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The Big River, Co Louth, Ireland : a case study in recovery

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Results of analysis of the chemical and biological effects of organic wastes, from the Cooley Alcohol Factory, on the water quality of the Big River, Co. Louth, during the March/April period - from 1983 to 1986 - showed the river to be grossly polluted downstream of the factory outfall - being devoid of living organisms, with the exception of sewage fungus. When the factory ceased production in June 1986, water quality showed an immediate improvement and within eight months significant signs of recolonisation, by macroinvertebrates, were evident.

Water quality continued to improve until the end of the survey in March 1988, when the river returned to near pristine conditions.

La Big River, Co. Louth, Irlande : étude d'un cas de guérison

Mots clés : Pollution, guérison, macroinvertébrés, indice de qualité.

Les résultats d'une analyse des effets chimiques et biologiques des déchets organiques rejetés par l'usine « Cooley Alcohol Factory » sur l'eau de la rivière « Big » dans le comté de Louth, pendant les mois de mars-avril 1983 à 1986 ont montré une véritable pollution de la rivière à l'aval du déversoir de l'usine : absence d'organismes vivants à l'exception de champignons des eaux d'égoût. Lorsque l'usine a cessé sa production en juin une amélioration de la qualité de l'eau a été constatée. Huit mois après, la recolonisation des macroinvertébrés est apparue. L'eau s'est améliorée constamment et atteignait presque sa qualité originelle à la fin de l'étude, en mars 1988.

Introduction

As part of an ongoing programme of water quality monitoring, the chemical and biological effects of organic effluents, discharged into the Big River, Co. Louth, from the Cooley Alcohol Factory (Chemici Teo.) have been monitored during the months of March and April since 1983. Detailed long term studies were not carried out as sampling was intended to provide a synoptic view which would establish a base line evaluation. The alcohol factory started production in 1937 and manufactured alcohol from potatoes, which could not be sold elsewhere due to blight (*Phytophthora infestans*). A new plant was commissioned in 1984 producing, from molasses, some 200,000 L of potable alcohol each week.

As well as potable alcohol the factory produced industrial alcohols such as Industrial Methylated Spirits (I.M.S.), Mineralized Methylated Spirits (M.M.S.) and Absolute Alcohol. Organic wastes, produced by the factory, were discharged into the river in a largely untreated form. At the height of production the factory was operating 24 hours a day. The B.O.D. of the effluent at the mouth of the discharge pipe was measured at 1440 mg/L.

The condition in the river in the final 2 km, as a result of this continuous and potent discharge, has been one of gross pollution for many years (Clabby 1981, AFF 1986). The affected stretch of river was characterized by a virtual absence of macroinvertebrate life and was dominated by an extensive growth of heterotrophic slime which, because of its permanent nature and mature age was described by one colleague as a « national heritage of sewage fungus ».

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Conditions in the river were sharply divided between a pristine stretch above the Cooley Alcohol factory and the grossly polluted stretch below the factory. Pollution extended some distance beyond the mouth of the river into the sea, at Dundalk Bay.

Production in the Cooley Alcohol Factory ceased on 27/6/1986.

1. Description of the site

The Big River rises on Slievetrasna (near the Windy Gap) in the Cooley Mountains at a height of 409 m. It flows in a south-easterly direction to enter Dundalk Bay some 1.5 km east of Gyles Quay. The total length of the river is 10.5 km and it drains a catchment of some 28.16 km^2.

The geology of the catchment consists mainly of acid intrusive rocks near the source of the river with some outcrops of limestone in the lowlands. The main glacial influence in the catchment area is reflected in a glacial drift of sands, gravel and gravelly till.

The upland soils consist, in the greater part, of peaty podzols. In the lowlands grey/brown podzols predominate, with gley as the main associated soil type.

Five stations were sampled each year and their location is shown (*fig.* 1).

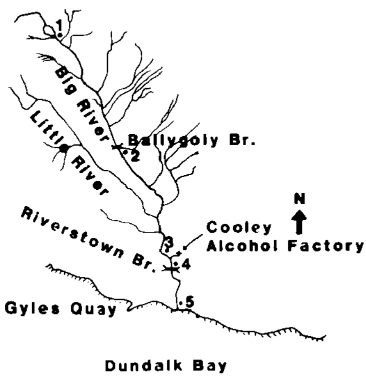

Fig. 1. Location of the sampling stations on the Big River.

