THE EFFECTS OF REFUSE-TIP LIQUOR UPON STREAM BIOLOGY

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ABSTRACT

An assessment was made of the effects of drainage from five refuse-tips upon the biology of the receiving watercourses. Three refuse-tips were found to be the cause of gross pollution of the stream, resulting in massive growths of sewage fungus Leptomitus lacteus, *with the invertebrate community dominated by the oligochaete* Nais elinguis *over a considerable distance downstream. Chironomidae and the oligochaetes* Tubifex ignotus, T. tubifex *and* Lumbriculus variegata *were frequent immediately below discharges. The absence of many invertebrate species appears to be associated with the presence of massive growths of sewage fungus in the stream trapping silt and blocking the interstices between stones, and the increase in pollution.*

INTRODUCTION

Refuse-tip liquor is a complex suspension and solution of organic and inorganic constituents, with an acid pH, high conductivity and usually high concentration of iron in solution (Table 1). Phosphate content is high and nitrogen, as free and saline ammonia, is usually high, but this is reduced by river dilution with a subsequent rise in the nitrate content. Refuse-tip liquor tends to have a high BOD and causes severe de-oxygenation of the river at the point of discharge.

Refuse-tip liquor has the necessary growth requirements for sewage fungus which have been described as (a) degradable organic nutrients, (b) inorganic nutrients (in particular nitrogen and phosphorus) and (c) growth factors, vitamins, etc. by Curtis & Harrington (1971). A phosphate content of 0·05 mg/l has been shown to support heavy slime growths (Curtis *et al.*, 1971) although concentrations lower than this are adequate for sewage fungus growth.

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TABLE 1

SUMMARY OF ANALYTICAL RESULTS OBTAINED FROM CHEMICAL SAMPLES

	pH	*Conductivity micromhos/cm*	*BOD*	*Free and saline ammonia*	*Nitrate*	*Nitrite*	*Calcium*	*Magnesium*	*Iron*	*Phosphate*
				←			*mg/l*			→
Station: Connon Bridge, 10 February, 1972										
1	6·7	510	230·0	26·0	3·8	0·21	41·0	11·0	25·0	0·4
2	7·1	1770	270·0	51·0	2·0	0·14	235·0	58·0	31·3	0·6
3	7·0	285	48·0	2·9	4·7	0·02	26·0	5·1	3·5	0·4
4	6·8	240	1·6	0·1	4·8	0·01	14·5	3·6	0·4	0·3
5	7·1	260	33·0	1·6	4·4	0·01	14·5	3·4	0·9	0·3
6	7·2	245	7·6	0·5	5·3	0·03	18·5	4·8	0·7	0·3
7	7·2	230	2·3	0·3	5·2	0·03	18·5	4·7	0·5	0·3
8	7·3	235	1·4	0·2	4·9	0·04	19·0	4·9	0·4	0·4
Station: Conce Moor, 22 February, 1972										
1	6·3	3450	3650·0	170·0	0·9	0·01	260·0	85·0	118·0	1·8
2	7·2	4300	2200·0	320·0	0·8	0·01	165·0	78·0	98·0	1·1
3	7·5	1340	100·0	150·0	0·7	0·01	31·0	36·0	40·0	0·6
4	6·8	595	360·0	22·5	1·3	0·13	21·0	11·0	15·5	0·7
5	6·8	225	28·0	1·2	4·0	0·02	7·0	3·7	2·8	0·6
6	6·6	205	6·7	0·6	4·9	0·02	6·0	4·1	1·5	0·4
7	7·0	205	2·0	0·6	5·4	0·02	6·0	4·8	0·5	0·4
Station: Hollacoombe, 29 February, 1972										
1	6·5	106	1·1	0·4	0·6	0·01	3·5	2·1	0·6	0·2
2	6·9	112	1·1	0·6	0·6	0·01	3·5	2·2	0·5	0·3
3	7·0	175	1·0	1·0	0·6	0·01	6·5	3·2	0·5	—
4	6·8	295	30·0	3·4	0·2	0·01	8·0	4·8	7·3	0·3
5	7·0	225	17·0	2·2	0·4	0·01	7·5	4·6	5·4	0·5
6	7·3	200	2·4	0·7	1·0	0·03	6·5	3·5	0·9	0·6

This paper describes the effects of drainage from refuse-tips upon stream biology and discusses the distribution of benthic invertebrates in the receiving watercourses.

MATERIALS AND METHODS

The five streams studied in this survey were all small, stony, hill-streams draining agricultural land, with an average width of 1·2 m and current velocity of 60 cm/sec. Eighteen sites on the watercourses were visited during February–April 1972 from which a total of twenty-two samples were collected (Fig. 1).

