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Microbiological surveillance of private water supplies in England – The impact of environmental and climate factors on water quality

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ABSTRACT

A passive surveillance system captured information on 34,904 microbiological samples from 11,233 private drinking water supplies within England as well as the associated constructional, climatic and environmental variables. *Escherichia coli* was detected in 6588 (18.87%) of samples and at least one positive sample was detected from 3638 (32.39%) of sites. However, this estimate of supplies failing to meet the European drinking water *E. coli* standard was probably an underestimate as the more samples taken per supply, the more likely the supply was to fail. A multivariable model of private water supplies data showed a strong seasonal impact, with samples between January and May being significantly less contaminated with *E. coli* than samples between June and December. Samples from springs (OR 2.5, CI 2.0–3.1) or surface waters (OR 2.4, CI 0.8–7.0) were more likely to fail than groundwater sources, as were supplies with no effective treatment (OR1.8, CI 1.5–2.3). Commercial supplies were less likely to fail than domestic supplies (OR 0.63, CI 0.48–0.83) and the probability of failure was linearly associated with the density of sheep in the area and rainfall on the previous day. A Monte Carlo modelling approach was used to estimate that, had sufficient samples been taken, 54% (95% confidence intervals 49–59%) of all private water supplies in England were likely to be unsatisfactory. These findings will be able to inform risk assessments of private water supplies prior to microbiological results being available.

1. Introduction

Water, sanitation and hygiene are important in protecting people from diarrhoeal and other diseases (Prüss-Üstün et al., 2008) and small water supplies represent a health risk to people served by them throughout the world. While the disease risks associated with inadequate drinking water in developing countries have been linked to substantial childhood mortality the burden of disease associated with private water supplies in developed countries has not been thoroughly investigated.

The large majority of people in European community have their water supplied by water utilities, some 10% receive their water from small or very small supplies that are often owned

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by the consumers, themselves (Hulsmann, 2005). Most of these private drinking water supplies serve single dwellings, small clusters of dwellings or small commercial sites in remote or rural areas. It is already well known that, as measured by detection of *Escherichia coli* these supplies are at higher risk of contamination and the quality is generally poorer than mains water supplies (Kay et al., 2007; Fewtrell et al., 1998; Humphrey and Cruickshank, 1985; Rutter et al., 2000). Furthermore, consumers of such supplies are more at risk of outbreaks of diarrhoeal illness (Said et al., 2003), particularly with pathogens that are normally eliminated by disinfection, such as *Campylobacter*. They are also probably at increased risk of endemic disease (Ferley et al., 1986). The relationship between water quality and adverse effects on human health is made more difficult by the small size of most of the supplies, making the identification of outbreaks difficult. In addition there is a view that people served continuously by such supplies develop a partial immunity to some of the pathogens they are exposed to (Frost et al., 2005). This means that the burden of disease may fall predominantly on children.

It is already known that a variety of factors can affect the vulnerability of these small supplies to bacteriological and chemical contamination. These factors include spatial issues such as their location, construction and proximity to sources of pollution such as proximity to a septic tank (Borchardt et al., 2003) or the presence of domestic or wild animals (Licence et al., 2001). Temporal factors such as rainfall (Lake et al., 2005) and temperature (Thomas et al., 2006) may also impact on quality.

Under the Private Water Supplies Regulations (1991), Local Authorities in England and Wales are responsible for ensuring that water from private water supplies is fit for human consumption. Local Authorities are local government (town, city, rural area or county). Under these regulations Local Authorities have the power to take monitoring samples for both microbiological and chemical analysis. Unlike the situation for public water supplies, there is no formal national data collection system for the results of this monitoring. However, many Local Authorities chose to send their samples to the Public Health Laboratory Service (PHLS) for analysis. Samples sent to PHLS laboratories were tested by methods that complied with standard water microbiological methods published by the Environment Agency (Standing Committee of Analysts, 2002). In 1995, the Communicable Disease Surveillance Centre (CDSC) of the PHLS created a passive surveillance system to collate microbial water quality results from private water supply (PWS) samples sent to PHLS laboratories for analyses with the aim of providing a national picture of the water quality from PWS in England and Wales (Rutter et al., 2000). A minimum dataset was collected, where possible for each sample including the testing laboratory name, private water supply class/category, sample date, use of supply, treatment details, local authority, name of supply, postcode of supply, reason for sampling and the results of total coliform and *E. coli* counts per 100 ml.

This study was designed to determine the proportion of private water supplies in England that meet current standards of quality (*E. coli* $<$ 1/100 ml) and to examine the relationship between constructional, climatic and environmental variables associated with poor quality results, particularly the presence of the main microbiological indicator organism (*E. coli*).

2. Methods

2.1. *Private water supply microbial water quality data*

A database of private water supply microbial water quality (PWS database) was set up in 1995 and maintained by the CDSC until 2003. During this surveillance period (between 1996 and 2003), there were 39,624 water quality results specifically related to the presence or absence of *E. coli* and total coliforms in water samples from private water supply in England and Wales. During this period the microbiological methods in use in all laboratories conformed to the recommendations of the Standing Committee of Analysts (2002).

Originally much of the data was neither complete nor standardised. The quantity and quality of the data in the database were dependant on information provided by the sampling Local Authority and testing laboratory, and field standardisation, data entry and data validation were controlled to reduce some of these. The data was from 16 PHLS water-testing laboratories that were regrouped into 9 groups. The PHLS region names were updated to the most recent names and were then matched against the PHLS laboratory groups. The Local Authority names were standardised, updated and matched with the PHLS regions.

Each of the water samples was given a unique alphanumeric identification code, but this was not possible for each private water supply site where the samples were taken from. The ability to identify each private water supply site depended on the information provided by the Local Authority and/or the water-testing lab. As this information was not always available, the site information for each water quality result from each Local Authority was assessed against a combination of identifiers including site's name, postcode, and water supply categories in order to identify the number of samples per site submitted for testing over the surveillance period. If there was any ambiguity in the site details, a private water supply registry collated in 1996 was used to confirm any discrepancies. Once the private water supply sites were identified, a unique code was created per site and the basic information from each site was standardised according to the available information on supply classification, source water type and treatment.

Of 39,624 results in the database, 2954 (7.46%) samples from non-private water supplies were removed from the database because the laboratory and/or the Local Authority were not known, there was evidence that the samples were not from a private water supply, or that the sampling year was incorrect. In addition, 1766 water quality results from Wales were also excluded from the analysis as it was not possible to identify private water supply sites according to the site identification process described above.

Each water supply is categorised into category 1 (used for domestic purposes) and category 2 (used for commercial purposes including food production) (Rutter et al., 2000). Domestic supplies are further subdivided into six classes dependant on how many people use the supply. For example