

URBAN DIFFUSE SOURCES OF FAECAL INDICATORSO'Keefe, B.¹, D'Arcy, B. J.¹, Davidson, J.¹, Barbarito B.² and Clelland, B.¹¹ Scottish Environment Protection Agency (SEPA)² Scottish Water;**ABSTRACT**

Increasing concern about bathing water quality in Scotland has led to renewed interest in diffuse sources, as well as the already closely monitored municipal sewage effluents and combined sewer overflows (CSOs) that have been the subject of multi-million pound capital expenditure schemes for several years. Early investigations of diffuse sources, focused on rural land uses (e.g. Wyer et al 2000). This paper is an initial effort to consider the possible significance of urban diffuse sources. A review of the potential for diffuse urban sources includes consideration of sewage pollution in surface water sewers, as well as non-human sources such as pigeon and other bird roosts, and faecal material from pets such as dogs and cats. Portobello beach in Edinburgh is the case study selected, because of earlier work done by Scottish Water and SEPA. The Figgate Burn crosses Edinburgh to discharge onto the beach at Portobello, and pollution sources in its catchment are described. Additional information is reported from Dunfermline, where the sewer network has provided examples of 3 ways in which sewage pollution can occur in urban streams, and also Scottish examples of measures to control some non-human sources (e.g. SUDS).

KEY WORDS: Urban diffuse pollution, faecal indicator organisms FIOs, sewage, pets, birds.**INTRODUCTION**

Increasing concern about bathing water quality in Scotland has led to renewed interest in diffuse sources, as well as the already closely monitored municipal sewage effluents and combined sewer overflows (CSOs) that have been the subject of multi-million pound capital expenditure schemes for several years. There are indications that most of the bathing waters in Scotland that are problems have a freshwater input to them, either rural or urban. Early investigations of diffuse sources, focused on rural land uses (e.g. Wyer et al 2000). This paper is an initial effort to consider the possible significance of urban diffuse sources.

URBAN SOURCES OF FIOS

Sources of FIOs in urban watercourses include contaminated runoff, and also mistakes by householders or builders in draining foul sewers into the surface water drain – and hence directly to watercourse. Wrong connections of foul into surface water sewers include toilets, sinks, baths, showers and washing machines; grey water as well as faecal material. Even grey water can contain notable levels of faecal indicators (Eriksson et al 2002). Such drainage errors can be at the level of individual households, perhaps associated with DIY ('do it yourself') enthusiasts and can occur in existing housing developments, or can result from errors during the construction of new developments, sometimes involving wrongly connected foul sewers from entire streets or blocks. The impacts of such errors is most evident during low flow conditions, since the foul flows, although intermittent, are broadly independent of weather conditions.

In the UK, a different cause of foul drainage entering surface water sewers and watercourses is a consequence of a cost-saving practice adopted for post-war separately sewered housing, whereby the two separate sewers are provided with common manholes; so-called dual manholes. That drainage arrangement facilitates overflows of foul into surface water at the manhole where there is only a low weir separating the two drainage channels, which is easily overtopped whenever the foul sewer gets blocked. In a conventional separate sewer network, with separate manholes for foul and surface runoff, foul sewer blockages due to improper disposal of rags, nappies, etc quickly result in a call-out to the drainage authority due to the failure of foul flows to go "away". In a dual manhole, the foul blockages is not noticed since water still gets "away" (into a watercourse via the surface water sewer) and gross pollution can result and continue until noticed by the pollution control authority or is the subject of public complaint about the pollution.

Humans and sewer systems are not, of course, the only potential diffuse sources of faecal indicator organisms liable to contaminate surface waters in urban areas. Other sources include birds such as starlings and pigeons (especially roosts – see section below), waterfowl and gulls (sometimes colonies of gulls on flat roof areas in some coastal towns), dogs, cats, and rats, the latter frequenting the surface water sewers that discharge direct to watercourse. Can these non-human diffuse sources be significant?

In Melbourne it has been estimated that the dog fouling load is the pollution equivalent of the untreated sewage from 90,000 people, and the Pipers Creek study in Seattle suggested that cats were most important. The population of dogs in the UK has been reported as between 6.5 million and 7.4 million, producing some 1000 tonnes of faeces every day. Estimates variously report that daily faecal output per dog is 100–200g (Keep Britain Tidy Web page, 19.03.03). Many people express a view that such sources are natural – certainly for pets such as cats and dogs there is nothing natural about the densities of those animals in urban areas when compared with equivalent wild species in natural habitats (see table 1).

