The water quality of a small urban catchment near Durban, South Africa

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Abstract

The results of fortnightly baseflow quality analyses of a small urban catchment are reported. It is shown that the geological formations in the catchment, consisting mainly of Table Mountain Sandstone, have a limited effect on the water quality. Pollution in the catchment is rather the determining agent. Variations in anion and cation concentrations at the different sampling points are explained and related to possible pollution sources. Seasonal variations in anion and cation concentrations are also illustrated and related to rainfall conditions.

Introduction

The effects of watershed changes on water quality are real and frequently of serious consequence. Such changes may be of great variety, ranging from construction of impoundments to urban development and industrial expansion. Urbanization usually has a detrimental effect on water quality and the aquatic environment which necessitates a policy of adequate treatment, nondegradation and water quality management (Moore, 1969).

The effects of urbanization on river water quality in South Africa have been studied, amongst others, by Hart, 1982; Watling and Watling 1982; Watling and Emmerson, 1981; Toerien and Walmsley, 1979 and Walmsley and Toerien, 1978.

The Natal Town and Regional Planning Commission in conjunction with the National Institute for Water Research, CSIR, also published several reports on water quality and abatement of pollution in Natal rivers (Natal Town and Regional Planning Commission, 1967, 1967 (a), 1967 (b), 1969, 1976). Simpson and Kemp (1982) and Simpson and Hemens (1978), in their assessment of urban stormwater quality in two concrete stormwater pipes in Pinetown, included the impact of atmospheric fallout.

This paper is the result of a preliminary study of baseflow water quality of a small urban catchment some 15 km northwest of Durban. An attempt is made to explain the variations in anion and cation concentrations through on site inspections and discussions with the relevant local authorities. The data obtained will serve as a baseline for future monitoring programmes.

Study area

The Palmiet River drains a catchment of 37,02 km^2 with a mean annual rainfall of 1 000 mm and an estimated mean annual runoff of 4,5 x 10^6 m^3. Seventy five per cent of the rain falls during the summer months October to March, mainly in the form of nocturnal thunderstorms. It follows that the summer runoff is relatively high (60 % of the total), whilst the winter runoff is relatively low, with August and September together yielding less than 6 % of the total. Most of the discharge is in the form of quickflow. Baseflow in the main channel hardly ever exceeds a cumec and in the tributaries the baseflow seldom exceeds 50 ℓ/s.

The geology in the western and central parts of the catchment consists mainly of Table Mountain Sandstone, with Dwyka, Ecca and Alluvium the main formations in the eastern part. Apart from the Pinetown basin in the west which is relatively flat, the topography is undulating and well dissected by the river.

With the exception of a small nature reserve and relics of sub-tropical forest here and there, the catchment is fully urbanized (Fig. 1). Housing consists of detached dwellings, on plots of 2 000 m^2, with established gardens which could be categorized as high income-group housing, and middle income-group housing on plots of 1 000 m^2. Tree lined water courses often cut through the residential plots. There is no water-borne sewerage in Westville, in the central part of the catchment. (Fig. 1 and Fig. 2, stations 4 to 7). 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 South Africa.

Methods and materials

Nine water sampling points were selected to cover the main channel and its tributaries (Fig. 2). Samples were taken at fourteen day intervals during the period January 1980 to December 1981. All water samples refer to surface water samples at depths of less than 250 mm. Sampling commenced just after 08h00 on sampling days, which were predetermined for the whole sampling period of 2 years. Samples were collected in clean 250 ml high density polyethylene bottles containing preservatives in the form of nitric acid or mercuric chloride. Two samples were taken at each sampling point, one with nitric acid as preservative and the other with mercuric chloride as preservative. The Hydrological Research Institute, Department of Environmental Affairs, Pretoria, undertook to do all the water quality analyses. Samples were dispatched to this Institute by rail, arriving about four days after sampling. SO_4, Cl, Na, Ca, Mg, K, F and Si were determined in the filtrate from the samples preserved by the nitric acid and NO_3-N, NH_4-N, PO_4-P, total alkalinity (TAL) and pH were determined in the filtrate yielded by the mercuric chloride preserved samples.

Discussion

Figure 2 and Table 1 show variations in the total dissolved solid contents of the surface waters at the nine sampling points in the catchment for the period January 1980 to December 1981. An indication of both total mineral content as well as ionic composition is given by the pie charts in Figure 2.

