SCI LECTURE PAPERS SERIES

Pollution from highway runoff: the Highways Agency approach

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ISSN 1353-114X
LPS 101/99

Key words *highways, runoff, pollution, drainage, spillages*

1. Introduction

1.1 This paper gives a general introduction to the Highways Agency's understanding of the current state of knowledge of pollution that can arise from highway runoff and of the relevant legislation. It outlines the advice published by the Agency and indicates where research and consultancy projects are being undertaken both to improve this advice and to determine whether additional treatment is needed for some existing highway discharges.

1.2 Section 100 of the Highways Act 1980 gives a highway authority the power to discharge surface water from highway drains into any inland waters, whether natural or artificial, or into any tidal waters. Whereas the discharge of polluting matters into controlled waters would normally be an offence under Section 85 of the Water Resources Act 1991, Section 89(4) of that Act provides a defence for a highway authority whereby discharge of highway runoff will not be an offence unless it is made in contravention of a specific prohibition made under Section 86 of the Act.

1.3 Section 86 gives the Environment Agency the power to serve a notice prohibiting a discharge, or to allow it subject to conditions. By this means the requirement for a consent may be imposed on a particular outfall. The view of the Highways Agency is, however, that this is a site specific power and proper grounds would have exist for it to be applied in any particular case.

1.4 Discharge consents are not therefore normally required for highway runoff. Other consents may be required for interference to a watercourse for the purpose of constructing the outfall, but such consents cannot be unreasonably withheld and do not relate to the discharge itself. The lack of a need for a discharge consent does not, however, give a highway authority the right to cause pollution. Highway Authorities are not exempt from the provisions of the requirements of relevant EU directives, such as the groundwater directive and the dangerous substances directive. The implementation into UK law of the former has recently been updated and clarified by the Groundwater Regulations 1998. There is also the potential for civil liability if a highway discharge could be shown to cause "sensible alteration" to the quality of a watercourse in a way which interferes with rightful enjoyment or use of the watercourse by the riparian owner.

1.5 Highway authorities therefore have a duty to take action themselves to ensure that discharges of highway runoff do not cause unacceptable harm or pollution. To this end the Highways Agency agreed liaison procedures for consulting the National Rivers Authority and these are to be updated now that the responsibilities of that body have passed to the Environment Agency.

1.6 The principles of the responsibilities of highway authorities for the effects of highway runoff are thus fairly clear, but fulfilling those responsibilities is difficult. This is due both to the complex nature of the problem and to the fact that the current state of knowledge is not yet sufficient for accurate prediction of either the polluting effects of the runoff on the receiving waters, or for the efficient design of treatment measures.

2. The main sources of pollution in runoff

2.1 The pollutants found in highway runoff arise from a number of sources:

a) the effects of traffic;

b) the effects of maintenance

c) normal depositions on the highway;

d) spillages.

2.2 Pollutants generated by traffic arise either from the workings of the vehicle itself, or from its contact with the road. The former includes both the content of exhaust emissions and the products of leakage and corrosion. Vehicle exhausts contain unburnt fuel and combustion products in the form of volatile solids, which act as carriers for various metallic products of engine wear. Substances dropped from vehicles include lubricating oils, hydraulic fluids and metallic corrosion products. Contact of the vehicle with the road surface gives rise to products of abrasion from both tyres and from the road surface itself.

2.3 Pollution from maintenance operations arises from regular maintenance or from structural maintenance, renewal and repairs. Regular maintenance includes de-icing and weed control, which involve the use of chemicals (de-icing salts and compounds, herbicides) that will be flushed from the highway surface by runoff. Structural maintenance and repairs are usually planned construction operations for which appropriate precautions can be taken.

2.4 Depositions on the highway arise either from the atmosphere or from human or animal activity. The latter includes litter, agricultural activities, animal wastes and pollutants arising from roadside vehicle maintenance. The extent and type of depositions are dependent on both the nature of the location and the climate. Rain and snow scavenge atmospheric pollutants and can transmit them some distance from the source. Industrial areas can generate dust containing pollutants. In rural areas dust can arise from soil erosion and is then more inert in content. Urban runoff contains pollutants generated by many of the activities associated with urban living, enhanced by the extent of hard surfacing adjacent to the roads.

 ISSN 1353-114X

2.5 Significant spillages are usually the result of accidents, though, particularly in urban areas "spillages" can arise from construction operations or other activities on land adjacent to the highway.

