Long Term Monitoring of Pollutants in Highway Runoff

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INTRODUCTION

Highway surface runoff discharges may contain pollutants that have accumulated on the carriageway, particularly following periods of dry weather. These pollutants can then be transported via the surface water drainage system to discharge to ground or receiving watercourses. The Highways Agency has the responsibility for ensuring that discharges of runoff from motorways and trunk roads in England meet relevant legislative requirements and good environmental practice. The implementation of the EU Water Framework Directive will require the additional assessment of a surface water's ecological status coupled with the need to ensure that there is no deterioration in its status. The focus of the Highways Agency's ongoing research into the nature and impact of highway runoff is aimed at ensuring that the Highways Agency will meet the requirements of the Directive.

The Design Manual for Roads and Bridges Vol. 11, Section 3.10 (HMSO, 1998) presents guidance on the current assessment methodology for the impact of highway runoff and is largely based on the findings of a study completed in 1994 (CIRIA, 1994). Although developed from the most up-to-date information available at that time it is recognised that aspects of this guidance are outdated and limited. The study was based on the use of limited UK and overseas data collected during the 1970s and 1980s. These data may no longer be representative of pollutants currently present in highway runoff. As a consequence, the Highways Agency now wishes to update their guidance so that more robust assessment advice, coupled with an improved assessment methodology, can be developed to meet the requirements of the Directive. Improved data on pollutant concentrations in highway runoff is a key factor in developing improved guidance to assess and control the impact of highway runoff on receiving waters, and to assist in the future design of highway drainage systems.

In 1997, the Highways Agency, in association with the Environment Agency, commissioned WRc to undertake a data collection study to improve the understanding of contaminants in routine non-urban highway runoff, and to examine the treatment efficiency of associated drainage systems and drainage devices. Many systems have been installed to provide environmental protection through hydraulic control and while the potential for additional treatment is recognised it has not been quantified.

The objectives of the study were:
- to undertake a programme of data collection for non-urban highways under a range of site conditions;
- to create a database of flows, pollutant loads, rainfall and site details obtained during the study;

- to identify key determinands and their concentrations in highway runoff;
- to establish any relationships between pollutant concentrations and traffic flows, rainfall totals, rainfall intensity, rainfall duration and antecedent dry periods;
- to identify the treatment efficiency of a number of specified highway drainage types or combinations of treatment devices or facilities; and,
- to evaluate the chemical and biological impact of highway runoff on receiving water quality.

The study was completed in 2003. This paper presents an overview of the data collection programme and summarises the key results. Full details of the outcome of the study are presented elsewhere (Moy F, Crabtree R and Simms T, 2003).

DATA COLLECTION PROGRAMME

The data collection programme was designed to obtain information on the quantity and quality of non-urban highway runoff and of the receiving waters at 6 sites incorporating untreated runoff and 8 different drainage treatment facilities. Sites were selected on the basis of drainage system/drainage feature types specified by the Highways Agency and a minimum Annual Average Daily Traffic (AADT) of 15,000 vehicles/day. Off-carriageway access to monitoring equipment was a key safety factor in site selection. The characteristics of the sites are shown in Table 1.

Table 1. Monitoring Site Characteristics

Site	Lanes	AADT	Surface	Treatment Devices Monitored
M4/Brinkworth Brook	3	71929	Asphalt	Untreated runoff
A417/River Frome	2	23647	Asphalt	Runoff Bypass oil interceptor Dry balancing pond
M4/River Ray	3	36107*	Asphalt	Runoff Oil trap manhole Sedimentation tank
M40/Souldern Brook	3	83579	Asphalt	Runoff Full retention oil trap Wet balancing pond
A34/Gallos Brook	2	64953	Concrete	Untreated runoff Filter drain
A34/Newbury Bypass	2	37192	Porous Asphalt	Runoff Bypass oil interceptor Surface flow wetland/ wet balancing pond

* single direction only

The major selection criteria for the receiving waters were that they should have similar characteristics to allow inter site comparisons to be made; they should be unaffected by other sources of pollutants; and, that the downstream watercourse impact may be determined without other influences. However, in practice the characteristics of the watercourse became a secondary consideration to finding suitable monitoring conditions for the specified drainage and treatment facilities. Each site was monitored for a minimum of 1 year. This included continuous rainfall measurement and flow monitoring of the watercourse upstream and downstream of the highway runoff outfall. Background water quality samples and in situ measurements were taken at quasi-monthly intervals. Sediment samples were taken at the beginning and end of the monitoring period from the drainage system and from the watercourse.

