Chemical inputs to Table Bay — a mass balance study

PD Bartlett*

National Research Institute for Oceanology, CSIR, P.O. Box 320, Stellenbosch 7600, South Africa

Abstract

A catalogue of all the known chemical inputs to Table Bay has been prepared. Daily and annual loadings of metals and nutrients have been calculated. Municipal sources contributed significant quantities of nutrients together with some metals. The harbour area was the source of significant amounts of metals especially Cu, Ni and Zn. The metal inputs have been compared to the mass of metals already present in the water column and sediment. Cu, Ni and Hg were the most dominant metals when compared in this fashion.

A simple mass-balance model has been proposed for Table Bay and the imports and exports identified. Data for Cu, Pb and Zn obtained above were inserted into the model together with other estimated data obtained from a variety of sources. The model was not in balance but as the marine circulations represent the major component, any inaccuracies in calculating these will affect the model greatly. This model is regarded as a first step towards obtaining an accurate mass-balance model for Table Bay.

Introduction

The marine chemistry of Table Bay has been studied by the National Research Institute for Oceanology (NRIO) since 1980. The emphasis has been on pollution aspects and initially the study investigated the behaviour of sewage discharged from the Green Point outfall. More recently the study was extended to an examination of all identifiable potential pollutant discharges to Table Bay. The idea of a mass-balance study for the bay whereby inputs are related to the masses of material present in the bay and to any removal mechanisms, was proposed. This report describes attempts to undertake such a study which, in turn could provide data for possible prediction of the assimilative capacity of Table Bay for various pollutants.

Data for this paper are drawn from published works or from data which have been collected for pollution monitoring by industry or public authorities. The NRIO has published marine chemistry data on Table Bay and the Green Point outfall (Orren et al., 1979; Eagle, et al., 1982; Bartlett, et al., 1985). File data were available from the Cape Town City Council (City Engineer's Department), Milnerton Municipality and the Directorate of Water Affairs (for industrial data submitted under discharge permit conditions) on the various inputs to Table Bay. The NRIO specifically collected field data to estimate inputs from Table Bay Harbour (Bartlett, 1985a). The inputs examined were the Salt and Diep Rivers, Green Point outfall, Fedmis and Caltex industrial outfalls and Table Bay Harbour complex (Figure 1).

A mass-balance model can be derived for a system such as Table Bay. The system must be defined within boundaries and a catalogue produced of all the relevant inputs and exports. Bender et al. (1979) have produced a diagram of such a system. This is reproduced in Figure 2. The figure shows chemical inputs and exports into the water column "box" together with transformations of chemical species within the water column. A simplified version of this diagram was applied to Table Bay. Assessments of the relevant inputs and exports were made and totalled to see if a balance could be obtained which would indicate if the system is in equilibrium.

*Present address: 47 Beaumont Avenue, Weymouth, Dorset, UK.
Received 20 November 1985.

Techniques

Field and laboratory work

The details of the field programme and the laboratory techniques used in the Table Bay studies are outlined by Eagle et al. (1982), Bartlett (1985a) and Bartlett et al. (1985). Water samples were collected in Niskin bottles and were analysed for several chemical parameters including nutrients, trace metals and suspended solids. Sediment samples were collected by diver or by grab and analysed for trace metals, organic components and particle sizes. The analytical techniques used were mainly standard as currently used in the SA Marine Pollution programme and are given in more detail by Watling (1981).

Calculation of chemical loadings

Data for known chemical inputs to Table Bay have been obtained from various sources as described in the introduction. These sources are listed in Bartlett (1985b) together with the wide range of parameters known to be available. The additional data may be available, by arrangement, from the responsible authority or the Directorate of Water Affairs. Certain parameters have been extracted for further consideration as input to Table Bay. These are nitrogen nutrients, phosphorus nutrients and metals, and were chosen because they match most closely the data available for the bay. Generally the chemical and flow data from the inputs were available as a single or mean monthly figure. For the purposes of this study a mean daily loading and a mean annual loading have been calculated from flow and analytical information. This assumes a 30-day month and a 365-day year.

The daily loading figure is assumed to be more relevant to the flushing time of the bay which was estimated as 3 to 4 days (Van Ieperen, 1971). The calculated daily and annual loadings for each discharge point are shown by Bartlett (1985b).

