The measurement and reduction of urban litter entering stormwater drainage systems: Paper 1 – Quantifying the problem using the City of Cape Town as a case study

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Abstract

The wash-off of solid waste into the drainage systems of urban areas is not only unsightly; it seriously interferes with aquatic life in the receiving streams, rivers, lakes and oceans. Litter management in South Africa is currently, however, severely hindered by the lack of good quality data on the quantities and types of urban litter emanating from different types of land-use. This paper describes a monitoring programme that was implemented between 2000 and 2002 in nine subcatchments representing various land uses and demographic profiles located within the boundaries of the City of Cape Town. Measured quantities of urban litter, vegetation, and building debris are given for each of the nine subcatchments. These data are then used as input to a GIS-based model of the City of Cape Town in order to estimate the quantity of urban litter that is currently entering the drainage systems of that city.

Keywords: litter management, stormwater drainage systems, water quality management, quantity of litter

Introduction

Much attention has been given to the problem of eradicating what the South African Minister for Environmental Affairs, Valli Moosa (Nedlac Executive Council, 2001), has termed South Africa's new "national flower", the ubiquitous plastic bag. Although highly visible, festooning fences and thorn trees, and clogging drainage systems and waterways, the plastic bag is only one of many items that contribute to the litter stream. It has, however, served to capture the imagination of the South African public and focus the attention of increasing numbers of South Africans on the problem of litter. One aspect of the litter problem (here defined as visible solid waste in the public domain) is its impact on urban stormwater runoff. While it may appear to be mainly of visual and aesthetic importance, litter also seriously interferes with aquatic life in the receiving streams, rivers, lakes and oceans (Victoria Stormwater Committee, 1999). This makes it imperative that the amount of urban litter finding its way into the drainage catchments be severely reduced through proper catchment litter management strategies. Key to the success of such strategies is the quantification of the scale of the problem. However, as Armitage et al. (1998) noted, there are currently few scientifically verified data available on the nature and quantities of the litter that finds its way into stormwater systems. This is despite the CSIR (1991) estimating in 1991 that 780 000t of waste a year was entering the drainage systems of South Africa representing a potential removal cost in excess of two billion Rand per annum (Armitage and Rooseboom, 2000a).

In 1999, the Water Research Commission (WRC) of South Africa appointed the Department of Civil Engineering at the University of Cape Town (UCT) to carry out a study into the measurement and reduction of urban litter entering stormwater drainage systems. Part of this study involved the implementation of a monitoring programme between 2000 and 2002 in nine pilot catchments in the Cape Metropolitan Area (now all part of the City of Cape Town, hereinafter simply called "Cape Town") representing a range of different land uses, socio-economic levels and population densities. The study was co-funded by the then Cape Metropolitan Council who paid for the installation of traps and assisted with the collection of data. One of the aims of this monitoring programme was to improve the knowledge of the source, type and amount of litter reaching the drainage systems from different types of urban catchments. To achieve this aim:

- A number of urban catchments representing a spread of land uses, income levels, densities and service levels were selected
- Litter traps and nets were installed in the catch-pits and stormwater outlet pipes
- A monitoring programme was instituted to record the types and amounts of litter trapped
- The data obtained from the monitoring were analysed to arrive at a litter profile for each of the study catchments
- The litter profile was then considered in tandem with the land-use and socio-economic characteristics for each catchment.

This paper summarises the data obtained, and uses these to estimate the total quantity of urban litter reaching the drainage systems of Cape Town under various operational scenarios.

Over the course of the monitoring programme, the greater Cape Town area underwent a series of profound administrative changes. The six local municipalities and the metropolitan authority providing joint and bulk services to these local municipalities, in existence at the commencement of the monitoring programme at the end of 1999, were merged into one Unicity at the end of 2000. However,

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as a transitional measure, the former local municipalities continued to operate as administrations within the Unicity. To complicate the situation further, various litter management strategies were implemented without prior consultation with the monitoring team in several of the catchments. This clearly had an impact on the quantities of litter measured in those catchments. The data obtained from the programme need to be seen against the background of these changes.

The urban litter problem

Types of litter

The consumer culture, to which most South Africans belong, creates a massive demand for the supply of all kinds of products. Plastics are often major constituents in the packaging of these products. Once the product is unwrapped, the discarded packaging frequently becomes a major contributor to the litter stream. The plastics could be in the form of bags, wrappings, containers, bottles, crates, polystyrene blocks, or straps. Whatever the form, a common finding in litter studies carried out in Coburg (Australia) (Allison and Chiew, 1995), Auckland (New Zealand) (Cornelius et al., 1994), Springs (South Africa) (Armitage and Rooseboom, 2000a), and Cape Town (South Africa) (Arnold and Ryan, 1999; Armitage and Rooseboom, 2000a) is that plastics are frequently the biggest problem. Even studies in very poor countries, for example the city of Bamako (Mali) (Ouedraogo et al., 2000), showed that whilst plastics formed only a small percentage of the total litter load, they became the majority once sand, stones and organic matter (including food remains) were excluded. An exception was in the urban centre of Bamako where the contribution of paper was of the same order as that of plastic. Plastics are a particularly acute problem in South Africa. Ryan (1996) noted that some of the pelagic seabirds visiting South African waters have among the highest levels of plastic ingestion recorded, with almost every Great Shearwater or Blue Petrel containing plastic in its stomach. Coastal clean-ups in the Western Cape confirm that the major component of coastal pollution is plastic waste, and that most of it originates from the land.

Plastics are not the only problem. Large quantities of paper are often found in the litter stream. For example, a study carried out into littering patterns in the informal urban settlements of Vingulgati and Mtambani in Dar es Salaam (Tanzania) indicated that paper predominated once sand, stones, and vegetable and organic matter (including food remains) were excluded (Kivaisi and Rubindamayugi, 2000). Other common components in the litter stream include cardboard, bottles, cans, bottle tops, rotten fruit and vegetables, and construction debris. More unusual types of litter that are also observed from time to time include motor car parts, dead animals, old clothing and old mattresses.

Factors influencing litter composition and quantity

The rate at which litter is deposited on a catchment and the composition of that litter is highly variable and depends on a large number of factors including the (Armitage and Rooseboom, 2000a):

- **Type of development**, e.g. commercial, industrial, or residential – generally commercial and industrial areas produce higher litter loading rates than residential areas
- **Density of development** – higher densities usually imply greater human activity therefore higher litter loads
- **Income level of the community** – it has been hypothesised that very poor people don't have access to many consumer products, hence they are not in a position to waste them or their containers
- **Type of industry** - some industries tend to produce more pollutants than others
- **Rainfall pattern**, e.g. does the rain come in one season only or year-round? Litter will build up in the catchment until it is either picked up by refuse removal, or is swept into the drains by a downpour. Long dry spells give greater opportunity to the local authority to pick up the litter, but also tend to result in heavy concentrations of accumulated rubbish being brought down the channels with the first rains of the season - the so-called "first flush"
- **Type of vegetation** in the catchment - in well-treed areas, leaves may form the major proportion of "litter" collected in traps with the highest proportions recorded in residential areas. This is particularly the case where there are many deciduous trees which drop their leaves over a short period in autumn. Whilst not strictly causing an environmental problem, they can interfere with stormwater drainage systems
- **Efficiency and effectiveness of refuse removal by the local authority** - it is important that the local authority not only clean the streets and bins regularly, but also that the cleansing staff do not sweep or flush the street litter into the stormwater drains
- **Level of environmental concern in the community** - leading to, for example, the reduction in the use of certain products, and the recycling of others
- **Extent of legislation** prohibiting or reducing waste, with which is associated the effectiveness of the policing of the legislation, and the level of the fines.