From Figure 2 several points are significant. Firstly, mineralisation of the surface waters is still reasonably low, with the mean TDS for the period at all the sampling points at 185 mg/ℓ. This is well below the mean TDS value of 284 mg/ℓ

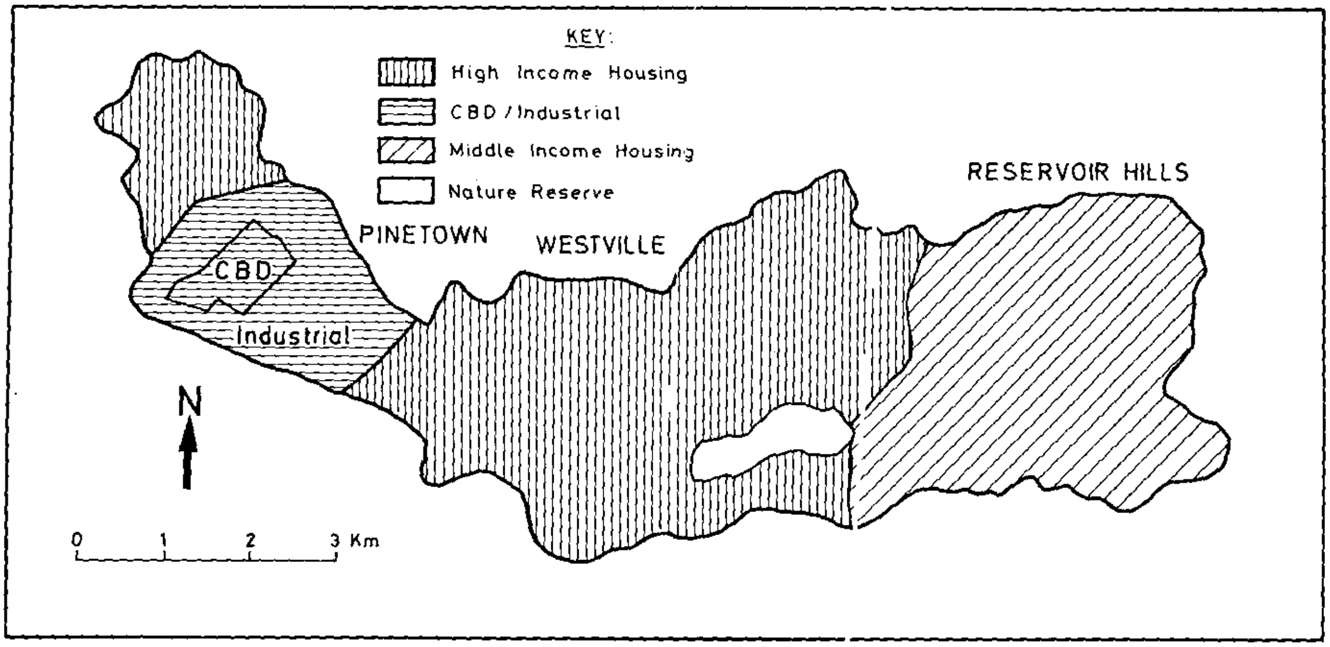

Figure 1
Palmiet River catchment – land use.

reported for the Umbilo River, which rises in the Pinetown area just south of the Palmiet River (Natal Town and Regional Planning Commission, 1967).

The 185 mg/ℓ value is however substantially higher than the mean TDS content of 85 mg/ℓ reported for the Umgeni River, west of Pinetown (Natal Town and Regional Planning Commission, 1967). For this river, mean Na, Ca, Mg and K concentrations of 12,3, 6,5, 3,4 and 1,1 mg/ℓ respectively have been reported. In comparison the concentrations for the same cations in the Palmiet River are 33,9, 15,7, 7,7 and 3,4 mg/ℓ. The mean Cl content of 39,9 mg/ℓ for the Palmiet River catchment also contrasts unfavourably with the 11,3 mg/ℓ for the part of the Umgeni catchment to the west of Pinetown. The mean Cl content for the Umbilo River catchment is however substantially higher at 71,1 mg/ℓ (Natal Town and Regional Planning Commission, 1967).

Secondly, the waters are dominated by sodium with the relative concentrations Na > Ca > Mg > K. This pattern contrasts with the worldwide and African river dominance pattern of Ca > Na > Mg > K (Wetzel, 1975). Likewise, in contrast to mean global and African river waters where $SO_4 > Cl$, the waters of the Palmiet River catchment show a strong reverse trend, *viz.*, $Cl > SO_4$. The geological formations discussed earlier, would only have a limited effect on the dominant patterns and the TDS value. Rather, pollution in the Palmiet catchment is the determining agent. This is substantiated by earlier findings regarding the Umkomaas River, the Umbilo River and the Umgeni River east of Pinetown (Natal Town and Regional Planning Commission, 1967; 1976).

