Metal Surveys in South African Estuaries V. Kromme and Gamtoos Rivers (St Francis Bay)

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Abstract

Surveys to study the distribution of selected metals in the Kromme and Gamtoos Rivers were undertaken during August 1979. Water samples were analysed for thirteen elements and surface sediments and sediment core samples for sixteen elements using atomic absorption spectroscopy. Interelement relationships as well as absolute metal concentrations were examined before interpreting the data obtained.

The results of these initial surveys indicate that neither of these estuaries is contaminated significantly with respect to metals. Elevated metal levels in the Geelhoutboom River (a tributary of the Kromme River) are thought to be of geochemical origin while increased metal concentrations in the lower reaches of the Gamtoos estuary may be a combination of physico-chemical mechanisms and runoff from the extensive cultivated areas in the flood plain.

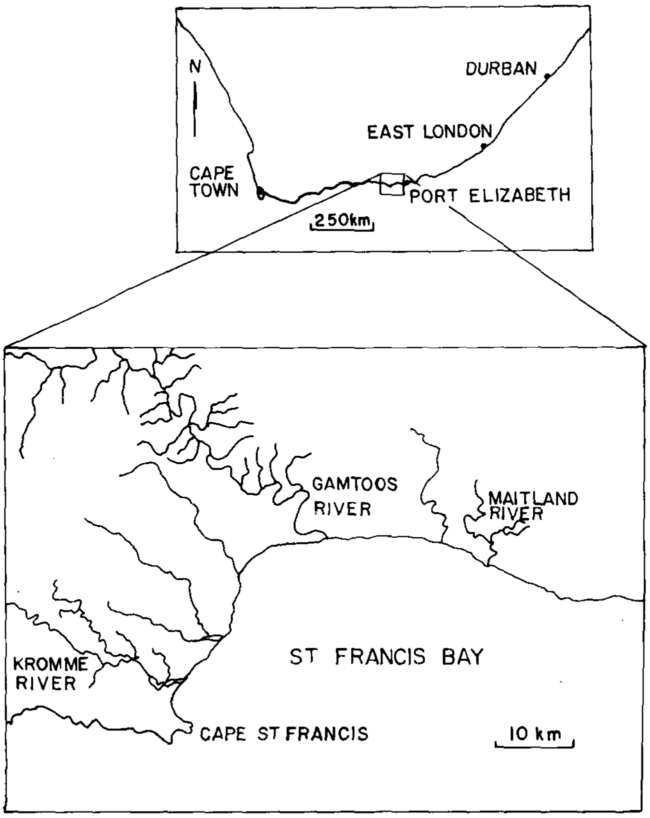

Figure 1
Location of study areas

Introduction

The Kromme and Gamtoos Rivers flow into St Francis Bay on the southern coast of South Africa (Fig. 1).

The Kromme River has its origin in the Tsitsikama Mountains in the Blueliliesbush Forest Reserve. The main tributary is the Dwars River which flows into the Kromme River above the Churchill Dam which is approximately 43 km from the river mouth. About 14 km from the mouth, the river descends in a series of rapids which mark the limit of seawater penetration. Below these rapids the main tributary is the Geelhoutboom River which flows into the estuary about 9 km from the mouth. Other tributaries include the Klein, Boskloof, Sand and Brakfontein Rivers which flow into the Kromme River 11, 5, 2 and 1 km from the mouth respectively.

The inflow of fresh water is regulated by the Churchill Dam. During the dry season (December to March) the sluices are kept closed with the result that little freshwater enters the estuary and a reversed salinity gradient can occur; this situation is then reversed in the rainy season (April to November) (Erasmus *et al.*, 1980).

The estuary is bordered by rocky cliffs on both sides from the upper limits to the confluence with the Klein River. It widens downstream, particularly on the south bank of the river, into a broad floor plain. The north and South banks of the upper and middle reaches are overgrown with dense bush. Salt marshes occur on the south bank of the middle reaches and on the north bank of the lower reaches of the estuary. The substrate at the mouth area varies between medium- and coarse-grained sand with some silt. In the lower and middle reaches, mud and silt are encountered whereas the substrate of the upper reaches consists of a coarse silty sand and stones.