Samples of fungus and aquatic plants were collected in polythene bags at each site for later examination and identification.

The macro-invertebrate population was sampled by means of a closed, triangular hand-net (64 mesh/cm^2) at riffle sections of the stream. The bottom of the stream was disturbed by kicking and allowing the current to carry the dislodged material into the net (Elliott, 1971). By slowly moving upstream for a fixed period of two minutes this technique ensured collecting a representative quantity of material over a large area of bottom. One sample was taken at each station and this was preserved with formalin for later examination.

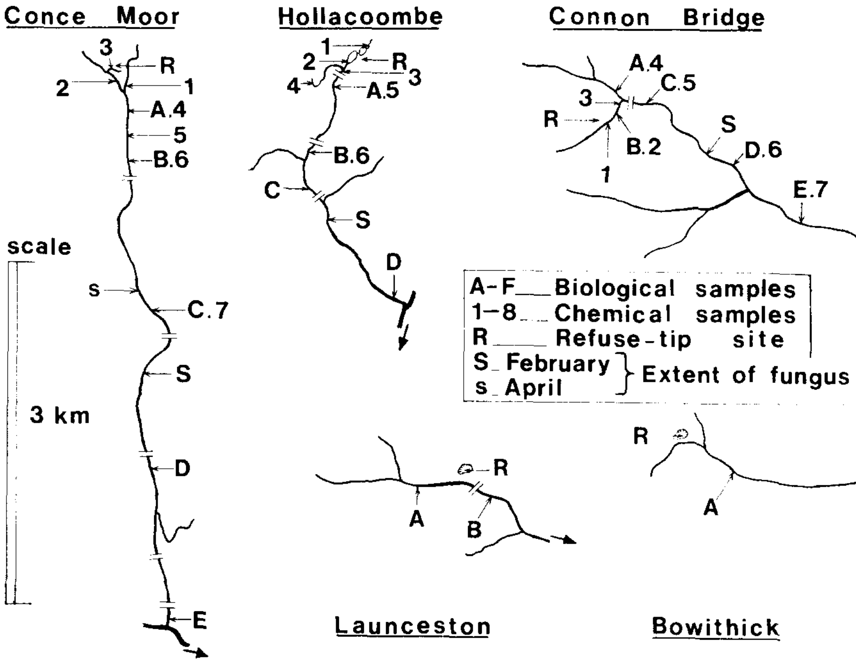

Fig. 1. Maps of biological and chemical sampling points on the receiving watercourses for five refuse-tips studied in this survey.

Samples were individually washed in an Endecott sieve (140 mesh/cm^2) and then transferred to a large sorting tray (35 × 26 cm) marked out by grid lines into six equal divisions. Animals were picked out from 1 or 1–6 of the divisions according to the amount of material present, and placed in a petri-dish for counting. Large animals and members of each species present in the samples were also removed and placed in a separate petri-dish for identification.

RESULTS AND DISCUSSION

Two (Launceston and Bowithick) of the five refuse-tips studied in this survey were found to have little or no effect upon the stream biology. It is significant that both