Table 1. Potential sources of faecal indicator organisms in urban areas.

Non-human source Species	Example urban density	Comments	Reference
Cats	160 / km ²	Bristol study	Baker et al 2000
Dogs	260/km ² 1 dog per 10 people	Dunfermline UK, and Urban USA	- Simmons et al 2000
Pigeons	10 – 250 /flock	At least 200,000 Breeding pairs in UK	Murton et al 1972
Rats	Similar to human population	60M rats in UK	Jeffery, S. 2002
For comparison: natural densities of some equivalent species in the wild Wildcat: 1 cat/3km ² – 1 cat/10km ² (Mammal Society website) Wolf: 2.6-43 per 1000km ² (max range of values from several studies, e.g. Atkinson & Janz, 1994, Ballard et al 1987)			

Table 2 gives estimates of the numbers of some faecal indicator organisms per gram of faecal matter produced by some of these urban animals. This data is used to derive the crude estimates in the case studies below to assess the possible significance of non-human diffuse sources in Scotland. The effects of urban sources of diffuse pollution such as dog fouling, droppings from bird roosts and the faeces of wild animals on water quality are most severe after a storm event when this matter is mobilised by rainfall. Not all contaminating material will be deposited on impermeable surfaces, positively drained to a surface water sewer and hence watercourse, and some such areas will be in older parts of towns that are drained into combined sewers.

Table 2. Faecal indicator organisms per gram of host faeces (from Haejin Ha and Michael K Methods to Identify Human and Animal Faecal pollution in Water: A Review).

Source	Faecal Coliform (density/gram)	Faecal strep (density/gram)	Ratio FC/FS
Human	1.3×10^7	3.0×10^6	4.33
Cats	7.9×10^6	2.7×10^7	0.29
Dogs	2.3×10^7	9.8×10^8	0.02
Rats	1.6×10^5	4.6×10^7	0.003
Ducks	3.3×10^7	5.4×10^7	0.61

CASE STUDIES: PORTOBELLO BEACH AND FIGGATE BURN

Portobello

Up until the mid 1970s, untreated sewage was discharged at a number of short outfalls along the Edinburgh and Portobello coast. Bacteriological results from this time record levels over 10 times the EC Mandatory Standard for faecal coliforms. Bathing water quality started to improve after the commissioning of Edinburgh's STW at Seafield in 1978. The last major untreated discharge affecting Portobello was diverted and pumped to Seafield after the commissioning of the Joppa pumping station in 1994. Despite the improvements carried out, Portobello West again failed the mandatory standard in 2000. Samples taken from the Figgate Burn at the same time as the bathing water surveys strongly implicated CSO or contaminated SWO operations in the Figgate Burn as the cause of the failure (low salinity).

The Figgate Burn

The Figgate Burn catchment is mainly urban; it rises in the Pentland hills and flows through Edinburgh to the Firth of Forth at Portobello. There are 12 CSOs potentially discharging into the burn. There is no discharge from the treatment works direct to the burn, though up until 2002 there was an industrial site with a private septic tank discharge.

The Figgate study involved sampling at several locations on the Figgate catchment to monitor the effects if any from the 12 CSOs and possibly unknown faecal sources. The most significant problems found were 3 CSOs, a septic tank discharge, and contaminated surface water from 3 sources within ½ mile of the beach. One of the surface water discharges contained in excess of 500,000 faecal coliforms per 100 ml on some occasions. Investigations traced the source of this contamination to a pigeon roost below a railway bridge. Cleaning the pavement below the roost, the local authority pressure hose the road and walkway twice a week. The washings entered the surface water via road gullies and thus to the burn. Other faecal sources were traced to guard dog kennel washings at a military establishment, sewage contaminated surface water outfalls, and a misconnected sewer to a minor culverted tributary (see table 3).

Table 3 Diffuse sources of FIOs at Figgate Burn

Source	Example Concentration	Comments
Pigeons	0.5 x 10 ⁶ FC's per 100ml in SW outfall to Figgate Burn.	Wet weather sample of SWO draining roost area
Dreghorn Barracks	0.27 x 10 ⁵ FC/100 ml (sample taken d/s of surface water outfall)	This high value was attributed to the water used to hose down the kennels entering the surface water drain and discharging in the Braid (Figgate) Burn
Wrong Connections	Pow Burn 0.65 x 10 ⁵ FC/100ml (18/08/99)	Wrongly connected housing development (this is the stream conc. just d/s of SWO).
Dogs in catchment	Theoretical estimates	12-56% load measured in burn

From data in tables 1 and 2, estimates have been made of the proportion of the measured faecal coliform load in the Figgate Burn that could be attributed to the local dog population, at various flow conditions in the burn. Dog input as a percent of total ranged from 12% to 56%; not inconsistent with other studies that have indicated around 20%. Whilst it is likely that the Figgate values are over estimates, since by no means all deposited material will contaminate the burn, it seems probable that dogs could be a significant factor.

