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Assessment of Ground-Water Quality in the South-East of England

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ABSTRACT: This study assesses the groundwater quality in the South-East England. Borehole water samples were collected at different locations across 7 different sites in the South-East of England. 14 physicochemical and 2 microbiological parameters (*E. coli* and *enterococci spp*) of the groundwater were analysed. Results showed that although all the physicochemical parameters met the WHO and EC Water Directive (98/83/EEC) guideline values, the presence of *E.coli* and *enterococci* were detected in the entire sites except for one. The presence of these micro-organisms could be attributed to the proximity to the sewage treatment discharge which could have mixed with the ground water via seepage and intrusion of animal faeces into the groundwater.

Keywords: *E.coli*, Groundwater Quality, WHO, Assessment, Physicochemical Parameter

ORIGINAL ARTICLE

INTRODUCTION

Groundwater is an important water resource in all parts of the world. In south east of England, the Chalk aquifer provides about 40% of all potable water and about 80% of total water (Pinault et al., 2005; Brouyere, 2006). The Chalk also provides 55% of UK groundwater-abstracted drinking water (Howden et al., 2004). The level of microorganisms in groundwater is fewer than surface water and this is due to its lengthy time of travel in the subsurface environment (Bendient et al., 1999; Fasunwon et al., 2008). Nevertheless, groundwater can still be polluted by surface runoff, feedlots, domestic sewage, as well as other sources of pollution (Gray, 2008; Fasunwon et al., 2008). The subsurface geology of an area has an influence on the aquifers vulnerability. In a case where the subsurface geology allows rapid downward infiltration of water from the surface runoff, the aquifer may become very vulnerable (Fasunwon et al., 2008).

Several organisations such as World Health Organisation (WHO), U.S Environmental Protection Agency (EPA) and EC directives have laid guideline values which are meant to protect the consumer's health by placing a limit value, in which a water parameter should not exceed. One of such parameter is the coliform. A coliform is made up of a large group of different species of bacteria. The group includes the faceal coliform (bacteria that occur naturally in the intestines of warm blooded animals) and non-faecal C*oliform* bacteria (Fasunwon et al., 2008; Gray, 2008). The coliform bacteria are one of the most associated bacteria with water quality. The WHO, U.S Environmental Protection Agency (EPA), and EC directives (98/83/EEC) guideline value for acceptable drinking water is a CFU count of 0/100ml (WHO, 2002; USEPA, 2004; Gray, 2008).

In this study, the level of some physical, chemical and microbial (i.e. the *E.coli* and *enterococci spp*) water quality parameters in the boreholes located in the residential areas and in the vicinity of a sewage treatment plant in the South-East of England was assessed.

MATERIAL AND METHODS

Study Area: The Patcham Catchment

The Patcham catchment is located in Brighton, South-East England (figure 1). The catchment was previously used as part of the flood 1 project. Since 1992, the Chalk country of England has been mapped using a new lithostratigraphy developed in Sussex and extended by BGS to Dorset and to the other regions of SE England. The Patcham catchment in the Brighton Chalk was part of the new BGS 1:50,000 which is a combination of the Brighton and Worthing Sheets 318/333 printed in 2006. The catchment had a great impact in the Flood 1 programme and is now revisited to carry out an in-depth field mapping to enhance and prove its geological framework.

Site selection

The sampling sites were selected in the Patcham catchment located in SE England to represent groundwater boreholes that are under influenced by human land use change. The site was considered appropriate for the project because the monitoring boreholes present are within a range of different land use. Seven monitoring sites were visited on a monthly basis, in which groundwater samples are collected and analysed for the purpose of the research. These monitoring sites have different land uses ranging from agricultural use, urban areas, forest dumps and animal rearing.