2. Methods

Where possible, analysis of water quality parameters was carried out on the spot. Temperature and dissolved oxygen were measured using a Syland DO meter ; conductivity was determined using a Type M.C.3 conductivity measuring bridge (Electronic Switchgear, London Ltd.) and pH was measured using an Orion Research portable pH meter, model 221. Samples for chemical analysis were collected in wide mouthed 2 L plastic bottles and returned to the laboratory for same day analysis. On one occasion an attempt was made to delay analysis over the weekend by freezing the samples. However, the alcohol residues discharged in the effluent depressed the freezing point rendering this method of preservation useless. The following methods were used for chemical analysis :

Phosphate (Ascorbic acid method) ; Ammonia (Phenate method) ; Nitrate (Brucine method) ; Hardness (E.D.T.A. titration using Eriochrome Black T as an indicator) ; Alkalinity (Titration with M/100 HCl using a mixed (pH 4.5) indicator ; B.O.D. was determined using the Azide modification of the Winkler Method. All methods of analysis were taken from Standard Methods (1986).

Methods for sampling the bottom fauna of rivers are reviewed by Macan (1958), Cummins (1962), Frost, Huni & Kershaw (1971), McGarrigle & Lucey (1983). The kick method, employing a standard F.B.A. handnet was adopted for this survey. This method has the advantage of covering a wide area in a short period of time and allows a number of microhabitats to be sampled. A standard sampling time of two minutes per sample was adopted. Samples were taken from the riffle areas, as much as possible, to provide comparability between the stations. Although this is not an absolutely quantitative method comparable results were obtained on a relative basis.

— *Station 1* is situated in a valley 200 m above sea level in the Windy Gap. It differs from subsequent stations in being slow flowing and depositing in nature.

— *Station 2* is located just daonstream of Ballygoly bridge. This is a fast flowing region of the river, with a predominantly stony/gravelly substrate.

— *Station 3* is located 50 m upstream of the factory outfall. It is located in a fast flowing region and has a stony/gravelly substrate.

— *Station 4* is located 100 m downstream of the factory outfall. It is predominantly stony in nature and is characterised by fast flowing water.

— *Station 5* is located 500 m from the mouth of the river. Like to previous stations it has a stony substrate and fast flowing water.

Except for a few small areas of relatively slow flowing water the river has an eroding nature over most of its length. There are few silted areas and very little plant growth. The nature of the fauna reflects this in being dominated by polyoxybiontic types from source to the mouth of the river.

3. Results

Conditions in the Big River were very clean from the source to just above the factory outfall. Below the factory outfall the river was grossly polluted until the factory ceased production in June 1986. Lush growths of sewage fungus could be seen from this point down to the sea. The effluent also had the effect of discolouring the river water (increased the mean colour, in Hazen units, from 10 to 500) and this discolouration extended some distance out to sea. Initially the effluent was channelled down the eastern bank, but the mixing zone extended across the whole width of the river within 200 m of the outfall.

Table I. Variation in physical and chemical parameters in the Big River : 1983-1988.