The loadings for each known discharge have been totalled in Table 1 to provide the daily and annual inputs to Table Bay. Estimated values were included where no data were available. These totals represent the inputs to Table Bay from known point sources but do not include inputs from diffuse sources such as storm water drains or atmospheric inputs for which no specific chemical data are known to exist.

TABLE 1
CHEMICAL DISCHARGES TO TABLE BAY

Parameter	Rivers[1]	Municipal kg d^{-1}	Industrial	Harbour	Total kg d^{-1}	Total t a^{-1}
Ammonia – N	3 172,92	(1 000,00)	1 478,15	– 7,41	5 658,48	2 065
Nitrate + Nitrite	474,07	(200,00)	535,20	– 30,63	1 178,64	430
Total phosphorus[2]	856,75	383,64	(50,00)	– 479,76	810,63	296
Cd	0,72	0,06	(0,02)	0,72	1,53	1
Cu	4,63	4,21	0,51	33,21	42,56	16
Fe	23,49	71,74	11,02	(30,00)	136,25	50
Hg	(0,05)	(0,07)	0,01	2,44	2,57	1
Mn	9,73	3,12	0,40	5,49	18,74	7
Ni	5,47	0,51	1,39	(20,00)	27,37	10
Pb	8,97	2,92	0,60	– 6,86	20,46	7
Zn	23,80	11,41	2,08	29,44	66,73	24

[1]Includes municipal effluent from Athlone sewage works.
[2]Assume total phosphorus = orthophosphate × 2.
()estimated values, where no data were available.

Mass of metals in water column and sediment

An attempt was made to estimate the masses of metals in the water column and in the sediment of Table Bay. To achieve this use was made of a computer contouring package which was available at the University of Cape Town Computing Service (Diederiks, 1979). The Saclant Graphics Package (Contouring and Three-Dimensional Graphics Package) was used in previous work on Table Bay to provide contoured distribution diagrams of the various chemical parameters. Edited versions of these diagrams have been presented in previous work (Eagle *et al.*, 1982; Bartlett *et al.*, 1985).

The programme takes the available data, which may be randomly distributed over the study area, and by interpolation produces a regular grid of interpolated data points. In this case a grid of 28 × 28 was chosen. The gridded data are then used in the contouring. For the present purpose, the gridded data were extracted and used as follows. Each data point was taken to represent a standard area (540 m²) and a depth (10 m). Each volume, therefore, contains a mass of metal derived from the concentration at the interpolated point. This exercise was repeated for data at depths of 0, 10 and 20 m. Blanking functions were incorporated to exclude areas shallower than the given depth. All the metal masses so obtained were summed to give a total mass of metal in Table Bay. The boundaries of Table Bay were defined as Green Point to Robben Island and Bloubergstrand to Robben Island. These calculations were carried out for water sampling exercises performed in July 1980, September 1980 and December 1981. The results are shown in Table 2.

Similar exercises were carried out on the sediments of Table Bay. The interpolation was carried out on surface sediments only and the depth function chosen was 5 cm as this was taken to represent the maximum depth of any sediment involved in reactions with the water column. Since sediment-metal data is expressed in μg g^{-1} a density function must be incorporated. The value of 1,5 g cm^{-3} was taken as derived for South African marine sediments (Flemming and Hay, 1983). The calculations were made for sediment sampling exercises carried out in July/September/October 1980 and September 1982.

This calculation assumes a uniform sediment cover over the entire bay. This is clearly not true (Woodbourne, 1983) but since some sediment was obtained at most sites and as the interpola-

TABLE 2
CALCULATED MASS OF METALS IN TABLE BAY WATER COLUMN (kg)

	July 1980	September 1980	December 1981	Mean
Cd	95	80		87
Cu	601	510	356	489
Fe	11 867	2 143	7 384	7 131
Hg	125	39	43	85
Mn	1 289	717	1 169	1 058
Ni	716	547	625	630
Pb	3 222	2 257		2 740
Zn	6 776	1 561	3 612	3 983

TABLE 3
CALCULATED MASS OF METALS IN TABLE BAY SEDIMENTS (TOP 5 cm) (kg)

	July/September/ October 1980	September 1982	Mean
Al		3 637 916	3 637 916
Cd	75	3 158	1 617
Cr		13 873	13 873
Cu	4 463	9 797	7 130
Fe	3 138 866	4 720 125	3 929 495
Hg		212	212
Mn	28 813	34 292	31 552
Ni	886	20 822	10 854
Pb	11 952	39 478	25 715
Zn	11 150	90 412	50 781

tion programme allows for missing values, this assumption remains. This variability probably accounts for the differences in the results shown in Table 3.

