

## 2. The amount of litter coming off urban catchments

### 2.1 Introduction

It is important for designers to be able to estimate the amount of litter coming off urban catchments because that will determine the volume of material that the trap must hold together with the frequency of cleaning. However, the rate of litter production is highly variable depending on a large number of independent factors including:

**the type of development**, ie. commercial, industrial, residential;

**the density of development**;

**the income level** of the community - poor people in poor countries don't have access to many products, hence are not in a position to waste them or their containers;

**the type of industry** - some industries tend to produce more pollutants than others;

**the rainfall patterns**, ie. does the rain come in one season only or all the 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";

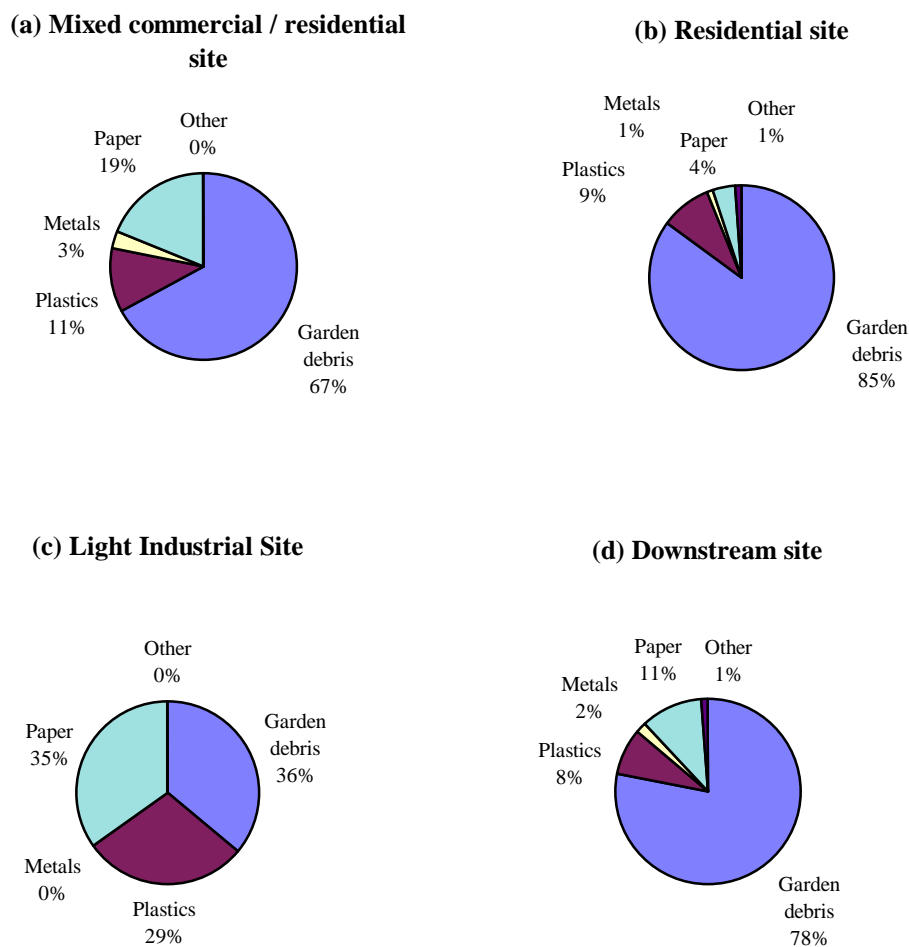
**the type of vegetation** in the catchment - in Australia for example, leaves form the majority of "litter" collected in traps. Some species of trees cause more problems than others eg. plane trees have relatively large leaves which are slow to decompose and are mostly shed over a very short period in Autumn;

**the 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 sweepers don't, for example, sweep or flush the street litter into the stormwater drains as so often happens in South Africa;

**the level of environmental concern in the community** - leading to, for example, reduction in the use of certain products, and the recycling of others;

**the 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 variability in the nature of the litter coming off different catchments has been identified by a number of researchers, for example, Allison and Chiew, 1995 who showed that for a fully urbanised catchment at Coburg, which is situated about 10 km north of Melbourne’s CBD, “garden debris” made up 85% of the litter collected from a residential site, but only 36% from a light industrial site; whilst “paper” and “plastics” made up 64% of the litter from the light industrial site, but only 13% from the residential site. Similar profiles have been obtained for Auckland (Cornelius et al., 1994; Island Care New Zealand Trust, 1996). See Figure 2-1:



**Figure 2-1 : Composition of collected gross pollutants by dry mass from different catchments in Coburg (after Allison & Chiew, 1995)**

Often, a single shop or factory eg. a fast food outlet, a bank, or a plastic recycling factory, is responsible for a large percentage of the litter collected in the drains, and the amount of litter can be substantially reduced once the situation has been brought to the attention of the offending company (Island Care New Zealand Trust, 1996; Allison, 1996).

