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A survey of the microbiological quality of private water supplies in England

M. RUTTER[1], G. L. NICHOLS[1]*, A. SWAN[2] AND J. DE LOUVOIS[1]

[1] *Environmental Surveillance Unit, CDSC, Public Health Laboratory Service, 61 Colindale Avenue, London NW9 5EQ*
[2] *Statistics Unit, Public Health Laboratory Service, 61 Colindale Avenue, London NW9 5EQ*

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SUMMARY

Results from statutory testing of private water supplies in nine Public Health Laboratories in England were compiled, and the effects of supply class, source, treatment and location on water quality were examined. A total of 6551 samples from 2911 supplies was examined, over a 2-year period, of which 1342 (21%) samples, and 949 (33%) supplies on at least one occasion, failed current regulations for *Escherichia coli*. Total coliforms, including *E. coli*, were detected in 1751 (27%) samples from 1215 (42%) supplies. The percentage of samples positive for *E. coli* was highest in summer and autumn, and lowest in winter. Samples taken from larger supplies and from boreholes were less frequently contaminated than those from other sources. Chlorination, filtration or UV light treatment improved the bacteriological quality of supplies, but still resulted in a low level of compliance with the regulations. The public health implications of the study are discussed.

INTRODUCTION

Private water supplies are supplies of drinking water that are not provided by a statutory water undertaker. The Water Industry Act of 1991 incorporated the 1980 EC drinking water directive and laid down quality standards for both public and private water supplies. It also reiterated a continuing requirement for local authorities to collect information on the wholesomeness of water supplies in their area.

The Private Water Supply Regulations provided guidance to local authorities on the classification of private supplies and specified the sampling frequencies required for each class of supply [1, 2]. Private water supplies are divided into Category 1, where water is used for wholly domestic purposes and Category 2 supplies, which include uses such as commercial food production, and drinking water provided to hospitals and holiday establishments. Category 1 supplies are further sub-divided, in decreasing size, as classes A–F, depending upon the number of people served. Category 2 supplies are sub-divided in decreasing size as classes 1–5, depending upon the quantity of water supplied. The statutory frequency of sampling is dependent upon the class, and ranges from 24 samples per annum, for the largest supplies (class A and class 1) to 1 sample every 5 years for the smaller (class E) supplies [3]. There is no statutory obligation to sample class F supplies, which serve a single dwelling, although local authorities have a duty to ensure the wholesomeness of these supplies. Private water supplies are subject to the same regulatory quality standards as mains water and these include a requirement that coliforms and *Escherichia coli* be absent from a 100 ml sample of water.

Private supplies provide approx. 1% of the population of England and Wales with domestic water [1]. However, a larger percentage of the population may be exposed to Category 2 supplies from time to time as campers and holidaymakers at residential establish-

* Author for correspondence. This paper is presented on behalf of the PHLS Water Working Group.

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ments or through their use in food production. A number of outbreaks of infection have been linked to those Category 2 supplies serving premises with a transient population. Such outbreaks can be difficult to detect and investigate as cases may disperse before symptoms become apparent and retrospective tracing is often problematic. Consequently, it is likely that many infections caused by the consumption of water from private supplies will not be attributed to that cause.

Monitoring and enforcement of the regulations with regard to the smaller supplies is often difficult due to their large numbers and inaccessibility. Private supplies are usually sited in rural locations and therefore vulnerable to contamination from a number of sources. Users of private supplies often have septic tanks, which may lead to an increased risk of contamination [4]. Many supplies are untreated and where water treatment procedures are in place, they are often inadequately monitored or maintained. Recent microbiological surveys of private supplies have found that many fail current legislative standards for indicator organisms and pathogens [5, 6].

The results of statutory testing of private water supplies are not collated nationally at present. Therefore, the aim of the study was to collect results from regulatory microbiological testing carried out at Public Health Laboratories to provide a national picture of the water quality from private supplies. Furthermore, this information was combined with background information on class, source, treatment and geographical location of supply to examine how these factors affected water quality.

METHODS AND MATERIALS

Collection of samples

Private water supplies were sampled by local authority employees in accordance with standard protocols [7]. Sampling was carried out for 'regulatory or routine', 'follow-up', in response to previously positive samples, or 'other' reasons, which included sampling in response to complaints.

Laboratory techniques

Water samples were examined for total coliforms and *E. coli* at Public Health Laboratories according to published standard methods [7].

