphuric acid pollution on the biology of streams in the Transvaal, South Africa

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With 5 tables in the text

Strongly acid effluents or drainage waters are produced during gold and coal mining activities in the Transvaal. Sulphuric acid is produced during oxidation of pyrites exposed by mining operations and much of it finds its way into streams and creates serious pollution problems. The object of this paper is to give a short account of the effects of this acid pollution on the biology of these streams.

The first streams considered are the Klip and Klipspruit near their confluence at Olifantsvlei, near Johannesburg. These were studied during a two-year investigation of the area. Both receive acid pollution from gold mine dumps and slimes dams, the seepages from which have pH values as low as 2.3. Both streams run over dolomite formations so the acid is gradually neutralised but highly mineralised, permanently hard water results.

The Klip and the Klipspruit join in the middle of a Y-shaped, swampy area, each stream coming down one of the upper arms of the Y. A sampling station was set up on each where it runs slowly through the swamp just before confluence.

1. The Klipspruit (Station A on tables 1 and 2)

During most of the period, July 1954 to August 1955, the water at this station was alkaline, neutral or slightly acid as most of the acid had been neutralised. However, during the rainy season, December to February, when there was a large run-off from the mining areas, the pH fell well into the acid range. The following were the water analysis figures (only the extremes of the range are given):

pH: Wet season (December to February) 5.2 to 6.8
Rest of year . . . . 6.1 to 7.8
Total dissolved solids: 1375 to 1450 mg/l
Sulphates: 570 to 1100 mg/l
Chlorides: 120 to 130 mg/l
Calcium: 350 to 516 mg/l (as $CaCO_3$)
Magnesium: 235 to 240 mg/l (as $CaCO_3$)
Turbidities: low.

As a sewage works effluent entered higher up, nitrate and saline ammonia values were high:

Saline ammonia, as nitrogen: 0.06 to 3.0 mg/l
Nitrate, as nitrogen: 1.4 to 5.6 mg/l

At the sampling station the stream was slow-flowing and shallow with large beds of *Lagarosiphon major*. *Spirogyra* sp. was common and *Oedogonium* was also found. Diatoms were very numerous as were *Scenedesmus* spp. and *Cosmarium* spp. The bottom was very muddy and the stream was very productive.

The nearby swamp was very muddy with little accumulated plant matter, and was covered with thick growths of *Phragmites communis, Typha latifolia* and other reeds. The margins of the stream were fringed here and there with patches of *Crassula natans, Cotula coronopifolia* and *Nasturtium officinale.*

2. The Klip (Station B on tables 1 and 2)

This stream was very acid all the year round. Analysis figures were:

pH: Wet season (December to February) 3.7 to 4.3
Rest of year . . . . 4.0 to 4.8
Total dissolved solids: 930 to 1530 mg/l
Sulphates: 405 to 1660 mg/l
Chlorides: 20 to 30 mg/l
Calcium: 358 to 580 mg/l (as $CaCO_3$)
Magnesium: 162 to 221 mg/l (as $CaCO_3$)
Turbidities: Nil
Saline ammonia, as nitrogen: undetectable to 0.45 mg/l
Nitrate, as nitrogen: 0.1 to 0.2 mg/l

The stream was shallow and slow-flowing, sometimes almost lost in the swamp, but it had been deepened here and there by peat cutting. The only aquatic plant was *Scirpus fluitans* which grew in some profusion. The dominant alga was a species of *Mougeotia* which varied in amount from abundant to merely common. There was also some *Sphaerocystis schroeteri* and *Oedogonium* sp. but few diatoms.

The stream was unproductive and there were large accumulations of undecayed plant débris.

This area must have been acid for at least 30 or 40 years and the surrounding swamp had become a typical acid peat bog. The peat was several feet thick in parts and was being cut by local farmers and used mainly as a source of organic manure. The bog was overgrown with *Typha latifolia, Phragmites communis, Juncus exsertus, Juncus oxycarpus* and the fern *Dryopteris thelypteris* (L.) var. *squamigera* SCHLECHT.

Comparison of the fauna of the two stations

The fauna was sampled by sweeping a hand net, of No. 3 grit gauze (about 27 mesh/cm), through the aquatic plants. Table 1 gives the percentage composition of the fauna for the months of October, January, April and July which were selected as being representative of spring, summer, autumn and winter.

Table 1. Klipspruit, A, and Klip, B, at Olifantsvlei, near Johannesburg. Fauna of aquatic vegetation.

