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SOURCES OF RIVERINE LITTER: THE RIVER TAFF, SOUTH WALES, UK

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Abstract. Riverine litter occupies a spatial and temporal position in any systematic analysis of river systems and is a problem that is increasing in scale. Quantifiable source factors of litter in the river Taff, South Wales, UK, system were found to be mainly two – sewage inputs through combined sewer overflows (CSO) and fly tipping. The greatest inputs of sewage derived solids were introduced to the river by malfunctioning CSO, the most numerous single component being sanitary towels. Whilst sewage-derived material constituted approximately 23% of all items on the river Taff, large quantities of waste, especially plastic sheeting, originated from fly tipping sites.

Keywords: fly tipping, riverine litter, sewage, sources

1. Introduction

The aesthetic quality of many river banks around the world is all too often marred by the presence of unsightly litter. Such aesthetic pollutants have been shown to significantly affect public perception of rivers as well as its potential for biofouling of the water body (House and Sangster, 1989). Public awareness has meant that it is increasingly on the pollution control list of, for example in the UK, the Environmental Protection Agency (EPA), formally the National Rivers Authority (NRA). Once a litter problem exists, not only will the public view the area less positively, but the adage *waste attracts more waste* may also follow. The implications of riverine litter are not just limited to aesthetic degradation. Bankside litter is likely to constitute a significant threat to wildlife due to the possibility of entanglement and is also potentially hazardous to man if riverine areas are used recreationally.

Increasing awareness regarding aesthetic pollutants such as litter, has been reflected in proposals for a revised water quality classification scheme (Williams and Brooker, 1985). In the 1970's, River Quality Objectives (RQOs) were introduced as an informal means of setting goals for local water quality. They provided a framework on which to base discharge consents and have acted as a platform for river management. In recent years, considerable investments (£30 billion in the UK) channelled towards water quality improvements have resulted in the need to review RQOs so they can reflect new higher standards. In this context the Department of Environment (DoE) and Welsh Office proposed the introduction of Statutory Water



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Quality Objectives (SWQOs) to reflect new requirements and assessment methods. SWQOs will enable the Secretary of State to serve notice to the EPA regarding quality classes for river stretches.

In addition to SWQOs, there are General Quality Assessments (GQAs), set up as a response to aesthetic pollutants unlike the RQOs and SWQOs. For rivers, it is intended that GQAs will not only involve standard chemical and biological measures, but also nutrient and aesthetic classifications and the different aspects of GQAs have been termed 'windows'. The aesthetic classification will reflect general water quality and deals for the first time with litter despoliation. The inclusion of aesthetic classification for rivers in the new River Quality Surveys has underlined the need for innovative research in the realm of aesthetic pollutants such as litter, both for rivers (Williams, 1986; Williams and Simmons, 1997a), estuaries (Williams and Simmons, 1995, 1997b), beaches (Williams *et al.*, 1993a,b; Simmons and Williams, 1993) and offshore (Simmons *et al.*, 1993). There are many potential sources of riverine litter; from bankside tipping, industrial discharges, discarded recreational material (fishing tackle etc.), boat discharges, urban/rural runoff, treatment work effluent and diffuse inputs as a result of sewage inputs from Combined Sewer Overflows (CSO) and untreated discharges. Localised point source input from bridges (cans, bottles, papers, etc.) near public houses can be identified but inputs from wind blown materials are minor in the Taff context. Most sources are difficult to pin-point, and even harder to control. Further difficulties in tackling the problem arise due to the mobile nature of litter. Once deposited within a catchment, litter may be rapidly transported away from its point of origin and become distributed throughout the catchment, thus increasing the scope of the problem. Details of litter movement pattern with respect to hydraulic parameters in the Taff system can be found in Williams and Simmons (1997a). Due to the dynamic nature of the litter system, no single method is capable of assessing the extent of the problem, or providing an understanding of the complex processes involved.

2. Location and Site Details

The River Taff in the UK was selected for study as it probably represents a worst case scenario for Riverine litter. It rises in the Brecon Beacons and flows 57 km to enter the Severn Estuary at Cardiff. Four major tributaries covering some 56% of the catchment join the river during its course through the South Wales coal field. These are the Taff Bargoed, Cynon, Nant Clydach and Rhondda (Figure 1). It drops 11 m in every kilometre, and rainfall ranges from 950 mm at Cardiff to 2400 mm in the Brecon Beacons. Heavy linear urban strip development and regulation resulting from flood protection works means that much bank channelisation has occurred. The high rainfall in South Wales (>2000 mm) exacerbates the flow fluctuation problems inherent in the combined nature of the sewage system in which both

