The chemical composition of the Palmiet River water

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Abstract

The water quality of the Palmiet River near Durban was determined over a period of two years to afford a baseline for future studies in the catchment and to give an indication as to the present state of the river:

There is a deterioration of water quality downstream; the Pinetown Central Business District has a marked impact on the river; the analyte values in the Palmiet River are noticeably higher than those of the Umgeni River; relative to other rivers in Southern Africa, Na^+, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, K^+, NH_4^+-N, NO_3^--N, As, B, Ba, Fe, Mn, Pb and Zn values are relatively high; measured by world standards Al, Fe and Mn values are high throughout the year, whilst other analytes randomly exceed world norms thus pointing to both continuous and random pollution taking place in the Palmiet River; macro-analytes exhibit well defined seasonal and spatial trends whilst micro-analytes generally do not.

Introduction

The Palmiet River drains a relatively small (37 km²) catchment some 15 km northwest of Durban. The catchment has a mean annual rainfall of 1 000 mm and is fully urbanised with the exception of a small nature reserve and a few isolated relics of sub-tropical forests here and there. Apart from the Pinetown basin in the west which is relatively flat, the topography is undulating and well dissected by the river. Housing consists of detached dwellings in both the high and middle income-group categories in Pinetown, Westville and Reservoir Hills (Durban). There is no water-borne sewerage in Westville, in the central part of the catchment, whilst industrial development in Pinetown, in the upper part of the catchment, increased considerably during the last decade, making Pinetown one of the important industrial centres in Natal and South Africa.

A preliminary study of the water quality of the Palmiet River was published (De Villiers and Malan, 1985). That data cannot, however, serve as a baseline for future studies in the area because:

- two important tributaries of the Palmiet River were not monitored/sampled;
- no trace element analyses were performed; and
- the Umgeni River was not sampled for comparative purposes.

Consequently it was decided to perform a detailed study of the water quality of the Palmiet River so that the new data would produce a reliable baseline for future studies in the catchment and also give an indication as to the present state of the water quality of the Palmiet River.

Materials and methods

Samples were taken at monthly intervals during the period September 1982 to December 1984. Sampling days were predetermined for the whole sampling period. Water samples refer to surface water sampled in high-density polyethylene bottles at depths of between 10 cm and 20 cm. Two water samples were collected at each sampling site; one sample was preserved with nitric acid for trace element analyses, and the other with mercury(II) chloride for macro analyses. As noted previously (Du Preez, 1985 a and b), the reported analyte concentrations for trace metals represent the total soluble metal concentrations, and include that fraction of metals leached by the nitric acid preservative from the suspended particulates prior to filtration. Upon receipt in the laboratory all samples were filtered through Whatman No 42 filter paper prior to dispatch to the Hydrological Research Institute, Department of Water Affairs, Pretoria, which undertook to do the water analyses.

Results and discussion

Eleven sampling sites were selected to cover the main channel and its tributaries (Figure 1). The Umgeni River just below its confluence with the Palmiet River was also sampled.

Macro elements

The annual geometric mean values of the macro-analytes for the period December 1982 to December 1984 are presented in Table 1. Figure 2 shows the variations in the annual mean dissolved solid content at the six sampling sites along the course of the main stream viz. sites 1, 2, 4, 6, 9 and 11; the tributaries of the Palmiet River are not included in the figure. The Umgeni River below its confluence with the Palmiet River is also included for a comparison.

From Figure 2 a number of points are apparent. Firstly, there is a general increase in the amount of total dissolved solids downstream. This is in keeping with previous findings that there is usually a deterioration in water quality downstream (Du Preez, 1985a). Secondly, there is a marked increase in total dissolved solids in, and just below, the Pinetown Central Business District area (sites 2 and 4); the effect of industrial pollution is thus quite visible. Thirdly, there is a marked decrease in values in going from the Palmiet River to the Umgeni River. A similar trend was reported during an earlier study by the CSIR (Natal Town and Regional Planning Commission, 1967). Interestingly, the Umbilo River, which rises in the Pinetown area just south of the Palmiet River, also exhibited a high mean TDS value of 284 mg/ℓ (Natal Town and Regional Planning Commission, 1967).

In view of the fact that the geology of the Palmiet River catchment consists of sedimentary rock only (Natal sandstone in the western and central parts; Dwyka, Ecca and Alluvium in the east), the soil and geological formations should not contribute