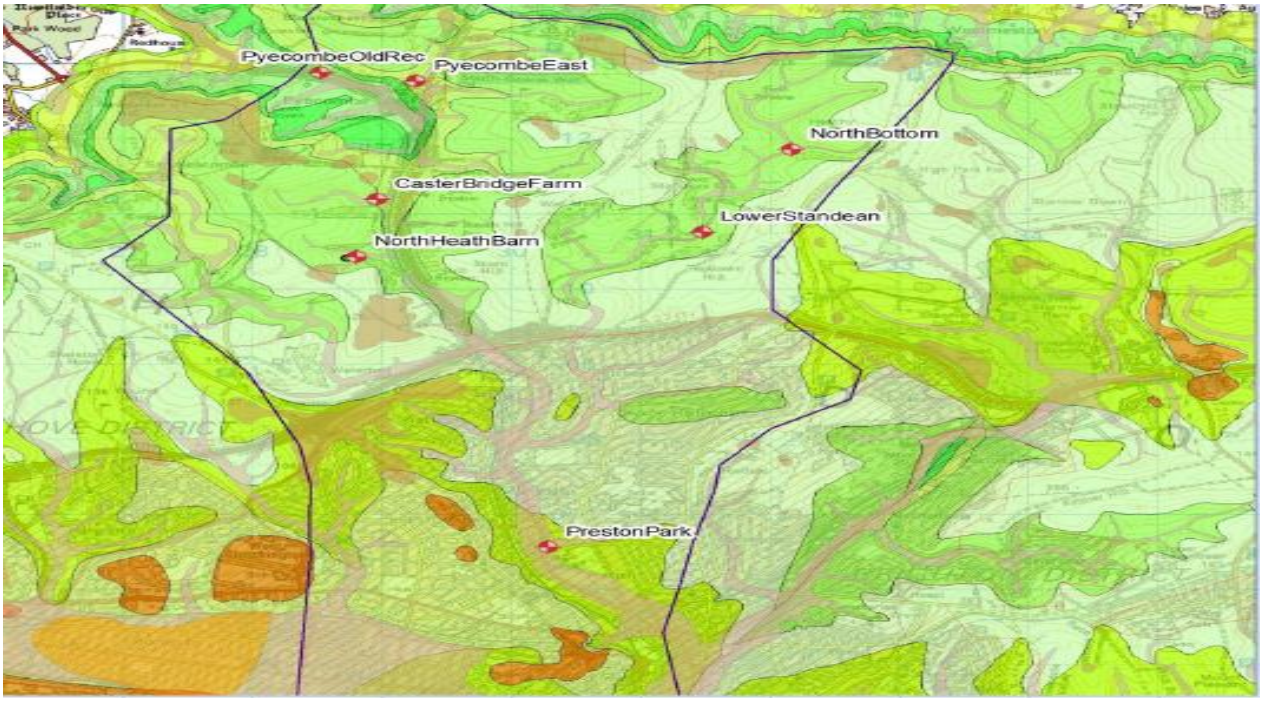

Figure 1. The Patcham Catchment (CLIMAWAT, 2011)

Laboratory procedures

Physicochemical assessment: The pH, water temperature, Dissolved Oxygen (DO) and Redox potential (ORP) was measured in the field at each monitoring site using the YSI 550A multimeter. Ammonical nitrogen (NH_3-N), nitrate-nitrogen (NO_3-N) and orthophosphate (PO_4-P) were also determined using a DR/2400 spectrophotometer (Hach Company, Loveland, USA) in accordance with standard methods (APHA, AWWA, WEF, 2005). All instruments were calibrated prior to use.

Water quality analysis was carried out using the standard methods of the ISO Standardized methods and Standard UK and American methods based on membrane filtration. The physicochemical and microbiological analysis of water samples were carried in the Environment and Public Health Research Unit laboratory in the University of Brighton. Macro nutrients such as ammonia, nitrate and phosphate were analysed using the Hatch Spectrophotometer. The ICP optical emission spectrometry equipment was used to analyse certain elements such as Iron (Fe), manganese (Mn), Stronitium (Sr), calcium (Ca), magnesium (Mg), sulphur (S) and phosphorus (P).