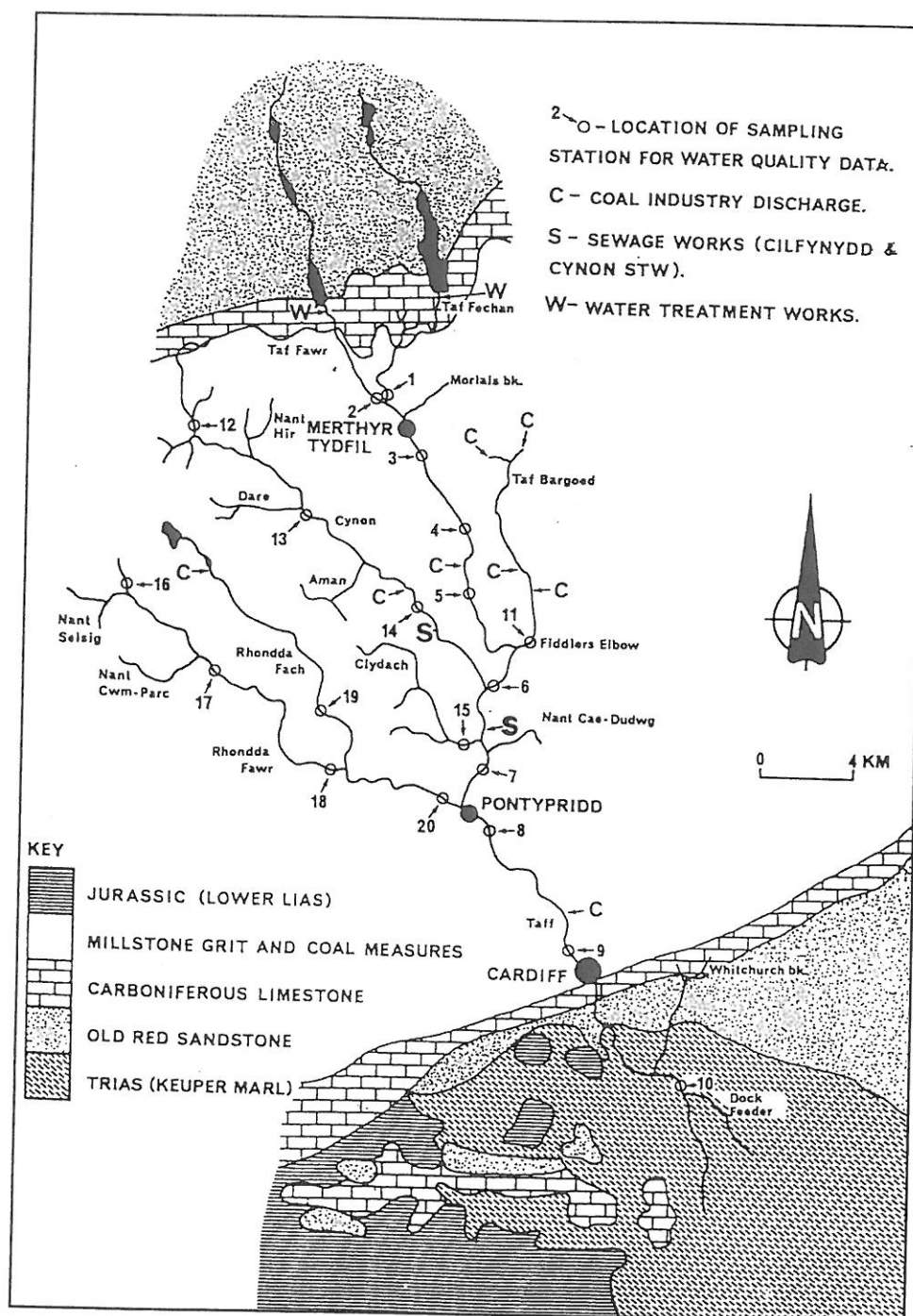


Figure 1. Taff catchment geology, location of sampling stations and major discharges.

surface water and sewage are transported together for appropriate treatment and disposal.

Three small sewage works serve the headwaters of the R. Taff. Upper and middle catchment treatment takes place at two large works, Cynon (ST 0825 9295) Sewage Treatment Works (STW), an activated sludge plant serving a population of approximately 75 000, and Cilfynydd STW (ST 0840 9290), a biological filtration plant serving a population of approximately 65 000 (Figure 1). To cope with periods of high flow, Combined Sewer Overflows (CSO) act as release valves along the length of the system, generally releasing untreated effluent direct to the river. They are numerous in the Taff catchment, and as most are unscreened, their potential impact is great. Sewage treatment hardly existed in the 19th century, raw sewage being one of the main pollutants of that time together with industrial inputs. In recent years, improvements have been made in both these areas but the characteristic linear urban development in South Wales where storm water and sewage usually occupy the same pipe, makes significant advances in reducing sewage contamination difficult. The end result is usually entangled sewage litter hanging from tree vegetation producing a 'Christmas tree effect' (Figure 2a).

3. Methodology

Fifty riverine sites were selected via random number tables. The river was 'stream ordered' (after Strahler, 1957), and based on the order, a weighting index given to sites; 15 for a 3rd order, 23 for a 4th order and 12 for the 5th order stream. The total litter at each site was assessed on two occasions (summer and subsequent winter) using three 5 metre transects down the bank and litter was analysed according to categories shown in Table I. Total litter composition results were then subdivided into litter from the Taff (Figure 3) and its tributaries (Figure 4) to determine uniformity or not for the whole catchment. Standard statistical techniques were then applied to the data sets. At fly tipping sites, litter was logged on sheets (Table I; Figure 2b). At each site presence or absence of tipping was recorded together with some indication of the type of tipping involved, i.e. household or commercial. The road network in the surrounding area was assessed, in addition to the presence of any direct vehicular access within 50 m of the site. Land-use was also designated for the area, as one of ten possible categories.

CSO overflow materials were assessed by retaining solids from the flow by the attachment of COPASACS. The sacs are specifically designed to retain gross solids from sewer systems, but they are usually used in more controlled conditions, e.g. gross solid samplers. They are made of strong plastic material with a 4 to 6 mm mesh, allowing sewer flows to pass through the mesh, whilst solids are retained. COPASACS are produced at a standard 12" (30 cm) diameter and their size was thus limiting as a means of sampling overflows. Selected overflows therefore had to be a certain size to allow attachment and ensure the sac was not by-passed by storm

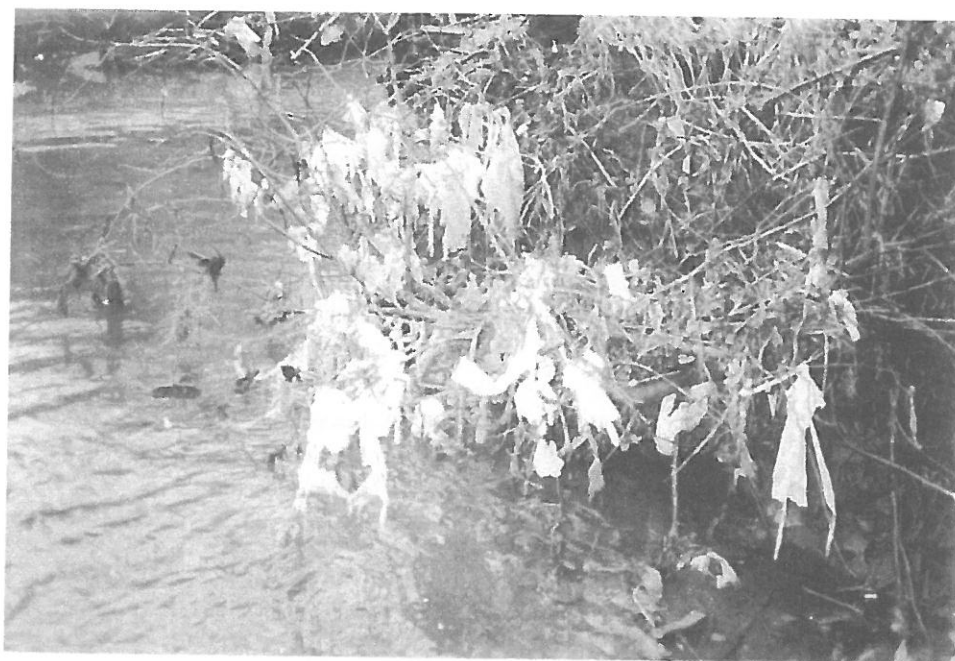


Figure 2. (a) The 'Christmas Tree' effect. (b) Fly tipping site, river Cynon.