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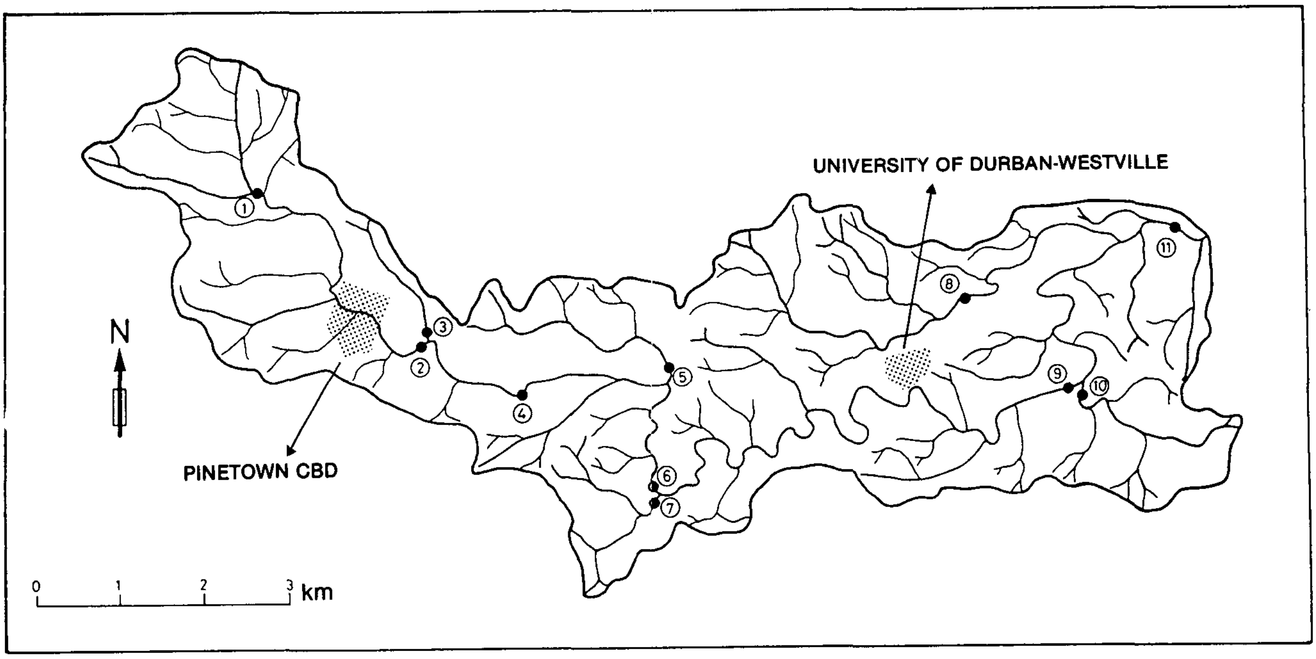

Figure 1
Sampling sites in the Palmiet River catchment.

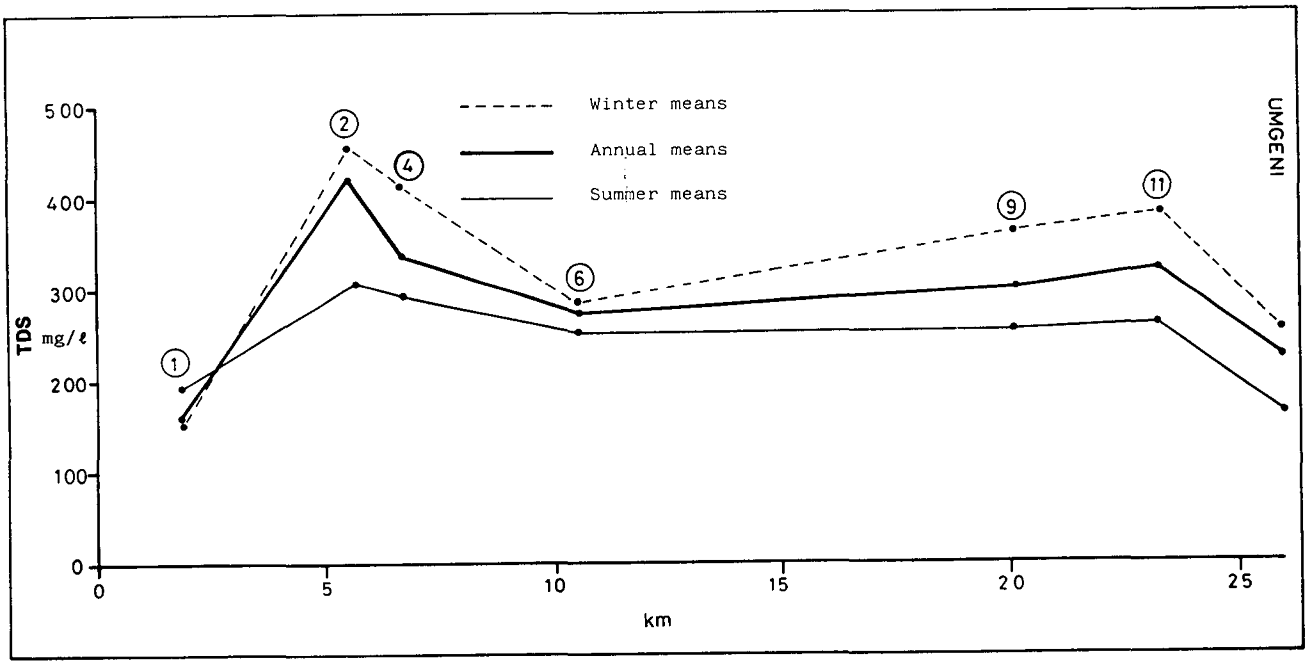

Figure 2
Changes in the mean dissolved solids content along the course of the Palmiet River.

substantially to the water quality. It is therefore proposed that high analyte concentrations found in the chemical composition of the river water may largely be attributed to exterior factors although the contribution of analyte elements leached from the fine particle fraction of the soils cannot be completely ignored.