Thirdly, in considering Table 1 and Figure 2 several outstanding features could be distinguished. The relatively high chloride content measured at stations 1, 5, 7 and 8 could possibly be attributed to swimming pool effluent after treatment with $Ca(OCl)_2$. The discharge at these points comes mainly from high income residential areas. An aerial photograph survey showed a large number of private pools in these areas, some of which are located close to the river. Sodium chloride from domestic and human origin could be a contributing factor. The discharge at sampling points 2 and 3 comes mainly from Pinetown's industrial and central business district, therefore, a slight decrease in the Cl values, but a relative increase in the Na to Cl ratio concentration. The high Na value at station 8, (discharge from an Indian residential area) is difficult to explain, but the high salt content in the Indian diet could be a contributing factor through seepage from the sewerage system.

The high SO_4 concentration (43,1 mg/ℓ) at station 3 is due to spillage by at least two industrial concerns. The one uses sulphuric acid to manufacture detergents, and the other to neutralize alkaline effluent. The contribution made by pyrites in coal dumps at a power station, in the form of seepage from the dumps to the stream, is not to be ignored. The increase of the SO_4 concentration at stations 7 and 8 could be linked to the extensive road building programme in progress in that river valley. The SO_4 leaches from the slaked lime which is used to stabilize the base of the road. This is also the reason for the increase in Mg content at the same stations. Other activities associated with road building, (e.g. exhaust gases), could be contributing factors.

The relatively high NH_4-N concentration at sampling stations 2 and 3 (discharge from the industrial and central business districts), could be due to spillage from an industry using urea, $\{CO(NH_2)_2\}$, in a polimerization process, and seepage from the nearby water-borne sewerage which regularly overflows. The higher NO_3-N content at most of the stations must be seen together with the relatively lower NH_4-N. Local inspections at

TABLE 1
MEAN CHEMICAL COMPOSITION OF WATER IN THE PALMIET RIVER CATCHMENT (mg/ℓ) FOR THE PERIOD JANUARY 1980 TO DECEMBER 1981

	Cl	SD	TAL	SD	Na	SD	SO_4	SD	Ca	SD	Si	SD	Mg	SD	K	SD	F	SD	NO_3-N	SD	NH_4-N	SD	PO_4-P	SD	TDS	SD	Cond (mS/m)	SD	pH	SD
Station 1	40,4	9,8	33,2	13,4	28,7	4,8	18,7	9,0	12,2	4,8	8,0	2,4	6,5	1,7	2,8	0,5	0,15	0,1	1,3	0,9	0,07	0,04	0,02	0,01	152,0	26,7	29,0	5,1	7,1	0,3
Station 2	33,3	14,4	48,4	21,7	30,1	12,8	23,8	14,1	16,3	6,7	5,2	2,1	6,6	2,5	3,4	1,8	0,14	0,07	0,67	0,9	0,2	0,4	0,07	0,1	168,2	65,0	30,4	10,3	7,3	0,5
Station 3	31,8	6,7	67,4	19,6	34,3	5,4	43,1	26,4	22,1	7,6	7,4	2,0	6,8	1,4	5,1	1,2	0,30	0,1	0,76	1,0	0,54	0,8	0,34	0,02	219,9	44,3	36,8	6,2	7,4	0,5
Station 4	30,5	10,9	47,0	8,6	26,3	7,6	21,8	12,6	16,0	4,1	5,1	1,5	5,6	1,7	3,3	0,8	0,17	0,08	0,91	1,0	0,13	0,2	0,17	0,4	157,0	41,0	28,7	7,1	7,3	0,4
Station 5	42,2	6,2	28,7	13,1	29,9	5,1	18,0	7,7	10,3	2,9	8,0	0,7	7,0	1,1	3,4	0,7	0,08	0,06	1,5	0,7	0,06	0,02	0,02	0,01	149,2	13,7	28,4	2,5	7,0	0,4
Station 6	36,1	12,6	47,0	6,3	30,4	8,1	19,7	8,8	15,2	2,5	6,0	1,9	6,0	1,8	3,2	0,7	0,12	0,07	0,79	0,5	0,13	0,3	0,04	0,03	164,7	37,1	30,5	7,0	7,3	0,4
Station 7	45,0	11,3	50,6	15,0	36,3	6,9	30,6	17,4	16,0	2,6	6,1	2,1	8,1	2,3	3,3	0,8	0,17	0,07	0,79	1,1	0,07	0,01	0,02	0,01	197,1	37,2	35,7	6,6	7,2	0,4
Station 8	53,5	26,5	74,2	19,2	48,5	19,6	32,0	27,9	16,5	6,1	6,0	2,5	13,0	5,1	2,8	1,3	0,18	0,06	1,4	2,0	0,06	0,02	0,04	0,06	248,2	93,2	43,3	16,2	7,6	0,3
Station 9	46,6	12,3	57,8	10,9	40,5	7,9	27,1	17,8	16,7	3,4	5,9	2,2	9,4	2,3	3,1	0,8	0,20	0,06	0,58	1,0	0,05	0,01	0,08	0,01	208,0	40,2	37,6	7,6	7,5	0,3
TOTAL	359,4	96,3	454,3	127,8	305,0	78,2	234,8	141,7	141,3	40,7	57,7	17,4	69,0	19,9	30,4	8,6	1,51	0,67	8,7	9,1	1,31	1,8	0,80	0,65	1664,3	398,4	300,4	68,6	65,7	3,5
AVERAGE	39,9	10,7	50,5	14,2	33,9	8,7	26,1	15,7	15,7	4,5	6,4	1,9	7,7	2,2	3,4	1,0	0,18	0,07	0,97	1,0	0,15	0,2	0,09	0,07	184,9	44,3	33,4	7,6	7,3	0,4