TABLE I
Litter identification key

Family	Genus	No.	Species
Sewage derived	Feminine	1	Sanitary towels
	Hygiene	2	Panty liners
		3	Tampon/applic.
	General	4	Toilet paper
		5	Cotton buds
		6	Other/unidentified
Housing materials	Combustible	7	Fencing
		8	Hardboard/wood
		9	Other/unidentified
	Non-combustible	10	Brick/rubble
		11	Floor cover
		12	Other/unidentified
Household (large)	Brown goods	13	Furniture
		14	Mattress/foam
	White goods	15	Other/unidentified
Household (small) /commercial /industrial	Metal	16	Cans/tins
		17	Container drums
		17	Sheeting
		19	Other/unidentified
		20	Polystyrene
	Plastic	21	Sheeting <30 cm
		22	Sheeting 30-60 cm
		23	Sheeting >60 cm
		24	Plastic bags
		25	Sweet papers
		26	Bottles
		27	Bottles
		28	Other/unidentified
	Glass	27	Bottles
		28	Other/unidentified
Transport associated	Motor vehicles	29	Carts/parts
		30	Motorbikes/parts
		31	Other/unidentified
	General	32	Signs/cones
General	Packaging	33	Cardboard
	Miscellaneous	34	Cloth/shoes
		35	Rope/fishing line
		36	Other/unidentified

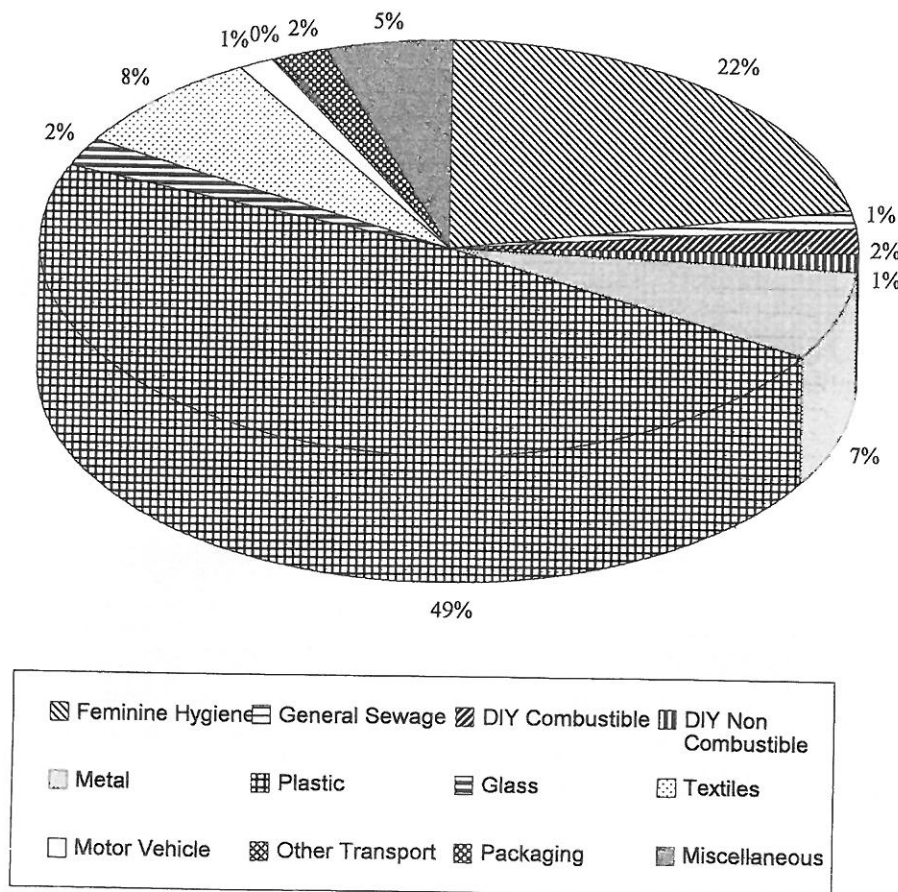


Figure 3. River Taff litter composition.

flows. Overflows were monitored on a weekly basis over a twenty week period, and if discharge had occurred, the sac was removed for analysis. COPASAC contents were weighted after excess water had been drained from the sample, after which contents were recorded. Assessments were made using three approaches: presence and absence, log score, and percentage volume so that the merits of each could be determined.

4. Results and Discussion

4.1. LITTER COMPOSITION IN THE RIVER TAFF AND ITS TRIBUTARIES

Results from both summer and winter litter surveys were initially combined to assess the overall composition of litter on the Taff (Figure 3). Plastics constituted almost half of all litter found. The Miscellaneous/Combination categories (Fig-