The major contributions to the high annual mean TDS values obtained for the Palmiet River are Na^+, Cl^- and SO_4^{2-} (Table 1). These values are generally quite high when compared with values for the same analytes in other rivers in Southern Africa (Du Preez, 1985a). In a similar comparison the annual mean values for Ca^{2+}, Mg^{2+}, K^+, NH_4^+-N and NO_3^--N are also somewhat high. With reference to the latter analytes, a closer inspection shows that for sites 2, 3 and 4, Ca^{2+} and Mg^{2+} values are particularly high whilst NO_3^--N values are quite high for sites 1 and 7.

The overall high annual mean values obtained for Cl^- could be ascribed in part to swimming pool effluent after treatment with $Ca(OCl)_2$ (De Villiers and Malan, 1985). A more significant contribution to the high Cl^-, as well as Na^+ values, is probably the proximity of the Palmiet River catchment to the ocean. High levels of chloride have often been observed in coastal regions (Marr and Cresser, 1983). River sampling sites within the coastal

TABLE 1
RESULTS OF CHEMICAL ANALYSES OF THE PALMIET RIVER WATER: ANNUAL GEOMETRIC MEAN VALUES FOR THE MACRO-ANALYTES (mg/ℓ) FOR THE PERIOD SEPTEMBER 1982 – DECEMBER 1984
(SD = Standard Deviation)

Sample Site No.	pH	Conductivity (mSm^{-1})	Ca^{2+}	K^+	Mg^{2+}	Na^+	Cl^-	PO_4^{3-}-P	SO_4^{2-}	NO_3^--N	NH_4^+-N	Si	F^-	Total Alkalinity*	Total Phosphorus	TDS
1	6,6	29,0	9,1	2,75	6,9	30,5	48,4	0,013	17,3	1,82	0,18	8,1	0,35	13,8	0,020	160
2	7,5	65,6	31,0	5,70	9,9	78,1	93,1	0,059	56,5	0,92	0,32	8,4	0,35	75,8	0,108	420
3	7,5	59,0	32,7	6,45	10,9	60,0	65,2	0,023	37,2	1,66	0,41	9,9	0,38	50,7	0,044	363
4	7,5	60,5	31,6	5,50	10,1	66,2	80,8	0,041	52,5	0,78	0,34	9,1	0,35	55,4	0,067	357
5	6,7	31,3	9,9	3,03	6,9	33,4	48,8	0,019	20,5	1,60	0,17	8,2	0,35	16,9	0,030	166
6	7,4	48,8	24,0	4,53	9,0	51,2	65,8	0,043	41,4	1,56	0,14	8,7	0,35	35,6	0,062	272
7	7,2	44,3	18,1	4,10	11,0	44,2	63,2	0,062	29,0	2,78	0,09	9,1	0,35	31,3	0,074	247
8	7,7	59,5	25,7	3,35	16,5	63,1	77,1	0,082	40,0	1,61	0,24	12,1	0,35	55,5	0,097	339
9	7,4	53,4	22,0	3,86	12,4	58,0	74,9	0,036	41,7	1,52	0,13	8,4	0,35	37,4	0,054	301
10	7,4	60,3	19,5	2,50	16,0	69,7	90,0	0,023	54,0	0,93	0,27	7,2	0,35	35,3	0,031	369
11	7,5	60,8	24,0	3,71	13,6	58,5	74,5	0,029	44,8	1,14	0,14	8,4	0,40	49,6	0,045	324
Mean	7,3	52,1	22,5	4,13	11,2	55,7	71,1	0,039	39,5	1,48	0,22	8,9	0,36	41,6	0,057	302
SD	0,4	12,4	8,0	1,29	3,2	14,8	14,6	0,021	12,9	0,56	0,10	1,3	0,02	18,1	0,028	83
Umgeni	7,3	44,0	15,5	3,57	9,2	42,9	58,7	0,038	23,5	1,64	0,31	5,7	0,35	30,2	0,089	223

*As $CaCO_3$
TDS = Total dissolved solids

TABLE 2
RESULTS OF CHEMICAL ANALYSES OF THE PALMIET RIVER WATER: SUMMER GEOMETRIC MEAN VALUES FOR THE MACRO-ANALYTES (mg/ℓ) FOR THE PERIOD SEPTEMBER 1982 – DECEMBER 1984
(SD = Standard Deviation)

