

HEAVY METALS IN AN INDUSTRIALLY POLLUTED RIVER, THE TEAM

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ABSTRACT

Industrial and domestic effluents have resulted in elevated levels of heavy metals and organic pollution in the River Team. An introduction is given to the historical background of this river and its pollution. An account of water chemistry includes the distribution of heavy metals down the river and their probable sources. The role of suspended matter, sediments and aquatic mosses in binding zinc is also discussed.

INTRODUCTION

Interest in the pollution of rivers, particularly from industrial sources, has centred in the past largely around organic matter, nutrients and suspended solids (Hynes, 1960; Toms, 1975). There is however now also a considerable literature on pollution by heavy metals (Whitton & Say, 1975), some of which concerns rivers subject to industrial pollution. Because such rivers may receive a variety of effluents, a considerable complexity of chemical conditions may prevail. Harding et al. (1981) have commented on the difficulties involved in the interpretation of biological changes in a river receiving both heavy metals and organic pollution.

The problems associated with interpreting the influence of pollution in the River Team are considerable. During the 1960's sites on the Team were among the worst in the area in terms of B.O.D. (Biological Oxygen Demand), dissolved solids and minimum oxygen concentrations as compared with other routine monitoring sites (Northumberland and Tyneside River Board, 1962, 1963, 1964). Although guidelines for such monitoring were stated to include "toxic substances", the only other reported problem at this time was continued gross intermittent pollution caused by effluents from a sand and gravel washing plant. By this time, the development of a major industrial estate in Team Valley required a complete river improvement scheme (including canalization and construction of weirs), which was necessary to deal with the increasing volume of discharge into the lower section of the river (Northumberland and Tyneside River Board, 1964) in order to prevent flooding. The development of industry within the catchment area has led to problems of heavy metal pollution in addition to the historically important organic

pollution. In 1973 alternate sections of the river were rated as either class 2, "doubtful" or class 3, "poor" quality (Northumbrian River Authority, 1973; see Toms, 1975, for details of ratings). More recently the lowest section of the Team was rated as class 4, "grossly polluted" (Department of the Environment, 1979). The present paper introduces the current situation with respect to pollution in this river.

ENVIRONMENTAL BACKGROUND

The River Team originates from an iron-rich spring at an elevation of 230 m, near the village of Annfield Plain, approximately 15 km south west of Newcastle-upon-Tyne (Fig. 1). Within 500 m of its source it receives waste water from old underground sewage tanks which vary in their discharge depending on rainfall. After this input the river flows roughly in a N-E. direction for about 16 km through several villages and an industrial estate. After this the Team changes direction and runs N-W. for about 10 km into the River Tyne. This lower section flows through farmland, villages and large industrial estates where the river has alternating meanders and canalized sections. The total length of the Team is approximately 27 km.

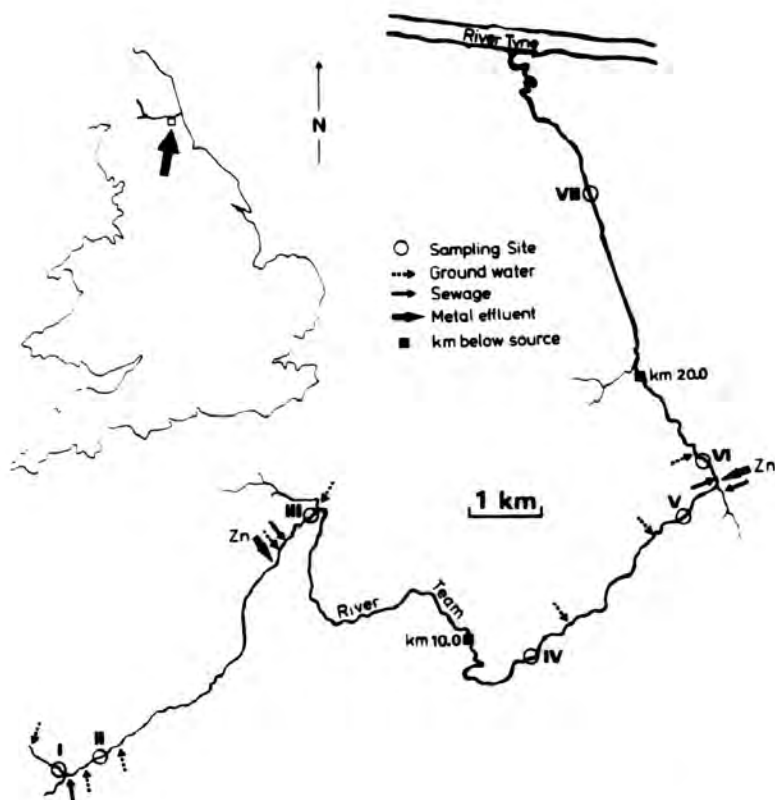


Fig. 1 Map of the River Team showing the main sources of pollution and sampling sites.

