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Persistent and emerging micro-organic contaminants in Chalk groundwater of England and France

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ABSTRACT

The Chalk aquifer of Northern Europe is an internationally important source of drinking water and sustains baseflow for surface water ecosystems. The areal distribution of microorganic (MO) contaminants, particularly non-regulated emerging MOs, in this aquifer is poorly understood. This study presents results from a reconnaissance survey of MOs in Chalk groundwater, including pharmaceuticals, personal care products and pesticides and their transformation products, conducted across the major Chalk aquifers of England and France. Data from a total of 345 sites collected during 2011 were included in this study to provide a representative baseline assessment of MO occurrence in groundwater. A suite of 42 MOs were analysed for at each site including industrial compounds (n = 16), pesticides (n = 14) and pharmaceuticals, personal care and lifestyle products (n = 12). Occurrence data is evaluated in relation to land use, aquifer exposure, well depth and depth to groundwater to provide an understanding of vulnerable groundwater settings.

1. Introduction

In the last few decades there has been a growing interest in the occurrence of micro-organic (MO) contaminants in the terrestrial and aquatic environment, and in their environmental fate and potential toxicity (Halling-Sørensen et al., 1998; Kolpin et al., 2002; Kümmerer, 2009). A large variety of MOs are used in huge quantities for a range of purposes including arable agriculture, industrial manufacturing processes, as well as human and animal healthcare. The contamination of groundwater resources by MOs is a growing concern and relatively poorly understood compared to other freshwater resources. While groundwaters often have a high degree of protection from pollution due to physical, chemical and biological attenuation processes in the subsurface compared to surface aquatic environments (e.g. Barnes et al., 2008) it is clear from recent studies that trace concentrations of a large range of compounds including emerging contaminants, that are not currently regulated, are still detected in groundwaters (Focazio et al., 2008; Lapworth et al., 2012; Loos et al., 2010; Lopez-Serna et al., 2013; Stuart et al., 2014, 2012).

The Chalk aquifers of NW Europe are a hugely important natural resource, providing drinking water and sustaining river flows across a large part of southern England and northern France (see Fig. 1), as well parts of as Belgium, Germany, the Netherlands and Denmark. The Chalk is the most significant aquifer in the United Kingdom, providing around 27% of all drinking water nationally and over 80% in areas of the south and east of England (UKWIR, 2004). In France it provides 15% nationally and locally up to 80% (Crampon et al., 2000). The groundwater-fed streams which drain this area support a diverse ecosystem including several internationally recognised special areas of conservation under the Habitats Directive (EC, 1992).

The Chalk aquifers of southern England and northern France are located in a region with a long history of dense population and industry, and underlie both of the capital cities. The population density in the UK, particularly in southeast England, is considerably higher than that in northwest France. Due to high population densities non-agricultural contaminant loading is anticipated to be highest in SE England and parts of NW France, a significant part of which is underlain by Chalk; these major aquifers are likely to be some of the most at risk for MO contamination from urban waste water sources.

As a result of a drive for greater agricultural productivity in the post war period, the thin soils which overly the exposed parts of the