The human factor

Litter has been considered a social behavioural problem since the 1970s. *Keep America Beautiful*, a national litter education and prevention organisation in the United States, found that people litter for three reasons (Florida Center for Solid and Hazardous Waste Management, 1998):

- They lack a sense of ownership
- They believe that someone else picks up their litter
- The area is already littered.

The overwhelming conclusion is that people are too lazy to dispose of trash properly (Florida Center for Solid and Hazardous Waste Management, 1998; 1999).

It has been found that the presence of only two pieces of litter can lead a person to conclude, "Everyone litters here" (Cialdini et al., 1990). In South Africa and other developing countries where litter collections are often infrequent except in the central business districts, the consequences of this perception are all too plainly apparent. Meanwhile, the general inadequacy of litter refuse services leads to a rapid and sustained accumulation of litter.
The temptation to litter is also increased where there is a general failure by authorities to enforce effective penalties as a deterrent to offenders, and where littering is not as yet countered by a strong environmental ethic amongst the population at large. Once again, this appears to be the case in South Africa.

Overview of the scope of the problem in Cape Town

In common with many other South African urban areas, many basic services such as waste removal are unequally distributed throughout Cape Town. Furthermore, rapid urbanisation has frequently exacerbated the problem. Although the city has made immense strides to close the developmental gap in recent years, the extent of the problem is illustrated by the fact that in 2000, approximately 19% of residential dwellings housing the metro population of approximately 3 million people were classed as informal (Van Deventer, 2000).

According to the Cape Metropolitan Council's State of the Environment Report for 1998 (Cape Metropolitan Council, 1998), approximately 1m.t of solid waste was received at the landfill sites, amounting to about 1kg of waste per person per day. Estimates for the amount of litter entering the stormwater systems differ wildly. The same report estimated that about 87t of litter enters the stormwater system per year, including about 239kg of plastic bags per day. This is an order of magnitude less than the Ryan (1996) estimate of 4 million litter items weighing more than 2.5t entering the stormwater drains daily, equating to more than 900t/yr. Ryan's estimate was based on extrapolating actual average litter loads obtained from monitoring the outfalls from three small urban catchments in Cape Town. This huge difference underlines the considerable uncertainty in the actual figures, and hence the need for the study described in this paper.

The pilot catchments

Nine pilot catchments, representing a range of different land uses and socio-economic levels, were equipped with litter traps and monitored over two periods between 2000 and 2002. Among the various aims were:

- The desire to establish the source, type and amount of urban litter for some typical urban catchments
- To gain some understanding of how land-use, population densities, level of servicing and socio-economic levels affect these parameters.

Selection criteria

As a key starting point of this study was that littering patterns are to some extent linked to the socio-economic profile and level of service within a catchment, it was essential that catchments covering a range of different land uses, income levels, population densities and service levels be selected. Each of the then Municipal Local Councils (MLCs) which made up the former Cape Metropolitan Area (now all part of Cape Town) were requested to identify candidate catchments within their area for inclusion in the study. The criteria for the selection of the catchments were:

- The catchments should ideally be between 10 and 30ha in area with a maximum of 100 catch-pits. This was to keep the monitoring process manageable and limit the cost of installing catch-pit traps. On the other hand the catchment should not be too small lest the data be distorted by a single litter source such as a fast-food outlet, a supermarket, or a fresh produce market
- The catchment must not receive flow from other areas, i.e. it should be at the head of a drainage system
- Ideally all the catch-pits within a catchment should drain to a single outlet where any litter bypassing the catch-pit traps could be caught in a net
- The catchment should have a distinctive land-use and socio-economic profile
- The catchments should cover a range of different land uses, income levels, population densities and service levels
- At least one catchment covered by an informal or site and service area should be included. There is a particular lack of research on litter loadings from such catchments despite the acute litter problem in these areas.

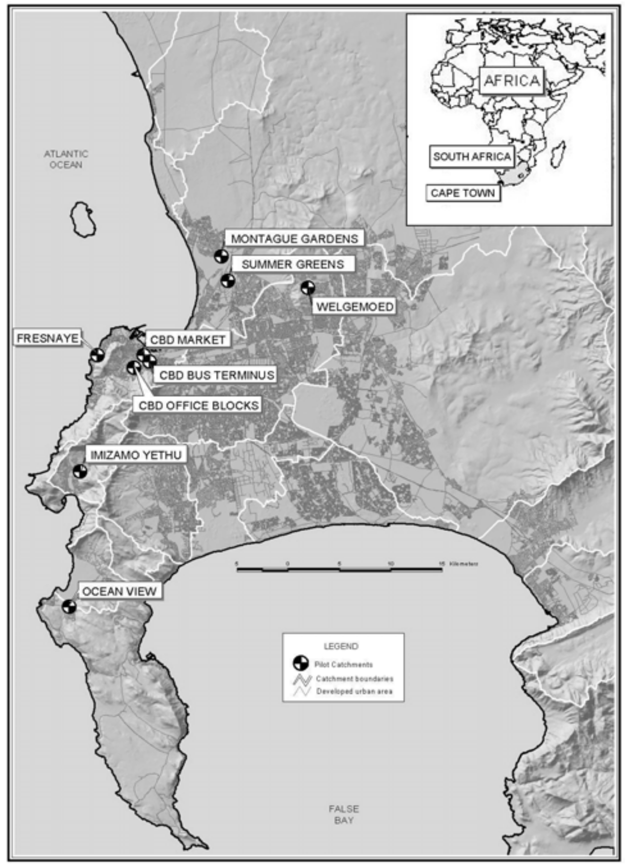

Figure 1
Map of the City of Cape Town showing the location of the nine pilot catchments

The pilot catchments selected

The following nine pilot catchments were selected. The average household incomes per annum are those given in the Census 1996 data (Statistics SA, 1996):

- Imizamo Yethu – a low income, (average of R21 000 per household per annum) high-density residential area comprised of site-and-service and informal (unplanned and, strictly speaking, illegal) plots
- Ocean View – a low income (average of R25 000 per household per annum), high-density residential area comprising a mixture of free-standing dwellings and apartments
- Summer Greens – a medium income (average of R75 000 per household per annum), medium-density residential area (free-standing dwellings)
- Fresnaye – a high income (average of R97 000 per household per annum), medium-density residential area (free-standing dwellings and apartments)
- Welgemoed - a very high income (average of R178 000 per household per annum), low-density residential area (free-standing dwellings)
- Cape Town Central Business District (CBD) – comprising mainly office blocks and hotels

- Cape Town CBD – comprising mainly an open-air market and row shops
- Cape Town CBD – comprising mainly a bus terminus
- Montague Gardens – light industrial park.

The approximate location of the pilot catchments is indicated in Fig. 1.

The pilot catchments ranged in area from 3.4 ha (for the market and row shops and the bus terminus in the Cape Town CBD) to 25.4 ha (Fresnaye) with an average area of 10.8 ha. They covered a wide range of topographies and vegetation types with significant variations in rainfall. Imizamo Yethu, Fresnaye and Welgemoed are situated on the sides of mountains or hills whilst the Cape Town CBD, Summer Greens and Montague Gardens are situated on flat terrain. The study area in Ocean View is characterised by gentle slopes. The mean annual precipitation in Imizamo Yethu exceeds 800 mm while the mean annual precipitation is less than 500 mm in Fresnaye.