Data management and analysis

Results from the laboratory examination of samples from private water supplies, carried out between January 1996 and December 1997, were collected from Bristol, Manchester, Newcastle, Norwich, Nottingham, Poole, Preston, Reading and Surrey Public Health Laboratories. Information was collected from participating laboratories, either as paper reports or electronically, and after verification entered in a spreadsheet computer program (Excel 97, Microsoft) for subsequent analysis.

Each supply was identified uniquely and consistently so that multiple samples from the same supply could be recognized. The premises or site of sampling were not ascertained in the study and hence were not included in the database.

Information was collected for coliform and *E. coli* contamination of private water supplies during the course of this study. A detailed analysis of the results was only carried out for *E. coli*, however, as it is a specific indicator of faecal contamination and therefore a better indicator of the likely presence of enteric pathogens.

RESULTS

Information was collected on 6551 samples from 2911 supplies during the study period. In total 1342 (21%) samples from 949 (33%) supplies were positive for *E. coli*. The figures were greater for total coliforms, including *E. coli*, with 1751 (27%) samples and 1215 (42%) supplies positive.

There were marked differences in the percentage of samples positive for *E. coli* according to the reason for sampling. A high percentage (52%) of the 350 follow-up and 58 samples taken for 'other reasons' (41%) were positive for *E. coli*, whereas only 18·5% of samples taken routinely or for reasons not stated, were positive. 'Follow-up' or 'other' samples only constituted 6% of the total and these samples were excluded from further analyses in order to avoid bias.

The effect of category and class

More Category 1 supplies were included than Category 2 supplies, with a ratio of 2·8 to 1. The smaller supplies made up the majority of Category 1 supplies included, with classes E and F combined constituting 91% of the total (Table 1). Similarly, for

Table 1. *Percentages of private water supplies in study and percentage of supplies and samples positive for* E. coli *by class. The distribution for England is included for comparison*

	% of supplies in England (*n*) [8]*	% of supplies in present study*	% positive for *E. coli* (total examined)*	
			Supplies†	Samples
Class				
A	< 0·1 (1)	0·0	0·0 (0)	0·0 (0)
B	< 0·1 (19)	0·1	0·0 (1)	0·0 (3)
C	0·2 (52)	1·5	28·6 (14)	20·0 (40)
D	2·3 (614)	7·6	29·6 (71)	27·2 (92)
E	22·7 (6169)	31·2	39·9 (293)	40·5 (412)
F	74·8 (20 308)	59·7	36·0 (561)	33·5 (746)
Total	(27 163)		36·6 (940)	34·8 (1293)
Category 1				
1	1·0 (62)	0·3	0·0 (1)	0·0 (631)
2	2·8 (168)	9·0	23·3 (30)	1·3 (1264)
3	7·0 (422)	17·7	32·2 (59)	15·0 (167)
4	22·1 (1326)	51·7	34·3 (172)	30·6 (330)
5	67·0 (4011)	21·3	26·8 (71)	25·0 (104)
Total	(5989)		31·2 (333)	6·8 (2496)
Category 2				
Category Unknown			27·1 (1570)	21·9 (2354)
Total	(33 152)		30·7 (2843)	18·5 (6143)

* As a percentage of the total for each category.
† A supply is classed as positive if one or more samples were positive.

Category 2 supplies, the smallest (classes 3–5) made up 91 % of the total (Table 1).

Samples from Category 1 supplies were more frequently contaminated with *E. coli* (35 %) than samples from Category 2 supplies (7 %). For Category 2 supplies, five class 1 and 2 hospital supplies provided 1746/2466 (71 %) of the samples. When these supplies were excluded from the analysis, 21 % of the remainder of the Category 2 samples were positive for *E. coli*. There was little difference in the percentage of supplies positive for *E. coli* within each Category, with 37 and 31 % positive for Category 1 and 2 supplies, respectively.

The percentage of samples from which *E. coli* was isolated, and the number of supplies from which at least one positive sample was obtained, also varied with supply class (Table 1). For both Category 1 and 2 supplies, the percentage of positive samples generally increased as the size of the supply decreased, although this trend was not sustained for the smallest supplies (class 5 and class F) in each Category. The numbers of samples taken from a supply varied greatly. Most of the smaller supplies (classes D, E, F 4 and 5) were only sampled once during the study period, while larger supplies tended to have multiple samples taken (Table 2).