The Kromme River estuary is one of the few relatively unspoilt estuaries in the Eastern Cape. There is no industrial development along its banks and effluent disposal into estuarine waters is minimal. A road bridge has recently been built across the river, approximately 3 km from the sea, bisecting the salt-marches while a large reservoir dam is planned for higher up in the catchment area to augment the freshwater supply to Port Elizabeth. A marina, consisting of a network of canals with water-front housing and mooring facilities for up to ten yachts, has been developed on the west bank of the estuary near the mouth. Two detailed surveys of the marina canal system and the mouth region of the main estuary have been undertaken. The results reported by Baird *et al.* (1981) indicate tht the marina has, in effect, caused an increase in the habitat area for plankton, benthic macro-invertebrate fauna and fish, and that it does not have an adverse effect on the ecology of the Kromme estuary.

The Gamtoos River flows into the sea 55 km west of Port Elizabeth and 13 km north-east of Jeffreys Bay. The Gamtoos River, together with its two main tributaries, drains the central part of the Karoo, but the 34 491 km² catchment is an area of low rainfall and both droughts and floods occur at intervals (Day, 1981).

The eastern banks of the river are steep and a broad flood plain stretches from the western bank to steep banks more than 2 km away from the river. The length of the estuary is very variable depending on the rains but the river is often saline at the coastal road bridge about 7 km from the mouth (Day, 1981). The river mouth itself changes position frequently as there are no rocks on the coast to anchor it and there is substantial re-working of the drift sand in the mouth region. There is a lagoon at the mouth of the river which is approximately 6 km long and 0,2 km broad and this is separated from the sea by eolean drift sand.

Various agricultural activities are undertaken in the Gamtoos valley including citrus and tobacco farming and market gardening.

The aim of these preliminary surveys was to determine the current metal levels in the sediments and water of these estuaries. The data obtained will serve as a baseline for future monitoring surveys should urban development or industrialization be planned for this region of the South African coast.

Materials and Methods

Surface water samples were collected in 2,5 ℓ high-density polythene bottles. Three subsamples were separated from each bulk and the preliminary sample preparation carried out on site as follows:

- a 500 mℓ sample acidified with 2 ml nitric acid for the determination of mercury;
- a 100 mℓ sample acidified with 12 mℓ nitric acid for the determination of calcium, magnesium, sodium and potassium, and
- a 1000 mℓ sample for the determination of zinc, cadmium, copper, lead, iron, manganese, nickel and cobalt; 10 mℓ of a buffered solution of sodium diethyldithiocarbamate were added immediately to this sample which was then shaken for 5 min.

Approximately 500 g of a composite surface sediment were collected using an aluminium scoop. These samples were air-dried between filter paper sheets, disaggregated in a porcelain mortar and sieved through a 210 μm nylon screen. The fraction which passed through the screen was reserved for analysis.

Sediment cores were collected by hammering PVC tubes directly into the sediment. Good penetration with very little compaction of the sediment was achieved using this method. The tube was then sealed at the top using a rubber stopper and withdrawn from the sediment. Both ends of the tube containing the sediment core were sealed using polythene-covered corks and the whole sample frozen to − 20 °C. Frozen cores had to be stored for up to eight weeks but no deterioration of the sediment was observed during this period.

Detailed descriptions of the further preparation of these samples and the determination of their metal contents are explained elsewhere (Watling and Watling, 1982a).

Results and discussions

Samples were collection from eight sites in the Kromme River (Fig. 2) and eight sites in the Gamtoos River (Fig. 3).

Water Samples

The concentrations of major, minor and trace elements in surface water samples collected from the Kromme and Gamtoos Rivers are listed in Table 1.

