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Review

Surface water sewer misconnections in England and Wales: Pollution sources and impacts

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HIGHLIGHTS

- Multiple method "weight-of-evidence" approaches for source verification of illicit discharges
- Continued and persistent impairment of urban water quality and ecological status by polluted stormwater outfalls
- Inefficiency of existing compliance and enforcement procedures for misconnections
- Significance of misconnected household appliances to potential in-stream pollution loadings
- Variability in national/local estimates of misconnection rates and remediation cost-estimates

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ABSTRACT

In urban areas served by separate sewerage consisting of separate pipe systems it is not uncommon for misconnections to be made either accidentally or deliberately, whereby the wrong effluent is connected to the wrong sewer. The main focus of this problem has been on in-household appliances that are wrongly connected to separate surface water sewers, potentially leading to pollution of receiving waters and non-compliance with statutory water quality standards. This paper examines the available evidence to evaluate the potential scale, severity and cost of the problem in England and Wales in comparison to that reported from investigations in the United States. The particular difficulties associated with distinguishing specific sewage sources in the wastewater "cocktail" discharged at polluted surface water outfalls are reviewed. The deficiencies of existing legislation and enforcing compliance with respect to misconnections are also discussed and the pollution potential resulting from domestic misconnections is explored based on sampled data.

Contents

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1. Introduction

Misconnections occur due to a pipe intended for one type of effluent conveyance being connected to the wrong sewer system. In separate sewer systems, surface runoff water or stormwater outfalls (SWOs) can become polluted for example, when wastewater (foul sewage) effluent or trade effluent is connected to the separate surface water sewer pipe. If misconnections occur the other way with surface runoff being diverted into the foul system, it can lead to hydraulic overloading, surcharging and flooding as well as placing increased burdens on conveyance and treatment processes and inhibiting development. In this respect the term misconnection is misleading as it covers a variety of urban sources including "greywater" and "blackwater" discharges as well as cross-connections between surface water and foul sewers in addition to the deliberate misuse of surface water drains for illicit disposal of unwanted substances and materials. Other potential illicit wastewater sources to the surface water network include septic tanks, spillages, vehicle washwater and contaminated groundwater as well as exfiltration from foul/sanitary sewer lines. The first three of these alternate sources as well as exfiltration are strictly not misconnections but cross-connection sources.

A principal focus in the misconnection issue has been on the wrong connection of household appliances (i.e., greywater discharges) into the separate surface water sewer although toilet (blackwater) misconnections present a particular problem due to their high pollution potential. Polluted stormwater outfall discharges from such misconnections might place receiving Water Quality Standards (WQSs) at risk of failure and prejudice good potential ecological status (Defra, 2012) in addition to causing aesthetic impacts. This potential source of urban receiving water pollution has been recently identified as a likely priority problem by the UK regulatory Environment Agency (Defra, 2012). Similar risks posed to receiving water bodies by such illicit discharges associated with municipal separate storm sewer systems (MS4s) have also been recognised in the United States (Brown et al., 2004). Illicit discharge detection and elimination (IDDE) regulations under Phase II of the National Pollutant Discharge Elimination System (NPDES) have specifically targeted misconnections as offenders prejudicing municipal permit consents (Brzozowski, 2004).

Despite the perception that misconnections potentially present a priority problem, the pervasiveness and severity of the problem are said to be uncertain or misunderstood (Brown et al., 2004; Irvine et al., 2011). Urban catchment studies in both the UK and the United States of pollution loading from illicit discharges to SWO/MS4 sewers have demonstrated that the majority of such discharges are undetected primarily due to a lack of survey and monitoring data for urban surface water sewer (stormwater) pipes (Johnson and Tuoman, 1998; Stationery Office Ltd., 2011; Lilly et al., 2012). Given the mixed surface water and combined sewer inputs as well as sewer infrastructure malfunctions, there will inevitably be substantial difficulties in specifically differentiating and attributing source SWO impacts on the overall quality status of a receiving water body and this issue is reviewed in the paper. Is it possible to distinguish between misconnection-derived sewage from that of cross-connections or exfiltrating sources when monitoring and analysing a polluted stormwater drain outfall?