Geology and Pollution

The entire catchment of the Team is within the Coal Measures (Dunham, 1948). There are large outcrops of limestone cliffs in the middle reaches, notably Causey Ridge (Anderson, 1940). Where the stream passes through the deep gorge at Causey, a large colliery bridge, Causey Arch, spans the ravine. This was used by local collieries for the transport of coal from the mid-1700's. The streambed consists largely of millstone grit, magnesian limestone and other limestones. Current speed in the upper two-thirds is often high ($>1 \text{ m s}^{-1}$), passing over sheet bedrock, boulders and cobbles. Current speeds are considerably slower in the lower third of the river. Here cobbles and sands are the predominant substrata.

The important tributaries include Bobgins Burn at km 6.5, which until 1976 and early 1979 received pumped minewater from two nearby collieries (Craggs, 1979; Taverner, 1979). Other than small gills, the next major tributary is Rowletch Burn at km 17.0, which itself receives discharges from various industries and sewage effluents.

The first major metal effluent is found at km 4.5 from a battery factory. This discharge occurs within a complicated series of effluents including first a combined industrial sewage, then the metal effluent followed by iron-rich pumped minewater from a colliery and next an effluent from a sewage works. The entire series of inputs enter along only a 500 m stretch of river. The pumped minewater which immediately follows the metal input usually has a discharge greater than the river, hence reducing zinc levels by about two-thirds. Other than iron-rich seepages, no other metal inputs occur until km 17.5, where a combined industrial effluent, which includes a chemical works discharge enters into the river. This section also soon receives discharges both from a sewage treatment plant and (intermittently) pumped minewater from a colliery. The lowest section receives no further effluents other than from storm sewage. A heavy load of suspended matter throughout the river gives the water a distinctly cloudy appearance.

METHODS

Details and location of seven sampling stations (Fig. 1) are given in Table 1. Water samples were collected for analysis between 1979 and 1981: two occasions in 1979, two in 1980, two in 1981. Sites II and IV-VII were sampled at all these times while I and III were sampled in 1980 and 1981 only. Methods of collection and analysis are similar to those given by Holmes and Whitton (1981) with the exception of a few variables. SO_4 -S was measured by the turbidimetric method (American Public Health Association, 1971) reactive PO_4 -P according to Mackereth et al. (1978) and Cd and Pb were analysed by atomic absorption spectrophotometry using a flameless graphite furnace. In addition, oxygen was measured *in situ* only during 1981, using an Orion specific ion meter (model 407A) fitted with an oxygen probe.

One study was made of the size fractions of selected metals in the water at site III. Water was filtered through four different pore sizes of Nuclepore membrane filters. These were 3.0, 1.0, 0.4 and 0.2 μm . Treatment and analysis were completed as described by Holmes and Whitton (1981). Turbidity of these samples was measured as the optical density at 440 and 750 nm (American Public Health Association, 1971) using a Shimadzu (model UV-150-02) double-beam spectrophotometer.

TABLE 1 Location and details of R. Team sampling sites

Site	Name	Durham code stream-reach	Grid ref.	km from source	substratum	environmental comments
I	Kyo Springs	0024-03	NZ 168527	0.5	cobbles, silt	fed by iron-rich spring
II	Kyo Heugh	0024-05	NZ 173529	1.0	cobbles	below small sewage input
III	Causey Arch	0024-20	NZ 202560	6.0	boulders, cobbles	below first zinc input and sewage
IV	Urpeth Forge	0024-40	NZ 235543	13.0	boulders, cobbles	below Bobgins Burn
V	Urpeth Bridge	0024-55	NZ 257561	16.5	boulders, cobbles, bricks	lowest site before second zinc input
VI	Birtley	0024-65	NZ 261567	17.5	cobbles, sand	below second zinc input and sewage
VII	Team Valley	0024-85	NZ 343610	23.0	cobbles, sand	no additional major effluents

Mosses and Sediments

An intensive collection of water, sediments and aquatic mosses was made at successive 0.5 km intervals on 2 - 4 May, 1980. Collections were made from 1 km below the first zinc effluent (km 5.5) until the second zinc input, beyond which no mosses were present. This represented a total of 21 sites. The procedures for field sampling, pretreatment and digestion of mosses and sediments are described in Say *et al.* (1981).