Sample Site No.	pH	Conductivity (mSm^{-1})	Ca^{2+}	K^+	Mg^{2+}	Na^+	Cl^-	PO_4^{3-}-P	SO_4^{2-}	NO_3^--N	NH_4^+-N	Si	F^-	Total Alkalinity*	Total Phosphorus	TDS
1	6,9	33,7	11,8	3,20	7,6	35,4	55,7	0,022	22,8	1,81	0,24	9,3	0,35	18,0	0,030	193
2	7,5	62,8	30,2	5,62	9,9	74,2	97,6	0,101	51,4	0,55	0,29	9,1	0,35	55,6	0,123	309
3	7,5	40,7	25,3	5,10	7,5	37,8	39,8	0,037	44,6	1,05	0,48	7,9	0,35	52,2	0,056	302
4	7,6	54,5	28,9	5,29	9,3	57,9	76,8	0,055	49,0	0,64	0,42	9,0	0,35	53,3	0,068	296
5	6,9	31,7	10,3	2,95	7,4	33,8	52,2	0,036	22,4	1,64	0,16	8,2	0,35	20,0	0,041	167
6	7,5	46,4	22,9	4,25	8,4	49,4	66,5	0,068	37,7	1,35	0,13	8,5	0,35	42,3	0,081	252
7	7,5	44,0	18,7	3,89	11,4	43,7	62,8	0,099	31,7	2,28	0,10	9,9	0,35	40,7	0,104	264
8	7,9	61,7	26,7	3,15	17,7	65,9	81,9	0,090	42,1	1,91	0,21	13,8	0,35	83,6	0,097	351
9	7,4	47,2	20,0	3,73	10,6	50,6	67,4	0,054	35,4	0,92	0,19	8,4	0,35	43,3	0,068	255
10	7,5	42,3	14,7	1,37	12,0	48,2	56,3	0,035	40,3	0,26	0,23	6,5	0,35	43,7	0,038	381
11	7,4	65,8	19,1	3,15	10,7	48,4	63,5	0,046	33,3	0,81	0,12	7,9	0,35	44,4	0,054	263
Mean	7,4	48,3	20,8	3,79	10,2	49,6	65,5	0,059	37,3	1,20	0,23	9,0	0,35	45,2	0,069	276
SD	0,3	11,6	6,7	1,24	3,0	12,5	15,7	0,028	9,5	0,64	0,12	1,8	0,0	17,6	0,030	62
Umgeni	7,3	30,6	11,2	3,36	7,5	31,1	40,9	0,059	15,9	1,37	0,39	7,0	0,35	33,3	0,086	164

*As $CaCO_3$
TDS = Total dissolved solids

region of Transkei similarly exhibited very high values of Cl^- (Du Preez, 1985a) and thus clearly illustrate the importance of the proximity of the ocean when evaluating Cl^- levels in river water.

The high SO_4^{2-} annual mean values at sites 2 and 4 are related to industrial pollution (De Villiers and Malan, 1985). The relatively high Ca^{2+} and Mg^{2+} values at sites 2, 3 and 4 must similarly be ascribed to industrial and urban pollution; these sites lie within, and just below, the Pinetown CBD and one of its industrial areas. In contrast sites 1 and 7 are situated in residential areas and the high NO_3^- values at these sites could be the result of either the use of fertilizer by the home owners, or the seepage from French drains/septic tanks into the river system. Because of the predominantly anaerobic processes associated with septic tanks, the formation of nitrates in sewage is not expected. However, the NO_3^- concentrations reported here refer to the sum of nitrate- and nitrite-nitrogen, and the latter may be formed in sewage by microbial action. Reduction of nitrogen to ammonia and ammonium salts by microbial action in septic tanks is, in contrast, the predominant process. The somewhat high values of NH_4^+ along the whole river system may thus, as for NO_3^-, be ascribed to the use of fertilizers by home owners or seepage from septic tanks. Industrial contamination of the river system by discharges of urea, and thus ammonia, also cannot be discounted at sites 2, 3 and 4 (De Villiers and Malan, 1985).

The sandy soil of the Palmiet River catchment is particularly poor in K^+ content and extensive use of K^+ is required particularly for the cultivation of healthy lawns. The somewhat high annual mean values obtained for K^+ along the entire river may thus be the result of excessive use of fertilizer by gardeners. At sites 2,3 and 4 the K^+ values are, however, markedly higher and contamination by the CBD area of Pinetown is thus obvious. The particular source of such pollution is unfortunately unknown.

The change in the concentrations of all analytes along the course of the river is similar to that of TDS (Figure 2); the high input of the CBD area of Pinetown is in each case clearly discernable. Exceptions to this trend are F^-, Si and NO_3^-. Fluoride and Si mean annual values stay fairly constant along the course of the river, whilst NO_3^- values in fact appear to decrease.