Demographic profiles

Research carried out in the United States (Florida Center for Solid and Hazardous Waste Management, 1998) indicates that littering patterns are strongly linked to demographic profiles. To investigate this link, data from Census 1996 (Statistics SA, 1996) was used to compile the demographic and socio-economic profiles of the selected residential study areas. Although a more recent census took place in 2001 the results were not available at the time of the study. The motivation behind utilising such census data was to gain a broader understanding of the influence of socio-economic circumstances on the nature and amount of litter in these areas. The commercial study areas falling in the Cape Town Central Business District and the light industrial study area of Montague Gardens were not included for two reasons:

- The census data related to households and places of residence. The Cape Town CBD and Montague Gardens industrial park have few residents and their impact on littering is insignificant compared to that of the workers and passing vehicles in the area. Neither the people who commute to work in these areas nor traffic volumes are reflected in the census data.
- The set of characteristics should be comparable using a common reference system for all the catchments. This holds true for all the residential catchments where the characteristics are referenced per resident or household.

A literature review was carried out to guide the choices of "socio-economic" factors that could be extracted from the census database to formulate the socio-economic profiles of the catchments (Matzener, 2000). In the end, the selected characteristics could be divided into two main categories; basic demographics, and access to key services.

The basic demographics included:

- **Population group**. There are fundamental differences in the racial breakdown between the catchments. Imizamo Yethu was predominantly African/Black (87%). Ocean View was predominantly Coloured (95%), while Fresnaye and Welgemoed were predominantly White (81% and 91% respectively). Although the dominant population group in Summer Greens was White (47%), a significant number were Coloured (29%) or not specified (16%).
- **Age.** The age breakdown for the catchments also shows major differences. Although the proportion of the population below the age of 30 was similar in Imizamo Yethu, Ocean View and Summer Greens, the proportion of children below the age of 15 was greater in Ocean View (38%) than the other two areas. The relatively low proportion of children in Imizamo Yethu (22%) compared with Ocean View (38%) was possibly associated with the large proportion of males (70%) resident in Imizamo Yethu. The median age in Fresnaye and Welgemoed was older at 31 to 40 years than the other catchments at 21 to 30 years. In fact, over 20% of the population in Fresnaye was over 60 years of age compared to less than 10% in the other catchments. Imizamo Yethu and Summer Greens had a very low proportion of people over the age of 60 years (both 3%)
- **Type of dwelling and ownership.** Dwelling type and ownership are facets of a person's socio-economic status. Fresnaye and Ocean View were fairly evenly divided between ownership and non-ownership while the other catchments showed a predominance of ownership. However, in Imizamo Yethu this probably reflected the fact that the occupiers built their dwellings themselves (with, or without, permission) rather than a legal right of ownership (which, of course, would not apply to those dwelling on land invaded by them on the periphery of the formal "site and service" core). An examination of the dwelling type showed that 91% of Imizamo Yethu's residents lived in shacks constructed by them out of any material at hand at the time of the study, whereas more than 90% of the inhabitants in the other catchments lived in properly constructed houses or flats. In Summer Greens (97%) and Welgemoed (93%) inhabitants resided overwhelmingly in freestanding houses. In both Ocean View (39%) and Fresnaye (47%) significant proportions of the residents lived in blocks of flats
- **Employment status.** Imizamo Yethu (15%) and Ocean View (6%) had the greatest proportions of unemployed job seekers. Ocean View (35%) had the lowest proportion of employed people while Summer Greens (57%) had the highest
- **Individual income.** The individual monthly income level is considered here, not household income, as this can give an inaccurate picture (depending on how many members of a family work, for example). Fresnaye and Welgemoed had the greatest spread of incomes. The area with the highest median individual monthly income was Summer Greens (R1 501 to R2 000) although the area with the highest average household income was Welgemoed. It should also be noted that the proportions are biased by the "Unspecified" category which comprises over 23% of the inhabitants in the case of Imizamo Yethu. If most of these fall into the lowest earning categories the median income could have been considerably lower

The unequal access to services in the City of Cape Town was illustrated by the following characteristics:

- **Water supply.** The nature of the household water supply demonstrates the inequality in infrastructure between Imizamo Yethu and the other catchments. At the time of Census 1996 (Statistics SA, 1996), fewer than 20% of households in Imizamo Yethu had access to piped water in their dwelling, although 53% had access to piped water on their site. This compares with over 86% having access to piped water in their dwelling in all the other catchments. 40% of Imizamo Yethu households obtained their water from a "public tap".
- **Toilet facilities.** A similar pattern is evident with toilet facilities with only 56% of Imizamo Yethu households having flush or chemical toilets. More ominously the category "none

of the above" comprised 22% of Imizamo Yethu households. It is assumed this entails urination and defecation in the bush or public areas. In the absence of proper services, households might also be tempted to use the stormwater catch-pits as disposal points for night-soil (faeces deposited into a bucket) and refuse. Human faeces were indeed found in the Imizamo Yethu catch-pits on a number of occasions. 94% of Ocean View households had flush or chemical toilets whilst every household in the remaining catchments had a flush or chemical toilet.

- **Refuse removal.** The most critical household service relating to the problem of litter in the stormwater drainage systems is that of municipal household refuse removal. At the time of the Census (Statistics SA, 1996), only 52% of Imizamo Yethu households had their refuse removed at least once weekly and 24% had no refuse removal at all – presumably because they did not have legal right to the land they were occupying. In contrast, at least 97% of the households in the other catchments have their refuse removed at least once weekly. This must significantly increase the potential for household refuse to become part of the litter stream in the case of Imizamo Yethu.

Methodology

Trap installation

Initially it was envisaged that the routine monitoring and clearing of the traps would be conducted by the MLCs' cleansing field staff. Individual workshops in the four affected municipalities; South Peninsula, Cape Town, Blaauwberg, and Tygerberg were held to inform the field staff of the monitoring and recording procedure for the litter traps.

The Contractor commenced installing the litter traps and catchment outlet nets on 18 August 1999. The Imizamo Yethu, Ocean View, Summer Greens, Montague Gardens and Welgemoed catchments were handed over for monitoring on 26 November 1999 while the CBD catchments were handed over on 3 December 1999. The Fresnaye catchment was handed over much later on 28 February 2000.

The number of stormwater catch-pits equipped with traps in each catchment varied from 6 (draining the bus terminus in the Cape Town CBD) to 35 (Welgemoed) at an average density of 2.5 per ha. Each catch-pit was equipped with one or more litter traps (see Fig. 2). In the event of a spill from the catch-pit litter traps the litter should have been caught in the nets placed inside the catchment outlet pipes or at the grids placed at the outlets in the case of Imizamo Yethu, Ocean View and Summer Greens. These outlet pipes varied in diameter from 375 mm (Cape Town CBD) to 750 mm (Fresnaye, Montague Gardens).

Only the lower portion of Fresnaye was equipped with catch-pit traps although the outlet pipe was netted. This meant that those areas of Fresnaye along the main access route and amongst the blocks of flats could be studied in greater detail than the residential areas situated on the steep mountain slopes. This exception was made for reasons of economy in the installation and cleaning of the traps. Details of the pilot catchments are summarised in Table 1.