RESULTS

Physicochemical changes along the Team at the seven sampling stations are given in Table 2. In general there was a steady increase in dissolved

TABLE 2 Physicochemical variables in the R. Team: based on six surveys, with exceptions listed in Methods. (All elements as mg l⁻¹; Mg and Ca filtrable, 0.2 µm Nuclepore filter.)

Site	pH	total alkalinity (meq l ⁻¹)	O ₂ %	conductivity (µS cm ⁻¹)	PO ₄ -P	SO ₄ -P	Cl	Mg	Ca
I	6.8	3.4	90	680	0.001	76	32	55	100
II	7.7	2.1	96	770	0.0025	70	50	36	87
III	7.5	2.9	73	800	0.710	58	60	30	110
IV	8.1	4.3	94	1000	0.320	102	52	38	120
V	8.0	2.8	95	940	0.310	50	48	35	91
VI	7.4	4.2	75	2200	0.345	50	350	30	105
VII	7.4	6.2	88	3100	0.400	150	380	42	130

salts on passing downstream, as shown by conductivity, chloride and sulphate levels. Oxygen and pH tended to drop below the two major metal/sewage effluents (sites III and VI). Phosphorus showed a large increase below the first set of effluents and remained high all the way downstream. Total alkalinity, magnesium and calcium are high throughout the river, with no apparent longitudinal pattern.

Concentrations of heavy metals in the Team are given in Table 3.

TABLE 3 Filtrable heavy metals (0.2 µm Nuclepore filter) in the R. Team (mg l⁻¹)

Site	Mn	Fe	Cu	Zn	Cd	Pb
I	1.0	0.35	0.004	0.025	0.0004	<0.0004
II	0.16	0.09	0.004	0.037	0.0001	<0.0004
III	0.28	0.14	0.005	0.28	0.0005	0.0010
IV	0.31	0.14	0.004	0.15	0.0004	<0.0004
V	0.31	0.22	0.008	0.09	0.0005	0.0004
VI	0.42	0.28	0.024	3.6	0.0060	0.0015
VII	0.71	0.12	0.008	0.96	0.0020	0.0020

Cr: all sites <0.01

Ni and Co: all sites <0.02

The river carries elevated levels of zinc below both metal effluents (sites III, VI) with the highest zinc, as well as cadmium and lead, in the lower-most section of the river. Iron and manganese are highest near the spring source.

The influence of filter pore size on the filtrable component of metals and turbidity was tested at site III (Fig. 2). Calcium, manganese and zinc in the water are reduced only slightly over a range of reducing pore sizes.