	October		January		April		July	
	A %	B %	A %	B %	A %	B %	A %	B %
Nais sp.	—	9.8	—	—	0.6	—	2.3	—
Chaetogaster sp.	—	6.6	—	—	0.6	5.8	5.8	—
Simocephalus sp.	1.2	—	—	—	—	—	—	—
Cyclops sp.	64.0	—	78.6	5.6	30.6	—	54.0	—
Platycyclops sp.	—	11.5	—	—	—	p	—	1.9
Hydrozetes sp. (Oribatoides)	—	4.9	1.9	27.8	—	15.6	—	43.3
Austrocloeon virgiliae	—	3.3	p	—	11.7	—	8.1	—
Enallagma glaucum	0.6	3.3	p	5.6	0.9	0.6	—	p
Annax imperator	0.6	p	p	p	p	p	—	—
Trithemis spp.	—	—	0.6	—	0.3	0.6	—	1.2
Micronecta piccanin	3.5	—	—	—	p	—	—	—
Leptocerus harrisoni	p	—	—	—	0.3	—	p	p
Argyrobothrus sp.	p	9.8	0.6	11.1	1.2	9.7	—	18.9
Tanypodinae	4.1	—	—	—	0.3	—	—	—
Corynoneura spp.	12.8	6.6	4.5	5.6	19.8	0.6	7.3	—
Tanytarsus spp.	5.2	—	3.9	p	—	—	—	—
Other Chironomidae	5.2	23.0	7.1	22.2	33.8	66.9	23.8	34.0
Culecidae	—	18.0	p	11.1	—	p	—	—
Pisidium georgeanum	—	—	p	—	—	—	—	—

"p" indicates species present in small numbers.

In spite of the sewage works pollution and the temporary acid conditions in summer (January), the fauna in the Klipspruit at Station A was fairly typical of a normal stream of this type in the region. Acid conditions in the Klip at Station B produced profound changes; these were mainly the virtual absence of *Cyclops* spp. and the domination of the fauna by *Hydrozetes* sp. (Oribatoides), *Argyrobothrus* sp. (Hydroptilidae) and Chironominae. It will be noted that *Enallagma glaucum* and *Annax imperator* were tolerant of the acid conditions. Tanypodinae did not appear in the acid water.

Samples were kept alive in the laboratory and the Chironomidae bred out, resulting adults are listed in table 2, numbers are not indicated but by far the commonest species taken from the Klipspruit were the two *Tanytarsus* spp. and *Corynoneura elongata.* In the Klip *Pentapedilum anale* was by far the most abundant species, but *Chironomus linearis* was very characteristic. The lack of Tanypodinae was notable.

Coal Mine pollution near Witbank

Witbank lies on an elevated hilly plain at an altitude of 4500 to 5000 feet and about 76 miles east north east of Johannesburg. In the coal mining areas

Table 2. Klipspruit and Klip at Olifantsvlei, Johannesburg.
Chironomidae bred out in laboratory.

	From samples taken from Klipspruit at Station A	From samples taken from Klip at Station B (acid)
Tanypodinae	*Tanypus guttatipennis* KIEF.	—
	Clinotanypus claripennis KIEF.	—
	Pentaneura dusoleili GOET.	—
	Pentaneura nigromarmorata GOET.	—
	P r o c l a d i u s a p i c a l i s KIEF.	—
	Procladius albitalus FR.	—
Corynoneurinae	*C o r y n o n e u r a e l o n g a t a* FR.	*C o r y n o n e u r a e l o n g a t a* FR.
Orthocladinae	*Orthocladius bergensis* FR.	—
	Psectrocladius viridescens FR.	—
	Cricotopus scotti FR.	—
	—	*Limnophyes spinosa* FR.
Chironominae	—	*Chironomus linearis* KIEF.
	Dicrotendipes pictipennis KIEF.	—
	T a n y t a r s u s a t e r r i m u s FR.	—
	T a n y t a r s u s p a l l i d u l u s FR.	*Tanytarsus pallidulus* FR.
	Tanytarsus sp. nov.	—
	—	*P e n t a p e d i l u m a n a l e* FR.

Species printed in *w i d e s p a c i n g* were numerous.

around the town pyrites rock is exposed in some of the mines and the pH of effluents may be as low as 2.3. In some parts acid water continues to seep or run out of old, unworked mines.

In this area it was possible to sample two streams in adjacent valleys, one completely unpolluted and the other with a pH of 2.9. The unpolluted stream is known as the Sadelboom and the polluted one as the Klip; the description and results given here are from two short, preliminary visits on 17th November, 1954, and 16th May, 1956.

C o m p a r i s o n o f w a t e r q u a l i t y

A few analysis figures are available.