The mouth of the Kromme River is open to the sea and there is strong evidence of saline conditions in the river up to the area

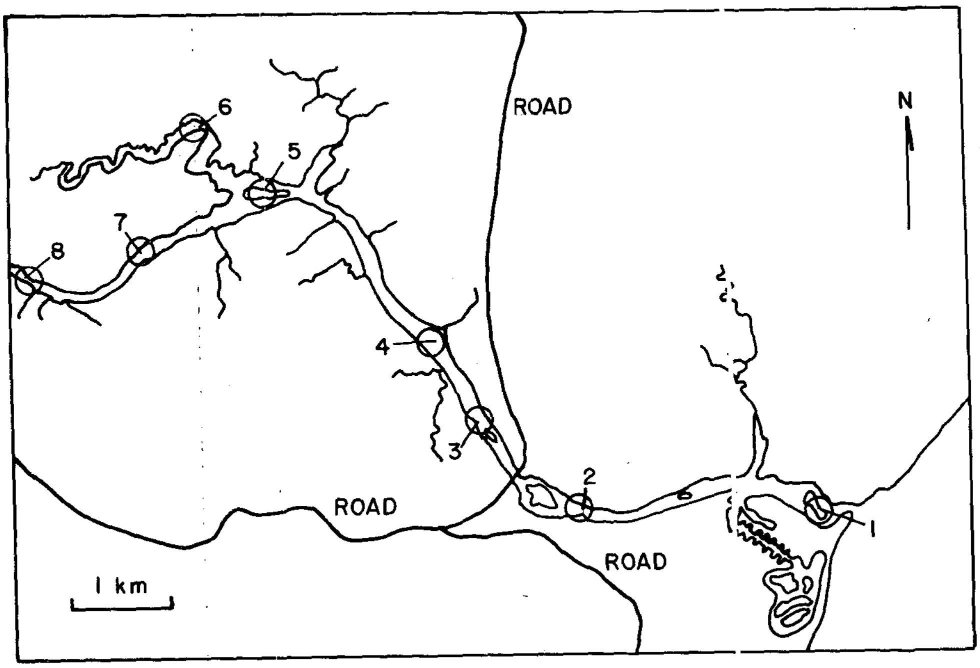

Figure 2
Sampling sites in the Kromme River

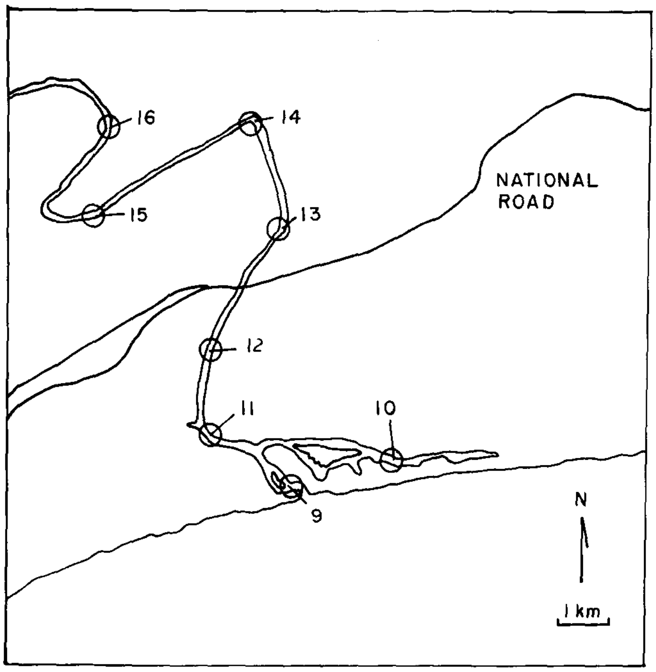

Figure 3
Sampling sites in the Gamtoos River

of site 8 (Fig. 2). Freshwater input at the rapids above site 8 was minimal at the time of this survey (August 1979) and several jelly fish were found in the pools of the area.

Concentrations of major and minor elements in Gamtoos River water again indicate that there is a significant marine influence up to and including site 16 (Fig. 3). Although the position of the Gamtoos River mouth changes there is no record of it being completely closed for any prolonged period so that the water level in this river is determined mainly by the tide. Navigation by boat was impossible at locations upstream of site 15 (Fig. 3) and hypersaline conditions could occur in this region of the river because of the warming influence of shallow sandbanks together with increased evaporation.

The trace element concentrations determined for Kromme River water samples are generally low and there is no indication of contamination by these elements. This is to be expected as there is no industrialization and very little urbanization in this area of the catchment. The marina complex at the mouth of the estuary apparently has no effect on trace metal input to the estuary.