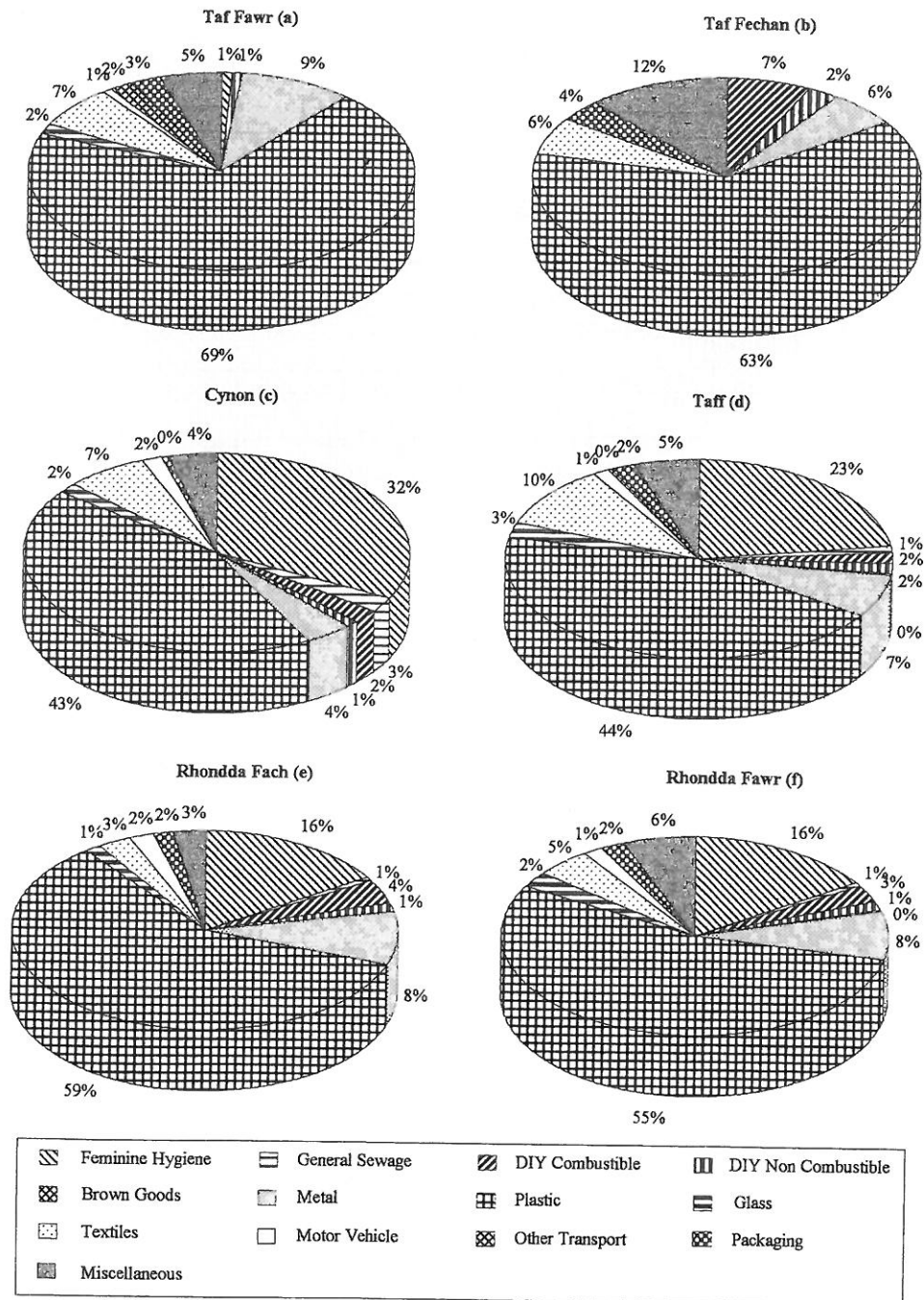


Figure 4. Litter composition of River Taff tributaries.

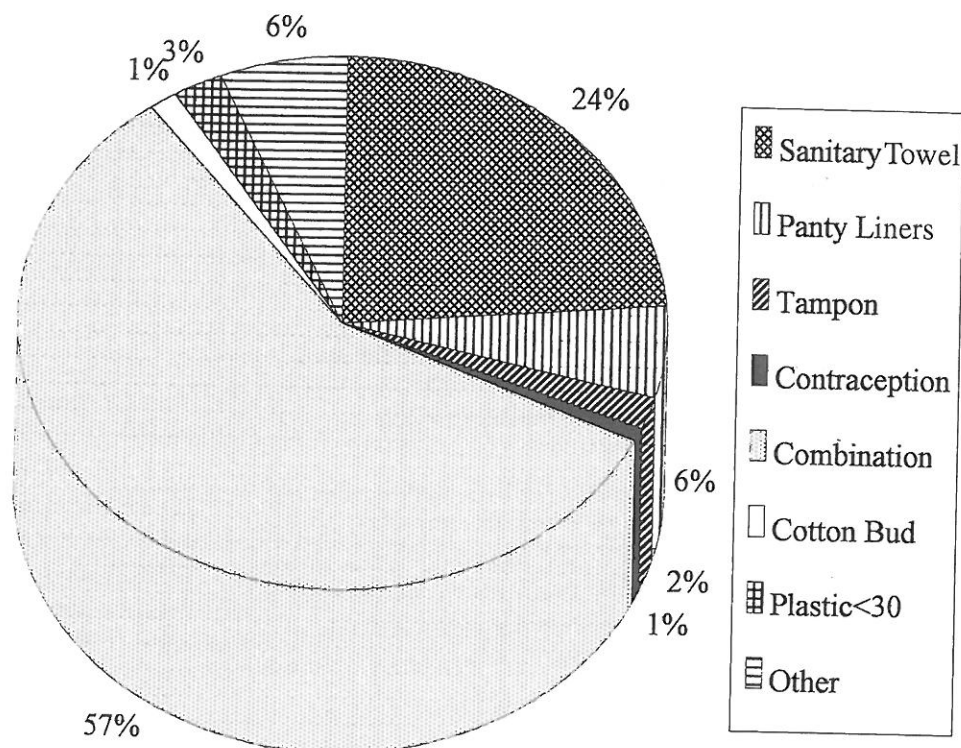


Figure 5. Sewage litter composition: percentage volume from CSO.

ures 3–5) represented material that could not be identified or was too entangled for proper analysis. When divided into constituent parts, plastic sheeting formed 57% of the plastic total. Sewage-derived items were also found in considerable quantities; feminine hygiene products alone forming 22% of all waste recorded. Other general sewage items formed a comparatively small 1% of all litter. Remaining waste groups found in relatively high numbers were textiles (8%), metal (7%) and miscellaneous items (5%). Only twelve groups are represented in Figure 3. Brown (e.g. furniture) and white goods (e.g. refrigerators) were found in such small quantities, eight and two respectively, in comparison to other wastes that they did not form visible graph sectors.

Total litter composition results were then subdivided into litter from the Taff tributaries to determine the uniformity of this litter profile for the whole catchment (Figure 4). In the Taff Fawr and Taff Fechan (Figures 4a–b), the upper-most reaches of the Taff, only small quantities of litter were recorded. Plastics still formed the majority of items found, but in these upper reaches sewage items were almost completely absent. Feminine hygiene products constituted only 1% of litter on the Taff Fawr, whilst no sewage-derived material was found on the Fechan. Both tributaries

are situated above the first major conurbation and as such would not be expected to exhibit sewage pollution to any serious level.

The Rhondda Fach and Rhondda Fawr (Figures 4e-f) are tributaries with considerable urbanisation along their lengths. They demonstrated almost identical composition and showed a much closer likeness to the Taff overall litter profile than its headwater streams. Contrastingly, the River Cynon (Figure 4c), also a fairly urbanised tributary, showed a very different profile. For example, plastic components formed only 43% of total litter. This was however counteracted by a rise in sewage-derived material. Within the Cynon, feminine hygiene products alone constituted 32% of all litter, with an additional 3% for general sewage items. A plot was also generated for the River Taff from its formation at Merthyr Tydfil to its seaward boundary (Figure 4d) and results did not appear to differ significantly from the overall catchment profile.