There is an infinite variety in the types and quantities of litter washed off a catchment. In fact, **each catchment has a unique litter “footprint” which is indicative of the state of the catchment at the time of measurement.**

## **2.2 The Springs study**

Probably the most comprehensive measurement of the types and quantities of litter coming off South African catchments was that carried out over a period of four months starting from 1 December 1990 and ending 31 March 1991 for the Central Business District (CBD) of Springs (Nel, 1996).

The size of the catchment area considered in the study was about 299 ha and had a commercial / industrial component of about 254 ha (85%) and a residential component of about 45 ha (15%). The entire catchment drains to a single point from where it flows via an open canal to the Blesbokspruit.

A single structure, capable of handling a flow of 7,5 m<sup>3</sup>/s before partial bypassing commenced, was used to screen out all particles with a minimum dimension larger than about 20 mm. Bypassing occurred only for short periods during approximately 60% of storms. This structure will be described in greater detail in Section 5.5.

In an attempt to standardise the method of reporting, measurements were made of the density of litter collected from various sources including streets (35 kg/m<sup>3</sup>), the Blesbokspruit (95 kg/m<sup>3</sup>), refuse vehicles (150 kg/m<sup>3</sup>), and the structure itself (95 kg/m<sup>3</sup>). In the end, all volumes were adjusted to a standard density of 95 kg/m<sup>3</sup>.

Estimates of the runoff from each storm were calculated by multiplying the area of the catchment by the depth of rainfall measured by the City Council of Springs multiplied by a runoff factor of 0,4. The town has a mean annual precipitation (MAP) of about 750 mm and falls within the summer rainfall region of South Africa.

The volumes of solid waste trapped by the structure are detailed in Table 2-1.

In addition to the above, fourteen samples of litter trapped in the structure were removed and analysed. A typical analysis of the litter in the samples expressed in terms of the average number per cubic metre, the percentage of volume, the average number per storm, the maximum number per cubic metre, and the minimum number per cubic metre is given in Table 2-2.

Some more unusual items trapped by the structure included items of clothing, hand bags, stockings, tyres, car number plates, dead dogs and cats, oil cans, and oil filters.

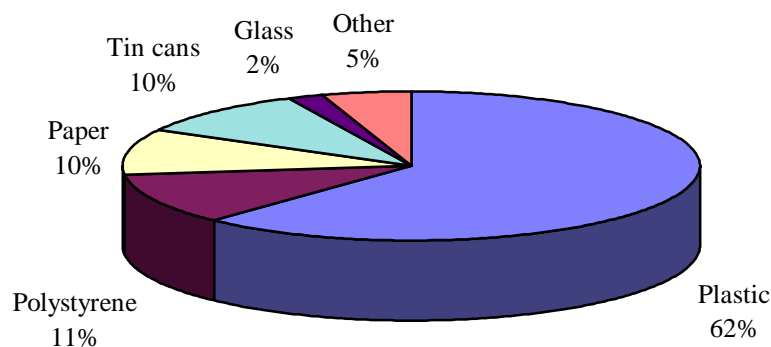
Figure 2-2 shows the breakdown in types of litter in the form of a pie-chart. It should be noted that the quantity of vegetation trapped by the structure formed a negligible portion of the total amount and was not measured.