Trace metal levels in the Gamtoos River water are similar to those found in Kromme River samples and are average for Eastern Cape rivers (Watling and Watling, 1982 a, b, c, d) with the exception of those found at site 10 (Fig. 3) in the lagoonal area near the mouth of the river. Here, many metals are present at slightly higher concentrations and this is probably due to local input and the entrainment of a relatively high suspended solids fraction in the water column.

Surface Sediment Samples

Samples were collected from sites 1-7 and sites 9-15 (Figs 2 and 3). No sample was collected at site 8 in the Kromme River as only coarse stony material was available. In the case of the Gamtoos River the substrate at site 16 consisted mainly of dislodged bank material rather than sediment. Metal concentrations in these samples are listed in Table 2.

Metal concentrations in Kromme River sediments are average for Eastern Cape rivers with the exception of those found in samples from two sites. Chromium, cobalt and nickel are particularly elevated at site 6 in the Geelhoutboom River and also at site 5 on the northern side of a small island situated mid-stream at the confluence of the two rivers. It is likely that suspended material from the tributary enters the main river and is deposited on this island. Elevated levels of copper, lead and zinc are also encountered in the site 6 sample. The extent of this metal-rich area in the Geelhoutboom catchment should be determined as it is possible that these metals could be remobilized during floods and may then affect the estuary to a greater extent.

Generally, metal levels in surface sediments from the Gamtoos River are significantly higher than those found in the Kromme River. The sample from site 10 is particularly interesting in that it contains the highest levels of copper, zinc, iron and

TABLE 1
METAL CONCENTRATIONS (µg/ℓ) IN WATER SAMPLES

Site	Zn	Cd	Cu	Pb	Fe	Mn	Ni	Co	Hg	Na	K	Ca	Mg
Kromme River													
1	0,50	0,05	0,6	0,10	141	2,3	0,05	0,05	0,001	11 200	350	467	1 510
2	0,05	0,05	0,6	0,20	90	4,6	0,05	0,05	0,008	10 900	320	424	1 440
3	0,20	0,05	0,5	0,05	93	4,8	0,05	0,05	0,014	10 900	290	426	1 430
4	0,80	0,30	0,6	0,30	116	6,9	0,05	0,05	0,010	10 500	290	416	1 390
5	0,70	0,05	0,7	0,20	137	9,0	0,05	0,05	0,008	13 400	310	413	1 350
6	0,30	0,05	0,8	0,05	181	22,0	0,05	0,10	0,002	9 600	310	387	1 280
7	0,10	0,05	1,4	0,05	72	11,3	0,05	0,05	0,002	9 700	280	381	1 270
8	0,20	0,05	1,7	0,10	228	6,6	0,05	0,05	0,060	1 830	56	82	242
Gamtoos River													
9	3,00	0,10	0,6	0,50	154	16,5	0,20	0,10	0,040	10 600	330	413	1 360
10	4,60	0,20	2,3	2,30	2 400	67,0	1,50	0,60	0,037	9 200	270	375	1 220
11	0,40	0,10	0,6	0,80	258	22,3	0,40	0,05	0,016	6 600	163	291	910
12	0,40	0,20	0,5	0,20	380	28,2	0,20	0,30	0,004	4 700	121	220	640
13	2,20	0,10	0,6	0,50	330	42,0	0,10	0,20	0,012	3 700	92	181	510
14	1,50	0,10	0,8	0,80	520	72,0	0,20	0,20	0,012	510	3	75	96
15	0,10	0,10	0,4	0,20	300	51,0	1,30	0,05	0,010	480	5	76	88
16	0,40	0,05	0,2	0,20	68	5,4	0,05	0,10	0,010	480	4	73	87