All samples were initially calibrated using distilled water samples before the actual samples from the sites were analysed using the ICP optical emission spectrometer in order to get a more accurate reading from the field samples.

Microbiological assessment: Water quality detection and enumeration of *Escherichia coli* and *intestinal Enterococci* were carried in line with European Standards EN ISO 93081-1-2000 and EN ISO 7899-2:2000 respectively. The British Standards were maintained throughout the water quality analysis to measure the physicochemical and microbiological properties of water samples.

The detection and enumeration of presumptive *Enteroccoci* (PEnt) and presumptive *E.coli* (PE) were carried out based on the membrane filtration in accordance with the UK and American methods (APHA, 1998; Anon, 1994). The enumeration is expressed in colony-forming units (CFU/100ml). The identification and enumeration involved two persons, counting of colony forming units so as to increase the accuracy of counting of the right type and number of colonies. The final count was derived from the average of two counts (Vinten et al., 2008).

The analysis of *E.coli* was achieved via the standard methods 9222B and 9222D, the membrane filtration methods for total coliform and faecal coliforms respectively (APHA, 1998). The m-FC agar was used for faecal colifrom analyses. In accordance with standardized methods, the m-FC agar plates were incubated for 24h at 44.5°C. The enumeration was carried out on a 0.45µm pore sized membranes. ENT was enumerated on a 0.45µm pore size membrane as well by membrane filtration followed by incubation on m-Enteroccocus agar (Difco, BDMS, UK) at 37°c for 48h in accordance with standardized methods. The CFU/100ml of sample will be used to express all bacterial counts. All the samples were pipetted and filtered onto pre-wetted 0.45µm gridded membranes.

RESULTS AND DISCUSSIONS

The results of the analysis of the water samples from the seven monitoring sites are shown in tables 1, 2 and 3. The tables show the physicochemical and microbial analysis of the water samples.

Physiochemical analyses

Physical properties of water are equally important in determining degree of biological and chemical contaminations. Most biological and chemical reactions are dependent upon temperature and major chemical changes take place at high temperature. Microbial activities often rise with increase in temperature up to an optimal temperature which is specific to each micro-organism. Temperature also affects the rate at which pollution substances are broken down in the natural environment. In this study, temperature values ranged from 8°C to 14.80°C (mean ± SD = 11.605 ± 1.426). The average temperature is relatively at an acceptable level when compared to the WHO guideline value. The measured pH value ranged from 7.20 to 8.08 (Mean ± SD = 7.65 ± 0.20), which is within the EC Water Directive (98/83/EEC) guideline for drinking water of 6.5-9.5 (Gray, 2008). Acceptable level of DO is normally observed in clean water resources. The presence of organic pollution will normally result in the disintegration of DO levels by micro-organisms. Overall levels of DO ranged from 1.69 to 13.04mg/l (Mean ±SD=10.89 ± 4.01). Redox potential (ORP) ranged from 124mV to 178mV. Conductivity values range from 285.10µS/cm to 493.1µS/cm. This result is also within range of the Water Directive (98/83/EECEEC) guideline value of 2500 µs/cm (Gray, 2008) and WHOs guideline value of 1400µs/cm. The above physical properties of the water samples were seen to be within the EC Water Directive (98/83/EEC), thereby indicating that if there are no microbial activity observed, and then it could be certified safe for drinking.