Results do not appear to agree directly with Davies and Boden's (1991) work on the River Taff tributaries, in which the Rhondda valley was highlighted as the most sewage polluted area. The EPA has recently placed considerable emphasis on addressing malfunctioning CSO problems within the Welsh Region. Reductions in sewage-derived material in the Rhondda valley between the two periods (1991 and 1996) could therefore be reflecting the effectiveness of these measures.

4.2. SEASONAL LITTER VARIATIONS

The complete data set was then subdivided into summer and winter assessments to investigate possible seasonal variation in litter composition. In addition, paired t-tests were carried out for the fourteen litter subgroups between summer and winter to determine if differences were significant at the $P \leq 0.05$ level. Total item numbers found were less in the winter (4.058) than summer (4.629), an average of 584 per 100 metre of bank, but this overall trend was not statistically significant. This figure may not be a true representation as the upper-most source streams (1st and 2nd order) which are more pristine were not included in the survey. However, significant differences (at the 0.05 level) were present within seven of the fourteen sub-groups tested. Five of the seven groups showed significant decreases (at the 0.01 level) from summer to winter; Do it Yourself (DIY) consumables, plastic, glass, motor vehicle, and packaging. Whilst results did not indicate the reasons for this trend, decreases in these items during the winter may be due to the more dynamic conditions (higher flows) at this time. The two other groups with significant seasonal differences, textiles and miscellaneous items, were more abundant during winter assessments. Unidentifiable litter items, often fragments of larger objects, were recorded under 'miscellaneous'. It is therefore possible that such items increased in winter due to increased litter fragmentation. Increased textile numbers during the winter is however more difficult to explain and will be considered in future multivariate analyses. Surprisingly, sewage items did not increase in the winter assessment, even though inputs were likely to be at their highest due

to CSO discharges. Instead, feminine hygiene products and general sewage items both showed slight reductions in numbers. It is possible that an equilibrium exists whereby increased inputs during winter are equalled by increased output to sea during high flows, or by physical breakdown. If this was the case a build-up of sewage items on the river bank with time may not be apparent.

4.3. FLY TIPPING

At each site, indexed recordings were made of characteristics viewed as potentially important in relation to litter; land-use, road network and vehicular access categories. As fly-tipping is a known problem on rivers – even though there is a code of practice (HMSO, 1990) – these characteristics were adopted for inclusion in the river survey. Results from these recordings were analysed by a simple cross-tabulation technique (Table II) and revealed interesting trends. For all fifty sites assessed, exactly half had a fly-tipping problem. Initially the simplest data split was considered; sites with or without direct vehicular access. Sites without vehicular access were tipped in 28% (4 out of 14) cases, in contrast to sites with access, of which 60% (21 out of 36) were tipped, indicating that the presence of a road or track within close proximity to the river considerably elevated the chances of that site being fly-tipped. Many of the tipped sites without vehicular access showed signs of boundary tipping so it could be useful to include a boundary tipping category in future surveys.

The split into three road network types showed less conclusive results. Fifty-six percent of sites with 'A' graded roads were tipped as opposed to 42% with 'B' graded roads and 45% in sites with ungraded roads. This category appeared to be less influential and was regarded as unnecessary for future surveys. Caution was necessary when interpreting results relating to land-use as in some cases only a few sites were recorded in each group (Table III). Groups with large data sets, residential/industrial and the industrial/commercial mix, had the highest tipping incidence (80%). Industrial/open (60%) and residential/open (50%) also had fairly high tipping levels. Tipping was most prevalent in mixed land-use areas and industrial areas in particular were susceptible to tipping.

Applying the mixed land-use results to both categories from which it was derived, formed only four land-use types. Results from this unbiased data manipulation showed a clear ranking of land-uses and related tipping incidents. Sites with an industrial element were tipped in 75% of cases, followed by commercial areas (62%), residential (48%) and lastly open space (45%). Land-use followed by direct access were the most important factors in determining a site's fly-tipping potential.

Land-use types and their respective data were once again reduced to only four land-use categories, by allocating results from mixed land-use areas to their component parts. These clarified which forms of tipping predominated in the main land-use categories (Table IV). Within all land-use types, household tipping was the most common form of tipping. Therefore, it would appear that although indus-

TABLE II
Cross-tabulation of site information categories related to fly-tipping

Access	Land use	'A' Grade roads			'B' Grade roads			Ungraded roads			Grand Total
		NoTip	Tip	Total	NoTip	Tip	Total	NoTip	Tip	Total	
Yes	Residential	1	0	1	2	1	3	0	0	0	4
	Open space	3	0	3	0	0	0	1	0	1	4
	Indus/Comm.	0	1	1	0	0	0	0	0	0	1
	Res/Open	0	0	0	0	0	0	2	0	2	2
	Indus/Open	0	1	1	0	0	0	0	0	0	1
	Comm./Open	0	1	1	1	0	1	0	0	0	2
	Total	4	3		3	1		3	0		14
No	Residential	1	1	2	1	0	1	2	1	3	6
	Industrial	0	0	0	0	1	1	0	0	0	1
	Open space	1	3	4	0	0	0	2	1	3	7
	Res/Indus	0	3	3	0	0	0	1	1	2	5
	Indus/Comm.	0	2	2	0	0	0	1	1	2	4
	Res/Open	2	0	2	0	1	1	1	4	5	8
	Indus/Open	1	1	2	0	0	0	1	1	2	4
	Comm./Open	1	0	1	0	0	0	0	0	0	1
	Total	6	10		1	2		8	9		36
Grand total		10	13	23	4	3	7	11	9	20	50

trial areas are most commonly tipped, material found in such areas consists of more household than industrial/commercial waste. It is plausible that members of the public wanting to tip waste would employ a 'Not In My Back Yard' (NIMBY) type principle, and would take the waste to industrial areas, which offer a certain amount of seclusion and are perhaps viewed as aesthetically less valuable. An alternative explanation could also be that industrial areas are disposing of small quantities of household-type waste from collection sites within their premises, e.g. cafeterias, to avoid removal costs.