Monitoring procedure

Monitoring of the installed litter traps and nets began during January 2000 and ended in January 2002. It had originally been anticipated that the traps and nets in each catchment would undergo a routine clearout by the local authorities at least once a month. The following data were to be recorded on a standard recording sheet supplied to them:

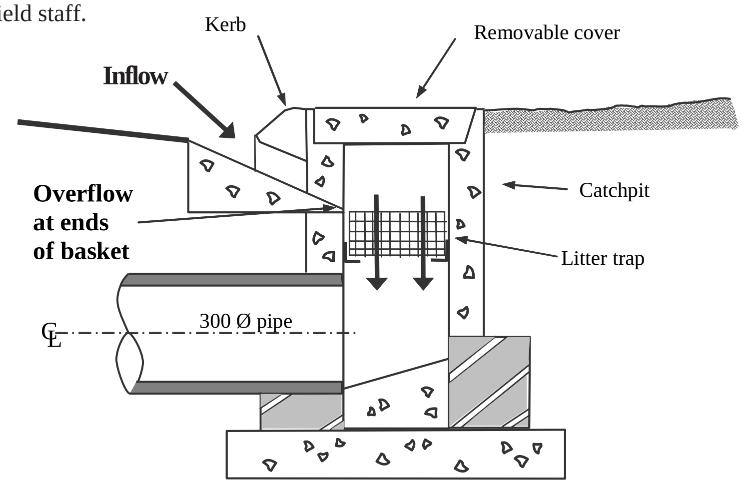

Figure 2 *Typical catchpit litter trap*

TABLE 1
Details of the pilot catchments

Catchment code	Suburb	Former MLC	Area (m²)	Side inlet catchpits (No)	Grid catchpits (No)	Catchment outlets (No)
A	Imizamo Yethu	South Peninsula	53 150	6	15	1 (525ϕ)
B	Ocean View	South Peninsula	115 250	29	5	1 (450ϕ)
C	Cape Town CBD	Cape Town	66 000	9	23	1 (450ϕ)
D	Cape Town CBD	Cape Town	34 000	-	14	1 (525ϕ)
E	Cape Town CBD	Cape Town		-	6	1 (375ϕ)
F	Fresnaye	Cape Town	254 000	-	20	1 (750ϕ)
G	Summer Greens	Blaauwberg	53 200	8	15	2 (600ϕ,300ϕ)
H	Montague Gardens	Blaauwberg	140 685	16	14	1 (750ϕ)
I	Welgemoed	Tygerberg	144 000	-	35	1 (600ϕ)
ALL			**860 285**	**68**	**147**	**10**

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TABLE 2
Litter classification system

Main categories	Subcategories	Examples of items
1. Plastic	1.1 Packaging 1.2 Polystyrene 1.3 Containers 1.4 Miscellaneous	Shopping bags, wrapping. Polystyrene blocks and pellets, cooler boxes. Containers, bottles, crates. Straws, straps, ropes, nets, music cassettes, syringes, eating utensils.
2. Paper	2.1 Packaging 2.2 News/stationery 2.3 Cardboard 2.4 Miscellaneous	Wrappers, serviettes. Newspapers, advertising flyers, ATM dockets. Food and drink containers, bus tickets.
3. Metal	3.1 Cans 3.2 Miscellaneous	 Foil, bottle tops, number plates.
4. Glass	4.1 Bottles	
5. Vegetation	5.1 Leaves and branches 5.2 Food	 Rotten fruit and vegetables.
6. Sediment	6.1 Sand	
7. Miscellaneous	7.1 Animal 7.2 Construction material 7.3 Cloth 7.4 Fibre-glass 7.5 Miscellaneous	Dead dogs and cats, sundry skeletons. Shutters, planks, timber props, broken bricks, lumps of concrete. Old clothing, rags. Shoes, sponges, balls, pens and pencils, balloons, oil filters, cigarette butts, tyres.

- The date of the clearout
- The duration of the rainfall and precipitation (if any) during the period preceding the clearout
- The total volume of litter removed from the streets and from the dustbins in the catchment between clearouts
- The degree of fullness of each uniquely numbered trap and outlet net.

Initially, a detailed analysis was only to be undertaken once a month in each catchment during the rainy season (April to September). In addition to recording the above data, the contents of each trap and net were to be emptied into large bags clearly labelled with the trap/net reference number for sorting and detailed analysis in the UCT Laboratory. To carry out the sorting and detailed analysis of the litter, an independent *Waste Auditor* was appointed full-time for six months over the winter period April to September of 2000 with the intention of having a second six month appointment in 2001. In the course of the six months the *Waste Auditor* should have been able to carry out about six full analyses of each catchment at a rate of about two per week. As it turned out, the *Waste Auditor* played a vital role in ensuring that trap contents were collected and analysed in an accurate and consistent way. His tasks were soon modified to include:

- Carrying out checks on each catchment in the field to ensure that the local authority teams were properly clearing the catch-pits
- Assisting with the entry of field data on the standard recording sheet. Although this was done by the local authorities' teams it was found to be essential that the *Waste Auditor* assist with this function from experience gained in April to September of 2000. Without supervision, the local authority teams did not record the data correctly and tended to assign the same degree of fullness to every trap.
- Working with the local authority team collecting litter for a detailed analysis to ensure that bags were correctly labelled with trap and net numbers before being transported to the UCT Laboratory.
- Sorting, weighing, and measuring the bag contents in the laboratory; recording the results onto a standard check list; and transferring them from the checklist onto the project database. The results recorded were the trap contents by type and mass and the likely sources of litter.

The hierarchical classification system set out in Table 2 was employed for recording the litter items. The main categories were selected on the basis of research experience from elsewhere (Armitage and Rooseboom, 2000a). This classification system allowed considerable flexibility as it could be further subdivided as the study progressed if it was thought to be important to record the incidence of a specific item. For example plastic potato chip packets were often encountered in Ocean View. Implementing a litter reduction strategy that targeted this one item might significantly reduce the amount of litter emanating from this catchment. This would not have been apparent if the incidence of this specific item was not monitored nor recorded.

Experience gained on site over the first monitoring period (January to September 2000) also led to a number of changes to the monitoring procedure particularly during the second main monitoring period from February 2001 to January 2002:

- From October 2000 onwards, the local authorities were asked to deliver the litter collected from their routine clearouts in clearly labelled bags to the UCT laboratory as for the detailed clearouts so that the total mass of each bag could be determined and recorded for routine clearouts. This was requested because the degree of fullness of traps had been found to be inconsistently recorded by the local authorities. The volume derived from the degree of fullness of the trap was also found to be an unreliable indicator of mass as the densities of the litter varied so widely. Sorting into different litter categories was not however carried out for these routine clearouts.

- With notable exceptions it was found that without independent supervision it could not be guaranteed that the data was collected by the local authorities in such a way that its integrity was assured. In particular the degree of fullness recorded was found in many cases to be almost completely arbitrary. As a consequence it was decided to employ the *Waste Auditor* for the entire 12-month monitoring period commencing February 2001 so that he could accompany all collections.
- It was also decided to dispense with the counting of litter items in 2001 as this had proved extremely time consuming and once the litter profile had been established there was little need to continue with this. Litter counts do however give a better indication of the aesthetic impact of lighter materials such as plastic bags and packaging which can appear to be negligible in terms of mass. The litter count profiles obtained in 2000 are included in the **Appendices** of the final report to the WRC (Marais and Armitage, 2003).
- Partly due to the large mass of silt accumulating in the Imizamo Yethu traps, the clearing on a monthly basis conducted in 2000 had proven to be inadequate. Blockage of catch-pits had occurred with consequent limited flooding. The frequency of clearing was thus increased to once a week from mid May of 2001 to lessen the chances of the traps filling to capacity and causing flooding between clearouts, and to ease the task of removing the baskets by reducing the weight of the litter and sediment trapped in them. Following the same reasoning, the frequency of clearouts in Ocean View was increased with clearouts taking place on a fortnightly basis from mid May 2001. Meanwhile the frequency of clearouts for Summer Greens and Welgemoed was decreased to once every second or third month owing to the small litter loads in those catchments. The frequency of clearouts for the other catchments was maintained at roughly once a month.