Descriptive statistical analysis of chemical constituents of ammonia, sulphate, phosphate, nitrate and nitrite were conducted to investigate sources of chemical pollution. The results of the descriptive analysis gave the following: ammonia ranged from 0.00mg/l to 0.5mg/l, (Mean± SD = 0.07 ± 0.0941), sulphate ranged from 4mg/l to 47mg/l (Mean ±SD = 21.98 ± 12.10), phosphate ranged from 0.01mg/l to 2.44mg/l (Mean ± SD = 0.464 ± 0.647), nitrate ranged from 0.04mg/l to 8.800mg/l (Mean ± SD = 3.166 ± 1.963) while nitrite ranged from 0 to 0.3mg/l (Mean ± SD = 0.02 ± 0.04). The highest mean concentration of sulphate was observed in Pyecoombe Old rec (Mean = 40.50mg/l) (table 1, figure 2), while the highest concentration of nitrate was found in Pyecoombe East (mean = 3.05mg/l) (table 1 figure 2). The lowest mean concentration of sulphate was however observed in North Heath Barn (mean = 8.38mg/l) (table 1, figure 2) and the lowest concentration of nitrate was observed in North heath Barn (mean = 2.29) (table 1, figure 1). Other chemical contaminants such as ammonia has its highest observation in North heath barn (mean = 0.14mg/l) and its lowest observation in Lower Standean (mean = 0.02mg/l) (figure 4).

Phosphate had its highest observation in Pyecoombe East (mean = 1.89mg/l) and its lowest observation in Lower Standean (mean= 0.12mg/l) (table 1). Nitrite concentration had its highest observations in Preston Park (0.08mg/l) and its lowest observation in Pyecoombe East (mean = 0.001mg/l) (table 1, figure 4). After the comparison of the results in table 1 with the WHO guideline values and the EC Water Directive (98/83/EEC), it was observed that all that results were below and within the acceptable limits for drinking water.

Table 1. Mean values of some physiochemical properties of water from sampling sites

Site	Temp (°C)	DO (mg/l)	pH	ORP	Cond (us/cm)	Sulphate (mg/l)	Phosphate (mg/l)	Nitrate (mg/l)	Ammonia (mg/l)	Nitrite (mg/l)
Preston Park	12.40	7.74	7.67	145.20	457.50	36.44	0.16	3.00	0.09	0.080
Lowerstandean	11.09	10.06	7.57	146.5	406.00	28.78	0.12	5.02	0.02	0.010
North Bottom	10.82	10.06	7.77	134.68	307.64	13.63	0.19	2.74	0.04	0.020
North.Heath Barn	11.30	8.90	7.84	154.00	285.10	8.38	0.23	2.29	0.14	0.003
Casterbridge	11.68	7.74	7.69	128.44	344.96	13.33	0.18	3.00	0.04	0.004
Pyecoomb Old Rec	11.64	8.06	7.57	141.03	481.40	40.50	0.36	2.38	0.07	0.011
Pyecoombe East	12.16	8.73	7.48	131.38	493.1	30.13	1.89	3.05	0.08	0.001