Mass-balance estimations

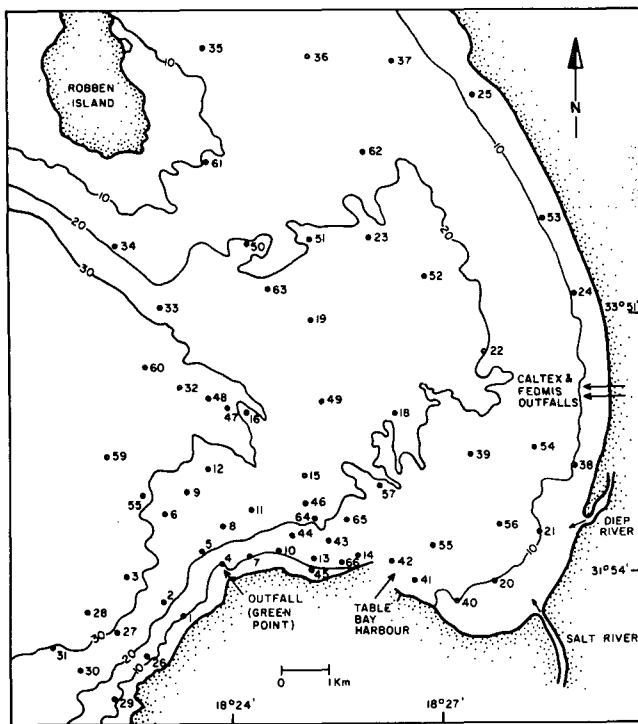The main purpose of this part of the study was to obtain a mass-

Figure 1
Table Bay showing point-source inputs and sampling stations.

balance picture of Table Bay. This means providing data on inputs and exports from the bay and trying to obtain a balance. A model diagram (Figure 2) for a study of this type was shown by Bender *et al.* (1979). In that diagram the various inputs, exports and transformations are shown for a typical pollutant, and a simplified version (Figure 3) has been applied to Table Bay. The examples worked are Cu, Pb and Zn, as metals can be considered less biologically active than nutrient compounds. Metal concentrations will remain more consistent than nutrients which can change widely within a short time.

Table Bay is considered as a black-box system with inputs and exports only. No transformations within the box are considered here. Some of the inputs are detailed above and for these measured data are available. These data were gathered specifically for the Table Bay study or in routine pollution monitoring exercises. The remaining data needed to complete the requirements of Figure 3 have been calculated and estimated using figures from a variety of sources. The derivation of each component is described below.

Diffuse runoff

Runoff water from urban areas is often regarded as a source of pollutants to the aquatic environment especially during storm events following a drought. Storm water can contribute metals and hydrocarbons. No metal concentrations are available for storm water in Cape Town and values from Los Angeles are used (Young *et al.*, 1979-80). These are Cu 108/36; Pb 940/150; Zn 980/220 (μg ℓ^{-1}, storm/dry, respectively). The Cu and Zn values were means for 1971-72 and 1979-80 whilst the Pb values were means from 1971-72 only. Pb levels in US petrol have been reduced in recent years whilst Pb levels in SA petrol remain high.

The catchment areas where drainage is direct into Table Bay rather than via rivers are considered as the City Centre, Wood-

stock and parts of Table Mountain, an area of 24 km². Various storm water outfalls flow into the harbour and might be considered part of the harbour contribution but as the harbour studies were done in dry weather this factor has been ignored here and this storm water is regarded as a direct input to Table Bay. The annual mean rainfall at Molteno Reservoir in the central city up to 1980 is 822,8 mm per year (Cape Town City Engineer, 1980). Is is assumed that half the rainfall occurred under storm conditions. Runoff water totals are shown in Table 4.