Constraints and lessons learned

The catch-pits equipped with litter traps (wire baskets) were of three basic types; those with side inlets only, those with horizontal grid covered inlets and those with both side inlets and horizontal grid covered inlets. In the case of the latter type the litter baskets were found to trap only a portion of the litter. For fear of blockages leading to flooding, the baskets did not generally fill the entire catch-pit, but allowed for an overflow section at the back. The items found in the baskets were mostly the smaller items (e.g. small paper and plastic wrappings) while the larger items tended to escape the basket. Sometimes they were wedged in the gap between the basket and the back of the catch-pit. All the litter trapped in the catch-pits, both inside and outside the baskets, was however collected and recorded. Furthermore, the litter escaping the catch-pit was generally captured in the downstream nets / grids. Based on the quantities trapped in the catch-pit types not manifesting this shortcoming, the data loss was less than 10%. The incidence of this situation was also noted when encountered.

From time to time, missing baskets and / or nets, or difficulties in the opening of catch-pit lids complicated data collection. This was due to a number of reasons which included traps being stolen or not yet being installed, and the removal of nets due to flooding. During the course of 2001 the missing traps and nets were replaced with the most severely affected areas of Imizamo Yethu and Ocean View enjoying precedence.

Another problem was inherent in the classification and recording of the litter items. Certain litter items have an impact on the environment (even if aesthetic only) which is disproportionate to their mass or volume. Statistically, litter items contributing a small percentage to the litter loading in terms of mass or volume should not be assigned a subcategory. However, if there is a high incidence of the items they may still merit a separate sub-category. An example is plastic shopping bags that have a noticeable and persistent negative impact on the environment even though their contribution by mass or volume to the litter stream was always low. They were therefore assigned a separate subcategory.

Throughout the study, it was apparent that the litter environment within South Africa was rapidly changing making it impossible to determine accurate baseline litter data. Examples of this were:

- The declaration by the Minister of Environmental Affairs that the minimum specification for polyethylene shopping bags was to be substantially increased and that a deposit was now payable, which in turn impacted the numbers of bags finding their way onto the streets.
- Cape Town introduced a minimum street sweeping service in all the areas under its jurisdiction.
- Increasingly local authorities, NGOs and ratepayers became more pro-active in reducing the quantity of litter in the environment.

Even within the pilot catchments, the data were affected by local initiatives. In Imizamo Yethu, a litter awareness campaign involving the training of co-ordinators from within the community by the Fairest Cape Association in the first year of monitoring undoubtedly helped to reduce the quantity of litter finding its way into the drainage system. The installation of grates over catch-pit openings in Summer Greens and Montague Gardens by the Blaauwberg MLC in the second year of monitoring had a similar effect. Unfortunately, both these two initiatives were carried out without prior consultation with the research team and undoubtedly led to an underestimate of litter generation rates. This must be borne in mind when examining the litter data.

Litter data gathered

The litter data gathered show that an analysis by mass is distorted by the large volumes of sand that were washed into the catchments. This was particularly so in the case of Imizamo Yethu (95% sand by mass) and Ocean View (69% sand by mass) and, to a lesser extent, Summer Greens (30%) and Montague Gardens (37%). In the Cape Town CBD catchments, very little sand was recorded in 2000 although a large increase was noted in the vicinity of the open air market and row shops in 2001. Strictly speaking, sand cannot be quantified as litter although it is a problem that needs to be addressed. Construction materials such as rubble and stone, or vegetation, likewise tended to dominate the data and reduce the impact of the conventional litter items which were the focus of the study. The results are thus reported in Table 3 in three ways:

- Excluding sand
- Excluding sand, stone, vegetation and rubble (what most people would understand as urban litter)
- Vegetation only (because vegetation can easily fill litter traps even in the absence of appreciable quantities of urban litter)

In each instance, there are three columns representing the first monitoring period that ran from February to September of 2000 (2000), the second monitoring period that ran from February 2001 to January 2002 (2001), and the two periods combined (2000/2001). Table 4 focuses on the two key litter items; plastics and paper

TABLE 3
Pilot catchment litter data

Catchment name	Annual litter loads(kg/ha.yr)								
	Excluding sand			Excluding sand, stone, vegetation and rubble			Vegetation only		
	2000	2001	2000/ 2001	2000	2001	2000/ 2001	2000	2001	2000/ 2001
Imizamo Yethu	67	55	58	59	40	45	1	11	8
Ocean View	130	84	102	72	19	41	42	60	53
Cape Town CBD (C)	69	66	67	42	14	23	26	50	42
Cape Town CBD (D)	87	56	65	46	10	22	41	42	41
Cape Town CBD (E)	155	94	113	111	35	59	40	44	43
Fresnaye	-	62	62	-	0	0	-	62	62
Summer Greens	20	11	14	6	6	6	2	3	3
Montague Gardens	86	22	45	51	14	28	5	1	2
Welgemoed	27	30	29	0	0	0	27	29	29

TABLE 4
Plastics and paper only (combined monitoring periods)

Catchment name	Description	Area(ha)	Annual load 2000/2001 Plastic (kg/ha.yr)	Annual load 2000/2001 Paper (kg/ha.yr)
Imizamo Yethu	Informal "site and service" residential area for very poor people – no street sweeping	5.3	23	4
Ocean View	Sub-economic residential area for poor people including both freestanding dwellings and 3-storey high-density apartment blocks– no street sweeping	11.5	16	5
Cape Town CBD (C)	Central Business District including office blocks, hotels, line shops, informal traders and a bus terminus, extensive street sweeping (up to 3 times daily) with a removal efficiency of approximately 99%	6.6	9	3
Cape Town CBD (D)		2.0	7	3
Cape Town CBD (E)		1.4	12	6
Fresnaye	High income, medium density residential area which includes some apartments	25.4	0	0
Summer Greens	Medium density, medium income residential area – no street sweeping	5.3	1	1
Montague Gardens	Light industrial park – no street sweeping	14.1	6	3
Welgemoed	Low density, high income residential area – no street sweeping	14.4	0	0

(averaged over both monitoring periods). The breakdown in the types of material trapped is summarised in Fig. 3. The "miscellaneous" category includes rubble and stone.

With the exception of Ocean View in 2000, an increase in income level was generally matched by a decrease in litter load in the residential areas when sand, stone rubble and vegetation were omitted. This trend was particularly marked between low (Imizamo Yethu) and medium income catchments (Summer Greens) where litter loads were 45 and 6 kg/ha·yr respectively for the combined period. An explanation for this is that formal residential areas generally receive a reliable and effective household refuse removal service while informal areas frequently do not. Also, as income rises, population density generally decreases resulting in fewer people to litter. Thus, whilst the litter load per unit area in Imizamo Yethu was over seven times that in Summer Greens, it was only double when measured per person (0.10 and 0.05 kg/person·yr in Imizamo Yethu and Summer Greens respectively).