Date	Day No.	Rainfall (mm)	Volume removed (m <sup>3</sup> )	Volume runoff (x 1 000 m <sup>3</sup> )	Volume removed per storm (m <sup>3</sup> )
1/12/90	1				
3/12/90	3	2		2	
4/12/90	4	2		2	
5/12/90	5		4		2
6/12/90	6	26		31	
7/12/90	7	16		19	
10/12/90	10		5		2,5
12/12/90	12	14	4	17	4
13/12/90	13	7	3	8	3
14/12/90	14	28		34	
17/12/90	17	25		30	
18/12/90	18		4		2
24/12/90	24	3		4	
30/12/90	30	5	5	6	2,5
1/1/91	32	5		6	
3/1/91	34	4	11	5	5
7/1/91	38	14		17	
8/1/91	39	10		12	
9/1/91	40		6		3
10/1/91	41	16		19	
15/1/91	46	24	10	29	5
17/1/91	48	2		2	
24/1/91	55	14		17	
28/1/91	59		5		5
30/1/91	61	14		17	
31/1/91	62	109		131	
1/2/91	63	10	8	12	2,7
4/2/91	66	10		12	
7/2/91	69		4		4
8/2/91	70	7		8	
11/2/91	73	13		16	
12/2/91	74		3		1,5
18/2/91	80	88		106	
21/2/91	83		12		12
25/2/91	87	7		8	
27/2/91	89		4		4
4/3/91	95	65		78	
5/3/91	96		8		8
6/3/91	97	9		11	
7/3/91	98	18		22	
11/3/91	102	6		7	
14/3/91	105		6		2
17/3/91	108	40		48	
18/3/91	109	55		66	
19/3/91	110		4		2
31/3/91	122				
<b>Total</b>	<b>122</b>	<b>668</b>	<b>106</b>	<b>802</b>	

**Table 2-1 : Volumes of solid waste from the Springs CBD Catchment trapped over the period 1 December 1990 to 31 March 1991 (after Nel, 1996)**

Item No.	Description	No. per m <sup>3</sup>	% of volume	No. per storm	Max. no. per m <sup>3</sup>	Min. no. per m <sup>3</sup>
1	Tin cans	267	9,7	890	383	106
2	Glass bottles	14,8	2,1	49	60	0
3	Plastic bags	1 660	47,3	5 533	2 333	660
4	Plastic containers	10,2	10,2	34	27	0
5	Plastic bottles	99	5,1	332	143	0
6	Straws	153	negl.	512	203	50
7	Paper	1 227	7	424	403	33
8	Cartons	95	3	317	300	0
9	Matches	8,8	negl.	29	40	0
10	Polystyrene blocks	196	10,8	655	423	33
11	Stalks	11	negl.	37	37	0
12	Plastic nets / straps	7,1	negl.	11	37	0
13	String / rope	1,4	negl.	5	7	0
14	Pens / pencils	4,8	negl.	16	60	0
15	Bottle tops	21	negl.	70	47	7
16	Sponges	5,5	negl.	18	23	0
17	Music cassettes	negl.	negl.	2	2	0
18	Blocks of wood	6,4	negl.	21	27	0
19	Bones / skeletons	3,6	negl.	12	12	0
20	Tennis balls	2,1	negl.	7	7	0
21	Tissue boxes	2,4	negl.	8	10	0
22	Plastic utensils	6,7	negl.	22	27	0
23	Spray cans	3,3	negl.	8	10	0
24	Other		4,8			
<b>Total</b>		<b>2 709</b>	<b>100</b>	<b>8 982</b>		

**Table 2-2 : Analysis of litter commonly found trapped in the Springs structure, measured by volume (after Nel, 1996)**



**Figure 2-2 : The types of litter trapped by the Springs structure (after Nel, 1996)**

A total of 106 cubic metres of litter, transported by 32 separate storm events, was removed from the structure over the 122 day measuring period. Records kept by the Springs City Council show that there had been an average of 56 storm events per year over the previous three years giving an effective removal rate of about  $106 \text{ m}^3 \times 56/32 = 186 \text{ m}^3$  litter per year ( $3,3 \text{ m}^3$  per storm) at a density of  $95 \text{ kg/m}^3$ . The structure was estimated to be about 72% effective in the removal of litter, indicating that some  $71 \text{ m}^3$  per year (at a density of  $95 \text{ kg/m}^3$ ) currently finds its way past the structure into the Blesbokspruit.

Approximately  $1\ 210 \text{ m}^3$  per year (at a density of  $95 \text{ kg/m}^3$ ) is removed from the catchment area by various street cleaning services. Thus, the total quantity of litter that currently finds its way onto the streets is approximately  $1\ 467 \text{ m}^3$  per year (or 139 tonnes), of which some 18% (or 24 tonnes) finds its way into the stormwater drainage system.