TABLE 2
METAL CONCENTRATIONS (μg/g) IN SURFACE SEDIMENTS

Site	Cu	Pb	Zn	Fe	Mn	Co	Ni	Cd	Na	K	Ca	Mg	Sr	Al	Cr
Kromme River															
1	1	4	1	873	17	0,2	0,4	0,096	3 820	301	1[illegible]1 000	2 710	780	790	5
2	1	4	3	890	16	0,2	0,6	0,041	2 120	248	[illegible]7 000	1 100	380	850	5
3	1	2	2	870	13	0,2	0,6	0,032	3 200	390	[illegible]6 500	1 190	530	670	4
4	2	2	7	6 200	30	2,6	4,1	0,021	3 200	570	1[illegible]4 000	1 260	73	5 920	12
5	2	4	7	5 720	17	1,4	2,0	0,009	2 920	530	12 100	1 710	12	7 790	124
6	12	36	59	31 000	570	7,8	15,6	0,029	9 800	2 500	720	4 690	12	27 000	297
7	2	7	5	5 920	120	2,6	2,9	0,006	3 520	490	270	996	6	5 700	7
Gamtoos River															
9	8	7	16	7 600	100	3,2	5,8	0,465	4 110	2 340	115 000	4 730	849	10 000	17
10	21	20	61	28 600	470	12,4	23,0	0,248	8 040	6 680	2 730	10 100	29	359	48
11	6	7	19	10 000	91	4,4	7,7	0,874	3 070	1 160	981	2 120	10	8 750	14
12	5	8	18	10 100	90	4,5	8,2	0,322	2 560	1 070	1 040	2 120	10	10 300	15
13	4	6	13	7 750	59	2,6	6,3	0,016	1 200	1 190	681	1 520	9	6 800	13
14	4	7	15	8 870	74	2,8	7,7	0,017	457	1 170	862	1 180	11	8 270	17
15	4	5	12	7 800	100	3,1	5,3	0,037	449	572	720	1 290	9	5 510	10

manganese encountered during this survey. The reason for these higher concentrations may be due simply to a variation in catchment geochemistry in this lagoonal area. But there is also the possibility that these metals are being introduced to the river as a result of the extensive utilization of the valley and that they are precipitating from the water column in this relatively calm lagoonal area.

Sediment Cores

Seven sediment cores were collected in the Kromme River (Fig. 2) and eight sediment cores were collected in the Gamtoos River (Fig. 3). Sample locations are coincident with those of water and surface sediment samples but sediment cores were collected from the side of the nearest available mud or sand bank. Consequently the concentrations measured at the top of each core may not correspond with those for the equivalent surface sediment. Specific metals which can vary in the space of a few metres are not necessarily indicative of pollution. Conclusions should be drawn on the basis of overall trends and metal inter-relationships rather than on absolute levels.

Metal concentrations in every core sample, together with a scale drawing and sedimentological description of the core and an interelement correlation matrix have been detailed elsewhere (Watling and Watling, 1982 e). The geometric means for the concentrations of each element in these cores have been calculated and are listed in Table 3. While this is not an ideal way to display core data, it does serve as an easy method for identifying anomalous areas.

The anomalous metal contents of the sediment from site 6 in the Geelhoutboom River are apparent from the summarized results. Throughout the entire sequence of this core, the concen-

TABLE 3
GEOMETRIC MEANS OF METAL CONCENTRATIONS (μg/g) IN SEDIMENT CORES

SITE	Cu	Pb	Zn	Fe	Mn	Co	Ni	Cd	Na	K	Ca	Mg	Sr	Al	Cr	Hg
Kromme River																
1	1,4	2,7	1,4	943	19	0,2	0,3	0,11	3 230	287	143 000	3 840	1 070	752	4	0,003
2	1,1	1,3	2,1	1 030	15	0,2	0,6	0,04	2 560	342	72 600	1 430	453	1 110	4	0,006
3	1,1	1,6	2,1	1 210	13	0,3	0,6	0,03	2 180	258	65 600	1 220	447	1 210	4	0,014
4	1,7	3,1	7,9	7 380	33	1,6	3,2	0,02	3 300	576	11 400	1 700	95	4 950	8	0,018
5	1,7	4,0	6,9	6 810	25	1,8	2,8	0,01	3 590	744	694	1 370	6	6 530	164	0,032
6	11,8	18,7	44,8	21 200	202	8,4	18,4	0,04	8 710	3 370	776	4 860	18	28 200	343	0,047
7	1,3	5,6	5,9	6 500	85	2,3	2,8	0,01	2 920	628	247	2 070	5	5 630	6	0,009
Gamtoos River																
9	3,8	0,6	1,7	1 060	22	0,2	0,1	0,03	4 500	140	80 300	3 900	2 260	485	3	0,007
10	20,9	19,0	61,1	28 600	469	12,4	23,0	0,24	8 040	6 680	2 720	10 100	28	359	48	0,031
11	7.6	7,4	15,9	7 500	100	3,2	5,8	0,46	4 110	2 740	116 000	4 730	848	10 000	17	0,009
12	5,6	7,4	18,7	10 100	90	4,4	7,7	0,12	3 080	1 170	990	2 130	10	8 730	15	0,006
13	5,2	7,7	17,8	10 100	89	4,5	8,2	0,32	2 560	1 070	1 040	2 110	10	10 300	15	0,008
14	3,9	6,1	13,5	7 750	58	2,6	6,3	0,02	1 200	1 180	680	1 520	9	6 790	13	0,007
15	4,1	6,6	15,0	8 870	74	2,8	7,7	0,02	456	1 170	860	1 680	11	8 270	16	0,007
16	4,1	5,3	11,6	7 660	132	2.9	6,9	0,02	450	620	700	1 240	10	5 100	10	0,008