Improvement Actions

Duddingston road CSO spill frequency was reduced from 74 incidents a year to 3 per bathing season in November 2001 by raising the height of the overflow weir by 500 mm. (The original plan for this was to build in storm storage at the cost of several £100,000s). Dual manholes in the Figgate Burn Park were addressed in November 2000. The septic tank was replaced by connection to the main sewer system in 2002, and sewer misconnections to the Pow Burn tributary of the Figgate were resolved in July 2001. The pigeon roosts were netted off to reduce opportunities for roosting birds in December 2001. In addition, when the council carry out cleaning duties, they now block off the outlet from the road gullies and remove wastewater.

Effect of Improvements on water quality in the Figgate burn

Figure 1 shows total coliforms as seasonal medians, as these are thought to give a truer reflection of microbiological water quality than mean values. As can be seen, in the years after the improvement actions were carried out there has been a drop in the TC number.

CASE STUDY: DUNFERMLINE AND THE LYNE BURN

Urban sources

A survey of surface water outfalls discharging into the Lyne Burn and its tributaries was undertaken prior to a major capital scheme to build storm sewage storage tanks and replace old sections of combined sewer with new, increased capacity trunk sewers. For many of the outfalls there was clear evidence of sewage pollution. That was in most instances associated with either storm sewage discharges (surcharging manholes along a length of old combined sewer) or foul sewer blockages leading to dry weather discharges via surface water sewers, facilitated by dual manholes. Other sewage pollution was due to direct wrong-connections. In addition, levels of contamination were detected that did not appear to be associated with any sewage contamination. The possible sources of contamination include dogs and other pets, and roosting birds, as discussed above.

Figure 2 shows the faecal coliforms counts of samples taken on the Tower burn at Pittencrieff Park (combined sewer catchment area) and on the Calais burn (separate sewer catchment), taken on 5 days between November 1987 and February 1988. It also shows the estimated percentile flow condition based on an Daily Mean Flows recorded at a SEPA gauging station on a nearby watercourse (River Ore) for the same days. This gives an idea of the river flow on the sampling days, as an indication of antecedent rainfall. It is clear that consistently the highest level of contamination was present in the nominally uncontaminated (separately sewer) tributary, the Calais Burn. The level of contamination was sufficiently high to still be significant even when river flows were up. The sources of sewage pollution in the Calais Burn were wrong connections and blockages causing overflows at dual manholes: chronic and severe pollution.

The other tributary stream shown, the Tower Burn in Pittencrief Park, was influenced by wet weather pollution from surcharging manholes on the old combined sewer that ran parallel to the burn through the park. High values were only evident after wet weather (higher river flows, e.g. 2nd December on figure 2).