Springs is in a summer rainfall area. An average litter volume of  $12 \text{ m}^3$  per storm was trapped by the structure during the first storm after winter over the period 1991 - 1993. This was some 3,6 times the average. This phenomenon where an unusually large quantity of litter is transported through the drainage system following a long dry period is often termed a "first flush", and comprises largely of material that has been accumulating in the drains. Although the litter load is much higher than the average, the accumulation rate of litter in the system prior to the first storm is much lower. Presumably street cleaning is more efficient during the dry season when the cleansing department can generally get to the litter before wind and rainfall can carry it into the catch-pits.

If the contribution by the residential area to the total is ignored, then litter is currently deposited at a rate of about  $5,8 \text{ m}^3/\text{ha}$  per year (at a density of  $95 \text{ kg/m}^3$ , ie. about  $550 \text{ kg/ha}$  per year) in the commercial / industrial area of Springs.  $1,0 \text{ m}^3/\text{ha}$  per year (at a density of  $95 \text{ kg/m}^3$ , ie. about  $95 \text{ kg/ha}$  per year) is washed into the stormwater system. If we add back the residential area, then the rate of deposition is  $4,9 \text{ m}^3/\text{ha}$  per year ( $470 \text{ kg/ha}$  per year) with  $0,86 \text{ m}^3/\text{ha}$  per year ( $82 \text{ kg/ha}$  per year) ending up in the canal.

### **2.3 The Robinson Canal Trap, Johannesburg**

The Robinson Canal is situated in the Central Metropolitan Council District of Johannesburg. The canal drains approximately  $8 \text{ km}^2$  (800 ha) of highly developed urban area, and flows southwards from the Braamfontein ridge through the areas of Selby, Orphitton and Booyens to join with the headwaters of the Klipspruit. The catchment area includes a mix of residential, commercial, industrial and informal trading areas. Johannesburg has a similar climate to Springs.

A single structure, capable of handling a flow of  $15 \text{ m}^3/\text{s}$  before partial bypassing commenced, was used to screen out all particles with a minimum dimension larger than about 20 mm. This structure is believed to have an efficiency of about 70%. It is described in greater detail in Section 6.6.

The first rains of the season carry the most debris. In the 1995/6 rainy season, more than 150 garbage bags were collected from the first rains. Typically 70 to 100 bags were collected from ongoing storms, the larger amount being associated with longer periods between storms (more than 10 days).

The trapped material consisted of roughly equal amounts of sediment, “suspended debris” and flotsam. The sediment consisted mostly of coarse objects such as tyres, stones, and bricks, grading down to silty sands. The “suspended debris” comprised about 80% plastic bags. The flotsam was mostly polystyrene fast food containers, floating tins and bottles. Some large objects such as tractor tyres were also occasionally trapped. A particular health hazard was the number of carcasses that are carried down the canal and deposited in the trap. These had to be disposed of immediately as they rapidly decomposed in the heat.

Each garbage bag holds about  $0,06 \text{ m}^3$ , and if the density of material in each bag is assumed to be the same as for the Springs structure ie.  $95 \text{ kg/m}^3$ , and there are also about 56 storms a year, then this implies that approximately  $0,50 \text{ m}^3/\text{ha}$  per year (ie. about  $48 \text{ kg/ha}$  per year) is washed into the stormwater system from this part of Johannesburg.

## **2.4 The Capel Slout culverts, Cape Town**

The Capel Slout culverts drain an area of about 1 092 ha of Cape Town into Duncan docks. The catchment includes an undeveloped portion of Table Mountain (60,4%), a residential component (18,3%), park land (8,0%), an industrial component (4,2%), a commercial component (7,1%), and railway land (2,0%) (Arnold, 1996).

The mouths of the culverts are closed by fishing nets with square openings of approximately 75 mm a side.

Portnet, the harbour authority, have not kept accurate records, but they estimate that they empty the nets about four times a year, each time removing approximately  $12 \text{ m}^3$ . Once again, a lot of litter comes down the culverts with the first rains of wet season (Coetzee, 1996).