TABLE 2

DISTRIBUTION AND RELATIVE ABUNDANCE OF THE MACRO-INVERTEBRATE SPECIES IN COLLECTIONS

	Connon Bridge 25 February 1972						Conce Moor 22 February 1972					Conce Moor 21 April 1972				Hollacoombe 1 March 1972				Launceston 15 March 1972		Bowithick 9 March 1972
Species	*A*	*B*	*C*	*D*	*E*	*F*	*A*	*B*	*C*	*D*	*E*	*B*	*C*	*D*	*E*	*A*	*B*	*C*	*D*	*A*	*B*	*A*
Turbellaria																						
Phagocata vitta	—	—	—	—	—	—	—	—	—	1·2	—	—	P	0·8	—	P	—	—	—	—	—	—
Polycelis felina	2·0	—	—	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17·9	34·9	1·6
Polycelis nigra	—	—	—	—	—	—	—	—	1·6	—	—	—	0·3	P	—	—	—	—	—	—	—	—
Oligochaeta																						
Nais alpina	2·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nais elinguis	—	4·9	54·4	31·3	42·9	22·6	P	12·7	42·3	49·3	29·5	12·2	95·0	83·8	88·8	81·6	37·0	45·0	2·1	—	P	—
Branchiura sowerbyi	7·9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhyacodrilus coccineus	—	—	—	—	—	—	—	—	4·4	4·8	26·3	7·3	1·3	2·3	2·8	—	—	—	—	—	—	—
Tubifex ignotus	—	—	P	P	P	—	—	—	—	—	—	—	—	—	—	P	45·0	30·0	32·5	—	—	—
Tubifex tubifex	—	—	P	P	P	—	—	—	—	—	—	—	—	—	—	P	10·6	P	11·5	—	—	—
Lumbriculus variegata	10·0	P	—	P	—	P	—	P	—	P	3·2	P	—	1·6	—	11·7	4·9	3·3	—	18·0	18·5	14·3
Stylodrilus heringianus	—	—	—	—	P	—	—	—	—	—	—	—	—	—	—	—	—	P	P	—	—	—
Enchytraeidae	—	—	—	—	—	—	—	—	P	—	—	—	—	—	—	—	—	P	P	—	—	—
Eiseniella tetrahedra	—	—	—	—	P	—	—	—	—	P	—	—	—	—	—	P	—	—	—	P	P	1·6
Hirudinea																						
Helobdella stagnalis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	P	—	—	—	—	—
Glossiphonia complanata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	P	—	—	—
Crustacea																						
Gammarus pulex	—	—	—	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	P	4·6	—
Plecoptera																						
Amphinemura standfussi	2·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Amphinemura sulcicollis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6·6	4·0	—	—	—
Brachyptera risi	P	—	4·7	—	—	—	—	—	—	—	P	—	—	—	P	—	—	—	—	—	—	1·6
Chloroperla torrentium	3·9	—	—	—	3·6	2·9	—	—	—	—	—	—	—	—	—	—	—	—	—	4·4	2·4	—
Isoperla grammatica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	P	—	1·6
Leuctra hippopus	8·0	—	4·7	—	—	—	—	—	—	P	—	—	—	0·8	P	—	—	—	6·1	—	—	—
Nemurella picteti	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	P	—	—	—	—	—
Nemoura cinerea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2·3	—	—
Perlodes microcephala	P	—	—	—	P	P	—	—	—	—	—	—	—	—	—	—	—	—	2·1	—	—	—
Protonemoura meyeri	—	—	—	—	—	—	—	—	—	1·2	1·6	—	—	—	—	—	—	—	—	—	—	3·2
Rhabdiopteryx acuminata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4·4	P	—

Ephemeroptera																						
Baetis rhodani	20·0	P	P	25·0	14·3	37·0	—	12·7	22·6	19·2	6·1	9·8	2·0	4·6	4·7	—	—	—	6·1	13·5	23·3	14·3
Ecdyonurus dispar	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	P	—	P	—	P	P
Ephemerella notata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·9	—	—	—	—	—	—	—
Paraleptophlebia submarginata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	P	—	2·4	—
Rhithrogena semicolorata	12·0	—	—	—	—	8·5	—	—	1·6	—	1·6	—	—	P	P	—	—	—	21·5	21·9	4·6	P
Trichoptera																						
Hydropsyche instabilis	6·0	—	—	—	3·6	P	—	—	1·6	1·2	1·6	—	—	P	—	—	—	—	—	—	—	1·6
Limnephilidae	P	—	—	P	—	2·9	—	—	—	P	3·2	—	—	P	—	—	P	—	2·1	—	P	P
Polycentropus kingi	—	—	—	—	—	2·9	—	—	—	—	—	—	—	—	—	3·4	—	—	—	—	—	—
Rhyacophila dorsalis	2·0	—	—	—	—	—	—	12·7	—	P	—	—	—	P	P	—	—	—	—	P	—	P
Sericostoma personatum	2·0	—	P	P	—	P	—	—	—	1·2	1·6	—	—	P	P	—	—	—	—	2·3	P	—
Silo nigricornis	—	—	—	—	—	P	—	—	—	—	3·2	—	—	—	—	—	—	—	—	P	—	—
Coleoptera																						
Elmis aenea	—	—	—	—	7·2	—	—	—	—	P	3·2	—	—	—	—	—	—	—	—	2·3	P	—
Gyrinus sp.	P	—	—	P	P	2·9	—	—	—	—	—	—	—	—	—	—	—	—	2·1	4·4	P	—
Limnius volckmari	P	—	—	—	3·6	11·4	—	—	—	—	1·6	—	—	—	0·9	—	—	—	—	P	—	—
Diptera																						
Clinocera sp.	—	—	—	6·3	—	2·9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	P
Chironomidae	—	90·2	31·6	37·5	25·0	2·9	P	48·9	12·2	8·5	3·2	65·9	0·3	4·6	0·9	3·4	2·5	16·1	2·1	4·4	2·4	1·6
Dicranota sp.	P	—	—	—	—	P	—	—	—	—	3·2	—	—	—	0·9	—	—	—	—	2·3	P	1·6
Simulium ornatum	6·0	4·9	4·7	P	P	P	—	12·7	—	P	3·2	4·9	—	—	—	—	—	—	2·1	—	—	1·6
Simulium cf. *S. variegatum*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	P	—	—	—
Tipula sp.	—	—	—	—	—	—	—	—	—	P	—	—	—	P	—	—	—	—	P	—	—	P
Odonata																						
Libellula sp.	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mollusca																						
Ancylastrum fluviatile	3·9	—	—	P	P	2·9	—	—	1·6	1·2	1·6	—	—	P	P	—	—	P	2·1	—	—	—
Hydrobia jenkinsi	12·0	—	—	P	—	—	—	—	12·2	12·1	6·1	—	1·0	0·8	P	—	—	—	4·0	2·3	7·0	47·6
Pisidium sp.	—	—	—	—	—	—	P	—	—	P	—	—	—	—	—	—	—	—	—	P	—	6·4
Planorbis contortus	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Planorbis spirorbis	—	—	—	—	—	—	—	—	—	—	P	—	P	—	—	—	—	—	—	—	—	—
Number of individuals	585	369	386	560	980	411	9	47	385	970	376	1435	10430	4554	3745	179	1418	545	875	560	502	2205
Number of species	24	5	9	15	15	18	3	6	10	19	19	6	8	16	14	8	9	9	21	20	18	19