TABLE 4
ESTIMATED METAL LOADINGS FROM URBAN RUNOFF TO TABLE BAY

	Storm	Dry	Total (t a^{-1})	Total (kg d^{-1})
Cu	1,1	0,4	1,5	4,1
Pb	9,3	1,5	10,8	29,6
Zn	9,7	2,2	11,9	32,6

TABLE 5
ESTIMATED ATMOSPHERIC DEPOSITIONS OF METALS INTO TABLE BAY

	kg a^{-1}	kg d^{-1} (100 d)	kg d^{-1} (365 d)
Cu			2,0
Pb	3 264	32,6	8,9
Zn			6,9

Atmospheric inputs

The area of Table Bay under consideration is 92 728 800 m². The typical cloud base on a wet day is 400 m and rainfall is recorded on approximately 100 d a^{-1}. Atmospheric Pb concentrations have been measured in central Cape Town (Cape Town City Engineer, 1980) and a mean value of 0,88 μg m^{-3} obtained. It is assumed that the contents of the entire air column up to 400 m is washed
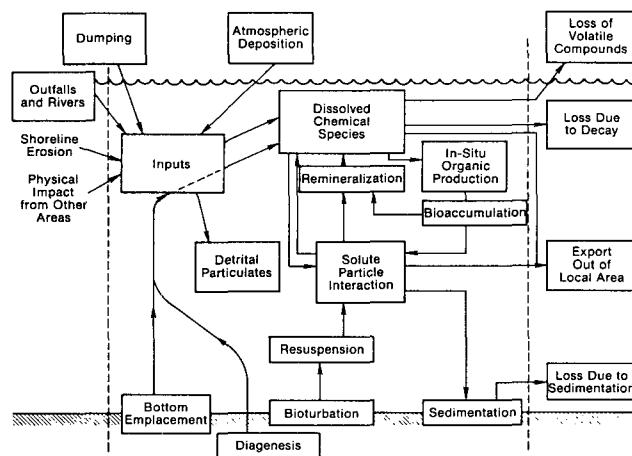

Figure 2
Mass-balance model and possible transformations of a pollutant in the water column (after Bender et al., 1979).

into the sea once on each of 100 rainy days. This results in 3 264 kg a^{-1} Pb being deposited in Table Bay. Atmospheric deposition figures for Southern California (Bascom *et al.*, 1979) and Puget Sound (Cline *et al.*, 1979) are available. These show mass depositions in the following ratios:

	Cu	:	Pb	:	Zn
South California	1		3		5
Puget Sound	1		6		2
Mean	1		4,5		3,5

The Pb data obtained in Cape Town, as above, can be combined with these ratios to give deposition values for Cu and Zn. These appear in Table 5. This technique may give high estimates since it assumes that the metal concentration over the whole of Table Bay is the same as central Cape Town.

Marine circulations

Circulation in the sea, whether tidal, wind or current induced, transports large volumes of water in and out of Table Bay. Van Ieperen (1971) found the residence time of water in the bay to be 3 to 4 days. The volume of the bay considered in this report is 2,01 × 10^9 m³ and hence with a flushing time of 4 days, 0,50 × 10^9 m³ of water is exchanged per day. Therefore, 0,5 × 10^9 m³ of water from offshore is imported per day. Metal concentrations for this offshore water are obtainable from a few sources but for this purpose data collected during the West Coast Marine Pollution Monitoring Cruises (1975 – 1980) (NRIO, unpublished data) were used. A line of stations off Saldanha Bay was worked down
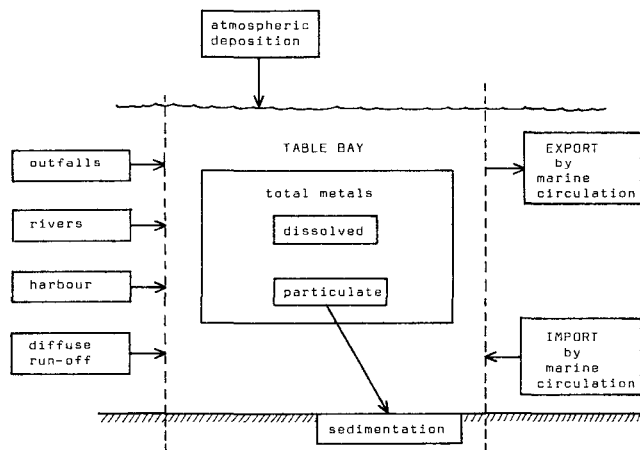

Figure 3
Simplified mass-balance model of Table Bay.

to depths of 400 m. Mean values of Cu, Pb and Zn over 2 years (1978-80) are 1,1; 0,4 and 2,9 µg ℓ$^{-1}$ respectively. Using these concentrations the masses of metals imported from offshore were calculated. These are shown in Table 6.