Bearing in mind that many particles with a minimum dimension smaller than 75 mm will escape the nets, and considering only the industrial, commercial and railway areas, this amounts to about  $0,33 \text{ m}^3/\text{ha}$  per year ( $31 \text{ kg/ha}$  per year assuming a density of  $95 \text{ kg/m}^3$ ). The efficiency of the structure is unknown, but is undoubtedly less than 50%. If we assume a trap efficiency of 50%, then  $0,66 \text{ m}^3/\text{ha}$  per year ( $63 \text{ kg/ha}$  per year assuming a density of  $95 \text{ kg/m}^3$ ) is washed off the catchment.

Including the residential component in the calculation reduces the wash-off rate to  $0,28 \text{ m}^3/\text{ha}$  per year ( $26 \text{ kg/m}^3$  per year).

## **2.5 Australian and New Zealand experience**

Although litter in the aquatic environment is a universal problem, surprisingly little has been done to address it. In Europe and some parts of North America, relatively low rainfall intensities and a greater environmental consciousness makes it relatively easy to exclude the majority of the litter from the stormwater system through the use of grids over the catchpits. Also, many of the stormwater systems are so-called “combined” systems ie. sewage and stormwater are mixed together and transported directly to the waste water treatment works in all except severe storms.

Some work into aquatic litter removal has been conducted in the UK, USA and Canada, but by far the greatest research effort to date, relevant to South African conditions, seems to have been carried out by the Australians, and to a lesser extent the New Zealanders (generally using Australian technology). Australian technology has particular relevance to South Africa because the climates are similar and the Australians also use “separate” systems ie. sewage and stormwater are reticulated in separate networks - although, of course, the socio-economic situations are totally different. In consequence, considerable effort was made to research Australian and New Zealand experience.

### **2.5.1 The Merri Creek study, Melbourne**

Late in 1986, the Merri Creek Co-ordinating Committee (a joint community and local government group) approached the Board of Works, Melbourne and the Victorian Environmental Protection Authority to request support for an investigation into the litter problem on the Merri Creek. Merri Creek is a major tributary of the Yarra River and flows through the northern suburbs of Melbourne.

A working group was established with representatives from the three bodies, and one of the eight local municipalities (Coburg) agreed to provide logistical support for the project. The resultant study is detailed in the publication “Litter Control in Urban Waterways” (Board of Works, Melbourne et. al., 1989), which was a land-mark study in Australia. The study involved the identification of litter types and sources, assessment of a variety of simple litter trap devices and the development of recommendations arising from these investigations and associated observations.

The area selected for the study comprised the catchments of three underground drains discharging into Merri Creek. In addition to trapping litter from these underground drains, a floating litter boom was installed on Coburg Lake, a small water feature on Merri Creek (Senior, 1992).

Although the trapping devices were crude and generally inefficient, and although monitoring took place over fairly limited time periods, it was possible to establish that there is a strong correlation between the land-use and the type of material being trapped. Altogether, 2 231 items of litter were collected and separated into paper, plastic, aluminium cans, glass and miscellaneous. Plastic based products comprised 66% (by item count) of the total litter collected. Paper items comprised 21% of the total litter count.

The report concluded that a significant component of plastic-based litter in waterways is due to poor handling and disposal techniques in industrial and commercial areas. Pedestrians and motorists were also identified as being the “most probable” major source of litter (Board of Works, 1989).

The Merri Creek study has proved to be a landmark in pollution identification and control as it suggested methods of pollution mitigation which have been taken up in further studies. Some of the recommendations will be discussed further in Section 3.2.

### **2.5.2 The Coburg study**

The Merri Creek study also laid the groundwork for an in-depth study of litter deposition and removal in the Coburg catchment as part of a PhD thesis (Allison, 1997). The study was almost certainly the most comprehensive to date carried out by anyone anywhere. It has already been alluded to in Section 2.1 above.

The location for the field experiments was a 50 hectare catchment encompassing some 35% commercial (shopping centre, library and fast food outlets) and 65% residential (middle income single storey dwelling units at a density of about 10 units per hectare) land-uses. Side-entry catchpit traps (see Section 6.2) were placed in all 192 road entrances to the drainage system (some privately owned outlets - mainly carrying discharges from roofs - were not trapped). A CDS device (see Section 5.9) was installed on the single 1 220 mm diameter outlet to the catchment site.