A survey of Table 1 also indicates that the various tributaries (sites 3, 5, 7, 8 and 10) do not significantly pollute the main stream except for some minor exceptions. The relatively high mean annual level of NO_3^- at site 7 has already been mentioned above. The same tributary also features a high mean value for phosphate, again with fertilizer from urban gardens the most probable culprit. The tributary sampled at site 8 also exhibits high values for nitrate-nitrogen and phosphate which can again be ascribed to the use of fertilizer by gardeners in the Reservoir Hills suburb of Durban, although detergent pollution of the tributary may also add to the relatively high total phosphorus value. The mean annual values of some other analytes at site 8 are also somewhat higher than those for the main stream at site 9, thus indicating that the Reservoir Hills area has a substantial impact on the lower Palmiet River and its water quality. The relatively high annual mean nitrate- and ammonium-nitrogen values at site 3 must be related to industrial pollution; this tributary passes for example close to the Pinetown power station.

Figure 2 also illustrates the seasonal variation of the TDS along the course of the river. Summer is taken as the months of December, January and February, whilst winter is taken as June, July and August (Tables 2 and 3). From the graph it is apparent that the general pattern along the course of the river does not change from season to season. The most significant change is rather the general decrease in TDS values in summer and the concomitant increase in TDS values in winter. With the exception of phosphate and ammonium, all other analyte values are also lower in summer and higher in winter. This trend conforms to trends found for Transkei rivers in general (Du Preez, 1985a) where rivers contain relatively low and relatively high concentrations of dissolved substances in the rainy and dry seasons respectively; ammonium is also an exception as is the case for the Palmiet River (Tables 2 and 3). The fact that ammonium values peak in summer may be related to the shorter residence times which favour washout of ammonium, before biological oxidation processes have converted the ammonium into nitrate.

Trace elements

The annual geometric mean values for the micro-analytes for the period September 1982 to December 1984 are presented in Table 4. From the table a number of points are significant:

- The impact of the Pinetown CBD on the water quality of the Palmiet River is well illustrated by the relatively high values for the elements Al, B, Cr, Cu, Fe, Mn, Pb, Sr and Zn (Figure 3). Of these elements B, Fe, Pb and Zn are high even in absolute terms i.e. relative to Southern Africa (Du Preez, 1985a).
- The tributary sampled at site 8 contributes substantially to the TDS of the Palmiet River. This observation is illustrated by the relatively high values for the elements Al, As, Ba, Co, Fe, Mn, Mo, Ti and V. Of the latter elements As, Ba, Fe and Mn are high even in absolute terms i.e. relative to Southern Africa (Du Preez, 1985a and b).
- Relative to the rest of Southern Africa (du Preez, 1985a), the whole Palmiet River exhibits relatively high mean annual values for the elements As, B, Ba, Fe, Mn, Pb and Zn.
- As is the case for the macro-elements, values for most analytes are higher in the Palmiet River compared to the Umgeni River just below its confluence with the Palmiet River. Exceptions to

TABLE 3
RESULTS OF CHEMICAL ANALYSES OF THE PALMIET RIVER WATER: WINTER GEOMETRIC MEAN VALUES FOR THE MACRO-ANALYTES (mg/ℓ) FOR THE PERIOD SEPTEMBER 1982 – DECEMBER 1984
(SD = Standard Deviation)

Sample Site No.	pH	Conductivity (mSm^{-1})	Ca^{2+}	K^+	Mg^{2+}	Na^+	Cl^-	PO_4^{3-}-P	SO_4^{2-}	NO_3^--N	NH_4^+-N	Si	F^-	Total Alkalinity*	Total Phosphorus	TDS
1	6,3	28,0	8,7	2,89	7,3	30,3	47,2	0,011	16,6	1,86	0,13	8,3	0,35	18,2	0,012	155
2	7,6	73,3	32,9	5,86	10,3	94,4	103,1	0,032	73,1	0,95	0,26	7,5	0,35	99,8	0,115	457
3	7,7	73,4	37,1	6,61	11,7	85,1	89,5	0,026	83,0	1,26	0,47	9,1	0,35	93,1	0,062	448
4	7,7	67,6	35,6	5,16	10,6	81,4	89,2	0,028	68,9	0,93	0,17	8,4	0,35	87,7	0,075	415
5	6,8	31,8	9,7	3,12	7,1	34,6	50,1	0,011	20,3	1,51	0,13	8,1	0,35	22,7	0,022	169
6	7,4	49,8	24,0	4,37	9,3	54,4	66,3	0,032	43,1	1,40	0,06	7,7	0,35	55,6	0,063	286
7	7,3	43,9	19,3	3,82	12,1	42,5	59,5	0,053	32,0	3,00	0,05	8,6	0,35	47,0	0,062	252
8	7,7	57,9	26,1	3,82	16,3	61,5	76,6	0,105	43,4	1,03	0,35	10,4	0,35	92,9	0,113	360
9	7,4	62,0	25,9	4,10	15,0	69,8	87,0	0,027	54,1	2,42	0,07	8,3	0,35	63,7	0,061	365
10	7,5	68,2	21,9	3,03	20,2	74,4	101,4	0,021	73,3	1,31	0,32	5,9	0,35	55,7	0,028	391
11	7,6	64,9	28,4	3,73	17,7	67,3	85,0	0,022	57,9	1,13	0,07	7,9	0,48	88,0	0,044	385
Mean	7,4	56,4	24,5	4,23	12,5	63,3	77,7	0,033	51,4	1,53	0,19	8,2	0,36	65,9	0,060	335
SD	0,4	16,0	9,4	1,19	4,3	20,9	19,4	0,026	22,3	0,66	0,14	1,1	0,04	28,8	0,033	105
Umgeni	7,4	44,4	15,7	4,22	9,6	50,2	60,3	0,037	29,0	1,79	0,26	4,8	0,35	54,1	0,103	252

*As $CaCO_3$
TDS = Total dissolved solids

this trend are Al, Cu, Fe, Mn, Ti and V. Of these latter elements, Al is again relatively high when compared to the rest of Southern Africa (Du Preez, 1985a).