SD = Standard Deviation
TAL = Total alkalinity
TDS = Total dissolved solids
Cond. = Conductivity

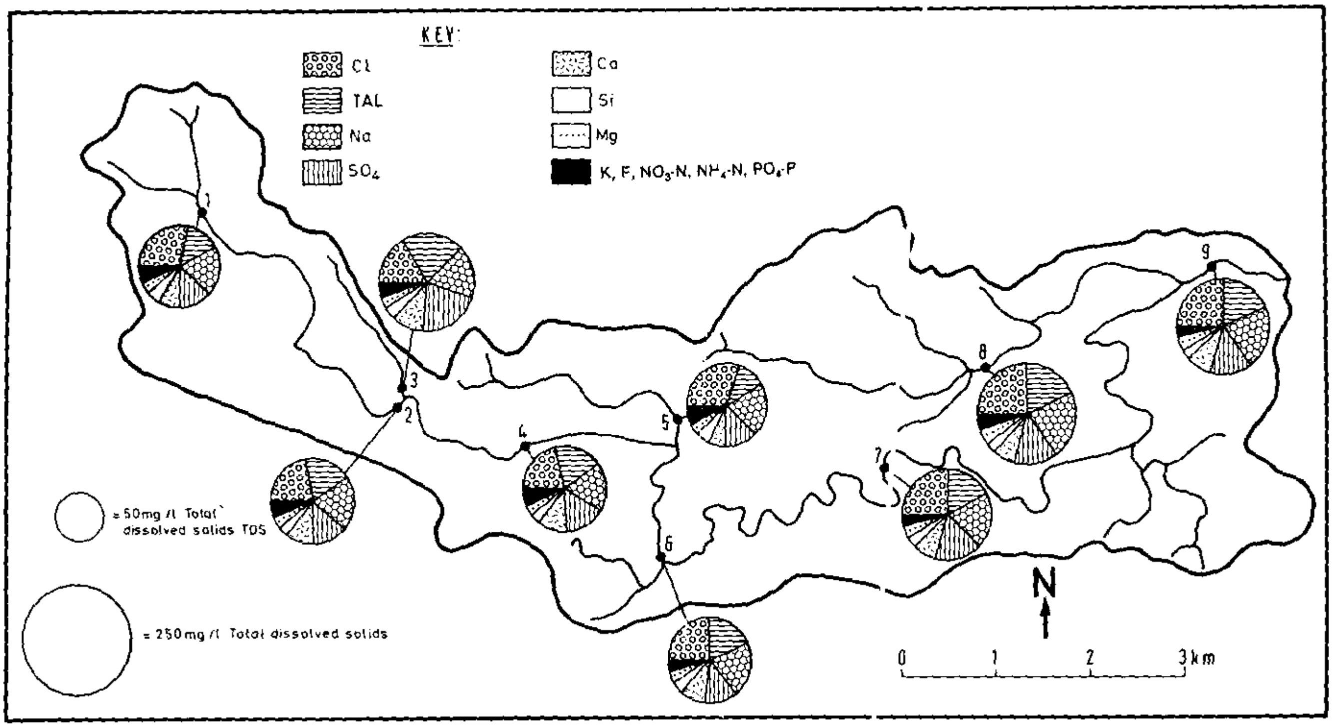

Figure 2
Palmiet River catchment – water quality.