It was noted that the metal concentrations obtained from West Coast data seemed rather high, although the Cu and Zn levels are consistent with those found by Chester and Stoner (1974). As the marine inputs will constitute a large portion of the mass-balance, alternative data have been provided. Typical concentrations of Cu and Zn found at the seaward extremities of

Table Bay during the various surveys have been used in addition. The values chosen for Cu and Zn were 0,3 and 1,5 µg ℓ$^{-1}$, respectively. The resultant marine inputs are shown bracketed in Table 6.

For export, the calculated mass of metals in Table Bay (Table 2) was used. It was assumed that one quarter of this mass is exported per day. These masses are shown in Table 6.

TABLE 6
ESTIMATED METAL TRANSPORT BY MARINE CIRCULATION IN TABLE BAY

	Import		Export	
	kg d^{-1}	t a^{-1}	kg d^{-1}	t a^{-1}
Cu	550 (150)	201 (55)	122,2	44,6
Pb	200	73	684,9	250,0
Zn	1 450 (750)	529 (274)	995,7	363,4

()Estimated values using metal concentrations found at "extremities" of Table Bay.

Sedimentation

The settling of suspended material and its incorporation into the sediment is a further removal mechanism for metals from the water column. Data were obtained from a variety of sources. Measured sediment settling rates for the West Coast vary considerably from 20 to 42 g m^{-2} d^{-1} at St. Helena Bay, 3 to 5 g m^{-2} d^{-1} at Oudekraal (Bailey, 1985) and 2 to 65 g m^{-2} d^{-1} in Saldanha Bay (Henry, 1985). A value of 10 g m^{-2} d^{-1} was arbitrarily chosen as representative of Table Bay.

Total suspended solids (TSS) in the harbour mouth area were averaged at 3,5 g m^{-3} (Bartlett, 1985a). Metal concentrations in suspended solids were averaged as 0,38; 0,1 and 0,47 mg m^{-3} for Cu, Pb and Zn respectively (Bartlett *et al.*, 1985; Bartlett, 1985a). This represents 0,38 ÷ 3,5 = 0,109 mg Cu per gram of TSS. Therefore, 10 × 0,109 g Cu m^{-2} d^{-1} settle in Table Bay. Multiplied by the area of the bay (92 728 800 m²), 101,1 kg d^{-1} Cu settle in the bay. Similarly for Pb and Zn, the settling rates for metals are shown in Table 7.

TABLE 7
ESTIMATED SEDIMENTATION RATES OF METALS IN TABLE BAY

	kg d^{-1}	t a^{-1}
Cu	101,1	36,9
Pb	26,5	2,9
Zn	124,3	13,7

Mass-balance summation

The various imports and exports for Table Bay have been listed and totalled in Table 8. In view of the variations in marine circulation imports (Table 6) only the lower values have been used for Cu and Zn in Table 8. This gives a net export for all three metals. These results will be discussed below.

	Cu	Pb	Zn
Imports			
Rivers	4,6	9,0	23,8
Municipal	4,2	2,9	11,4
Industrial	0,5	0,6	2,1
Harbour	33,2	-6,9	29,4
Diffuse runoff	4,1	29,6	32,6
Atmosphere	2,0	8,9	6,9
Marine circulation	150	200	750
Total Imports	198,6	244,1	856,2
Exports			
Sedimentation	101,1	26,5	37,7
Marine circulation	122,2	684,9	995,7
Total Exports	223,3	711,4	1 033,4
NET EXPORT	24,7	467,3	177,2

Discussion

Using the black-box model of Table Bay shown in Figure 3, all the imports and exports have been quantified with varying degrees of accuracy. The imports and exports have been totalled and the net export for Cu, Pb and Zn is shown in Table 8.

The first important conclusion is that ideally, if all imports and exports have been identified and quantified correctly, the imports should balance the exports. In this model there is a net export for the three metals. This is a logical conclusion indicating that urban or coastal areas are a source of metals which are then exported to the sediments and the open ocean. As discussed above there are two values proposed for Cu and Zn marine circulation imports. Use of the smaller figures improves the balance but it is uncertain which is the more correct. However, use of the larger figures would produce a net import which is less logical. The marine circulation imports and exports represent the major parts of each total and their magnitude affects the balance considerably. The particular uncertainty of the marine import is of special importance in not obtaining a balance. This is a simple model and various factors are missing which may play a role. The metals are treated as more conservative species but there may be export of metals in biological materials. Sediment import/export are not considered here and nor are any exchanges between sediment and the dissolved phase. If these processes are of importance in this model then their omission can affect the balance. This model does assume that the sediment is outside the box so that theoretically it should play no role. The marine circulations play such a dominant role with the "pollutants" being less important in the overall budget. Therefore the imbalance comes from the possible errors which are inherent in this type of calculation, especially when data are derived from sources unrelated to Table Bay, as was necessary above.