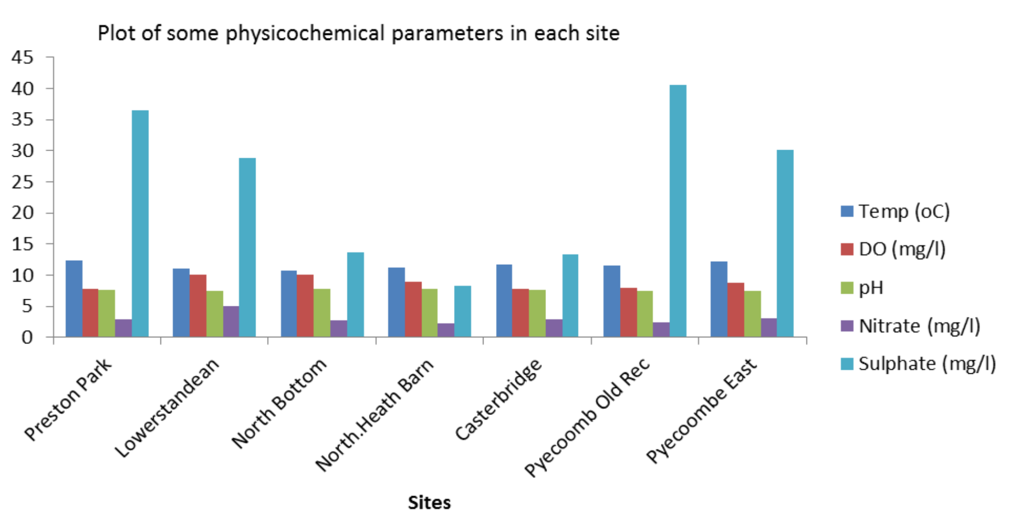

Figure 2. Plot for some physicochemical properties in each site

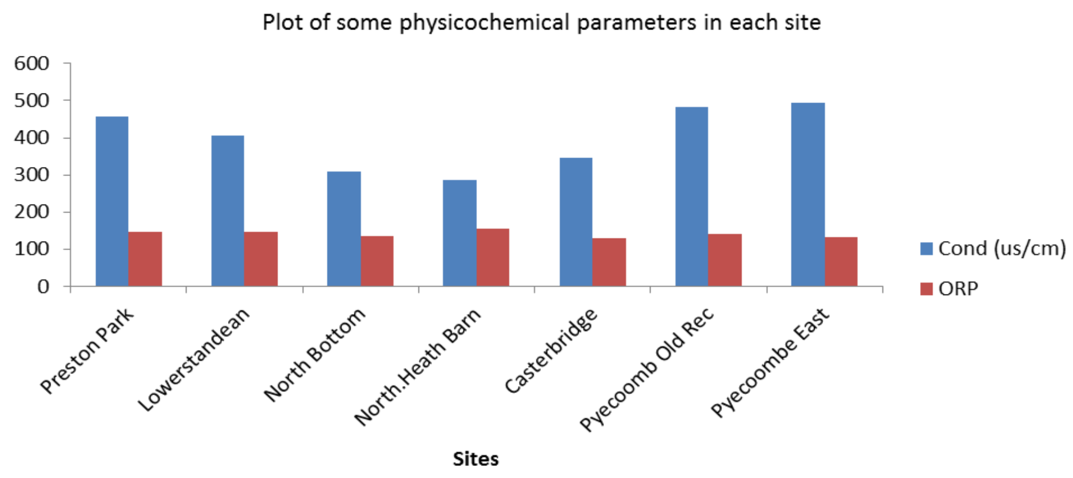

Figure 3. Plot for conductivity and ORP for all the sites

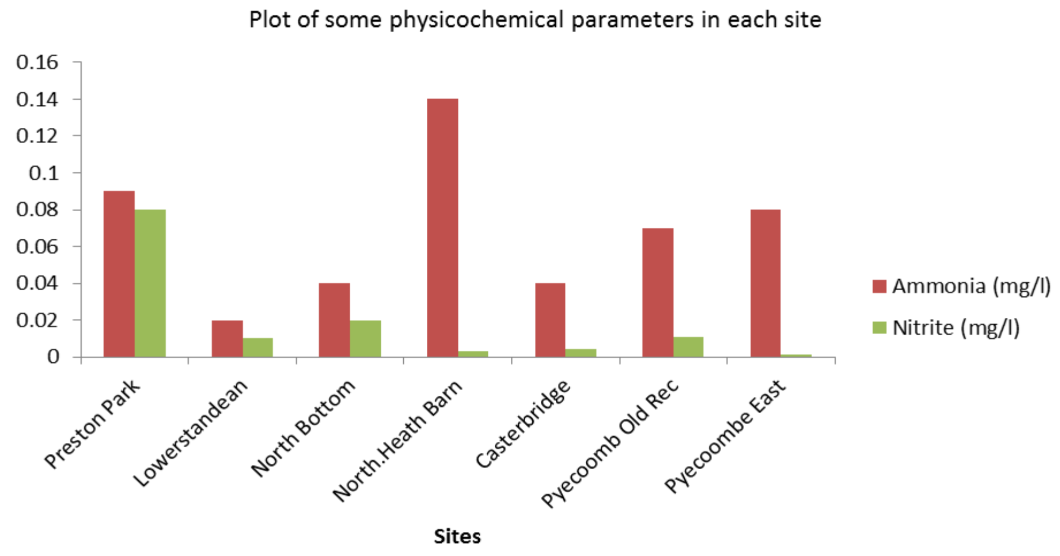

Figure 4. Plot for ammonia and nitrate for all the sites

Microbiological analyses

Descriptive statistics for microbial counts of *E.coli* (PE) ranged from 0.00 to 1.50 x 10^2 CFU/100ml. (Mean ± SD = 7.83 ± 24.66 CFU/100ml), while *Enterococci* (PEnt) vary between 0.00 and 1.57 x 10^2 (mean ± SD = 14.39 ± 33.09 CFU/100ml). The highest level of microbial contaminations was noticed at the Pyecombe East for PE (mean = 26CFU/100ml) and that for Pent was Pyecoombe Old Rec (mean = 48), whereas the minimum levels of microbial counts were noticed from the Lower Standean for PE (mean = 0.00CFU/100ml) and Pyecombe East for PEnt. (mean = 1CFU/100ml) (Table 2).

From table 2 and figure 5, it could be seen that almost all the water samples are microbially contaminated. The WHO and the EC Water Directive (98/83/EEC) guideline values for *E. coli* and *enterococci spp* are 0CFU/100ml. All the water samples except from Lower stand were found to contain *E.coli*, while all the water samples tested positive to *enterococci spp.