Highway runoff was sampled for 10 wet weather events at each site under a range of background and event characteristics. Flow measurement was undertaken at the point of highway runoff discharge and liquid samples were taken upstream and downstream of each runoff treatment device. Water quality probes were deployed at the upstream and downstream watercourse locations. in addition to flow measurement. Event mean flow weighted composite samples were analysed for the presence of 40 determinands, including 12 metals (total plus 2 dissolved metals), 16 Polyaromatic Hydrocarbons (PAHs), 5 herbicides, BOD, COD, Hardness, Chloride, TSS and Ammonia. A remote telemetry system was developed to control and monitor wet weather data capture at each site. All data from the monitoring programme were collated and archived in a database and used to identify: pollutant concentrations in highway runoff; pollutant concentration relationships with event and site characteristics; the efficiency of the treatment facilities in removing the pollutants; and, the impact of the highway runoff on the receiving water.

SUMMARY OF RESULTS

Pollutants in Highway Runoff

In the course of the study, all determinands (with the exception of the herbicide Amitrole) were detected during a monitored event. However, a number of determinands were only detected at a singe location for a limited number of events. A strong correlation was found between concentrations of metals and PAHs at all sites.

Of the determinands monitored a number were present at low concentrations or below the limit of detection (LOD) during a number of events and/or at a number of sites. Other determinands were consistently detected, some at concentrations at or slightly above LODs and some at consistently higher concentration levels. Determinands detected in over 50% of the events with concentrations 50% above LOD have been identified as being potentially significant, key determinands, as shown in Table 2.

Table 2. Observed average event mean concentrations for key determinands

Determinand	% events detected	LOD µg/l	Average Event Mean Concentration µg/l
Copper	100	0.3	40.4
Filtered Copper	100	0.3	17.5
Zinc	100	0.6	139.2
Lead	88	0.1	24.6
Glyphosate	28	0.02	0.87
Benzo(b)fluoranthene	70	0.01-0.05	0.14
Benzo(k)fluoranthene	67	0.01-0.05	0.08
Benzo(a)pyrene	75	0.01-0.05	0.14
Indeno(123)cdpyrene	63	0.01-0.05	0.10
Benzo(ghi)perylene	50	0.01-0.05	0.09
Na mg/l	100	0.5 mg/l	171.5
BOD mg/l	100	1.0 mg/l	6.6
TSS mg/l	100	1.0 mg/l	114.6

Comparison with the ranges of pollutant levels for rural roads as listed in Table 5 of the Design Manual for Roads and Bridges, Volume 11, Section 3, Part 10, Water Quality and Drainage (DMRB), is limited to 5 determinands. The ranges of mean concentrations monitored during the study are greater than those presented in the DMRB with the exception of lead concentrations. This may reflect the current use of lead free fuels. Table 3 compares the ranges listed in the DMRB with the study results. Also presented are the minimum/maximum event mean concentration ranges identified during this study. The DMRB values for rural highways are based on the results from 31 sites in the USA (Strecker et al, 1990) and are presented for illustrative purposes.

Table 3. Comparison of ranges of pollutant levels.

Pollutant	DMRB (Rural Roads) Median EMC*	WRc Study Average EMC	WRc Study Min/Max Range EMC
Total Copper (µg/l)	10 - 50	24 – 64	<4.0 - 242
Total Zinc (µg/l)	35 - 85	53 – 222	21 - 688
Lead (µg/l)	24 – 272	4 – 45	0.2 - 178
COD (mg/l)	28 – 85	70 – 138	28 – 458
Total Suspended Solids	12 – 135	53 - 318	<1.0 - 256

* value exceeded by 10% and 90% of sites respectively

Analysis of intra and inter site event response characteristics identified a number of possible relationships associated with pollutant concentrations in highway runoff:

- a relationship exists between climatic season and highway runoff quality. Pollutant concentrations, and in particular metals, appear in higher concentrations following winter salting;
- a relationship may exist between runoff concentration and rainfall intensity;
- no relationship can be identified between runoff concentrations and antecedent dry period; event total rainfall and event duration;
- no relationship can be identified between runoff concentrations and traffic flow, carriageway catchment area and carriageway width

Treatment Efficiency

The comparison between the 4 monitored sites where it was possible to measure treatment efficiency (excluding the A34 Gallos Brook site due to the presence of gully pots) examined the overall efficiency of the combinations of devices at the individual sites. A ranking of the combined efficiency of the treatment devices at these sites is shown in Table 4.