	Sadelboom		Klip	
	Nov. 1954	May 1956	Nov. 1954	May 1956
pH	7.6	7.4	2.9	2.9
Total dissolved solids, mg/l	75	99	624	241
Sulphates, mg/l	10,7		475	
Chlorides, mg/l	8		15	
Calcium, as mg/l $CaCO_3$	15.7			
Magnesium, as mg/l $CaCO_3$	16.3			

The Sadelboom was slightly trubid on both occasions but the Klip was quite clear and colourless.

The Sadelboom is a small trout stream with stony runs and stickles, interspersed with small pools with sandy bottoms. The banks are fringed with marginal reeds and grasses which trail in the water. There are no aquatic plants.

The Klip must have been polluted for at least 30 years and presents a completely different picture. The whole bottom of the small valley, through which it runs, is becoming swampy and the stream bed is much overgrown with *Phragmites communis, Typha latifolia* and Cyperaceae. The flow is impeded here and there by masses of partially decayed or undecayed vegetable matter covered with a jellylike growth of the alga *Frustulia rhomboides* (E.) DE TONI, var. *saxonia* (RABL.) DE TONI. Deeper pools are floored with a thick growth of *Sphagnum truncatum* HORNS, emend. GARSIDE, growing luxuriantly to a depth of a metre or more. Here and there are small stony stickles and on the stones are deposits of ferric compounds and thick growths of *Frustulia rhomboides.*

The fauna

The fauna of stony stickles and submerged vegetation of the two streams are compared in tables 3 and 4.

Stony stickles: The Sadelboom fauna is rather similar to that of other trout streams in the region, it is very varied and many groups are represented. That of the Klip is poor in species and number (about one third of the density of the Sadelboom fauna); it is dominated by Oribatoides and Chironominae, mostly *Pentapedilum anale.* May-flies, caddis, aquatic beetles, *Simulium* spp. and Orthocladinae are eliminated by the acid conditions.

Marginal and submerged vegetation: The effect of the pollution was similar so that on the above biotope. Table 4 shows the predominance of Oribatoides and Chironomidae in the polluted stream. Some caddis are tolerant, e. g. *Leptocerus harrisoni,* and *Argyrobothrus* sp. thrives.

The Chironomidae are further analysed in table 5. No collection of adults was made at the Sadelboom but column one of the table gives the species collected alongside normal streams in the district. Those listed from the Klip include both those caught in the vicinity and a large number bred out in the laboratory. Most of the latter were *Pentapedilum anale* FREEMAN.

Conclusions

1. Mineral acid pollution tends to produce the same peat bog conditions as do poorly mineralised waters containing humic acids. This is in spite of the fact that the waters containing the mineral acids also contain relatively high concentrations of dissolved salts, including those of calcium and magnesium.

2. Specialised flora and fauna develop when the pH falls below 5, as seen in the case of the first two streams described, and may be found to pH values as least as low as 2.9, as seen in the case of the Witbank Klip. Some species common

Table 3. Fauna of stones in fast current.

	Sadelboom near Witbank 16th May 1956 pH 7.4 %	Klip near Witbank 16th May 1956 pH 2.9, ferric deposits and *Frustulia rhomboides* %
Planarians	3.2	—
Cypridopsis sp.	0.2	—
Other Ostracoda	0.8	—
Cyclops sp.	0.2	—
Potamon warreni (crab)	0.2	—
Hydrozetes sp.	0.2	7.1
Other Oribatoides	—	10.7
Hydrachnellae	1.9	—
Baetis harrisoni	32.8	—
Baetis sp. A	0.5	—
Pseudocloeon maculosum	0.5	—
Euthraulus elegans	22.0	—
Tricorythus discolor	9.5	—
Austrocaenis sp.	3.2	—
Afronurus harrisoni	1.3	—
Aeschna sp.	0.5	—
Leptocerus sp.	0.2	—
Cheumatopsyche maculata	0.8	—
Cheumatopsyche zuluensis	1.6	—
Chloropsyche sp.	0.2	—
Chimarrha sp.	0.2	—
Hydroptila capensis	0.5	—
Argyrobothrus sp.	—	0.7
Hydroptilid Type A	0.2	—
Hydraenidae	1.3	—
Helmidae (larvae)	2.1	—
Psephinidae	0.2	—
Simulium spp.	3.2	—
Bezzia-type larvae	0.8	—
Tanypodinae	0.2	—
Corynoneurinae	—	0.7
Other Chironomidae	10.8 mostly Orthocladinae	80.7 mostly *Pentapedilum anale*

in alkaline or neutral waters do live down to pH values of about 4.0 but, at this stage, the fauna and flora is dominated by specialised species. At lower pH values only the latter thrive.