* This could be attributed to the intrusion of animal faeces into the groundwater. The Pyecoombe Old Rec and Pyecoombe East recorded the highest count of microbial contamination for PEnt and PE respectively. The high rate in the Pyecoombe Old Rec could be attributed to the construction pattern of the well which paved way for the intrusion of animal faeces into the underground water, while the high rate in Pyecoombe East could also be attributed to the proximity to the sewage treatment discharge which could have mixed with the underground water via seepage. Other sites have relatively low counts of microbial contamination but have values which exceed the EC directive and the WHO guideline.

Groundwater is assumed to have a generally stable quality and therefore requires less or no treatment to make it fit for human consumption. This is because it is well protected by soil layers and is expected to have undergone natural filtration as the rainwater or surface runoff percolates into the soil. However, according to the findings in this study, this assumption may not always be true.

The soils in the area had a high leaching potential and therefore were unable to keep pollutants, including faecal matter from reaching the source and also from entering the aquifer especially after a rainfall event.

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Table 2. Mean microbial counts from the sampling sites

Site	*E.coli*(CFU/100ml)	Ent (CFU/100mll)
Preston park	2	10
Lowerstand	0	10
North bottom	7	10
N.heath barn	9	17
Casterbridge	3	17
Pyecombe old rec	15	48
Pyecombe east	26	1