In addition, the scale and financial impacts of misconnections have never been fully ascertained and this situation is exacerbated by the reporting of divergent national, regional and local estimates both in the UK and US. This paper examines the data available from national agency, regional wastewater company and local sources to evaluate the potential scale, severity and cost of the problem for the situation in England and Wales. Referenced comparison is made to work in the United States as a means of identifying generic issues, approaches and solutions for improved stormwater management. The particular difficulties posed by the existing legislation and administrative responsibilities for identifying misconnections and enforcing compliance are discussed and the receiving water pollution potential resulting from domestic misconnections are explored based on sampled data.

2. Illicit discharges

There is a substantial US literature and data availability on illicit discharges (i.e., effluent which is not composed entirely of strormwater runoff) which has been driven by NPDES and IDDE regulation and associated MS4 consent permitting as well as a need for determining MS4 wasteload allocation to meet receiving water Total Maximum Daily Loads (TMDLs) and minimise urban discharge impacts. All US states and urban municipalities are involved in NPDES and IDDE programmes and the US EPA has identified some 7500 MS4s to be subject to Phase I and II requirements (www.epa.gov/npdes/stormwater). Table 1 provides detail on a small selection of these US studies together with those which have been undertaken in the UK specifically to investigate the potential contribution of domestic misconnections to polluted SWOs (PSWOs). Only very limited studies have been reported outside North America and the UK although Australia does have an IDDE programme based on the US regulatory template (Taylor and Wong, 2002).

A substantial part of the US work has focussed on the incidence and nature of illicit MS4 discharges rather than with detailed investigations of the exact source of the sewage contributions. This can be illustrated by referenced to the detailed survey of 313 MS4 outfalls undertaken by Lilly et al. (2012) on a 16 km river reach of a 130 ha urban catchment (35% impervious) in Maryland which identified 180 previously unknown MS4s with 30 possessing sewage indicators of concern e.g., high ($\geq$0.5 mg l^{-1}) ammonia concentrations. It was estimated that 96% of total in-stream *Escherichia coli* under dry weather flow conditions could be directly attributed to illicit discharges from the polluted MS4s. It was further estimated that elimination of such offending discharges would reduce over 50% of the Total Maximum Daily Load (TMDL) of bacteria as well as up to 43% of the nitrogen TMDL for the receiving water. However, this survey was only able to source track 15% of the MS4 discharges all of which were related to cross-connections. Similar conclusions can be drawn from the investigations of some 5000 MS4s in western New York state where 23% exhibited elevated NH_3–N concentrations in the range of 3–5 mg l^{-1} whilst only a small fraction of the total (91) were subject to permits under the USEPA MS4 Phase II stormwater regulations (Irvine et al., 2011). Source typing of the MS4 discharges using the Pitt (2004) flow chart benchmarking protocol was unable to distinguish between misconnection, cross-connection and exfiltration contributions.

Diffuse urban drainage and illicit discharges associated with polluted SWOs (PSWOs) are collectively regarded as being responsible for some 24% of designated "poor" or "bad" receiving water status in the UK (Defra, 2012) on the basis of persistently elevated chemical and bacterial loadings. Within the London Basin and elsewhere in UK metropolitan centres, a majority of the urbanised receiving waters have been designated as "heavily modified water bodies" (HMWBs) due to their channelized condition, poor water quality and depressed in-stream ecology (Environment Agency, 2009). These HMWBs are characterised by elevated bacterial (*E. coli*, *F. streptococci*) and BOD_5 concentrations together with high NH_3:K ratios as recorded for example, on the Pymmes's Brook in NE London (Edmunds-Brown and Faulkner, 1995). Whilst the sewage