The predominance of household tipping within the Taff catchment could indicate shortcomings in public waste disposal services in the area, or may result from low public awareness regarding available disposal options. Cross-tabulation of site information categories related to fly-tipping were based on identification of point-source tipping sites (Figure 2b). A question posed was whether actual site litter items would quantitatively reflect the same trends, i.e. could the survey detect fly-tipping through composition and quantities of litter at sites? Such results were

TABLE III
Cross-tabulation of land-use and fly-tipping categories

Land use	Fly-tipping				Total 1,2,3	Grand total
	None	1. Indus/com	2. Household	3. Combination		
Residential	7	0	3	0	3	10
Industrial	0	1	0	0	1	1
Open space	7	1	2	1	4	11
Res/indus.	1	1	1	2	4	5
Indus/comm.	1	0	4	0	4	5
Res/open	5	0	4	1	5	10
Indus/open	2	2	1	0	3	5
Comm./open	2	1	0	0	1	3
Grand total	25	6	15	4	25	50

TABLE IV
Summary of tipping types and land-use

Land-use	Type of tipping			
	None	Indus/comm	Household	Combination
Residential	52%	4%	32%	12%
Industrial	25%	25%	38%	12%
Open space	55%	14%	24%	7%
Commercial	38%	12%	50%	0%

likely to be less conclusive as the composition of survey sites reflects not only point-source inputs, but also upstream inputs and outputs with time.

Of the six main litter groups (sewage-derived, building/DIY related, consumer durables, household/commercial/industrial, transport associated, general) only four were tested, as sewage-derived litter was not relevant to fly-tipping and consumer durables did not contain enough recordings. Analysis of Variance (ANOVA) was used for the comparisons to allow testing of more than two sample means.

Building/DIY-related and transport-associated groups showed no significance with any of the variables tested, probably due to the relatively small numbers found. Results of the remaining two larger groups, household/commercial/industrial and general, were significantly related to land-use categories and road networks. Household/commercial/industrial items were recorded in significantly higher numbers in residential/industrial and industrial/commercial areas than open space. Although

overall road network was found to be a significant variable for this litter group, the Sheffes test showed no individual road networks were significantly different. For general items, land-uses of residential, open space and residential/open space mix had significantly lower numbers than industrial/commercial areas. Some individual road networks were found to be significantly different, with 'A' graded road network areas having higher litter numbers than ungraded areas. The universal non-significant result between litter quantities and access may reflect a certain mobility of tipped items causing a spread away from point sources, preventing detection in the quantitative survey.

Litter groups with the most recordings, household/commercial/industrial and general, confirmed earlier results reflecting the significance of land-use (Table IV). For both groups, higher numbers were recorded for industrial/commercial land-use areas than open space. It seems that the presence of fly-tipping could be detected using quantitative survey results, and that household/commercial/industrial items were the best indicator to reflect tipping due to their abundance.

4.4. SEWAGE

The sewage-derived group was split into its two subgroups, feminine hygiene and general sewage items (Table I). Sewage pipe proximity was highly significant for feminine hygiene items but not for general sewage items, the latter being found in few numbers. Results indicated that feminine hygiene products might be suitable sewage pollution indicators. It appeared that feminine hygiene material was diverse throughout the catchment, actual quantities did show up as sewage 'hot spots'.

Davies and Boden (1991) noted that treatment works are not the main point source of sewage-derived litter, many gross inputs occurring from Combined Sewer Overflows (CSO) discharges. Foland and Zagar (1990) also showed for the Mississippi river in Minn. USA, that 58% of the riverine litter by volume come from storm sewers and CSO, with the latter contributing the most. CSO were constructed for the purpose of relieving a system of flows in excess of a selected rate, the value being based on a multiple of the Dry Weather Flow (DWF), the excess flow being discharged to a convenient watercourse.

The principal of CSO is that they only discharge during storm events when inherent high flows ensures adequate dilution rendering the effluent harmless. This is not always the case as they often discharge outside of storm events and their impact is not always harmless due to a disregard in design towards receiving water sensitivity. In general the public regard sewers as the natural disposal point for virtually any wastes – both liquid and solid, but people do not expect to see again, items disposed of in this manner and find it aesthetically unacceptable when deposition occurs on riverbanks and beach faces. Sewage-derived litter encompasses all litter that is disposed of via the sewer system. However, litter origins are not always so easily determined. Items such as nappies are known to be common on fly-tipping sites and typical domestic wastes are sometimes found in sewer systems. The spe-

cific sewage litter components that cause offence are as yet underdetermined, and is a research area currently being tackled by the EPA (Welsh Region) in collaboration with the WRc.

The most easily interpreted representation CSO material derived from COPASAC analysis was volume, with the highest proportion of waste being a combination of toilet paper, faecal matter, cotton material and food. These materials from an aesthetic viewpoint, would have limited impact due to their ease of dispersion and breakdown. But they could have the maximum ecological and possible water quality impacts. Contrastingly, the next two largest groups, sanitary towels (24%) and panty liners (6%) are likely to cause greater aesthetic degradation due to their persistence (Figure 5).

In all cases, the dominance of sanitary towels as the most numerous CSO discharge component, highlights the need to tackle this particular litter pollutant (Figure 5). To date no practical fool-proof method is available to remove such products. As the vast majority of sanitary towels enter water courses via CSO, removal of these inputs would seem to be the solution. Unfortunately, CSO form an integral part of Combined Sewer systems, and their presence is likely to be necessary for the foreseeable future. A rationalisation of storm overflows may improve the situation. Certain advances could be made by repairing malfunctioning CSO and upgrading crude 'hole in the wall' overflows with ones capable of retaining 'first flush' pollutants. However, inputs could only be minimised, not completely removed. The only means of complete removal is to prevent disposal via the sewer system. The trend in 1992 was for 72% of all towels and 96% of all tampons to be disposed by this route, a dramatic change in customer habits would need to be encouraged (Howarth, *pers comm*). This is happening now with groups such as the Womens Environmental Network (WEN) advocating 'bag it and bin it' campaigns.

4.5. DATA SET ANALYSES

Copntroversy exists regarding litter data analyses (Simmons and Williams, 1997). Principal Component Analysis (PCA), a powerful pattern recognition tool was applied to the data set. This procedure successfully identified factors that accounted for the major variations within the data set, with Factor one accounting for the greatest variation within the data set, followed by Factor two and then Factor three etc. Analysis of the entire data set provided three main factors which accounted for 57.4% of the overall variance within the data set. A varimax rotation was carried out to simplify interpretation, as rotations help to produce the most meaningful data representations to allow interpretation.