tips were situated in quarries so that refuse-tip drainage entered the watercourse only after percolating through rock strata.

The further three refuse-tips (Hollacoombe, Conce Moor and Connon Bridge) caused similar effects upon stream biology and this is described below.

Massive growths of sewage fungus *Leptomitus lacteus* occurred immediately below the liquor discharges and persisted for a considerable distance downstream (>2 km). No other species of fungus could be found present in samples. *L. lacteus* occurs where there is an ample supply of oxygen, calcium and nitrogenous organic matter of high molecular weight (Stjerna–Pooth, 1957). Vallin (1958) and Mossevitch & Gussew (1958) have reported that *Leptomitus* replaces the more common *Sphaerotilus* below the discharge from wood-pulping factories.

Algae were absent from collecting sites, although blue-green algae were present at some distance further downstream. Butcher (1947) has described the occurrence of a zone of dense growths of blue-green algae downstream of the fungus zone and associated with organic pollution. This zone was not found in the streams investigated in this survey.

Aquatic vascular plants were sparse and limited to *Ranunculus* sp. and *Callitriche* sp. *Fontinalis* sp. was frequent beyond the fungus zone.

The distribution of macro-invertebrates expressed in percentage abundance is given in Table 2. Low species diversity and low total number of individuals typified the streams immediately below refuse-tip liquor discharges, but high total numbers of individuals were collected further downstream in the fungus zone.

The most abundant group in all samples was the Oligochaeta, which comprised numerically at least half of the invertebrate community. *Nais elinguis* dominated the fauna, and *Tubifex ignotus, T. tubifex* and *Lumbriculus variegata* were frequent in samples taken through the fungus zone. According to Hynes (1966) the naidids are essentially inhabitants of soft substrata in the depositing regions of rivers. The abundance of *N. elinguis* in the stony streams below refuse-tips appears to be associated with the presence of massive growths of sewage fungus trapping silt and blocking the interstices between stones. *Nais alpina* and *Branchiura sowerbyi*, however, appear to be either sensitive to liquor pollution or to the unstable substrate provided by slime growths, since both species were found restricted to an unpolluted side-stream. Learner *et al.* (1971) found *N. alpina* restricted to the tributaries and headwaters of the River Cynon upstream of coal-waste pollution. The unusual occurrence of *B. sowerbyi* at natural temperatures in Britain has previously been reported by Aston (1967) and it is considered unnecessary to digress here on the local origins of this species.

Chironomidae (unidentified species) were the most abundant insects found downstream of refuse-tip discharges. Chironomid larvae were found at all stations but in greater abundance in the fungus zone. *Baetis rhodani* was fairly numerous in samples but was absent immediately below discharge points. This species is quite tolerant of organic pollution (Woodiwiss, 1964) and is more prevalent in smaller streams than in rivers (Macan, 1957).

Ancylastrum, *Polycelis* and *Phagocata* were found in the lower region of the fungus zone. Hynes (1970) observed *Ancylastrum* living in polluted, but well-oxygenated, waters, keeping small areas free of sewage fungus by feeding. Triclads, in general, are intolerant of organic pollution (Hawkes, 1962) and this probably explains their absence immediately below refuse-tip discharges.

The macro-invertebrate fauna re-established itself beyond the fungus zone, as shown by an increase in species diversity (Table 2). Oligochaetes, however, remained the most abundant group.

Stundl (1958) has shown that fish and other animals disappear from areas blanketed by sewage fungus even when the water is neither toxic nor severely de-oxygenated. This effect is caused by the change in substratum, although loose filaments of fungus in the water tend to smother small animals (Mossevitch & Gussew, 1958).

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