A supply was counted as positive if one sample failed. Consequently, a stratified analysis of grouped sampling frequency showed that the percentage of supplies failing increased with increasing sampling frequency within each class (Table 2). It also showed that sampling frequency affected the differences between classes in the percentage of supplies positive. A comparison of Category 2 supplies showed that class 2 supplies were of higher quality overall than smaller supplies. For those supplies sampled once only, however, the percentage of positive supplies decreased with decreasing supply size from class 3 to class 5 (Table 2). In contrast, for Category 1 supplies sampled once, the smallest supplies (classes E and F) had the highest percentages of positive supplies. A logistic regression model was fitted to summarize the variation in the proportion of samples positive for each supply with respect to supply class, stratified by 'sampling frequency' groups. This showed that differences in the percentage of positive supplies

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Table 2. *The percentage of supplies positive for* E. coli *by frequency of sampling and supply class, with the total number of supplies in parentheses*

No. of samples from a supply	Class … Category 1: 1	2	3	4	5	Category 2: B	C	D	E	F
1	0 (0)	16·7 (6)	29·2 (24)	25·0 (92)	21·8 (55)	0 (0)	0·0 (7)	25·4 (59)	32·2 (233)	32·6 (454)
2–9	0 (0)	6·3 (16)	31·3 (32)	44·3 (79)	43·8 (16)	0 (1)	50·0 (6)	50·0 (12)	70·0 (60)	50·0 (106)
10–100	0 (0)	50·0 (4)	66·7 (3)	100 (1)	0·0 (0)	0 (0)	100·0 (1)	0·0 (0)	0·0 (0)	100·0 (1)
> 100	0 (1)	75·0 (4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total (mean)	0 (1)	23·3 (30)	32·2 (59)	34·3 (172)	26·8 (71)	0 (1)	28·6 (14)	29·6 (71)	39·9 (293)	36·0 (561)

between classes were significantly affected by sampling frequency (χ^2 $P < 0{\cdot}005$).

Overall, most (82%) of those supplies from which *E. coli* was isolated, only had a single sample positive, with a further 12% with two samples positive. Only 8 (< 1%) supplies had more than 5 positive samples and these supplies were classes 2, 4, E, F and an unknown class.

Geographical variations

Geographical variation in water quality was examined by comparing results for the same classes of supply from different laboratories. Some variation was evident (Table 3). Samples from class E and F supplies in the north east, north west and central south coastal regions of England were the most frequently contaminated, with over 35% positive for *E. coli*. Samples from supplies in south east England averaged approx. 25% positive and those in the east midlands, 9%. The geographical variation in the quality of class 4 and 5 supplies also showed that supplies in the north east and south coast of England had the highest percentage of positive samples. Comparatively, the percentage of positive samples from these supplies in the north west and south west was much reduced. The number of samples from class 4 and 5 supplies from other regions examined was insufficient for a meaningful comparison.

The effect of source

Borehole supplies were the most numerous, comprising almost one third of all supplies included in the study. Surface water showed a higher level of *E. coli* contamination with lakes and reservoirs the most frequently contaminated, followed by springs and wells, with supplies derived from boreholes the least contaminated (Table 4). No firm conclusions could be drawn from the low level of contamination of rivers and streams due to the low numbers involved (11 samples from 5 supplies).

The effect of water treatment

The principal water treatments in use for private water supplies were identified as chlorination, UV light and filtration. The larger Category 1 and Category 2 supplies were more likely to receive one or a combination of these treatments. For samples from Category 1 supplies where information on treatment

Table 3. *Regional variations in percentage of private water supplies and samples positive for* E. coli *with total numbers in parentheses*

	% positive for *E. coli*			
	Classes E and F		Classes 4 and 5	
Region	Samples	Supplies	Samples	Supplies
South west	26·5 (102)	31·3 (64)	12·5 (56)	15·2 (33)
North west	37·7 (583)	40·4 (460)	11·6 (95)	17·6 (51)
North east	47·9 (188)	42·9 (119)	38·8 (240)	41·1 (129)
East midlands	8·8 (34)	11·1 (18)	0·0 (2)	0·0 (1)
Central south coast	54·0 (50)	65·5 (29)	44·4 (36)	47·8 (23)
South east	24·7 (198)	25·3 (154)	0·0 (5)	0·0 (5)