Examination of Table 8 shows the relative importance of the components. The marine circulations dominate these estimates particularly for Pb and Zn exports. Comparatively high Pb levels were found in Table Bay. Diffuse runoff is also important for Pb and Zn. Atmospheric inputs also make an important contribution, again for Pb and Zn, compared to the remaining aquatic

routes. Sedimentation seems an important sink for Cu, which may due to the affinity of Cu for the organics in suspended material.

It has been shown that anthropogenic and other inputs from land do not make a major contribution to the chemical budgets in Table Bay. However, it is worth examining these inputs again in more detail. Table 1 shows that the rivers represent the major nutrient input from land. It should be especially noted that Black River data include runoff water and also treated sewage effluent. Diep River data will also contain runoff water and some sewage effluent at times. The source of the high nutrients may be mainly municipal, from sewage, since Athlone works contributes 48 per cent of the water, 83 per cent of the ammonia, 40 per cent of the nitrate and 85 per cent of the phosphorus in the river (Morrison, 1982). Municipal sources may therefore make the largest contribution of nutrient compounds. Turning to metals, the harbour represents a significant source of some metals especially Cu, Hg, and Zn. The municipal effluents alone are also sources of Cu, Pb and Zn. Of the total inputs from these sources ammonia is the greatest of the nutrients whilst Fe, Zn, Cu and Ni are the major metal inputs.

Water quality criteria have been compiled for the South African coastal zone (Lusher, 1984) and maximum concentrations desirable in the sea for ammonia and metals are proposed. These must be attained after an initial dilution. Many of the anthropogenic inputs exceed these figures substantially but after dilution with sea water in the bay there is no indication that they are being exceeded or even approached. Particular note should be taken of the harbour which is to some extent a special case. Some levels in the harbour reported in Bartlett (1985a) exceed the criteria for Cu and Hg. Table Bay Harbour is the principal source for some of the metals but since they are derived from diffuse sources within, any control will prove extremely difficult. The overall situation in Table Bay is healthy when considering metal and nutrient toxicities. Organic and bacterial pollution must be considered as a separate issue elsewhere.

Conclusions

A catalogue of anthropogenic inputs to Table Bay has been compiled. The river inputs were shown to be major sources of nutrients and metals, but because the Black River also carried sewage effluents, it seems that municipal sources produce the greatest nutrient loadings. Table Bay Harbour is a major source of metals and exceeds inputs classified as municipal for several of the metals.

When the total anthropogenic inputs are compared with the masses of metals in the water column and sediment, Cu, Hg and Ni represent the major inputs.

Water quality criteria are not exceeded for the marine component of Table Bay but the harbour should be examined as a special case.

A mass-balance study has been completed for Cu, Pb and Zn using a simple black-box model for Table Bay. Total exports exceed the imports and the marine circulations play the dominant role.

This minimizes the importance of any "pollutant" inputs to Table Bay. This study contains many sources of error considering the varying sources of data. Any imbalance in the calculations could be caused by data errors, omission of important processes from the model, or especially, by the wrong choice of a suitable metal concentration in calculating the marine circulation input. Any error in this figure will lead to a large imbalance in the mass-

balance calculation.

Special emphasis should be placed on the quality of data used in this study. The data used to calculate the anthropogenic or "pollutant" inputs to Table Bay were gathered specifically for the purpose or derived from monitoring measurements of various kinds.

The data are valid, but because various assumptions were made in the derivation of loadings etc., different answers can easily be obtained from the same data. The data and calculations used in the preparation of the remainder of the mass-balance were drawn from a wide variety of sources and many potentially doubtful assumptions are made. This again could lead to wide errors. It is, however, gratifying that correct order-of-magnitude values are obtained and that a near balance can be found.

This paper represents only a first step in obtaining a reliable model. The areas requiring further study and further data collection can be identified and it is hoped that interested parties will be able to pursue these points and help to improve the quality of material used and hence, the final mass-balance equation.