Figure 3 illustrates the changes in Fe values along the course of the main stream. At sites 2 and 9 summer produces the lowest values, whilst the lowest Fe values at site 6 and the Umgeni River in contrast are produced in winter. Further, at sites 1, 2 and 3 the relatively high Fe values in spring and autumn have the effect of boosting the annual mean values to higher levels than either summer or winter respectively. It is thus clear that no simple seasonal trend regarding variation of Fe along the course of the river exists although a study of the mean Fe values (Tables 4, 5, 6) for the whole river system does give the impression that Fe values overall are lower in summer and higher in winter.

The fairly anomalous trends in the values of Fe discussed above also apply to the other micro-analytes. For example, overall seasonal variations point to Mn miming Fe; the winter values are also the highest. Arsenic in contrast has its highest mean value in summer, whilst the seasonal variation of arsenic values along the course of the river, as for Fe and Mn, shows an anomalous pattern. This could be the result of a relatively short study period (26 months) which might have been insufficient to identify seasonal or spatial trends in micro-analyte values in the catchment. However, for the macro-elements a number of clearly defined trends were observed (see above). It may thus be concluded that no clear

TABLE 4
RESULTS OF CHEMICAL ANALYSES OF THE PALMIET RIVER WATER: ANNUAL GEOMETRIC MEAN VALUES FOR THE MICRO-ANALYTES ($\mu g/\ell$) FOR THE PERIOD SEPTEMBER 1982 – DECEMBER 1984
(SD = STANDARD DEVIATION)

Sample Site No.	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sr	Ti	V	Zn	Zr
1	151	28	39	64	1	3	11	5	3	1 082	36	7	8	12	62	2	2	21	7
2	280	28	444	92	1	4	9	8	7	1 682	141	7	11	22	169	3	3	143	8
3	190	39	253	81	1	10	10	8	13	1 577	100	9	11	24	199	2	3	291	8
4	170	31	366	83	1	5	9	7	3	1 215	82	8	9	32	158	1	3	77	8
5	153	22	72	56	1	5	10	6	3	974	29	7	10	8	62	2	3	19	6
6	161	30	228	93	1	5	10	6	4	757	32	8	10	13	124	2	3	54	6
7	82	25	76	90	1	3	10	5	4	235	9	8	8	12	84	1	3	10	6
8	539	55	74	167	2	5	14	8	6	1 779	503	13	12	20	138	7	6	22	6
9	346	30	146	111	1	4	12	6	5	1 436	107	12	11	28	131	3	4	33	8
10	224	46	81	78	1	5	11	6	5	1 202	512	9	9	30	102	2	3	17	7
11	283	24	148	92	1	4	10	5	4	1 077	147	10	7	14	138	2	3	22	9
Mean	234	33	175	92	1	5	11	6	5	1 183	154	9	10	20	124	2	3	64	7
SD	126	10	133	29	0	2	1	1	3	444	181	2	2	8	44	2	1	85	1
Umgeni	754	26	96	92	1	3	9	5	7	1 597	216	7	8	18	90	5	5	17	6