The effect of omitting vegetation, stone and rubble in addition

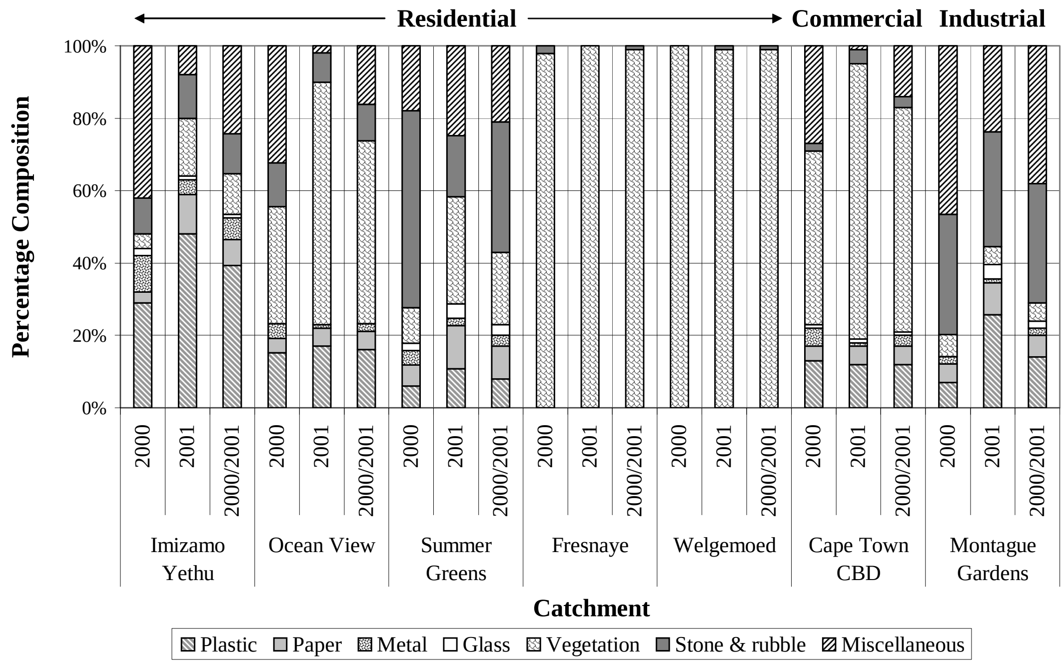

Figure 3
Breakdown in litter composition by catchment and year

to sand is particularly marked in Ocean View where the litter load dropped by 54% and in Fresnaye and Welgemoed where it effectively dropped to zero. The litter load in Summer Greens for 2000 was reduced by 70% (20 to 6 kg/ha·yr) when stone, vegetation and rubble were excluded in addition to sand. As the contribution of vegetation to the litter load was small (2 kg/ha·yr), this suggests that the illegal dumping of builder's rubble contributed significantly to the litter load in this area in 2000. Following the installation of grates over the catch-pit openings in this area in the spring of 2000, the stone and rubble load decreased from 12 kg/ha·yr in 2000 to 2 kg/ha·yr in 2001. In Montague Gardens the litter load for 2000 was reduced by 41% (86 to 51 kg/ha·yr) when stone, vegetation and rubble were excluded in addition to sand. This again suggests that illegal dumping of builder's rubble was taking place. As was the case in Summer Greens, the stone and rubble load was greatly reduced, in this case from 30 kg/ha·yr in 2000 to 7 kg/ha·yr in 2001, following the installation of grates in the spring of 2000.

It is instructive to note that the annualised litter loads for vegetation are of the same order as the urban litter loads (total load excluding sand, stone, vegetation and rubble). However, Summer Greens had a surprisingly low vegetation load for a residential area. This may have been due to the lack of deciduous trees and / or well-developed gardens in this comparatively new suburb.

The effectiveness of street sweeping and refuse bins in the CBD catchments was determined from measurements taken from six collections and then annualised (Table 5). They give a clear indication of the importance of these two operations and the quantities of litter generated in the CBD catchments. Since the masses measured in the catch-pits were only 1 and 3% of the total removed by the Municipal Cleansing Department, it indicates that the litter loads could have been up to 100 times as great were it not for the efficiency of the street sweeping and bin collection services. The street sweeping was carried out two to three times a day on weekdays. In the morning and again in the afternoon, litter was swept by hand into bags and removed by vehicle. In high litter areas (for example in the vicinity of restaurants and night clubs), the streets were swept mechanically late at night/very early in the morning after most people had gone home).

TABLE 5
Litter intercepted by street sweeping and removed from bins in the CBD

Catchment	Street sweeping (kg/ha·yr)	Bins (kg/ha·yr)	Total (kg/ha·yr)
C	1 852	437	2 289
D & E	4 836	8 527	13 363

Discussion of the litter data

Principal findings

A general trend is that the percentage contribution of plastic to the litter load rose in all catchments from 2000 to 2001. If the "miscellaneous" category is excluded, the litter category responsible for the largest contribution to the litter load in all the catchments, except Summer Greens and Welgemoed, was plastics. In those catchments the category responsible for the largest contribution was paper. In the case of Welgemoed and Fresnaye, vegetation accounted for 99% of the total litter load when sand was excluded.

The principal findings from the analysis of the data are:

- Comparison of the data from 2000 and 2001 shows that the contribution of plastic to the litter load increased across all the catchments.
- There appears to be an inverse relationship between income and litter loadings in residential areas when garden refuse is excluded. This is largely due to the more effective and reliable household refuse removal service enjoyed by the affluent areas (bearing in mind that in some parts of Imizamo Yethu, there was no municipal service at all). However when litter loadings are measured and compared per person rather than per unit area, it becomes obvious that the inverse relationship is also exagger-

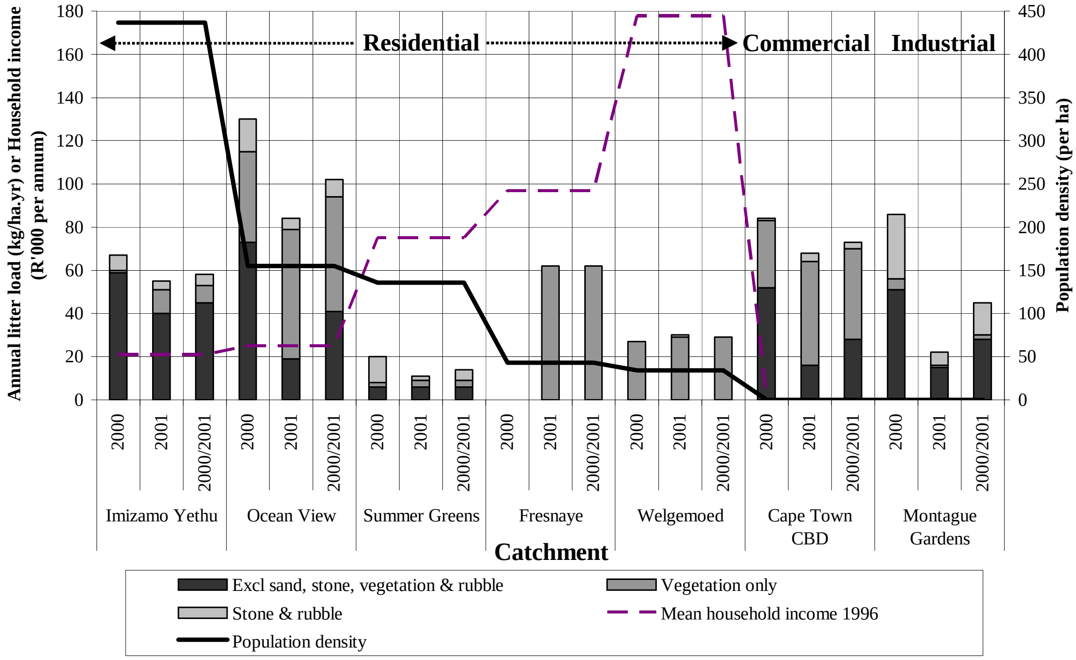

Figure 4
Summary of litter data results

ated as a result of the tendency for population density to decrease with increasing income.