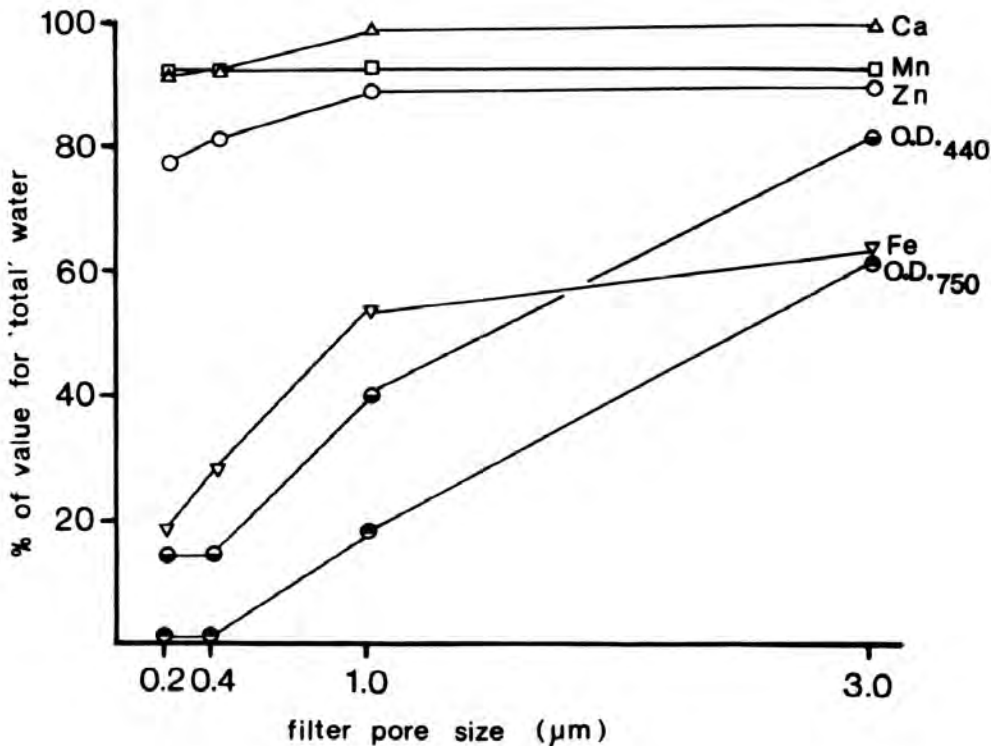


Fig. 2 Differences in selected metals and turbidity in R. Team water (site III) after filtration through a range of membrane filter pore sizes. Values expressed as a percentage of the maximum measured from un-filtered water; turbidity indicated by absorbance measured at 440 and 750 nm.

In contrast only 60% of the "total" iron remains when passed through a relatively large pore size and the majority is removed by smaller pore sizes. The turbidity (as indicated by absorbance at 750 nm) is reduced by more than a third after the removal of particles $>3.0 \mu\text{m}$ and more than 80% by removal of all particles $>1.0 \mu\text{m}$. In contrast, the absorbance of light at 440 nm is reduced mostly by removal of particles $<1.0 \mu\text{m}$ in size.

The decrease in zinc in water along a 12 km stretch downstream from the first metal effluent is shown on Fig. 3; the drop from 0.22 to

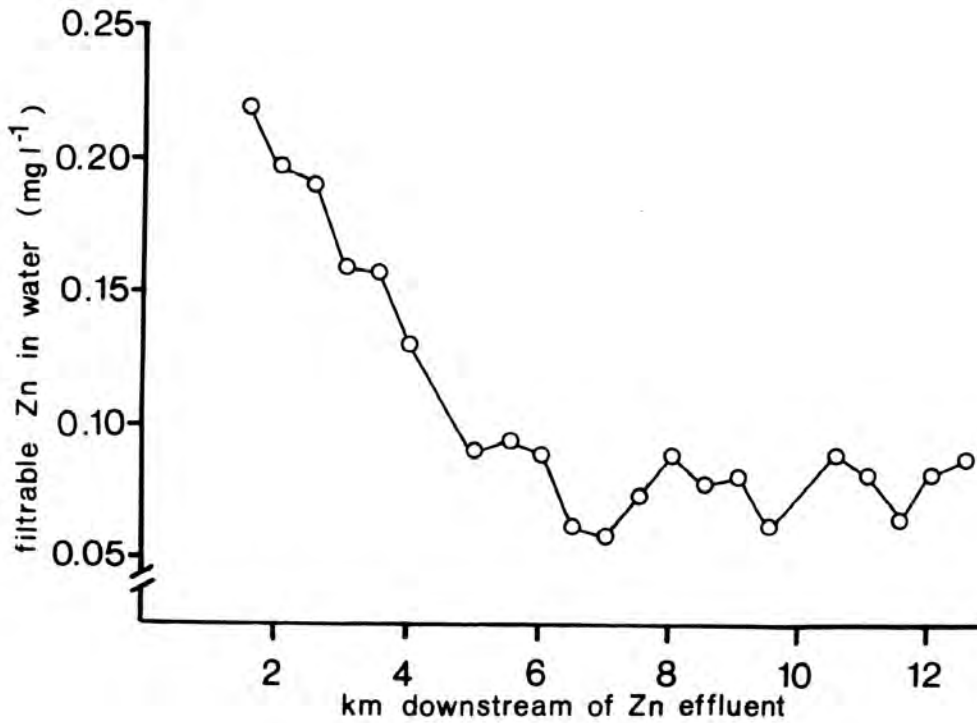


Fig. 3 Filtrable zinc ($0.2 \mu\text{m}$ pore size) in river water plotted against distance below the first major metal effluent.