stations 1 and 8 confirmed this to be due to nitrification of seepage from the leaking water-borne sewage systems. Station 5 is downstream from a residential area with a French drain system. Many of the residences are located on the banks of the stream and seepage from the drains occurs regularly.

Regional variation

Table 2 contains average water quality data for the Palmiet River catchment, the Buffalo River catchment, the Vaal River sampling point at Lindequesdrift, the Vaal River sampling point at Standerton and the Polela River at Himeville. The first three cases in the table illustrate urban impact on water quality, and the fourth case (Vaal at Standerton) an agricultural impact. The Polela at Himeville is an unpolluted mountain stream. From Table 2 it follows that the Palmiet River runoff compares favourably with the other urban runoff. Conductivity in the Buffalo and Vaal Rivers is for example nearly 100 per cent higher than in the Palmiet River, whilst the overall Palmiet River values are lower than most of the Vaal River values. The relatively high rainfall and fast runoff of the Palmiet River catchment undoubtedly contribute towards this favourable picture. Cl, however, corresponds quite well. Hart (1982) regards the Buffalo River as particularly sensitive and vulnerable. The higher SO_4, NO_3-N and K values in the Palmiet River are therefore disturbing.

TABLE 2
CONCENTRATIONS (mg/ℓ) AND CHEMICAL COMPOSITION OF THE WATER FROM SOME SOUTH AFRICAN RIVERS

	Palmiet River Catchment	Buffalo* River Catchment	Vaal** River	Vaal** River	Polela** River
pH	7,3	6,4	8,3	8,1	6,7
Cond (mS/m)	33 4	60,2	62,8	20,7	5,1
Na	33,9	70,2	52,0	14,1	2,3
Ca	15,7	21,1	62,6	19,7	4,4
K	[illegible],4	1,8	10,3	3,7	0,45
Mg	[illegible],7	17,5	22,7	12,9	1,9
SO_4	26,1	13,8	176,7	15,4	1,0
Cl	39,9	96,7	51,4	18,8	1,7
PO_4-P	0,09	0,33	0,67	0,61	0,04
NO_3-N	0,97	0,43			0,13
NH_4-N	0,15		0,59	0,44	0,06
TAL	[illegible]0,5		115,0	98,8	27,2
Si	6,4	7,8			4,8
F	0,18		0,75	0,19	0,04

*Hart (1982)
**Du Preez and Jonas (1983)

Seasonal variation

Hart (1982) found the major anions and cations in the Buffalo catchment present in concentrations of about one-third less in summer than in winter. He attributed this to a dilution of groundwater supplies by the higher rainfall in summer. Additionally the decreased retention time of water in the soil reduced the time available for mineralization (Hart, 1982). Table 3 shows the seasonal variation for major anions and cations in the Palmiet River catchment, and contrary to the Buffalo River, the Palmiet River has higher values in summer although the differences are relatively small, being less than 20% in most cases. The higher summer values are, probably due to an accumulation of minerals in winter which are washed down in summer. This is well illustrated in the case of station 3, Table 3, where pyrites from coal dumps are washed to the river during summer resulting in high summer SO_4 levels.

Long term variation

Given variable rainfall and associated climatic conditions, the analyses of long-term trends in water quality characteristics depend upon an adequate historical record (Hart, 1982).

Unfortunately such a record does not exist for the Palmiet catchment. The Pinetown municipality started a limited analytical monitoring programme in 1976, which at present runs concurrently with an extensive programme by the University of Durban-Westville.

The paucity of information makes any conclusions about water quality trends highly speculative, however with further industrialization a future deterioration of surface water quality in this area is imminent.

Conclusion

Urban effluent and runoff usually contain a high pollutant load. In spite of this, the water quality in the Palmiet River catchment is reasonable. This however, does not call for a laisser-faire attitude, but rather for a long-term management plan, based on socio-economic and environmental requirements. The new water amendment act should be a useful tool in such a plan. Short-term solutions (such as using water as a carrier of unwanted products) often have irreversible long-term implications.