Field trials on the CDS device indicated that almost 100% of all material larger than 4,7 mm (the aperture size of the separation screen) was trapped, and a considerable percentage of material much smaller than this.

Data from the study appeared to indicate that an average of approximately 30 kg/ha per year dry (100 kg/ha per year wet) or some 0,4 m<sup>3</sup>/ha litter per year is washed off Melbourne urban catchments. This amounts to a total of 230 000 cubic metres or 60 000 tonnes (wet) per year. However, as much as 80% of this material is leaf matter. Ignoring the leaf matter would give a loading rate of 6 kg/ha per year dry, 20 kg/ha per year wet, or 0,08 m<sup>3</sup>/ha per year. See Figure 2-1 for the breakdown of types of material by catchment type.

### **2.5.3 The North Sydney Council Litter Control Device programme**

Commencement of the North Sydney Council Litter Control Device programme began in May 1992 after strong pressure from the community to address the problem of “polluting stormwater drains”. By 1995, nine litter control devices accounting for a total catchment area of 322,5 ha had been installed. The catchment is highly urbanised and includes commercial, residential and industrial components (Brownlee, 1995).

The devices (see Section 6.5) were designed to trap particles with a minimum dimension of greater than 20 mm. A litter data collection programme was implemented to enable the Council to determine their effectiveness and efficiency. Initially the traps were emptied every 4-6 weeks or after a storm event. The litter was then sorted into three distinct categories: floatables, organics and sediment. The “floatable” category corresponds most closely to our definition of litter.

Over the period February 1993 to February 1995, the traps only caught an average of 109,3 m<sup>3</sup> of material of which only 6,2 m<sup>3</sup> was classified as “floatable”. This represents a litter wash-off rate of 0,019 m<sup>3</sup>/ha per year (1,8 kg/ha per year at an assumed density of 95 kg/m<sup>3</sup>). By way of comparison, the volume of organics, mainly leaves and grass clippings, amounted to 35,6 m<sup>3</sup>, whilst the sediment, which was bound up in the other two components, amounted to 67,5 m<sup>3</sup>.

Between February and June 1996 however, one of the traps (Smoothey Park) was cleaned more frequently to ensure that it was as empty as possible before the commencement of the next storm. This increased the volumes of material trapped by the device by 192% (Hocking, 1996)! This illustrates the unreliability of much of the data on litter wash-off rates.

The relative proportions of the three different components trapped by the Smoothey Park device was not reported.

#### **2.5.4 The Auckland Study**

This study was intended to provide information concerning discharges of litter from the Auckland stormwater drainage system into the Hauraki Gulf. The programme included sampling from commercial, industrial and residential catchments on the assumption that there would be differences in the composition of debris discharged from stormwater networks draining areas of differing land use (Cornelius et. al., 1994).

Nine outfalls were sampled, three each from the basic land use types. The litter traps were constructed of 22 gauge welded wire mesh with a mesh size of 19 mm. They were connected to the stormwater outfalls in December 1992 and were cleared at approximately weekly intervals through to the end of November 1993.

Converted to annual figures and assuming a density of 95 kg/m<sup>3</sup>, the results of the study indicated the following litter loading rates:

commercial	=	1,35 kg/ha per year (0,014 m <sup>3</sup> /ha per year)
industrial	=	0,88 kg/ha per year (0,009 m <sup>3</sup> /ha per year)
residential	=	0,53 kg/ha per year (0,006 m <sup>3</sup> /ha per year)

It is interesting to note that although the commercial and industrial areas produced higher litter loading rates than the residential areas, the residential areas, because they cover a much larger percentage of the city, contribute more litter than all the other areas put together.

Also of significance is the dramatically lower loading rates for Auckland compared with South African data.

## **2.6 Conclusions**

In Section 2.1, it was mentioned that the amount and type of litter coming off urban catchments is extremely variable and depends on a large number of independent factors. This is borne out by what little data is available. If the data presented in Sections 2.2 - 2.5 above is reliable, **litter wash-off rates appear to vary from about 0,53 kg/ha per year for the residential areas in Auckland, to about 96 kg/ha per year for the CBD of Springs.**

In reality, none of the trapping devices used to obtain the data in Sections 2.2 - 2.5 above are 100% effective, and many may be less than 50% efficient in the trapping of litter. The efficiency may also vary depending on the type of litter being trapped. It is easier to trap tin cans and polystyrene blocks than plastic bags and pieces of paper. This leads to **great uncertainties in the determination of the quantities of litter reaching the streams.**

The Auckland study seems to support the proposition that **commercial and industrial areas produce a higher litter loading rate than do residential areas**, but this may not hold in South Africa where services to many sub-economic residential areas have completely collapsed. It is also important to note that even in Auckland, **residential areas, by virtue of their much greater area, contribute a greater total of litter** to the Hauraki Gulf than the commercial and industrial areas combined.