0.07 mg l^{-1} zinc all takes place within the first 6 km. The concentrations of zinc in sediments and one aquatic moss (Fig. 4) show a gradual reduction

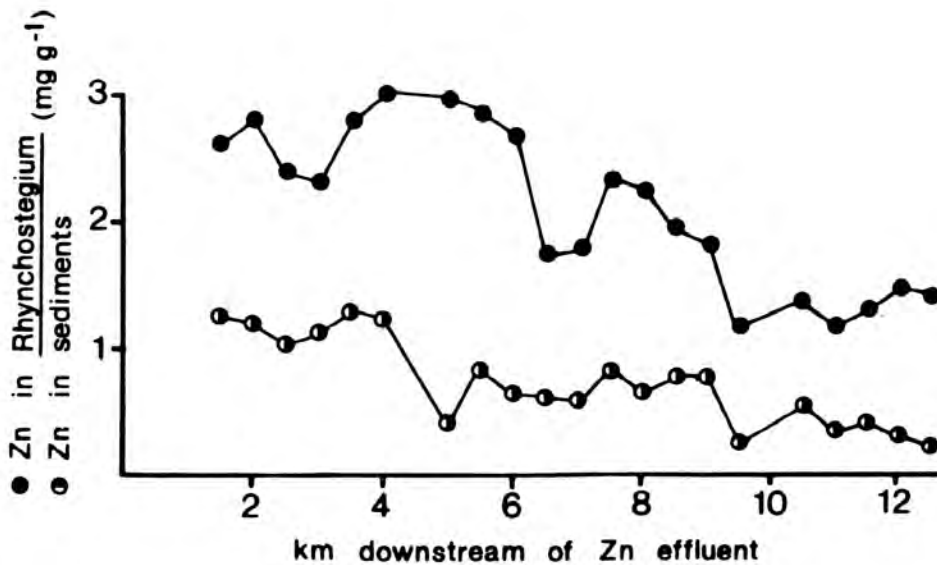


Fig. 4 Zinc (mg g^{-1}) in the aquatic moss *Rhynchosostegium riparioides* and sediments ($<210 \mu\text{m}$ size fraction) plotted against distance below the first major metal effluent.

on passing downstream, lacking the rapid loss found in the water. Even after 12 km, the percentage reduction is much less in sediments and moss than in the water. Throughout this stretch the moss always contained roughly twice the concentration of zinc per unit dry weight than the sediments.

DISCUSSION

It is apparent that industrial discharges which enter the Team have a deleterious effect on river water quality (Tables 2, 3). The river still merits the description made nearly 20 years ago, as one with reduced oxygen and elevated levels of nutrients; that is, it is a typical organically polluted river. The Cl and $\text{SO}_4\text{-S}$ levels here are comparable with those in the Rivers Trent and Team (Lester, 1975); $\text{PO}_4\text{-P}$ and Cl are higher than in the other metal-polluted industrial river described in the literature, the Etherow (Harding et al., 1981).

Concentrations of metals, especially zinc, are particularly high below the second major industrial effluent. These are comparable to those streams draining metalliferous mining areas (Whitton & Say, 1975). At present metal pollution in the upper half of the Team is not as severe, because of dilution by pumped groundwater from surrounding collieries.

The filter size fractions of water from site III indicate a strong relationship between suspended matter and metals in the Team. Iron appears to be present in large part as particulate matter, presumably iron hydroxides, which are likely to predominate near pH 7 (Stumm & Morgan, 1970). In contrast, the removal of turbidity-causing particles greater than $1.0 \mu\text{m}$ has only slight effects on the concentrations of calcium, manganese and zinc.

The reason why the level of zinc in the sediments and the moss (Fig. 4) below the first metal effluent fell off more slowly than in the water (Fig. 3) is not obvious. Perhaps the samples of water taken at one point in time did not give a good reflection of the average levels of zinc present in the river. In their study of the R. Etherow, Say et al. (1981) found that the relationship between concentrations of zinc in mosses and water was not constant and suggested that fluctuations in water chemistry were involved. If this can be confirmed for the R. Team, this suggests that analyses of sediments and moss can provide a better picture of average conditions in the river than a limited number of analyses of the water alone.

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