Station	Date	pH	Cond. μmhos	Alk mg/L	Hard. mg/L	Temp. mg/L	D.O. mg/L	PO4-P μg/L	NH3-N mg/l	NO3-N mg/l	B.O.D mg/l
1	23/3/83	5.65	50	nd	28	7	12.8	nd	.176	nd	nd
	14/3/84	6.65	2500	nd	20	6.3	11.6	t	.01	1.192	nd
	22/3/85	6.01	50	17	26	1.1	12.5	t	.02	nd	nd
	10/4/86	6.75	2500	29	57	2	12	2	.01	nd	nd
	20/3/87	6.1	90	15	34	4.1	12.1	17	nd	nd	nd
	18/3/88	5.26	48	19	175	4.9	11.3	t	.013	nd	2.5
2	23/3/83	6.1	90	nd	46	9	11	33	.038	nd	nd
	14/3/84	6.69	57	nd	40	5.1	11.6	nd	t	.919	nd
	22/3/85	5.65	70	23	62	2.4	13	9	t	nd	nd
	10/4/86	6.7	54	15.5	25	2	12	8	nd	nd	nd
	20/3/87	6.1	90	14	40	4.8	12.2	t	nd	nd	nd
	18/3/88	6.14	75	27	80	5.2	11.9	t	t	nd	3
3	23/3/83	5.7	120	nd	66	10	11.5	80	.59	nd	1.2
	14/3/84	5.15	90	nd	46	4.6	11.6	15	nd	.48	1.5
	22/3/85	6.3	80	75	75	3.2	14.4	22	t	nd	2.7
	10/4/86	6.71	65	30.5	128	2	12	nd	nd	nd	1.6
	20/3/87	6.35	100	34	54	4.8	12.9	t	nd	nd	1.5
	18/3/88	6.85	100	40	80	5.7	12.5	t	.129	nd	6.4
4	23/3/83	6	100	nd	60	8	11	19	.07	nd	58
	14/3/84	5.75	4000	nd	65	4.8	11.3	12	.244	3.69	130
	22/3/85	3.78	3000	58	66	19.5	7.8	163	t	nd	375
	10/4/86	5.15	4000	0	1080	15.2	8.4	620	.35	1.28	150
	20/3/87	6.53	110	33	62	4.5	12.6	t	nd	nd	2.8
	18/3/88	6.8	105	36	70	5.7	12.5	t	.096	nd	6.4
5	23/3/83	6	110	nd	82	8	9.4	63	.58	nd	nd
	14/3/84	6	1750	nd	82	5	10.1	3	nd	1.37	nd
	22/3/85	5.45	250	110	156	5.8	8.2	184	t	nd	nd
	10/4/86	6.7	2500	53	127	4.5	10.7	750	.07	.56	nd
	20/3/87	6.5	120	35	54	4.6	12.8	t	nd	nd	nd
	18/3/88	6.8	105	69	75	5.9	11.2	t	.074	nd	6.7

nd = not determined ; t = trace - i.e. PO4 < 1.0 μg/L ; NH3-N < 0,01 mg/L

Variation in the physico-chemical conditions in the river are given (Table I).

Results above the outfall are consistent with the very clean nature of the river. Elevated levels of nutrients are noticeable below the outfall - particularly in 1985 and 1986 - and this correlates with high levels of waste discharge in these years. At this time accelerated breakdown of organic matter was occurring as a result of elevated water temperatures, brought about by the high temperature of the effluent. Although the B.O.D. of the effluent was high in 1984 the effluent was much cooler and did not elevate the temperature of the river water on admixture. The effect of elevated temperatures and organic decay was also reflected in the dissolved oxygen levels, which fell at station four by almost 50 % in 1985 and 30 % in 1986. This depletion in dissolved oxygen persisted almost to the mouth of the river in 1985 when pollution was particularly severe. At this time the pH of the river was also dramatically affected, falling from 6.3 at station three to 3.78 at station four. This low level of pH is harmful to most organisms and undoubtedly affects the ability of bacteria to mineralize organic matter. The effect of low pH on bacteria may go some way towards explaining why ammonia and nitrate were not detected in samples taken this time. In 1984 and 1986 significant amounts of ammonia and nitrate could be detected below the point of pollution. Levels of phosphate were generally low in the river but elevated results can be seen downstream of the outfall.

The relative distribution of the major macroinvertebrate taxa at each of the station is given (*fig.* 2).