2.6 The terms "routine runoff" and "routine pollution" can be conveniently used to describe the normal runoff from the road and the pollutants contained within it respectively, that arise from everyday use and maintenance of the road. The composition of routine runoff is not, however, constant. It varies between storm events, depending on the length and climate of the antecedent dry period, and also during the storm event itself. It has been shown that there is usually a "first flush" effect, whereby there is a higher concentration of pollutants in the initial stages of the storm event.

2.7 Pollution is thus either "routine" or event sourced. Pollution from spillages, renewal and repairs and some human activities (for example an agricultural show or similar event) are event driven. Pollution from the other sources described is routine.

3. Pollutants in routine runoff

3.1 A very wide range of pollutants has been detected in highway runoff, though many occur in very low concentrations close to the limits of detection. It is therefore useful to identify those that are of most concern and which may be used as indicators of the overall level of pollution of runoff.

Sediments

3.2 Much of the larger suspended solids component is inert. Inert sediment can, however, be harmful in certain types of watercourse, where it can smother some fish, plants and invertebrates. The majority of the pollutant load is carried on, or associated with, the particles, but mostly on the smaller fraction (<63μm) which constitutes only about 6% of the suspended solids load. This smaller fraction is more readily maintained in suspension and can be dispersed widely from the outfall.

Hydrocarbons

3.3 This group includes both the heavier hydrocarbons derived from oil and the Polynuclear Aromatic Hydrocarbons (PAHs) derived from unburnt fuel. The latter have a greater affinity for the small sediment fraction. The presence of oil is aesthetically unpleasant on surface waters and can impart taste in very small concentrations. Some PAHs have been shown to be toxic to freshwater invertebrates.

Metals

3.4 The presence of many metals can be detected but the following are thought to be of most significance: cadmium, lead, copper and zinc. Iron and aluminium are detected in significant amounts, probably as corrosion products, but are not toxic in the concentrations observed. Due to source control the use of lead and cadmium is declining and should cease to be a problem in runoff in the medium term. Copper and zinc occur as both insoluble and soluble fractions. The former associate with sediment, but the soluble fractions are toxic to fish at low concentrations, particularly in soft waters. As maximum copper and zinc contents are laid down in the Environmental Quality Standards (EQS) current advice is to use these metals as indicators of the overall soluble pollutant content of runoff.

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Herbicides

3.5 Herbicides are toxic in very low concentrations. Persistent herbicides such as the atrazines and simazine should no longer be used, but may still be detectable because of their longevity. Degradable compounds, such as glyphosate, are now the preferred option for weed control.

Predicting the pollution content of highway runoff

3.6 Though there is a variety of published data on pollutants in highway runoff it is very variable in nature. Some is relatively old and does not reflect recent changes in fuels and vehicle construction; other data is drawn from the USA and continental Europe and may not always adequately reflect UK conditions. Added to this is the difficulty of measuring and reporting such a transient and variable phenomenon. The current state of knowledge is well summarised in CIRIA Report 142 – Control of pollution from highway discharges (CIRIA 1994). This document also provides methods of predicting concentrations for some pollutants and guidance in estimating the potential effects of others.

4. Effects of pollutants in routine runoff

4.1 It is important to keep the potential effects of routine runoff in perspective. There is a very wide range of highways in both urban and rural situations. Clearly a country lane is unlikely to pose a similar threat to a motorway. Even for the trunk roads and motorways for which the Highways Agency is responsible there is still a wide range of types of roads and traffic flows, from single carriageways with traffic flows of the order of 10,000 vehicles per day to dual 4 lane motorways carrying in excess of 150,000 vehicles per day.

4.2 The characters of the receiving waters into which highway runoff discharges can also differ widely. Surface receiving waters extend from large slow flowing lowland rivers to small upland streams. The following factors are important:

a) the dilution of the runoff by the receiving waters;

b) the quality of the receiving waters (normal pollutant content);

c) the sensitivity of the receiving waters (includes diverse factors such as species present, the ability to disperse discharges quickly, the nature of the bed and the vegetation).

Where discharge is to ground the quality of the ground waters and the presence and proximity of extraction points are the most significant factors in assessing the impact of the discharge.

4.3 The impact of highway runoff is therefore dependent on the attributes of both the highway and the receiving waters. It cannot be stressed too strongly that site specific assessment is necessary, particularly for major outfalls. The treatment of highway runoff should not be regarded as being amenable to "off the shelf" solutions.

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4.4 A research project undertaken for the Highways Agency by WS Atkins and Humphries Rowell Associates looked at the impact of untreated highway runoff at 100 discharge sites in England and Wales. The objective was to establish the impact on the watercourses by sampling macroinvertebrate fauna upstream and downstream of the discharge and also close to the point of discharge. Great care was taken to select sampling points having equivalent physical and biological characteristics. Using recognised biological indices as an indication of watercourse quality, the large amount of data collected was subjected to an intensive statistical analysis to try to establish whether there were any chronic (long term) effects.