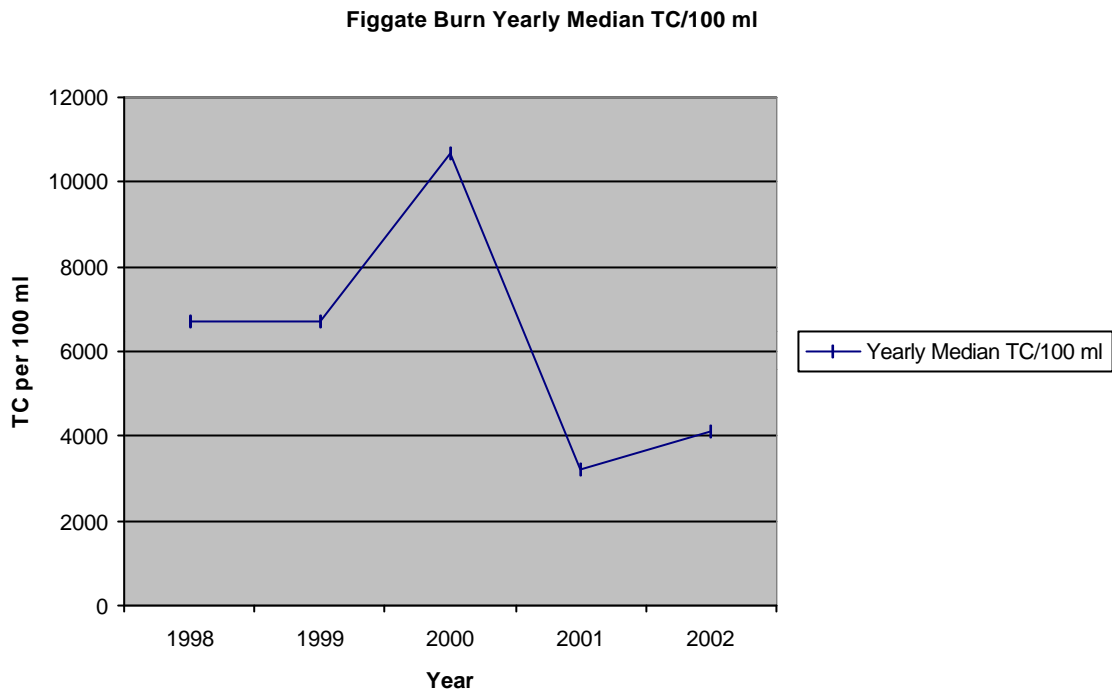


Figure 1. Figgate Burn Yearly Median TC/100ml

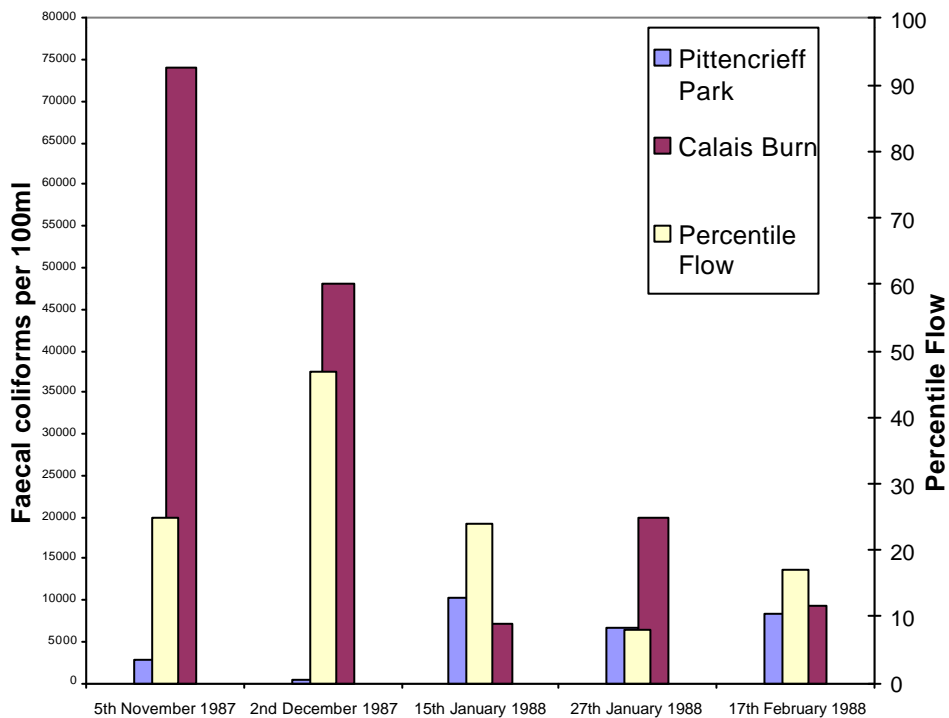


Figure 2. The Lyne Burn and tributaries, Dunfermline.

[Key: Tower burn in Pittencrieff park – at risk from surcharging combined sewer;
 Calais burn – at risk from wrong-connections and overflows at dual manholes;
 Percentile flows – values that are exceeded for those percentages of times (lowpercent, high flow).]

Pollution control and prevention in Dunfermline

Major capital works were initiated in the late 1980's to address sewage pollution:

- replace a major length of combined sewer through Pittencrieff Park, to eliminate surcharging problems affecting the Tower Burn
- build massive new storm sewage storage tanks
- rebuild dual manholes in worst affected parts of the town to provide pairs of separate sewer manholes

- divert parts of the separate sewer system with chronic and severe wrong-connections problems entirely into one of the new storm tanks (surface water and foul flows) as an interim measure, pending resolution of individual problems and further work on dual manholes that were also a feature of that catchment area (Calais Burn).