Table 4. *Numbers and percentages of total and samples and supplies positive for* E. coli *from various sources of private water supplies*

Source	% of PWS in present study	% Supplies positive for *E. coli* (total examined)	% Samples positive for *E. coli* (total examined)
Borehole	28·2	17·0 (863)	6·8 (3125)
Well	3·3	21·6 (102)	19·2 (151)
Spring	10·2	37·8 (312)	34·5 (464)
Lake/reservoir	0·6	38·9 (18)	44·0 (25)
River/stream	0·2	20·0 (5)	9·1 (11)
Unknown/other	57·6	33·2 (1764)	30·5 (2367)

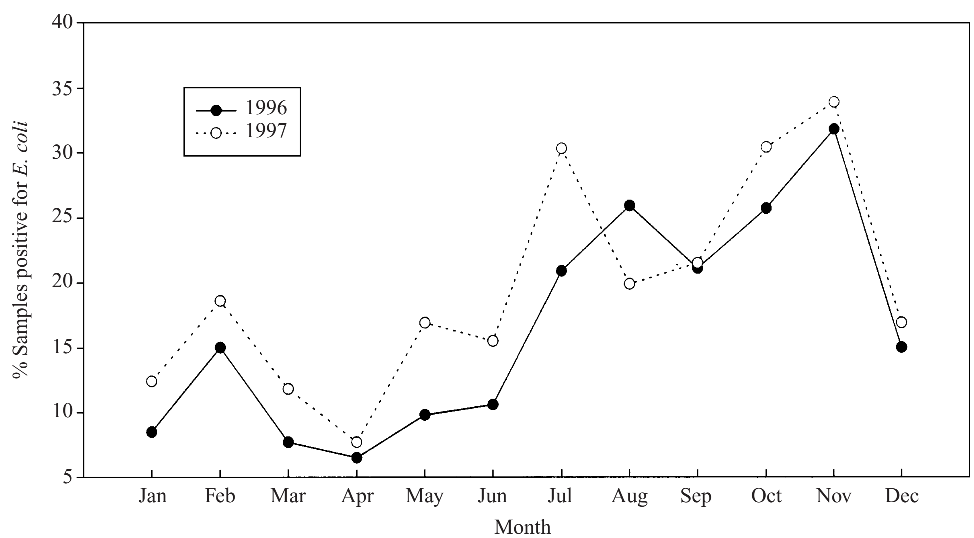

Fig. 1. Monthly % of samples from private water supplies positive for *E. coli*.

was provided, 67% of class A, B and C supplies were treated compared with 19% of class D, E and F supplies. Similarly for Category 2 supplies, 65% of class 1 and 2 supplies were treated compared with 33% of class 3, 4 and 5 supplies. Chlorination was the most effective treatment with 9·8% (11/112) of supplies positive for *E. coli*, compared with 18% (13/74) of supplies treated by filtration and 18% (18/101) treated with UV light. For untreated supplies however, 34% (314/923) were positive for *E. coli*.

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Seasonal variations

The seasonal trend in *E. coli* contamination of samples from private water supplies was similar for 1996 and 1997 (Fig. 1). In both years, the minimum contamination level occurred in April, after which there was an upward trend culminating in a peak in August during 1996 and in July during 1997. This was followed by a decrease in the following month, after which the percentage of positive samples increased again and reached a maximum in November for both years, before declining from December to April (Fig. 1). There was no seasonal sampling pattern with regard to private supply classes during 1996 or 1997. Thus, the seasonal trend observed for the percentage of samples positive was not the result of selective sampling of specific classes during certain times of the year.

DISCUSSION

The number of samples from private water supplies failing current drinking water regulations is of concern. In our study, 21 and 27% of samples contained *E. coli* and coliforms, respectively. Comparison with public water supplies highlights the extent of the problem. In 1997, 0·1% and 0·8% of samples taken in public water supply zones were positive for *E. coli* and coliforms, respectively [9]. Other investigations have also shown that the microbiological quality of water from private supplies is poor. A study in south-west England found that 62% (47/57) of supplies failed the regulations for *E. coli*, on at least one occasion [10]. Contamination was intermittent, as samples obtained from 71% of these passed at least once. In another study, *E. coli* was isolated from all 15 untreated supplies sampled at times of maximum risk of microbial contamination. *Cryptosporidium* and *Giardia* were also found in 9 and 8, respectively, of the 15 supplies [5]. A study of 91 Category 1 and 2 supplies found that approximately half failed the current regulatory standards, with coliforms, faecal streptococci or *E. coli* present in at least one sample over a 2-month period [6]. However, the overall sample failure rate of 9% for *E. coli* was considerably lower than in the present and previous studies. This may have been due to bias in selecting better quality supplies as they were chosen for easy access and included only one class E supply, the most contaminated class in our study. Also, the study was carried out during February and March, which was the time of least faecal contamination according to our findings. Analysis of regulatory sampling is likely to give a more representative picture of the national microbiological quality of private supplies as it avoids such sampling bias.