It is obvious from the results that the effluent had a severe impact on the aquatic fauna. The stations upstream of the effluent (1,2 and 3) all show conditions typical of a healthy environment with polyoxybiontic forms predominating. The increase in faunal numbers at station two (in 1986) was largely a result of the increase in numbers of the

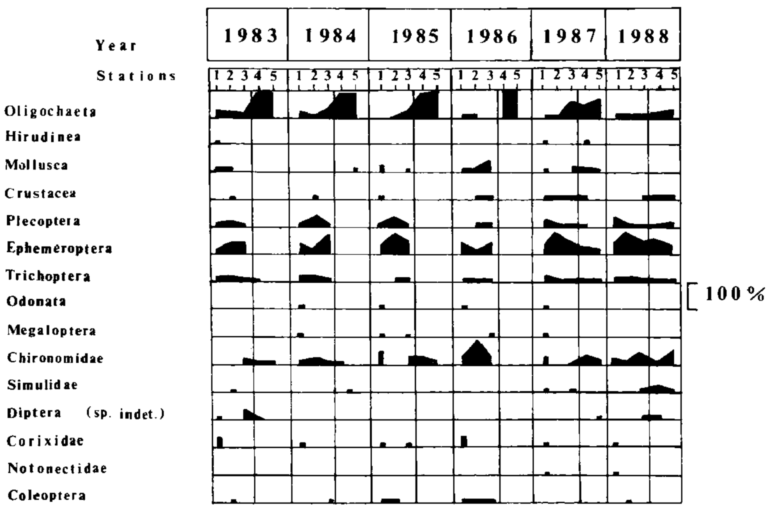

Fig. 2. Relative abundance of major macroinvertebrate taxa at each sampling station : 1983-1988.

Chironomidae. Whether this was due to an increase in the population or to more efficient sorting of samples (the specimens taken at this time were very small) is moot. Below the outfall (stations 4 and 5) conditions show distinct impairement of water quality with only oligochaetes (*Tubifex*) and some chironomids being able to survive.

4. Discussion

A single series of samples of the biota can be a useful monitoring tool as it may give a summary of water quality conditions over a past period of time (Hynes 1963). The effects of gross organic pollution are fairly easy to detect as the normal flora and fauna is replaced by sewage fungus and oligochaetes (Tubificidae). This condition could be clearly seen in the Big River, below the point of discharge, in every year up to the time the factory ceased production. Above the point of discharge gill breathing aquatic insects predominated (i.e. Plecoptera, Ephemeroptera and Trichoptera) indicating high quality (Gaufin 1956). Downstream, the increased concentration of organic matter from the effluent resulted in an increase in the decomposer component of the ecosystem. The respiratory demand of the microbial population, as the organic matter is mineralized, causes depletion of oxygen in the water changing the community from saprophobic to saprophilic species. The typical biocoenotic responses of the invertebrate community to disimprovement in water quality were evident below the point of discharge in the samples taken from 1983 to 1986. Sensitive taxa disappeared from the community leading to a reduction in the overall number of taxa (i.e. there was a drop in the number of taxa from 12 at station one to 1 or 2 at station four). This was followed by a change in the number of individuals of the tolerant taxa, with the oligochaetes increasing from a minimum of 0.6 % of the total fauna at station one to a maximum of 100 % of the fauna at station four, in 1986.

The change in water quality below the point of discharge has been recorded in several surveys undertaken by An Foras Forbartha (A.F.F.). In general, results of the physico-chemical analysis carried out between 1983 and 1985 are consistent with the results obtained during this survey. Differences in some parameters are probably explained by samples being taken at different times during the year.

The Biological Quality Ratings (Q values) for the full period the river has been surveyed, both by A.F.F. and during this project are given (Table II).

This rating scheme was devised by A.F.F. to detect the presence of pollution caused by organic, biodegradable wastes such as sewage, animal manure slurries and the discharges from food processing industries and other agriculture based activities. The characteristic changes brought about in the normal macroinvertebrate fauna under the influence of organic pollution form the basis of the scheme. The scheme uses the relative abundance and diversity of key groups of organisms, of known sensitivities, obtained from a two minute kick sample. It is a relatively simple and rapid method which can be fully completed in the field by experienced hydrobiologists. The level of taxonomic expertise required need not be high as the scheme relies on key groups readily identifiable in the field. When coupled with analysis of water chemistry, the scheme has proven adaptable to a wide range of conditions (Jorgensen 1978). A breakdown of the scheme (after McGarrigle & Lucey loc. cit.) is given (Table III).