Current control activities include regular checks for new wrong connection problems by the water utility (Scottish Water) and SEPA, and a programme of action by the local authority (Fife Council) to address non-human sources such as pets and pests. 120,000 pounds is to be spent on dog fouling problems by the local authority in 2003-04, including provision of 300 additional poop bins at 138-228 pounds each, and purchase of two million poop bags, at 8 pounds per 1000 bags. The dog warden service run by the local authority costs about 0.80 pounds sterling per person and the poop bags provided by the authority cost 8 pounds per 1000 bags. The dog bins are emptied by the local authority and contents disposed of to landfill. A pest control officer deals with pigeons and rat problems.

For new urban developments SUDS technology is routinely sought (see McKissock et al 2001). Where regional features such as wetlands and retention ponds have been provided it is expected that FIO loads will be adequately reduced; the effectiveness of other SUDS techniques (as used for smaller developments) is less certain.

DISCUSSION

Drainage options

Storm tanks and relief sewers provide expensive solutions to CSO and sewer surcharge problems in urban areas. For reducing the frequency of spills of storm sewage from combined sewers there may be circumstances where it is cost effective to divert rainwater runoff to SUDS features in the catchment of the combined sewer: possible applications of SUDS technology in this way are currently being sought for bathing waters at risk from urban areas. Proper provision of conventional pairs of separate manholes is the only long-term solution for dual manholes, since insertion of an ad hoc brick wall inside a dual manhole impedes work to clear subsequent blockages and usually gets demolished by the sewer choke squads. In other situations where free draining soils and adequate available land area could be used, it might be cheaper to divert surface runoff to grass plots or engineered soakaways; a source control solution. The loading from non-human sources suggests that additional measures will continue to be needed, if SUDS technology is applied, to prevent overloading systems with contaminated runoff.

Local authority actions and education campaigns

Actions to encourage the public to not dispose of nappies/cloths/other wastes down toilets and thereby cause sewer blockages have been taken in campaigns by the water utilities in the UK. In Scotland, Scottish Water are currently revisiting this idea with support from SEPA in a new Clean Drain Campaign, that in partnership with local authorities, can also pick up wider issues as below.

A variety of control measures have been tried to reduce pollution from birds and other urban creatures (see table 4). Once again, working in partnership and involving the public are pre-requisites for success. Evidence for the effectiveness of control measures is important, for pest control as for other measures. e.g. Nottingham City Hospital estimates that there has been a 50% decrease in its bird population in the first year of the trial. (PICAS).

Keeping streets clean, securing refuse sacks and reducing littering all help to reduce the amount of food available for animals such as rats, foxes and gulls in urban areas. If these populations are controlled, their waste will also be controlled.

Table 4 Measures to control pet/animal sources of diffuse pollution

Target	Measure	Regulator	Comments
Pigeons	Population Control	LA	Humane, population control methods (i.e. controlled nesting and feeding) seem to be more effective than culling.
Dogs	Education, more appropriate park design	The EPA 1990 places a duty on local authorities to keep public areas free of dog faeces.	Urban spaces are designed in a way that doesn't allow natural decomposition. New design may help but this must be in conjunction with education of the dog owning public.
Cats	Keep cats indoors more and dispose of cat litter correctly	Local authority pest control officer	Cats can contribute as much or more faecal pollution than dogs.
Waterfowl	Controlled nesting and feeding sites (population control)	Contamination to water bodies – SEPA?	Similar to pigeons.
Rats, urban foxes etc	Keep streets tidy	Environmental health departments of local authority	There is little information on their contribution to diffuse pollution. Their populations are increasing in response to more available food (i.e. human refuse).

CONCLUSIONS

Well recognised anthropogenic diffuse sources include sewer failures and blockages and wrongly connected foul drains into surface water sewers. There is considerable evidence also that non-human sources can be significant. These sources include dogs and cats, as well as bird roosts in urban areas (often on or above impervious, positively drained surfaces).

A less constrained approach to seeking solutions for improving water quality at bathing beaches needs to be sought. Conventional control measures for sewer problems remain a primary area for attention by the drainage authorities, but attention should increasingly be given to retro-fixing SUDS facilities, both to provide more cost-effective solutions to CSO pollution and to help address diffuse sources of pollution from urban areas not served by combined sewers.

The Portobello/ Figgate Burn, and Lyne Burn (Dunfermline) case studies above indicate what can be achieved by conventional sewerage technology, assisted by local authority actions and joint initiatives. It is suggested that the several options that need to be considered in urban areas in relation to bathing waters are:

- CSOs and storm tanks
- SUDS retrofits
- Education of public
- Regulation by local authorities (pets and pests)
- Government Regulation (where not already in place and effective)

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