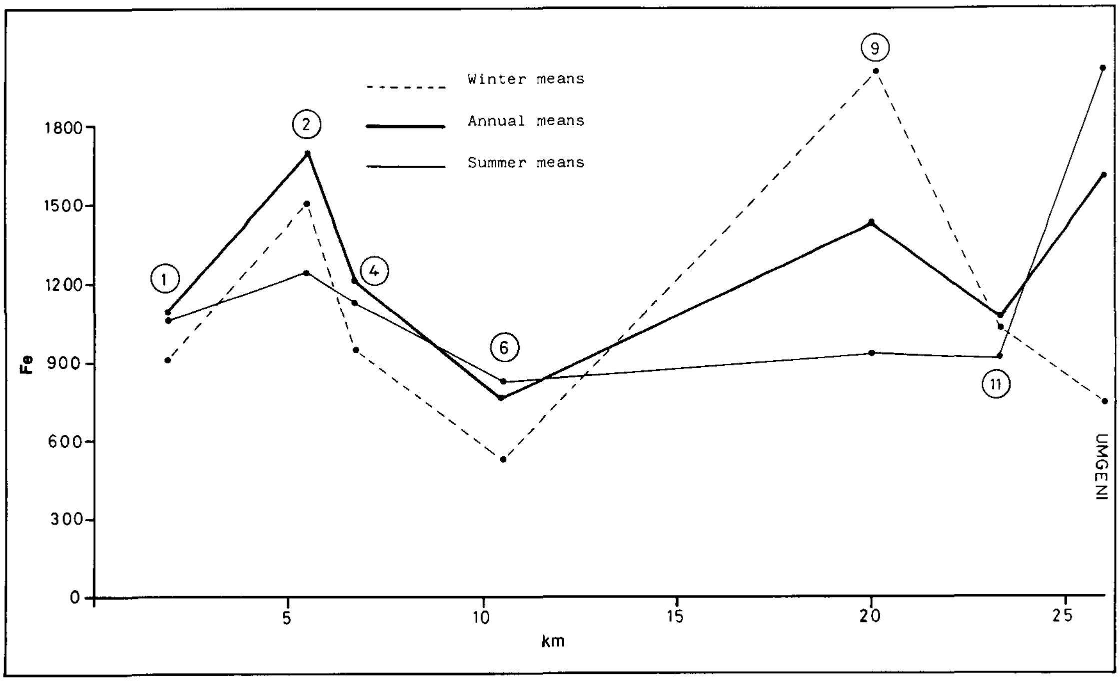

Figure 3
Changes in the mean Fe values along the course of the Palmiet River.

TABLE 5
RESULTS OF CHEMICAL ANALYSES OF THE PALMIET RIVER WATER: SUMMER GEOMETRIC MEAN VALUES FOR THE MICRO-ANALYTES ($\mu g/\ell$) FOR THE PERIOD SEPTEMBER 1982 – DECEMBER 1984
(SD = STANDARD DEVIATION)

Sample Site No.	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sr	Ti	V	Zn	Zr
1	229	20	46	56	1	3	9	5	4	1 076	42	11	8	13	85	2	4	23	8
2	190	30	409	94	2	3	10	13	4	1 252	95	8	8	73	172	2	3	102	5
3	184	42	252	76	2	34	17	18	13	1 464	84	14	19	34	166	3	5	265	9
4	133	20	356	84	1	3	8	11	3	1 132	62	11	9	19	172	1	3	81	10
5	104	20	84	49	1	13	10	8	3	971	33	9	11	61	65	2	3	18	5
6	171	36	261	107	2	31	13	14	5	838	37	10	17	5	138	3	4	76	5
7	79	35	83	95	1	3	8	4	5	222	11	10	11	14	96	1	2	12	8
8	351	99	87	164	3	27	21	13	5	1 377	407	19	20	27	148	5	7	25	6
9	221	44	189	91	2	6	15	11	4	934	56	16	19	19	127	3	4	60	7
10	111	80	75	46	2	23	15	14	10	731	369	15	14	14	96	2	3	33	8
11	158	25	182	78	1	10	10	7	3	911	76	11	14	21	129	2	3	25	13
Mean	176	41	184	85	2	14	12	11	5	992	116	12	14	27	127	2	4	65	8
SD	75	26	123	33	1	12	4	4	3	341	137	3	5	21	37	1	1	73	2
Umgeni	1 168	35	72	93	2	3	9	6	21	1 978	191	5	12	34	77	6	6	18	6

TABLE 6
RESULTS OF CHEMICAL ANALYSES OF THE PALMIET RIVER WATER: WINTER GEOMETRIC MEAN VALUES FOR THE MICRO-ANALYTES ($\mu g/\ell$) FOR THE PERIOD SEPTEMBER 1982 – DECEMBER 1984
(SD = STANDARD DEVIATION)

Sample Site No.	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sr	Ti	V	Zn	Zr
1	135	30	38	77	1	3	11	4	3	907	36	5	7	15	52	1	1	31	7
2	197	20	609	89	1	5	8	5	5	1 522	148	5	8	5	165	2	2	165	6
3	218	28	421	70	1	7	8	6	9	2 017	131	5	6	27	214	2	2	235	9
4	134	29	530	93	1	4	8	4	3	957	85	6	8	49	174	1	2	79	7
5	109	20	64	52	1	3	11	5	3	739	23	5	10	19	57	1	2	16	4
6	140	20	280	114	1	3	11	4	4	520	19	5	8	22	125	2	2	55	6
7	76	20	56	82	2	3	12	4	4	151	4	12	7	21	84	3	3	4	5
8	521	31	89	156	1	4	15	8	7	1 965	658	15	10	54	140	9	4	29	6
9	303	20	132	143	1	4	12	4	7	2 008	206	12	8	39	164	3	3	19	9
10	436	20	93	151	1	3	11	4	9	1 923	380	7	8	19	98	3	3	26	9
11	302	20	149	107	1	3	14	4	4	1 046	201	12	6	21	162	3	4	12	5
Mean	234	23	224	103	1	4	11	5	5	1 250	172	8	8	26	130	3	3	61	7
SD	143	5	205	35	0	1	2	1	2	667	196	4	1	15	52	2	1	74	2
Umgeni	369	20	112	80	1	3	11	4	6	723	124	12	8	12	94	4	6	8	5

trends exist for the micro-analytes and that the present data constitute an adequate baseline for future studies.