Initially, the entire data set was analysed and plotted for the first three factors (Figure 6). A plot of variable loadings for the three factors produced one very distinctive separation in the variables, between feminine hygiene items and tipped waste categories. The feminine hygiene group was overwhelming important in Factor 3 – termed the sewage factor, followed by general sewage items. This confirmed

Plot of Factors: Varimax Rotation

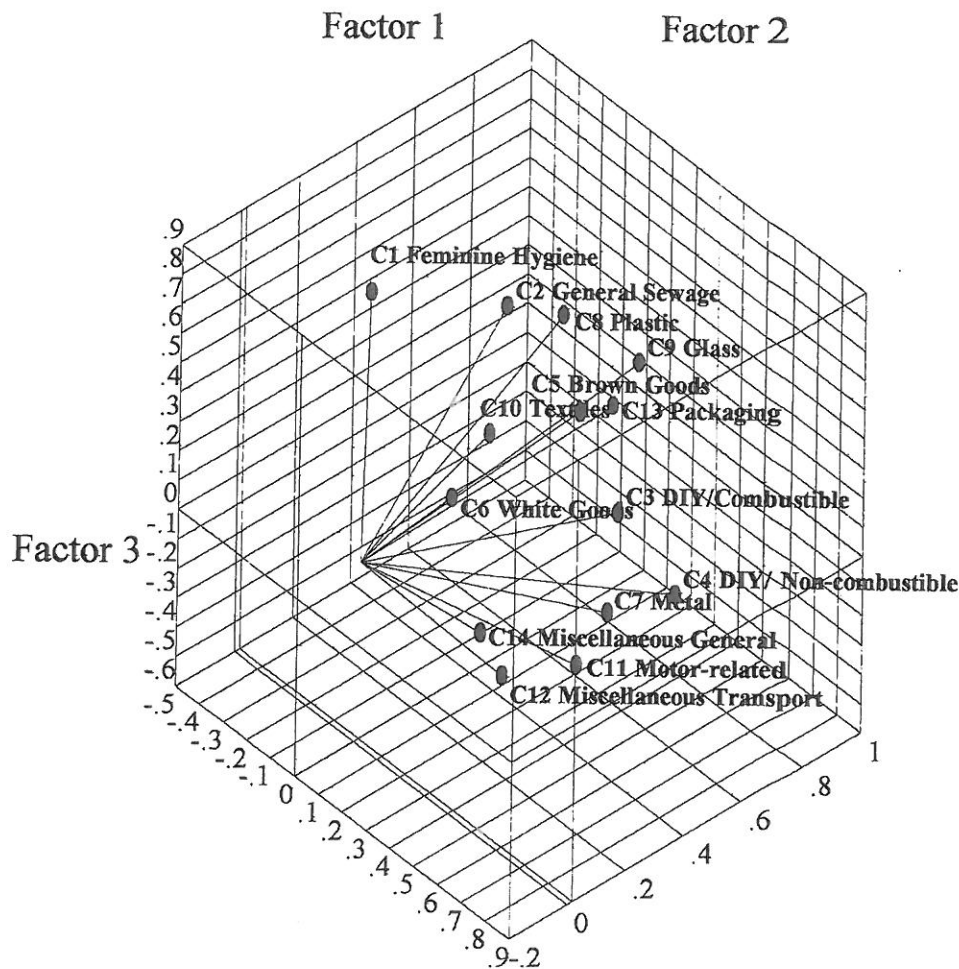


Figure 6. Principal component analysis for litter groups (Summer and Winter).

earlier suggestions regarding the suitability of feminine hygiene items as sewage contamination indicators. Despite forming the most obvious grouping, Factor 3 was the least important factor in determining overall variation in the data set. Factors 1 and 2, both seemed to relate to tipping wastes, but when examined closely, could be further split into two separate groupings. Those items most important in Factor 1, tended to be groups ordinarily related to household tipping, i.e. plastic, textiles, brown and white goods, whereas those items important in determining Factor 2 could potentially be industrial/commercial in origin, i.e. motor vehicles, metal, etc. These factors were therefore both considered to be fly-tipping factors, but with

Plot of Factors: Varimax Rotation

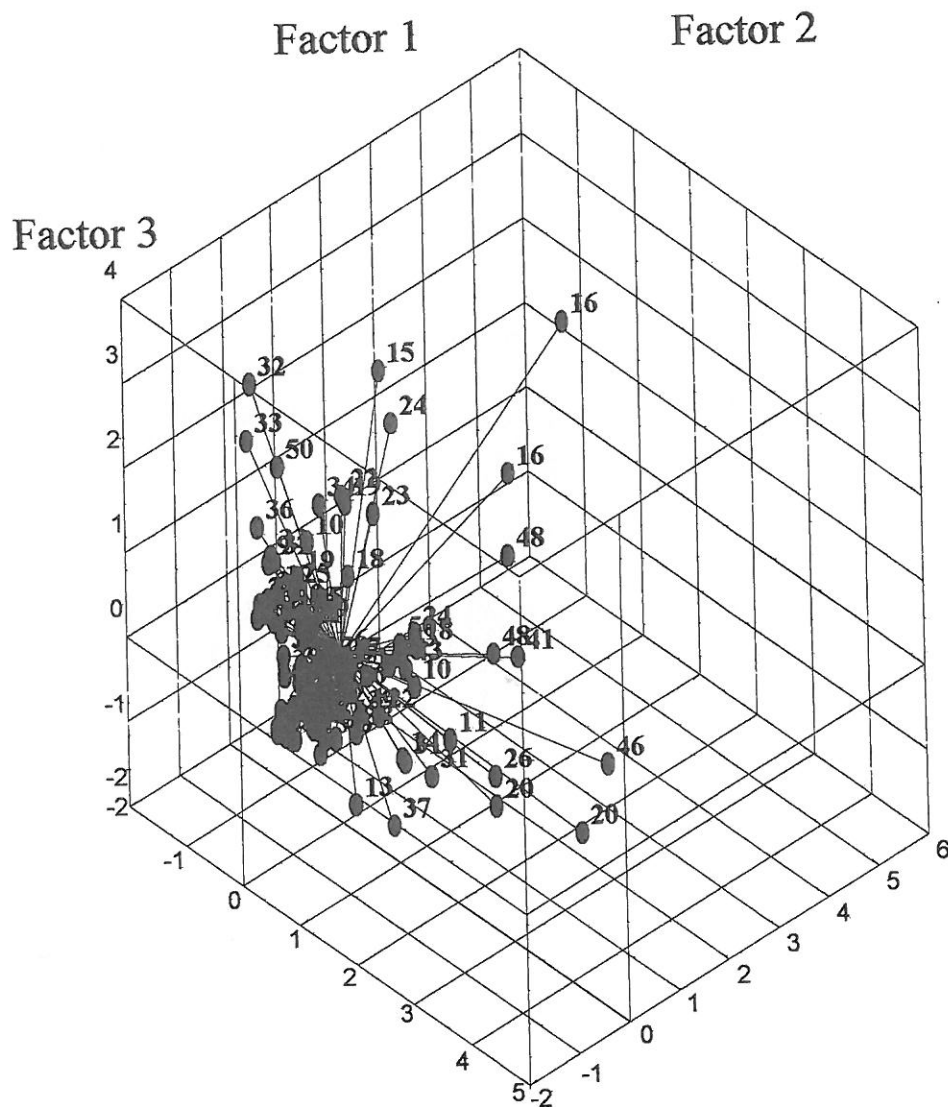


Figure 7. PCA of sites (Summer and Winter results).