trations of the elements copper, lead, zinc, cobalt, nickel and chromium are considerably elevated. This situation implies that there has been continuous deposition of metal-rich sediment and that these metals are probably derived from the weathering of mineralized rocks in the catchment. The presence of clay minerals in the sediment is indicated by the high potassium and aluminium concentrations while the concentration ratio of aluminium/iron suggests that a discrete hydrated oxide phase is also present in the sediment.

Suspended particles in the Geelhoutboom River are carried to the confluence of this and the Kromme River where apparently they are deposited on a midstream island (site 5). The strong relationship which exists between iron and some of the more hydrophilic elements such as copper, cobalt, nickel and zinc suggests that these elements were originally present in the soluble phase and have been coprecipitated with the hydrated iron oxide. Perhaps the most outstanding feature of cores 5 and 6 are their extremely high chromium concentrations. These are not found elsewhere in the Kromme River and are strong evidence for the presence of mineralization in the Geelhoutboom catchment.

The remaining cores collected from the Kromme River have relatively simple sedimentary sequences. Their major element assemblages suggest that the carbonate facies has been phased out by site 5 and that conversely the clay mineral facies, absent at site 1, has become an increasingly important constituent of the sediment. Minor and trace metal concentrations in these samples indicate that the possible mineralization in the Geelhoutboom does not affect the estuary significantly.

Metal levels are generally higher in the Gamtoos River than for equivalent sites in the Kromme River but they are not sufficiently high to have caused any deleterious effects in this estuary. However, the sediment core collected from site 10 in the lagoonal area near the mouth of the river contains some unusually high metal levels. Here a continuous sequence of elevated copper, lead, zinc, cobalt, nickel, cadmium, mercury and chromium concentrations indicates possible deposition of metal rich suspended material in association with input of metals from agricultural activities. In this case the absence of strong relationships between iron and the other elements suggests that these metals are not solely of geochemical origin.

The remaining cores from the Gamtoos River have relatively normal metal concentrations and, although these are slightly higher than those determined for the Kromme River samples, there is no indication of contamination of the river. It appears that once deposited in the sedimentary sequence, these metals are in a stable form and that only flooding causes their redistribution to other parts of the river.

Summary

The distribution of metals in water, surface sediment and sediment core samples from the Kromme and Gamtoos Rivers indicates that both rivers drain essentially unpolluted catchments. However, unusually high metal inputs were found at isolated sites in each river.

Trace toxic metals are introduced into the Kromme River via the Geelhoutboom tributary as a result of the weathering of a local mineralized sequence. The effects of this input are distinguishable as far as the midstream island at the confluence of the two rivers. No anomalous metal levels are easily discernible downstream of this site.

Anomalously high concentrations of manganese, copper, zinc and iron were found in the region of the Gamtoos River mouth and nearby lagoon and these may be related to a combination of the use of certain agricultural products in the cultivated area of the flood plain and physico-chemical phenomena occurring in the upper lagoonal area. Surface water runoff would account for their presence in the water column after which time the usual sedimentary processes could cause their deposition at particular sites downstream. This will be the subject of a further survey of the river.

Overall metal levels in the Gamtoos River are slightly higher than those in the Kromme River although no other significant source of metals was found. In the absence of urbanization or industrialization in these areas, it may be assumed that metals do not present a hazard in these estuarine environments.

Acknowledgement

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