The main potential pollution source is situated in the head waters, in Pinetown, where the local authorities should ensure that the capability of the catchment to absorb resiliently the pressure to which it could be subjected, is not exceeded. Recycling of water and alternative means of disposal of waste products, should be considered. This implies close co-operation between all the interested parties in the catchment and rigid application of water quality management principles.

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TABLE 3
SEASONAL COMPARISON OF WATER QUALITY FOR THE PALMIET RIVER CATCHMENT FOR THE PERIOD JANUARY 1980 TO DECEMBER 1981 (mg/ℓ)

	Cl	TAL	Na	SO_4	Ca	Si	Mg	K	F	NO_3-N	NH_4-N	PO_4-P	TDS	Cond. (mS/m)	pH	
Station 1	42,3	28,6	29,4	23,0	12,3	8,3	6,8	2,8	0,13	1,1	0,06	0,02	154,8	29,7	7,0	SUMMER: OCTOBER TO MARCH
Station 2	36,7	46,3	32,0	30,3	18,3	6,0	6,7	3,7	0,12	0,99	0,33	0,08	181,5	32,1	7,2	
Station 3	34,5	73,1	36,7	56,6	27,7	7,0	7,7	5,7	0,31	0,42	0,57	0,63	250,9	41,3	7,4	
Station 4	36,8	48,5	27,7	28,5	17,4	5,7	6,2	3,5	0,18	0,62	0,22	0,05	175,4	31,6	7,2	
Station 5	42,9	24,8	28,6	20,4	10,0	8,1	6,6	3,1	0,07	1,4	0,07	0,02	146,1	28,1	6,8	
Station 6	41,9	46,9	33,0	24,3	16,6	6,7	6,7	3,5	0,12	0,8	0,21	0,04	180,1	33,0	7,2	
Station 7	45,4	52,1	36,5	28,6	16,0	7,0	8,0	3,2	0,16	0,75	0,06	0,03	197,8	34,8	7,2	
Station 8	56,0	84,5	50,5	34,8	17,2	6,2	14,6	2,5	0,19	0,1	0,06	0,02	267,7	44,4	7,6	
Station 9	48,7	56,8	41,0	31,9	17,6	7,0	9,6	3,2	0,2	0,61	0,05	0,14	216,8	38,3	7,4	
TOTAL	385,2	461,6	315,4	278,4	153,1	62,0	72,9	31,2	1,5	7,8	1,6	1,03	1771,1	313,3	65,0	
AVERAGE	42,8	51,3	35,0	30,9	17,0	6,9	8,1	3,5	0,17	0,87	0,27	0,11	196,9	34,8	7,2	
Station 1	38,4	37,7	27,8	14,3	12,1	7,7	6,1	2,8	0,17	1,4	0,07	0,02	148,6	28,3	7,2	WINTER: APRIL TO SEPTEMBER
Station 2	29,8	50,5	28,1	17,2	14,2	4,4	6,4	3,0	0,15	0,34	0,07	0,05	154,2	28,6	7,4	
Station 3	29,0	61,6	31,8	29,6	16,4	7,8	5,8	4,4	0,29	1,10	0,50	0,05	188,3	32,3	7,3	
Station 4	24,2	45,4	24,9	15,1	14,5	4,5	5,0	3,0	0,15	1,20	0,04	0,28	138,3	25,7	7,4	
Station 5	41,4	32,6	31,2	15,5	10,5	7,9	7,4	3,6	0,09	1,50	0,04	0,02	151,8	28,6	7,0	
Station 6	30,3	47,1	27,7	15,1	13,7	5,3	5,3	2,9	0,12	0,78	0,05	0,03	148,4	27,9	7,3	
Station 7	44,5	49,1	36,0	32,5	16,0	5,2	8,1	3,3	0,17	0,83	0,07	0,01	195,8	36,5	7,1	
Station 8	51,0	63,9	46,5	29,1	15,8	5,8	11,3	3,0	0,16	1,70	0,05	0,05	228,4	42,2	7,6	
Station 9	44,5	58,7	40,0	22,3	15,7	4,7	9,2	2,9	0,20	0,55	0,04	0,01	198,8	36,9	7,6	
TOTAL	333,1	446,6	294,0	190,7	128,9	53,3	64,6	28,9	1,5	9,4	0,93	0,52	1552,6	287,0	65,9	
AVERAGE	37,0	49,6	32,7	21,2	14,3	5,9	7,2	3,2	0,17	1,0	0,10	0,06	172,5	31,9	7,3	

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