- The installation of grates over catch-pit openings resulted in a significant decrease in the amount of litter trapped in catch-pits in Summer Greens and Montague Gardens.
- There was a significant reduction in litter loads in Ocean View during the monitoring period. The sensitizing of the community to littering issues from the end of 2000 and a more frequent and comprehensive litter removal service by the local authority are plausible reasons for this improvement.
- Sand entering the catch-pits is a major problem in many catchments as it tends to become entrained in other litter such as plastic bags resulting in blockages and flooding of the stormwater system. The problem is particularly acute in informal areas such as Imizamo Yethu which have very little ground cover to stabilise the soil.
- Street sweeping is an extremely effective method of reducing the quantity of litter reaching the stormwater system as has been demonstrated in the Cape Town Central Business District.
- Construction rubble is a significant contributor to the waste stream. Catch-pit grates are an effective way of reducing the amount of rubble entering the stormwater drainage system.
- Plastic items contributed between 19% and 50% of the litter stream by mass when sand, stones, vegetation and rubble were excluded. Plastics were the largest major litter category in all the catchments except for Summer Greens and Welgemoed.

Figure 4 summarises the principal findings for the pilot catchments for the period February 2000 to January 2002. The mean household income figures are derived from the 1996 census. It should be noted that problems with the data collection in Imizamo Yethu might have led to an under-measurement and hence an underestimate of the annual litter loads for this catchment.

Comparison of findings with other similar studies

From Table 4 it can be seen that the highest litter loads of plastic items for the pilot catchments were from the low-income residential areas of Imizamo Yethu and Ocean View. The loads of paper items from these low income residential areas were similar to those from the commercial and light industrial areas. If these low- income residential areas are excluded it can be seen that higher loads of plastic and paper items were transported to drainage systems from commercial than residential or light industrial areas. This trend was also suggested by the Coburg Study, Australia (Allison and Chiew, 1995) which, however, did not include low-income residential areas. The Marine Litter Study carried out in Cape Town (Arnold and Ryan, 1999) found that the lowest annual load of plastic items was from the upper-income residential area of Milnerton (approximately 1 kg/ha·yr while both the industrial area of Paarden Eiland (74 kg/ha·yr) and the mixed commercial and residential area of Sea Point (5 kg/ha·yr) had higher annual loads (Arnold and Ryan, 1999). When sand, stones, vegetation and rubble were excluded the percentage contribution by mass of plastic items ranged from 19 to 50% for the pilot catchments. The comparative figures were 33 to 60% for the Coburg Study (Allison and Chiew, 1995) and 34 to 57% for the Marine Litter Study.

The annual litter loads for the residential pilot catchments, excluding sand, stones, vegetation and rubble, ranged from 0 to 72 kg/ha·yr (Table 3). However the range reduces to 0 to 6 kg/ha·yr if the low income residential areas of Imizamo Yethu and Ocean View are excluded. This compares with 0.5 kg/ha·yr obtained for the residential catchments in Auckland (Cornelius et al., 1994) and 4 kg/ha·yr for the residential area of Milnerton under the Marine Litter Study (Arnold and Ryan, 1999). The annual litter loads for the light industrial area of Montague Gardens were 51 kg/ha·yr in 2000, 14 kg/ha·yr in 2001 and 28 kg/ha·yr for the combined period 2000/2001. The latter figure is comparable with the annual litter load of 30 kg/ha·yr for the entire Coburg catchment, but is orders of magnitude greater than the figure of 0.9 kg/ha·yr for the industrial areas in Auckland. On the other hand the comparative figure for the industrial area of Paarden Eiland under the Marine Litter Study was 138 kg/ha·yr (Arnold and Ryan, 1999), which is more than double that for Montague Gardens in 2000. For the study carried out in Springs (Armitage et al., 1998), where the catchment was 85% commercial and industrial, the litter loading was 82 kg/ha·yr.

The annual litter loads for the commercial areas in the Cape Town CBD ranged from 42 to 111 kg/ha·yr in 2000 and 23 to

TABLE 6 Land use within the City of Cape Town (* indicates negligible contribution to the litter load)		
Land use	**Area (ha)**	**%**
Residential	38 034	13.3
Manufacture	4 732	1.7
Retail	1 521	0.5
Offices	1 969	0.7
Halls, Stadiums & Entertainment facilities	983	0.3
Taxi Ranks etc.	198	0.1
POS, green belts and open land *	11 783	4.1
Agriculture *	206 954	72.2
Other (e.g. National Park) *	20 460	7.1
Totals	**286 634**	**100.0**

59 kg/ha·yr in 2001. This is comparable to the figure of 82 kg/ha·yr for the Springs Study catchment but is one to two orders of magnitude greater than the figure for the Auckland commercial catchments of 1.3 kg/ha·yr. A general observation is that all the litter loads measured in Auckland (New Zealand) appear to be at least an order of magnitude lower than in the equivalent pilot catchments in the City of Cape Town.

In the pilot catchments, sand contributed as much as 96% and 71% of the litter loads in Imizamo Yethu and Ocean View respectively in 2000. A study carried out in Bamako, Mali (Ouedraogo et al.,2000) also attests to the problem of sand and sediment in low income informal areas. In Bamako the percentage contribution from soil in household refuse from the lowest income areas was 56%.

Garden refuse contributed 99% of the litter load, where sand was excluded, in the high income residential areas of Fresnaye and Welgemoed. A similar finding was made in Coburg, Australia (Allison and Chiew, 1995) where garden refuse contributed 85% of the litter load.

Conclusions relating to the analysis process and comparisons with other similar studies

The principal findings from the analysis of the data are set out in detail above. The following comments relate to the analysis process and comparisons of the results with other similar studies:

- An analysis of litter by mass can easily be distorted by large volumes of sand that may wash into sampling traps. Construction materials, such as rubble and stone, or vegetation can likewise dominate the data and reduce the impact of the conventional litter items. Because of this, the data should be analysed in at least the following three ways; excluding sand, excluding sand, stone, vegetation and rubble; and including vegetation only.
- Plastic items are a major and increasing contributor to the litter load. Moreover their detrimental aesthetic impact and effect on aquatic wildlife far outweigh their contribution by mass. Special attention should therefore be paid to measuring plastic items.
- Litter loads in low-income informal residential areas are always likely to be considerably higher than those in formal residential areas largely as a result of higher population densities and inferior and / or irregular refuse collection services.
- Litter loads in middle- and high-income formal residential areas are likely to be considerably lower than in commercial or industrial areas. This is despite the fact that street sweeping only rarely takes place in the residential areas. The low litter loads are probably due to the efficient and regular refuse collection services in these areas, the smaller movement of people through the area, and the greater sense of ownership. Community awareness of the environmental consequences of littering is also likely to be strong.
- Garden refuse can be expected to be a major contributor to litter loads in South African high-income residential areas (more than 90% by mass).

Estimating the amount of urban litter entering the stormwater drainage systems of the City of Cape Town

The following section shows how the litter-generation information can be extrapolated to quantify the amount of urban litter entering the stormwater drainage systems of the City of Cape Town.

Physical description

Cape Town (Fig. 1) has a total gross area of approximately 2 866 km^2 and contains numerous relatively small catchments. The area experiences a Mediterranean climate with winter rainfall. If the streams and rivers associated with the small catchments flow at all during the dry summer months, it is generally only as a consequence of effluent discharge from the several wastewater treatment works. The mean annual precipitation varies considerably across the study area from a little over 400 mm in the north to approximately 2 400 mm at the cable station on the top of Table Mountain. It is 508 mm at Cape Town International Airport, and 1 465 mm at the National Botanical Gardens at Kirstenbosch.

The land use varies, and includes agricultural, residential, commercial and industrial activities. A breakdown of the various land uses in the study area is given in Table 6. The land uses marked with an asterisk are those that do not generate significant volumes of litter and were thus not included in the calculations.