4.5 It was shown that downstream reductions in the biological indices were often associated with high biological water quality upstream and heavy traffic flows on the road. These relationships did not always apply, however, and, in some cases biological indices actually increased downstream of the outfall. Other factors were identified as being important, such as:

a) the type of watercourse (upland, lowland, slow flowing, fast flowing);

b) size of watercourse (and dilution of flow);

c) local rainfall.

4.6 The study established statistical relationships and likely trends only. It did not establish causes and further research will be needed before the ecological effects of runoff can be reliably predicted. The study does, however, confirm the site specific nature of the effects of highway runoff and the complexity of the interaction between the pollutants and the local environment. To provide an accurate prediction of effects it will be necessary to consider more than the flow volumes and chemicals present in the runoff and the receiving waters.

5. Control of pollutants in highway runoff

5.1 It is thought more appropriate to refer to "control of pollutants" rather than "treatment" because only some of the pollutants can be treated in the sense that they can either be broken down into compounds that can be discharged without harm, or removed from the runoff by "fixing".

5.2 The following principal methods are available:

a) trapping and sedimentation

b) treatment

c) source control

5.3 Trapping of the coarse sediment load occurs in traditional drainage systems such as gully pots and catchpits. Oil separators are used to trap oil in sensitive locations. It is thought, however, that up to 70% of the pollution load is associated with sediments, but much of it adheres to the fine particles, which will not be removed by traditional drainage systems. More sophisticated sedimentation may therefore have the potential provide effective pollution control if it can be designed to remove the fine particles.

5.4 Treatment in this context refers to biodegradation (of hydrocarbons) and "fixing" (of metals). It may prove possible to design vegetative treatment systems to provide this type of treatment to a sufficient degree. They will however, have to be capable of withstanding the variable and intermittent flows of highway runoff and be able to survive the long dry periods which are becoming more common in some areas of the UK. The Highways Agency is not convinced that reed beds provide a universal solution though, as a genre, vegetative systems are potentially promising.

5.5 Source control is the ideal means of control, but for most pollutants in runoff its implementation is not within the power of the highway authority. The uses of herbicides and de-icing salts are, however, the exception. There are also currently no realistic means of treating them within highway drainage systems. Use of de-icing salts and herbicides therefore needs to be restricted to the minimum necessary for the highway authority to comply with its responsibilities to maintain a safe highway.

6. Spillages - occurrence

6.1 In each Environment Agency region there have been, on average, 1 or 2 major spillage incidents on all trunk roads reported per year. About 70% of spillages involve hydrocarbons, which are hazardous substances and classified as such. It is important to appreciate, however, that some substances that are not hazardous to humans can cause considerable environmental damage, particularly to small watercourses; examples are milk, and foodstuffs such as sugar and beer.

6.2 Though a major spillage represents a very serious threat to the environment the probability of an occurrence at any particular location may be very small. A balanced assessment, related to the overall assessment of risk at a location, is needed to determine the justifiable level of expenditure on specific spillage control and containment measures.

6.3 Thorburn Colqhoun have undertaken a study for the Highways Agency on the accidental spillage of substances on highways. Following a comprehensive examination of available data they undertook a frequency risk analysis to enable the determination of the probability of a spillage incident, and a consequence risk analysis to determine the probability of the incident giving rise to major pollution. In devising a method to predict spillage event return periods they also made an allowance for under-reporting of incidents. Relevant factors in determining spillage return periods are traffic flows, accident rates, the local highway configuration and the time of response of the emergency services.

6.4 The Highways Agency advocate the use of the method devised by Thorburn Colqhoun to predict spillage return periods for drainage catchments as a tool for determining the extent of spillage control and containment facilities to be installed in the drainage systems of trunk roads and motorways.

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7. Spillages - control

7.1 Effective control of a spillage requires rapid action by the emergency services to contain the spillage by isolating part of the drainage system. Sufficient storage capacity will also be needed if the spilled substances are to be fully contained.

7.2 The following can be provided by the highway authority:

i) reliable and easy means of isolating part of the drainage system;

ii) information on the outfall catchment and the means of isolation;

iii) containment facilities to protect the outfall.