The greatest observed pollution removal efficiency was produced by a combination of a bypass oil separator and surface flow wetland/ wet balancing pond at the A34/Newbury Bypass site. Although metals removal was less efficient than at other sites, the high removal efficiency for PAHs and TSS gave an overall higher performance.

Table 4. Combined treatment efficiency ranking

				% reduction:inlet to outlet

Ranking	Site/Treatment Devices		Initial form of treatment	Second form of treatment	Total system treatment
1	A34/Newbury Bypass	Metals	15	11	24
	Bypass oil separator/ surface flow wetland/wet balancing pond	PAHs	-1	99	99
		TSS	37	73	83
2	M40/Souldern Brook	Metals	19	35	48
	Full retention oil separator/wet balancing pond	PAHs	13	50	57
		TSS	-9	62	58
3	A417/River Frome	Metals	27	39	56
	Bypass oil separator/dry balancing pond	PAHs	4	16	22
		TSS	56	-37	40
4	M4/River Ray	Metals	-7	41	30
	Oil trap manhole/ sedimentation tank	PAHs	-30	-26	indeterminate
		TSS	-19	43	33

River Impact

Receiving water event and background monitoring at the 5 sites where data could be collected showed no apparent impact of highway runoff over background and upstream conditions. Sediment analysis showed little significant accumulation of contaminated sediments downstream of highway runoff discharges in watercourses. The results of biological surveys undertaken at these sites suggest that the highway drainage system discharges did not appear to have adversely affected macro-invertebrate communities in the receiving waters. These results differ from previous studies where impacts have been reported at sites receiving runoff from urban highways.

CONCLUSIONS

While the overall quantity of runoff data is relatively large, with 60 events captured, the number of event data sets collected at individual sites is relatively small taking into consideration the observed variability of the events, background environmental conditions and highway characteristics. This has limited the identification of relationships between event and site characteristics and the resulting runoff quality at individual sites. In addition, the number of highway variables between sites has limited the conclusions that may be drawn from inter site comparisons of runoff, treatment device efficiency and environmental impact on the receiving watercourse.

A number of determinands were not detected. However, the sites monitored do not represent the full range of characteristics across the highway network and, therefore, these determinands may be identified elsewhere. A number of determinands were detected during all monitored rainfall events and at concentrations well above limits of detection. The range of observed event mean flow weighted pollutant concentrations is higher than those quoted in the DRMB. A number of possible relationships associated with highway runoff quality can be proposed. Determinand concentrations, and in particular metals, appear in higher concentrations following winter salting and a relationship may exist between runoff concentration and rainfall intensity. The outcome of the study indicates that, in general, pollutant concentrations in highway runoff are low and often close to analytical limits of detection. However, under certain conditions related to the nature and characteristics of the highway, the rainfall/runoff event and the receiving water, it is possible that the pollutants in highway runoff may exert an acute and or chronic impact on the chemical and ecological status of the receiving water.

Overall, the results from the study seem to differ from previous studies of runoff quality and receiving water impact, largely associated with urban highways, higher traffic densities and different regional climates and receiving water characteristics. As a consequence, the Highways Agency consider it necessary to enhance existing data to support the development of a methodology to predict the concentrations of soluble and insoluble pollutants in highway runoff and the potential for any resulting impact at any location. A systematic approach to measuring pollutants in highway runoff at locations under a range of site conditions throughout England is being undertaken by WRc as part of a new study. This will involve data collection from storm events at 24 locations. The aim of these measurements is to identify clearly the key contaminants in routine runoff and the relationships between pollutant concentrations and site characteristics. These data will be used to develop a predictive methodology for highway runoff pollution concentrations, and resulting pollutant loads, discharged to the receiving water. The study will help to facilitate the Highways Agency's long term objective of being able to offer improved advice on the circumstances where, and when, highway runoff is likely to have a significant impact. In turn, this will inform improved decision making on the need for the provision of appropriate facilities for the treatment of highway runoff at a given site.

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