Approximately 9% of the private water supplies in England were included in the survey. Not all PHLs analysing samples from private water supplies were included and some local authorities use private laboratories for microbiological analysis rather than PHLs. No data were collected from private laboratories. The proportions of the private water supply classes included within the study were compared with the national proportions. Category 1 supplies were under represented in our study, as the ratio of 2·8 to 1 for Category 1 supplies to Category 2 supplies, is below the ratio of 4·5 to 1 for England [8]. This under-representation of Category 1 supplies is mainly due to the relatively low numbers of class F supplies included, for which there is no regulatory sampling frequency. Class 5 supplies were also under-represented [8, 11]. The regulatory sampling frequency for this class is one per year, so any of the supplies within the surveillance areas should have been sampled at least once over the 2-year study period. The under-representation of class 5 supplies in the present study may have been due to a lower than average national proportion in our surveillance areas for this class of supply, or non-compliance with the regulatory sampling frequency by the authorities. As class F and class 5 supplies were among the most contaminated classes, the effect of the under-representation of these supplies in our study, would be to underestimate the true number of supplies failing the regulations. However, the vast majority of supplies included in our study were the smaller Category 1 (class E and F) and Category 2 (class 3, 4 and 5) supplies, which make up the bulk of private supplies in England [8] and the UK [11].

Supplies providing larger volumes of water were less frequently contaminated with *E. coli* compared with small supplies. Increased sampling and follow-up of failures by local authorities are likely to be more rigorously enforced for the larger supplies due to the greater number of people at risk. Larger supplies may also be subject to additional control and regulation, for example private supplies within hospitals that fail the regulations, may be subjected to investigations from the health authorities. Consequently, larger supplies are more likely to be better maintained, with increased source protection and more efficient water treatment procedures.

Samples from borehole supplies were less contaminated with *E. coli* than samples from surface water sources, probably because of the removal of microorganisms during percolation and natural filtration through the rock strata [12]. A higher proportion of borehole supplies and lower proportion of spring supplies were included in the present study than was previously estimated for the total in the UK [8]. This is probably because the supplies in our study are all in England, where there is a greater proportion of ground water sources compared with Scotland and Wales.

The most effective treatment for private supplies in this survey was chlorination, which has proved to be effective in water disinfection for many years. Since *E. coli* was isolated from 10% of chlorinated private supplies, it is likely that there were problems with managing and maintaining chlorination procedures. The high degree of regular maintenance required for filtration and UV devices also probably contributed to their low effectiveness. The relative efficiency of various water treatment procedures agrees with the findings of an earlier study [6]. As larger supplies were not only more likely to have received treatment, but in addition were probably better maintained with better source protection, the effect of treatment alone is difficult to assess.

The reasons for the seasonal variation and increase in contamination of private water supplies in the autumn in 1996 and 1997 are unclear. Because private supplies are frequently sited in rural areas, they may be influenced by seasonal agricultural practices such as numbers of livestock grazing and the application of slurry to land in the catchment area. Heavy rainfall may lead to deterioration of water quality in private supplies, either through directly washing more faecal material into source water, or by reducing the efficiency of treatment through washing organic and particulate material into the supply [4]. The rise in the number of samples containing *E. coli* from early spring to late summer coincides with drier periods, when animal faeces will accumulate on land and cracking of the ground enhances run-off of rainfall and contamination of supplies. A decline in the level of contamination in the winter months was also observed in both study years. Clapham & Franklin also found that the incidence of *Cryptosporidium* in private supplies declined in the winter [13]. They attributed this trend to fewer animals being present in the catchment zone and the absence of slurry spreading during the winter. There is also some evidence that low temperatures in the winter months reduce the levels of contamination by freezing surface run-off water [14].