Factor 1 possibly relating more to household tipping, and Factor 2 relating to other tipping forms. Thus Factors 1 and 2 were labelled more tentatively due to the more diffuse groups formed.

Overall results indicated that variation in site litter items can be identified through 3 factors; one definite sewage factor (3), and two tipping factors, interpreted as

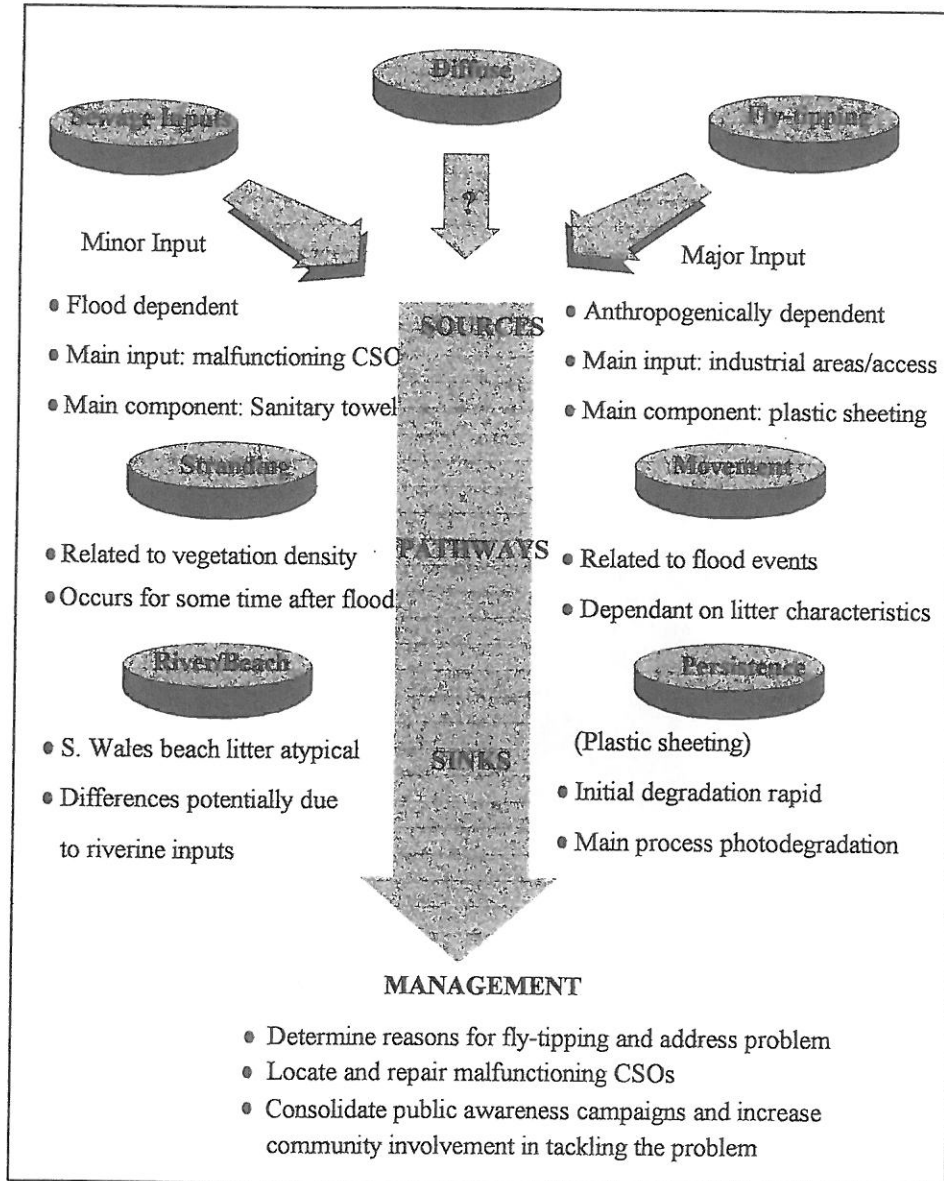


Figure 8. Schematic model showing processes and interactions governing riverine litter.

household (1) and industrial/commercial tipping (2). Site data was plotted in relation to the three factors for the overall data set (Figure 7). A certain amount of consistency was demonstrated by sites that were heavily influenced by the three factors. Sites 16, 20 and 48, for example, were plotted in very similar positions for both summer and winter surveys indicating a certain amount of uniformity in the quantities and composition of litter found at these sites on both occasions

(Figure 7). The plots indicated that sites 15, 32, and 33 were important in relation to Factor 3, the sewage factor. When cross-referenced with site information, all these sites were recorded as having large quantities of sewage-derived material and actually contained sewage pipes within them, confirming the appropriate naming of this factor. A predominance of sites numbered between thirty and forty were shown as being important in relation to sewage (Figure 7). Interestingly these were sites on the River Cynon, the tributary highlighted earlier as having the highest sewage composition within the catchment, and confirmed the importance of CSO discharges. The situation regarding the two fly-tipping factors was, however, a little more complicated with a possible seasonal change in the importance of different types of fly-tipping. Figure 8 draws together the various strands of this work indicating the various processes at work in the riverine litter model.

5. Conclusions

1. Fly tipping and sewage inputs have been pinpointed as major litter (point-source) contributors in riverine litter with the major input in the river Taff catchment coming from the former source. A warning should be made regarding fly tipping results. Caution is the key word when categorising tipping types. If doubt existed regarding origins, select a combination category. In taking steps towards reducing tipping within the catchment, an understanding of disposal problems is crucial and this is strongly recommended as an area for future investigation.

2. Tipping sites emerge where vehicular access or over the boundary tipping is possible. Much of the ordinary household waste/furniture could have been taken away from homes free of charge by local authorities. A question that could be asked is '*Is the public aware of this?*' This is clearly a social problem and beyond the scope of this paper.

3. Sewage litter comes from CSO. With increasing EC legislation this problem must be tackled on a systematic catchment basis and will probably take 20–30 yr before the bulk of the problem is solved (Lowe, Welsh Water plc, *pers. comm*).

4. PCA proved itself to be a useful tool for determining underlying trends in the Taff catchment data set. Its application is limited to data sets with only few zero recordings and therefore it cannot be used for analysis of catchments with low litter recordings.

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