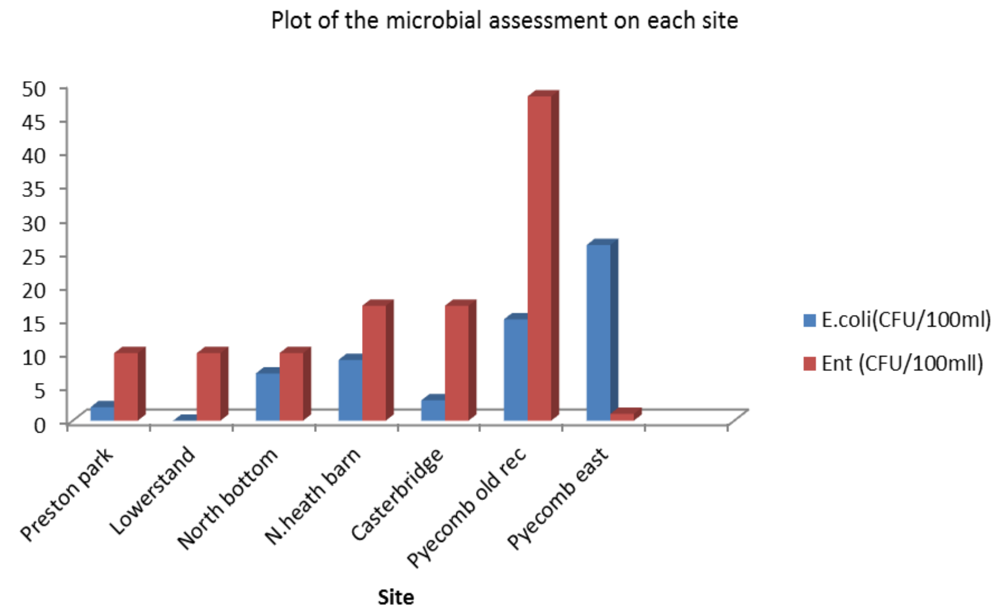

Figure 5. Plot for the mean *E. coli* and *enterococci spp* for all the sites

Results from the ICP optical emission spectrometry analyses

From table 3, it can be seen that Fe ranged between 0.034-0.43, with the highest obtained at North Heath Barn. Although no health-based guideline value for iron was proposed. The levels of Fe are will within the EC directives (98/83/EEC) and WHO guideline values except at North Heath Barn. The presence of iron and manganese in water can be easily identified with its rust coloured stains on fixtures and clothing or bad tasting and smelling water. The presence of Ca and Mg in water indicates that the water has a degree of hardness. It has been identified that the quality of most groundwater in South East England is predominantly hard in nature due to the Chalk formation. The presence of Ca and Mg ions in water is very important for the growth of fish populations (William, 2004). Calcium and magnesium values are well within the acceptable limits in the EC directive of 25mg/l.

The presence of phosphates and sulphate in water aid some plant growth in water such as Plankton (Brian, 2005). Phosphates occur in 3 forms in water which are: orthophosphates, metaphosphate and organically bound phosphate. Orthophosphates are majorly influenced by discharge of partially treated sewage n water. Relatively high values of phosphate values are observed in the Pyecoombe East site which is pretty close to a sewage treatment works discharge. Phosphate and sulphate levels are relatively within the acceptable limits of the EC directive.

Potassium does not dissolve in water and therefore settles as sediments. It is however a dietary requirement for nearly any organism but a number of bacteria. It also plays an important role plant growth. No guide and acceptable limits have been specified for potassium levels in the EC directive and the WHO standards for drinking water quality.

Table 3. Mean concentrations of elements analysed using the ICP optical spectrometry equipment

Site Names	Fe	Mn	Ca	K	Na	Mg	S	P	TOC
Preston park	0.056	0.057	86.63	1.815	2.83	2.5	13.25	0.24	2.13
Lowerstand	0.08	0.083	107	1.13	1.48	2.52	6.83	0.115	1.42
North bottom	0.105	0.064	74.6	0.139	1.15	1.22	7	0.74	0.7
N.Heath Barn	0.43	0.082	67.09	0.7	2.35	2.54	3.71	0.76	0.79
Casterbridge	0.1	0.1	70.8	1.35	1.3	2.38	5.28	1.11	0.54
Pyecombe old rec	0.034	0.1	65	26.75	3.7	8.13	18.5	0.3	1.242
Pyecombe east	0.067	0.058	114	12.48	0	3.32	14.8	1.021	1.82

CONCLUSIONS

This study assessed the physicochemical and microbiological quality of groundwater in the south-eastern part of England, in order to determine whether the water meets the recommended drinking water physicochemical and microbiological quality standards as set out in several drinking water related regulations and directives.

The following conclusions were drawn from the study; all the physicochemical parameters were within the WHO and the EC Water Directive (98/83/EEC) guideline values, but some microbial contaminations were detected in all the sites except that *E.coli* was not detected in Lowerstand. The presence of micro-organisms could be attributed to the proximity to the sewage treatment discharge which could have mixed with the ground water via seepage and intrusion of animal faeces into the groundwater.

Based on the results of our findings, the groundwater resource, without standard treatment is not safe for drinking but quite fit for domestic uses. It is therefore recommended that household treatment method should be applied to the water before drinking and a more regular monitoring of the groundwater quality should be done.

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