The contribution of private water supplies to disease in the general population is mainly unknown. Several outbreaks of gastrointestinal infection have occurred in the UK in the past 25 years and these have been reviewed recently [15, 16]. A variety of pathogens were linked to water consumption from private supplies, including *Giardia* and *Cryptosporidium*, with *Campylobacter* sp. the most common pathogen identified. Ingesting untreated lake and river water has been identified as a significant risk factor for *Campylobacter* sp. infection [17, 18]. Recently, several cases of *E. coli* O157 infection were traced to consumption of water from a private supply [19].

Previous studies have reported that consumers with domestic private water supplies do not experience significantly higher rates of gastrointestinal illness than people with domestic mains supplies [6, 20]. This may be due to an increased immunity to infection among regular consumers of water from private supplies, resulting from prolonged exposure. Visitors consuming the water, however, would not be protected.

Outbreaks of gastroenteritis have been linked to Category 2 supplies [16]. Exposure to these supplies will be intermittent or transient and therefore consumers are likely to be at a higher risk of infection than regular consumers of water from Category 1 supplies. As 33% of Category 2 supplies were positive for *E. coli* on at least one occasion, there is a risk that drinking water from such supplies may carry with it an increased risk of infection. Such potential widespread exposure is of public health concern.

The current study was limited by the difficulty of collecting information from local authorities. Background information such as the class, source and treatment of many supplies does not always accompany a water sample because of concern by local authorities about confidentiality. In some cases, the local authority does not know the relevant information. Confusion may arise in cases where a supply serves both domestic and commercial premises, when it may prove difficult to define what constitutes a supply according to the regulations [21]. A further complication arises when water undergoes treatment at the point of use so that only a portion of a supply is treated.

It is clear from this study that the general microbiological quality of private water supplies is poor in comparison with the public water supply. The regulatory framework of private and public supplies differs. The Drinking Water Inspectorate has a responsibility to ensure that public water supplies meet the standards set out in The Water Supply (Water Quality) Regulations. Its annual report provides a readily accessible account of checks made by the Inspectorate and the conclusions it has reached upon the quality of the water supplied by the water companies. Regulation of private supplies, however, is the responsibility of the local authorities. Registers containing information about individual private supplies, together with the results of statutory testing may be held locally, but are not readily accessible to the public. The Public Health Laboratory Service will continue its national surveillance of the microbiological quality of private water supplies and the number of laboratories from which information is collected is being increased. This surveillance will continue to enable regulatory microbiology test results to be compiled and interpreted centrally, and provide the information in a readily accessible form. However, its success is dependent upon the co-operation of local authorities in providing basic information on all samples sent for laboratory examination. A risk-based assessment of the likelihood of faecal contamination might also improve water quality and aid health protection, as the current regulatory monitoring frequencies for the smaller supplies are clearly insufficient to ensure safe drinking water.

In the short term, practical measures are also needed to improve the quality of private waters. Such measures should include informing and educating the owners and consumers of private supplies of the risks. The new European Council directive on drinking water [22] allows exemptions from water quality regulations for domestic supplies serving fewer than 50 persons. This would exclude many Category 1 supplies, including all class E and some class D supplies, from statutory sampling, as is the case for class F supplies under current legislation. The new directive states that when a danger to human health from the water occurs, the population using that supply should be informed and measures taken to protect human health. It is not clear what such an approach means in practice. As member states can impose stricter regulations than the new European water quality directive, it is not known at present what the implications will be for private water supplies in the UK.

Local authorities can serve a notice of improvement, such as the installation of treatment facilities, under section 80 of the Act [23]. If the person responsible for the supply objects to this notice, the Secretary of State will become involved. The Drinking Water Inspectorate may then be invited to act as technical adviser to aid in resolving the case. The extent of any enforcement action carried out with regard to private supplies is not easily assessed, as this information is not held centrally. We do not know whether any action was taken with regard to positive samples in this study.

There is also the need for further studies to assess the contribution of private water supplies to the incidence of intestinal infectious diseases in England and Wales. In particular, studies which show the degree to which private supplies are contaminated with pathogens and epidemiological investigations to estimate the prevalence of disease in users of private supplies. A requirement for local authorities to maintain a register of private water supplies, with national compilation and publication of testing results and of enforcement actions taken, would greatly enhance any future public health initiatives.

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