The recovery of the river after the cessation of pollution by the factory, in June 1986, is evident in the samples taken in March 1987. The number of taxa increased at station four from a total dominance

Table 2. Biological Quality Ratings for the Big River 1971-1988.
Q = 1 indacates very poor quality, Q = 5 indicates very good quality. Station 2 refers to Ballygoly Bridge, just above the factory outfall, and station 4 refers to Riverstown Bridge, just below the factory outfall.

	An Foras Forbartha							Dundalk R.T.C.					
	1971	1973	1978	1980	1982	1984	1986	1983	1984	1985	1986	1987	1988
St. 2	—	—	5	5	5	5	5	5	5	5	5	5	5
St. 4	1/0	1	1	2	1	1	1-2	1	1	1	1	3-4	4-5

Table III. Indicator species, Decision Tables and chemical quality v's Q rating for An Foras Forbartha water quality schemes.

Indicator species and decision tables for AFF Quality Rating Scheme

Group A - Sensitive Forms

Plecoptera (excluding Leuctra) Ecdyonuridae, Ephemeridae — A_1 Sub-Group: Most sensitive

Ephemeroptera (excluding *Baetis rhodani*, Cloeon, Caenis, Ephemerella) Cased Trichoptera. — A_2 Sub-Group: Sensitive

Group B - Less Sensitive Forms

Leuctra, *Baetis rhodani*, Cloeon, Caenis, Ephemerella, Gammarus, Uncased Trichoptera, Elminthidae larvae.

Group C - Tolerant Forms

Asellus, Sialis, Chironomidae (excluding Chironomus), Hirudineae Mollusca (excluding Physa)

Group D - Most Tolerant Forms

Chironomus, Physa, Eristalis, Tubificidae and other Oligochaeta

Chemical Quality and Q Ratings

B.O.D.	<3	5 and 4
	<7	3
	>7	2 and 1
Dissolved Oxygen % saturation		
	>70%	5 and 4
	30 - 70%	3
	<30%	2 and 1
NH_3 (mg L^{-1} N)		
	<0.1	5 and 4
	0.1 - 0.5	3
	>0.5	2 and 1

Decision Tables for Q - Values

Q1 Bad Quality

A1 Group Absent
A2 Group Absent
B Group Present
C Group Slight expression by some forms
D Group dominant, often only group.

Q2 Poor Quality

A1 group Absent
A2 Group Absent
B Group Absent or very sparse
C Group Dominant
D Group Generally well represented

Q3 Doubtful Quality

A1 Group Absent
A2 Group Absent
B Group Common or Numerous
C Group Common or Numerous
D Group May be Common

Q4 Fair Quality

A1 Group Sparse or Absent
A2 Group may be present in small numbers
B Group Numerous, usually dominant
C Group may be present in small numbers
D Group may be present in small numbers

Q5 Good Quality

A1 Group Well Represented
A2 Group May be well represented
B Group Numerous, may be dominant
C Group may be present in small numbers
D Group Usually absent or very sparse

by oligochaetes in 1986 to 8 taxa in 1987. These 8 taxa included the sensitive gill breathing groups, though not in as large numbers as is evident at stations upstream of the factory. Two of these taxa viz. the Ephemeroptera and the Trichoptera were present also at station five. In March 1988 Plecoptera were present at all stations for the first time and members of the Simulidae had appeared at both of the previously polluted stations (4 and 5). It is interesting to note that, while pollution persisted in this river for many years, self purification processes began almost immediately and significant signs of recovery were evident in only 8 months. By the time samples were taken in March 1987 the sewage fungus, which had been a feature of the lower reaches of this river for decades, had completely disappeared. Water colour had fallen to 7.5 Hazen units and the B.O.D. readings were characteristic of a clean river. Other chemical parameters had returned to values consistent with the results from the upstream - clean water - stations. The results of this survey clearly illustrate the enormous capacity for self-purification in rivers - once pollution ceases. The lessons of history appear to have been noted by the regulatory authorities and by industry in the region. The factory has re-opened, under new management, and effluent has been totally diverted from the river. Plans have been formulated to discharge all effluent directly into Dundalk bay where the volume of available dilution is much greater.

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