One thing is clear, **the litter problem is much worse in South Africa than it is in either Australia or New Zealand** - the figures seem to indicate up to about two orders of magnitude (ie. 100 times) worse. This is presumably a combination of many factors, but is probably mostly as a result of **the lack of proper environmental ethic in South Africa, coupled with poor levels of service in certain areas.**

**Vegetation** does not seem to cause the problems in South Africa that it causes in Australia, but there may local exceptions to this.

**Plastics are by far the biggest single problem.**

## 2.7 Recommendations

There is likely to be a much greater benefit in trying to **reduce the production of litter than by trying to trap it all once it has got into the drainage system**. A survey of municipal street cleaning methods among 54 councils in the metropolitan area of Melbourne by the Board of Works, Melbourne in 1990 showed that 67% of municipalities then used street flushing to some extent. Of these about half regularly and extensively used flushing equipment or street hydrants to clean shopping centres and similar litter accumulation areas (Senior, 1992). In other words, the cleansing departments of many municipalities are part of the problem rather than being part of the solution! Nevertheless, some litter will always escape into the drains, and for this reason, **litter removal structures will always be required in and around urban areas**.

Without data from the specific catchment, estimates of the amount of litter that comes from it are likely to be highly conjectural. **As a preliminary guide to design** however, the following formula, derived largely from the Springs (Nel, 1996) and Robinson Canal data, is tentatively suggested for South Africa until such time that better data is available:

$$T = \sum f_{sci} \cdot (V_i + B_i) \cdot A_i \quad \text{(Equation 2-1)}$$

where	T	=	total litter load in the waterways (m <sup>3</sup> /year)
	f <sub>sci</sub>	=	street cleaning factor for each land use (varies from 1,0 for regular street cleaning to about 6,0 for non-existent street cleaning / complete collapse of services)
	V <sub>i</sub>	=	vegetation load for each land use (varies from 0,0 m <sup>3</sup> /ha per year for poorly vegetated areas to about 0,5 m <sup>3</sup> /ha per year for densely vegetated areas)
	B <sub>i</sub>	=	basic litter load for each land use (commercial = 1,2 m <sup>3</sup> /ha per year industrial = 0,8 m <sup>3</sup> /ha per year residential = 0,01 m <sup>3</sup> /ha per year)
	A <sub>i</sub>	=	area of each land use (ha)

The data from Coburg, Australia suggests that **the basic litter load can easily be reduced by at least 90% with a little public awareness and co-operation**. The data from Auckland suggests much greater reductions are in fact achievable.

There is no consistent relationship between rainfall and transportation of litter, although the work carried out in Coburg suggests some correlation (Allison, 1997). What is certain is that **very little litter is carried by the drainage system between major downpours, and an abnormally high “first flush” is frequently seen after long dry periods.** To enable designers to calculate trap storage volumes and cleaning frequencies, it is suggested that the total litter load is assumed to be split between the significant downpours (with more than, say, 1 mm of rainfall) with the greater weighting given to those storms following long, dry periods. **As a preliminary guide to design,** the following formula, derived largely from the Springs (Nel, 1996) and Robinson Canal data, is tentatively suggested for South Africa until such time that better data is available:

$$S = f_s \cdot T / \sum f_{si} \quad \text{(Equation 2-2)}$$

where

S	=	storm load in the waterways (m <sup>3</sup> /storm)
f <sub>s</sub>	=	storm factor (varies from 1,0 for storms occurring less than a week after a previous downpour; to about 1,5 for a storm occurring after a dry period of about three weeks; to about 4,0 for a storm occurring after a dry period of more than about three months)
∑f <sub>si</sub>	=	the sum of all the storm factors for all of the storms in the year (since this information is generally not available, a suggested alternative is to count the average number of significant storms in a year and multiply by 1,1)