General

It was pointed out that in certain instances, mean annual analyte levels in the Palmiet River are relatively high when compared to other rivers in Southern Africa. To establish whether, according to international standards, the Palmiet River is badly contaminated, it is necessary to refer to criteria as accepted by the Department of Water Affairs, RSA (Water Act, 1956; Kempster *et al.*, 1982). For either drinking-water purposes, or for purposes of the protection of aquatic life in rivers and dams, the mean values as depicted in Tables 1 to 6 meet such criteria with only three exceptions i.e. Al, Fe and Mn levels, where the most commonly reported criteria (referred to as the median value) are exceeded. Iron in fact also exceeded the highest criterion (referred to as the maximum value) which is 1 000 $\mu g/\ell$ for Fe.

The reasons for the high Al and Fe values are not clear, but may be related to the geological and soil characteristics of the catchment of both the Palmiet and the Umgeni Rivers. High manganese values may be related to a manganese production plant (Feralloys) situated at Cato Ridge between Durban and Pietermaritzburg. Although it lies in the Umgeni River catchment, it could also affect the Palmiet River catchment via air pollution.

Conclusions derived from annual mean values and possible

TABLE 7
ANALYTES WHERE THE WATER QUALITY CRITERIA* ARE EXCEEDED FOR THE PALMIET RIVER
(VALUES IN PARENTHESES REFER TO THE UMGENI RIVER)

Criterion		Conductivity	K^+	Cl^-	PO_4^{3-}-P	SO_4^{2-}	NO_3^--N	NH_4^+-N	Total Phosphorus	Al	As	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Total no*. of samples for all sites		225	225	225	225	225	225	225	192	291	140	291	121	291	291	291	291	291	120	291
		(19)	(19)	(19)	(19)	(19)	(19)	(19)	(18)	(23)	(13)	(23)	(8)	(23)	(23)	(23)	(23)	(23)	(13)	(23)
No. of samples with analyte values greater than median but smaller than maximum value	a	6	1	1	11	1	1	36	2	91	34	6	2	4	0	225	166	5	14	0
	a	(1)	(0)	(1)	(4)	(0)	(0)	(5)	(0)	(4)	(2)	(0)	(0)	(0)	(0)	(0)	(22)	(0)	(3)	(0)
	b	†	0	2	†	0	†	3	25	11	4	0	31	3	84	222	12	0	31	0
	b	†	(0)	(0)	†	(0)	†	(1)	(7)	(5)	(0)	(0)	(0)	(0)	(11)	(10)	(1)	(0)	(7)	(0)
No. of samples with analyte values greater than maximum value	a	1	0	0	4	0	0	2	0	35	0	0	3	0	0	54	11	0	17	0
	a	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(12)	(0)	(0)	(0)	(0)	(0)	(13)	(0)	(0)	(0)	(0)
	b	†	0	0	†	0	†	0	0	6	0	0	5	1	0	54	11	5	17	61
	b	†	(0)	(0)	†	(0)	†	(0)	(0)	(3)	(0)	(0)	(0)	(0)	(0)	(13)	(0)	(0)	(0)	(0)

* P.L. Kempster, W.H.J. Hattingh and H.R. van Vliet (1982)
* Total number = no. of sites × no of samples actually analysed per site.
a Quality criteria for drinking water
b Quality criteria for river/dam water (protection of aquatic life)
† Criteria not available

pollution of the river water only relate to potential continuous and/or long-term pollution; Al, Fe and Mn fall into this category. Random pollution of the water on the other hand is more difficult to detect without a continuous monitoring programme. A study of the present individual sample values can, however, at least be used as an indicator of possible random pollution of the Palmiet River catchment.

Table 7 lists the number of times that certain analyte values exceeded the water quality criteria over the 26 month study period. The presence of ammonium, phosphate, Al, Mn and Fe in Table 7 was to be expected in view of discussions above. Other high single analyte values which are randomly found over the study period indicate that random pollution of the water is probable. As far as location is concerned, some trends do exist. Low Al, Fe, Mn and Pb values are found at sites 1,5 and 7 i.e. at the source of the Palmiet River or where its tributaries are short and flow only through residential areas. These latter sites then also exhibit the relatively high phosphate and ammonium values. All the other single high values (Table 7) refer mostly to sites along the course of the river; site 8 is anomalous as was also discussed above.

A comparison of the present macro-element data with the data relating to the preliminary study of De Villiers and Malan (1985) reveals that there has been a general increase in all analyte values (about 1,5 times) with time. Only for phosphate-phosphorus and total alkalinity was a decrease in values found. To what extent the difference in values between the two studies can be regarded as meaningful is, however, difficult to establish because an analysis of that data tends to confirm its preliminary nature. At the same time it must also be considered that the environmental conditions of the two studies showed some variation which could have influenced the results.

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