This research was carried out in the laboratories of the Water Research Division of the South African Council for Scientific and Industrial Research and this paper is published with their permission. The author would like to thank Miss D. Dimović

Table 4. Fauna of submerged vegetation.

	Sadelboom near Witbank 16th May 1956 pH 7.4 %	Klip near Witbank 16th May 1956 pH 2.9 %	Klip near Witbank 17th November 1954 pH 2.9
Nematoda	1.3	—	present
Nais sp.	1.0	—	—
Pionocypris sp.	0.5	—	—
Cyclops sp.	17.4	—	—
Hydrozetes sp.	1.0	73.2	common
Other Oribatoides	0.5	12.2	common
Hydrachnellae	1.0	—	—
Baetis harrisoni	2.9	—	present
Baetis bellus	1.6	—	—
Baetis sp. A	11.3	—	—
Centroptilum excisum	0.5	—	—
Austrocaenis sp.	6.6	—	—
Pseudagrion sp.	1.0	—	—
Plea pullula	0.8	—	—
Ranatra sp.	present	—	—
Sphaerodema sp.	present	—	—
Micronecta piccanin	0.8	—	—
Leptocerus harrisoni	present	—	present
Macronema sp.	0.2	—	—
Hydroptila capensis	1.0	—	—
Hydroptila sp.	0.8	—	—
Argyrobothrus sp.	—	2.9	common
Hydroptilid type A	1.0	—	—
Dytiscid type A	0.3	—	—
Dytiscid type B	0.3	—	—
Dytiscid larvae	—	present	—
Berosus sp.	0.5	—	—
Hydraenid type A	1.3	—	—
Hydraenid type B	0.8	—	—
Hydraenid larvae	1.0	—	—
Helmidae	1.0	—	—
Anopheles sp.	2.9	—	—
Dixa sp.	present	—	—
Simulium spp.	3.2	—	—
Bezzia-type larvae	0.5	—	—
Dasyhelea-type larvae	0.5	—	—
Pentaneura sp.	0.5	—	—
Corynoneurinae	9.8	—	—
Tanytarsus-type larvae	0.5	—	—
Other Chironomidae	21.9	10.5	common
Ancylidae	1.8	—	—

Table 5. Chironomidae from Witbank District.

	Chironomidae caught near normal streams	Chironomidae caught near or bred from acid stream
Tanypodinae	*Pentaneura dusoleili* GOET.	—
Corynoneurinae	*Corynoneura scotti* FREEMAN	—
	Thienemanniella lineola FR.	—
Orthocladinae	*Orthocladius scotti* FR.	—
	Metriocnemus dewulfi GOET.	—
	Cricotopus obscurus FR.	—
	Cricotopus harrisoni FR.	—
	Trichocladius capensis FR.	—
	Limnophyes spinosa FR.	—
	Smittia conigera FR.	—
	Nanocladius calviger FR.	—
Chironominae	*Chironomus peringueyi* KIEF.	—
	Chironomus pulcher WIEDEMANN	—
	—	*Chironomus linearis* KIEF.
	Microtendipes umbrosus FR.	—
	Cryptochironomus sp.	—
	Tanytarsus pallidulus FR.	—
	—	*Pentapedilum anale* FR.

for much of the information on plants and algae, the analytical section of the Division for water analyses, and the following systematists: Dr. P. FREEMAN of the British Museum (Chironomidae), Mr. S. S. GARSIDE *(Sphagnum)* and Dr. E. SCHELPE *(Dryopteris)* both of the University of Cape Town, and Dr. B. J. CHOLNOCKY *(Frustulia)*.

Discussion

PENTELOW: Most interesting because in England there is, so far as I know, no acid pollution uncomplicated by toxic metals, lead, zinc etc. With a sulphate so high, discharge of organic waste would be dangerous, for deoxygenation would cause production of H_2S. Were there fish in the acid waters?

HARRISON: The Inland Fisheries Department, in a preliminary survey, have found none in the stream of pH 2.9.

DAHL: I should like to know, if you have made any observations on the content of iron in these waters. A high content of iron in water rich in sulphate causes precipitation of ferric hydroxide, which precipitates on the gills of fishes and will kill them.

HARRISON: The areas investigated were all well below the sites of pollution and all ferric hydroxide had precipitated by the time the water reached them.

WINDLE TAYLOR: Was there any evidence of the growth of micro-fungi in these acid waters, possibly on the bed of the streams?

HARRISON: No.