7.3 Generally the Highways Agency advocate the provision of containment facilities where the calculated return period for a spillage event is less than 1 in 100 years for sensitive receiving waters or less than 1 in 50 years in other cases. If the discharge has to be to a site of exceptional ecological value it may be that containment facilities should be provided whatever the calculated return period, but this is a matter for local judgment. In the design of isolation control and containment for spillages, the length of the return period should be particularly borne in mind, together with the likelihood of effective maintenance over a long period of devices that will be used infrequently. The less sophisticated isolating devices such as sandbags, retention boards or simple flap valves may prove effective long after a penstock has seized up for want of attention.

7.4 Design of containment facilities and routine pollution treatment systems should be considered together. Elements of the system such as oil separators, sedimentation tanks and vegetative systems can provide both functions. It is essential that easy access is provided to the means of isolating the system.

8. Advice on the assessment of highway runoff

8.1 The Highways Agency has updated (February 1998) its advice in the Design Manual for Roads and Bridges (DMRB) on the assessment and control of highway runoff. This is to be found in Volume 11 – Environmental Assessment; the relevant part is Section 3 Part 10 – Water Quality and Drainage.

8.2 Methods are given for the assessment of pollutants in runoff based on those contained in CIRIA Report 142. Means of undertaking a probabilistic assessment of spillage events and advice on containment measures is based on the work undertaken by Thorburn Colquhoun. The document also contains brief advice on fisheries protection and general guidance on pollution mitigation measures.

8.3 Whilst the advice was drawn up for use in the assessment of new schemes, it is considered equally applicable to the assessment of existing installations.

8.4 The Highways Agency is conscious that further development of advice in this field is needed. This will be directly addressed by a contract that has been let to Thorburn Colquhoun for a study of the state of the art in the use of vegetative systems for the treatment of highway runoff. This study also includes surveys to assess the nature conservation value of balancing ponds that already exist. The end product of the study will be an advice note on the design and maintenance

of all types of vegetative systems, taking account of their contribution to nature conservation and the surrounding landscape.

9. Research needs

9. Though a considerable body of work has been done in this area much of this has been very specialised, or is now out of date, or is not very applicable to circumstances in the UK. The Highways Agency has identified a number of areas where more work is needed both to improve knowledge and to provide better solutions in the field.

9.2 Improved methods are needed for predicting the pollution load. In particular its relationship to traffic flows and vehicle type distribution needs to be better understood. More information is also needed on the relationship between pollution load and storm intensity, as this may assist in the design of treatment measures, especially for trapping the smaller fraction of the sediment.

9.3 More needs to be known about the contribution that standard drainage components can make in removing pollutants to allow the whole drainage system to be taken into account, rather than concentrating only on components provided specifically for pollution treatment. A long term study being undertaken by WRc, jointly funded by the Environment and Highways Agencies, will address this and will also provide data on the relationship between pollution loading and storm intensity and frequency.

9.4 The ecological study by WS Atkins and Humphries Rowell has already been mentioned. This needs to be followed by further more refined work to verify and enhance its conclusions, and, if appropriate, to provide data and advice that can be used for the prediction of the sensitivity of watercourses to pollution from highway runoff.

9.5 The project to devise an advice note on vegetative systems is mentioned above. Part of the aims of the project are to give advice on matching the choice of system to the pollution load and to the local geography and climate. It is anticipated that advice that can be given in these areas will be limited by current knowledge. The project consultant will be asked to identify what research needs to be undertaken to improve the scope and quality of the advice.

9.6 A toxic liquor can be produced in gully pots during dry periods, which can be washed out into the receiving waters at the next storm. This can give rise to damaging transient pollution loads. AEA Technology are undertaking a research project for the Highways Agency to investigate whether there are any means of "dosing" or modifying gully pots to improve their performance by promoting the breakdown of hydrocarbons within them.

10. The existing network

10. As water quality standards have improved appreciation of the possible threats posed by some highway runoff has increased. This awareness is, however, relatively recent and many highway drainage systems were designed without consideration being given as to whether measures to control pollution were necessary.

10.2 Two Highways Agency projects are addressing this:

i) a study is investigating highway soakaways located over sensitive groundwaters;

 ISSN 1353-114X

ii) a second study is attempting to identify all those outfalls posing a pollution risk sufficient to warrant the installation of addition treatment or containment measures.

10.3 Both projects cover the whole of the motorway and trunk road network in England and commenced in November 1998. Assessments will cover both routine runoff and spillage risks. The studies will, of course, have to be undertaken in the light of current knowledge.

11. Key references

11.1 Design Manual for Roads and Bridges: Volume 11 - Environmental Assessment: Section 3 Part 10 - Water Quality and Drainage (The Stationery Office; February 1998)

11.2 CIRIA Report 142: Control of pollution from highway drainage discharges (CIRIA; 1994)

 ISSN 1353-114X