Acknowledgements

References

BAILEY, G.W. (1985) Sea Fisheries Research Institute. Personal communication.
BARTLETT, P.D. (1985a) Table Bay Harbour – marine chemical studies. CSIR Report T/SEA 8502, Stellenbosch.
BARTLETT, P.D. (1985b) Table Bay chemical inputs – an overview and mass-balance study. CSIR Report T/SEA 8518, Stellenbosch.
BARTLETT, P.D., HENNIG, H.F.-K.O. and EAGLE, G.A. (1985) Table Bay – a marine chemical study, CSIR Research Report 565, Stellenbosch.

BASCOM, W., BROOKS, N., EPPLEY, R., HENDRICKS, T., KNAUER, G., PRITCHARD, D., SHERWOOD, J. and WORD, J. (1979) In E.D. Goldberg (Ed.) Proc. Workshop of Assimilative Capacity of US Coastal Waters for Pollutants. Crystal Mountain, Washington. 179-242. NOAA, Boulder, Colorado.
BENDER, M., CHURCH, T., EDGINGTON, D., GROSS, M.G., HAIDVOGEL, D.B., McCARTHY, J., NEEDLER, G., ROBINSON, A., SCHNEIDER, E. and STEELE, J. (1979) In E.D. Goldberg (Ed.) Proc. Workshop of Assimilative Capacity of US Coastal Waters for Pollutants. Crystal Mountain, Washington. 98-122. NOAA, Boulder, Colorado.
CAPE TOWN CITY ENGINEER (1980) Annual Report.
CHESTER, R. and STONER, J.H. (1974) The distribution of zinc, nickel, manganese, cadmium, copper and iron in some surface waters from the World Ocean. Mar. Chem. 2 17-32.
CLINE, J., CODISPOTI, L., CURL, H., EBBESMEYER, C., HARRIS, H.S., PAVLON, S.P., RATTRAY, M., SCHELL, W., WALDICHUK, M. and WESTLAKE, D.W.S. (1979) In E.D. Goldberg (Ed.) Proc. Workshop of Assimilative Capacity of US Coastal Waters for Pollutants. Crystal Mountain, Washington. 243-280. NOAA, Boulder, Colorado.
DIEDERIKS, R. (1979) Saclant graphics package. Contouring and three-dimensional graphics package. Computing Services, University of Cape Town.
EAGLE, G.A., BARTLETT, P.D. and LONG, M.V. (1982) The behaviour of sewage from the Green Point sewage outfall and its effect on Table Bay – a preliminary report. CSIR Research Report 571, Stellenbosch.
FLEMMING, B.W. and HAY, R. (1983) On the bulk density of SA marine sands. Joint GSO/UCT Mar. Geol. Proj. Tech. Rep. 14. 171-176. Geology Dept., University of Cape Town.
HENRY, J. (1985) Sea Fisheries Research Institute. Personal communication.
LUSHER, J.A. (Ed.) (1984) Water quality criteria for the South African coastal zone. SA National Scientific Programmes Report No. 94, CSIR, Pretoria.
MORRISON, J.R. (1982) Survey of water quality in Black River catchment 1968-80. Report CB 2/R4. City Engineer's Dept., Cape Town.
ORREN, M.J., FRICKE, A.H., EAGLE, G.A., GREENWOOD, P.J. and GLEDHILL, W.J. (1979) Preliminary pollution surveys around the South-western Cape coast. Part 2. Green Point sewage outfall. S. Afr. J. Sci. 75 456-459.
VAN IEPEREN, M.P. (1971) Hydrology of Table Bay. PhD. thesis. Institute of Oceanography. University of Cape Town.
WATLING, R.J. (Ed.) (1981) A manual of methods for use in the South African marine pollution monitoring programme. SA National Scientific Programmes Report 44. CSIR, Pretoria.
WOODBOURNE, M.W. (1983). Bathymetry, solid geology and quaternary sedimentology of Table Bay. Joint GSO/UCT Mar. Geol. Proj. Tech. Rep. 14, 266-277. Geology Dept., University of Cape Town.
YOUNG, D.R., TSU-KAI, J., GOSSET, R.W. and HERSHELMAN, G.P. (1979-80). In W. Bascom (Ed.) Coastal Water Research Project. Biennial Report. 163-169. Long Beach, California.