Methodology

Cape Town was split into its main land uses using information supplied on GIS. Eleven litter-producing land- use categories were identified:

- Informal settlements
- Low-density residential
- Medium-density residential
- High-density residential
- Manufacture / Industrial
- Retail
- Offices
- Halls, stadiums and entertainment facilities
- Taxi ranks and transportation interchanges
- Schools
- Hospitals

Each of these land-use groupings was assigned its own distinct litter generation characteristics. In defining low, medium and high density for residential areas, the following criteria were used:

- Low density: 0.5 to 50 persons/ha.
- Medium density: 50 to 175 persons/ha.
- High density: > 175 persons/ha.

TABLE 7
Litter loadings used in this study

Land use type	Assumed litter load excl. vegetation and sand (kg/ha.yr)	Vegetation load - location specific (kg/ha.yr)
Informal Settlements (on the banks of canals)	6 000	10
Informal Settlements (elsewhere)	50	10
Low Density Residential	1	30
Medium Density Residential	10	30
High Density Residential	50	50
Manufacture/Industrial	45	5
Retail	1 250	40
Offices	25	40
Halls, Stadiums & Entertainment Facilities	300	30
Taxi Ranks etc.	3 500	40
Schools	100	30
Hospitals	25	40

These criteria are based on recognised town-planning guideline documents such as *Guidelines for the Provision of Engineering Services and Amenities in Residential Township Development* (Department of Housing in collaboration with the National Housing Board, 1995).

The litter loading rates eventually used (Table 7) were determined with the aid of the data obtained in the course of the study, modified by audits carried out in the Lower Salt and Upper Lotus River catchments and rounded off. It must be emphasised that they are only estimates.

Assigning a litter generation characteristic to the informal settlements was particularly problematical as the quantities are extremely sensitive to the level of refuse service offered, and the existence of formal drainage. At the time of the study, there were many informal settlements that did not have a regular municipal refuse service. There were also many that did not have formal drainage. Where informal settlements lack both regular refuse removal and formal drainage, litter deposition into open stormwater canals occurs generally by means of direct dumping. The loading in these areas was thus estimated from the following assumptions:

- Dumped refuse originates from dwellings within 50 m of the river (easy walking distance)
- Density: 200 dwellings/ha
- Refuse per dwelling unit: 1 kg per week (rough estimate)
- Portion dumped into canal: 30%

These assumptions, which are considered to be conservative, resulted in an estimated litter load for informal settlements located on the banks of an open canal or river of approximately 6 000 kg/ha·yr. This rate was used only for those portions of the informal settlements adjacent to open drainage channels in the litter generation calculations. A litter loading rate of 50 kg/ha·yr was used for informal settlements that had both a regular refuse system and a proper drainage system.

The total litter load in the waterways for each land use in the study area is a product of the area, the litter generation for that land use, and the fraction of material not removed by street sweeping. Since the GIS land-use data were based on net areas (i.e. erven / plots only) excluding the associated road reserves, whilst the loading data (kg/ha·yr) is based on gross areas (i.e. erven / plots plus roads), the net areas had to be converted to gross areas using a factor calculated by comparing the net and gross areas on a random sampling of cadastral plans. The litter load equation by land use was thus:

$$T_L = \frac{A_G}{f_{EG}}.L_G.(1-\eta)$$

where:

- T_L = total annual litter load in the waterways for a specific land use (kg/yr)
- A_G = gross area (ha)
- f_{EG} = fraction of the gross area that is erven / plots only
- L_G = litter generation per gross area for the specific land use (kg/ha·yr)
- η = litter removal efficiency by street sweeping

The litter removal efficiency by street sweeping value was determined from Armitage (2001). The total annual litter load in the waterways for the entire study area was then calculated as the sum of the litter loads generated by each land-use category in the study area, as follows:

$$T_{catch} = \sum_{i=1}^{11} T_L^i$$

where:

- T_{catch} = total annual litter load for the study area (kg/yr)
- T_L^i = total annual litter load in the waterways for each specific land use (kg/yr).

Litter load computation

The litter load reaching the drainage system in the City of Cape Town was estimated as 3 544 t/yr based on 2003 land-use data and some assumptions regarding the levels of refuse service in the informal settlements, and the level of street sweeping services in the high litter generating areas (Table 8). In reality, the uncertainties associated with the estimation mean that it can only be said that, at best, the load is in the region of 3 000 to 4 000 t/yr. Also, the changing service levels in the city continue to influence the computed litter load. The results are instructive nevertheless. They show that the Ryan (1996) figures were of the correct order of magnitude. They also show that the big litter generators within the city are the informal settlements (34.6%) and retail facilities (30.0%).

In the absence of street sweeping, the total litter load was computed as 4 889 t/yr showing the value of this form of litter control. Without street sweeping, the percentage of the load generated by the informal settlements dropped to 25.2%, whilst the contribution from retail increased to 38.9%. On the other hand, it must be borne in mind that, to be effective, street sweeping needs to be frequent and properly supervised (otherwise there is a danger that litter is swept into the catch-pits). This is expensive and can only be justified in areas of heavy loading, e.g. the retail areas.

Armitage and Rooseboom (2000b) estimated the cost of removing urban litter from the drainage system as being between 137 and 3 874 R/m^3. Using a litter load of 3 000 t/yr, a litter density of 95 kg/m^3, a trap efficiency of about 86%, and a low average removal cost of 250 R/m^3, the cost of removing the urban litter load from the streams and rivers of Cape Town is at least R7 million per year at current costs. Some 14% or about 560 t/yr will still escape to pollute the environment. It is clearly a problem that needs attention.

Conclusions

TABLE 8
Litter generation in the City of Cape Town estimated from 2003 data

Land use type	Assumed litter loading (kg/ha·yr)	Effective area (ha)	Loading (kg/yr)	% of total loading (%)
Informal Settlements (on the banks of canals)	6 000	190	1 142	32.2
Informal Settlements (elsewhere)	50	1 714	86	2.4
Low Density Residential	1	25 378	21	0.6
Medium Density Residential	10	9 803	82	2.3
High Density Residential	50	949	40	1.1
Manufacture/Industrial	45	4 732	141	4.0
Retail	1 250	1 521	1 063	30.0
Offices	25	1 969	31	0.9
Halls, Stadiums & Entertainment Facilities	300	983	214	6.0
Taxi Ranks etc.	3 500	198	444	12.5
Schools	100	3 208	262	7.4
Hospitals	25	791	17	0.5
Totals		**51 436**	**3 544**	**100**

The wash-off of solid waste – here called urban litter – into the drainage systems of urban areas is a major problem. Litter management in South Africa is currently, however, severely hindered by the lack of good quality data on the quantities and types of urban litter emanating from different types of land use. A monitoring programme was thus implemented on nine sub-catchments representing various land uses and demographic profiles located within the boundaries of the City of Cape Town to measure quantities of urban litter, vegetation, and building debris. It proved to be quite difficult to obtain "accurate" results because so many factors influence litter loading. Also, various litter management options, implemented by others in the course of the study, undoubtedly affected the litter loadings. Nevertheless, the data that were collected are undoubtedly the best indications yet of the quantities of urban litter reaching the drainage system in a South African city. The latter part of the paper shows how these data can be used as input to a GIS-based model of the City of Cape Town in order to estimate the quantity of urban litter that is currently entering the drainage systems of that city. This has potential as a management tool.

Acknowledgements

Most of the information contained in this paper emanates from a project co-funded by the WRC of South Africa and the then Cape Metropolitan Council (now part of the City of Cape Town). The project is fully described in the report published by the WRC entitled: *The measurement and reduction of urban litter entering stormwater drainage systems* (Marais and Armitage, 2003). The methodology for estimating the amount of litter entering the stormwater systems was funded by the then Cape Metropolitan Council: Catchment Management Branch (now part of the City of Cape Town) and described in a report entitled: *Litter Removal: Salt and Lotus Rivers* (City of Cape Town, 2001).

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