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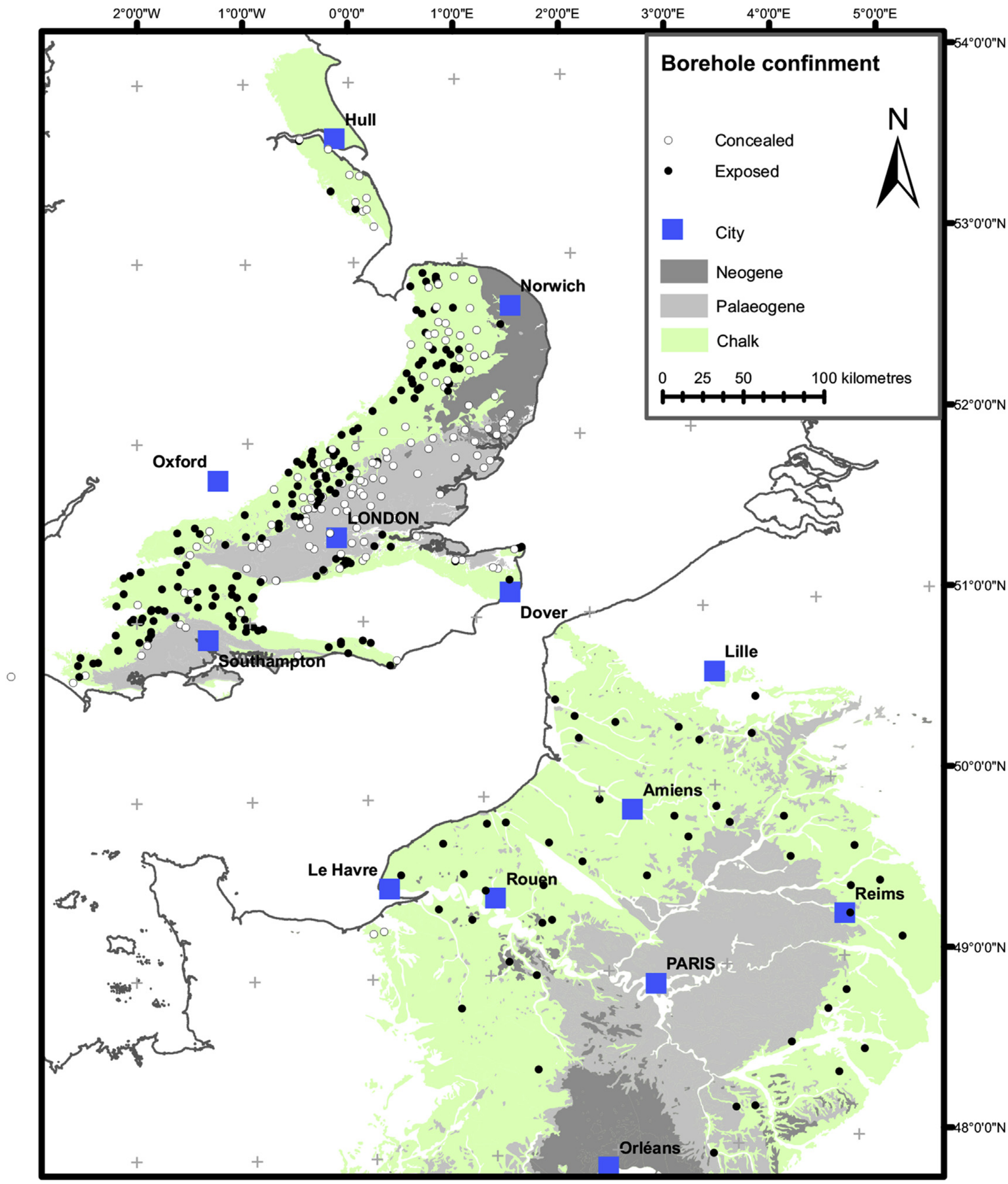

Fig. 1. Map of Southern England and northern France showing Chalk outcrop, Palaeogene cover and sample sites used in the study. Filled symbols are sites that are on exposed Chalk outcrop, unfilled symbols are sites that are either confined or covered with >10 m of impermeable superficial cover. Selected major cities are show with square symbols.

Chalk aquifers have supported increasingly intensive cultivation including cereal production, livestock farming as well as viniculture (Cun and Vilagines 1997; Burt et al., 2010). This move towards intensive farming has led to the use of a wide array of organic compounds for pest and disease control over this period, the natural nutrient-poor status of the soils has also meant that large quantities of fertilisers have been used. As such, for many decades these aquifers have had a high loading of MOs from a range of sources including diffuse arable agriculture, discrete sources such as reticulated sewage systems, effluent from treatment of domestic and industrial wastewater, landfills and septic tanks (Baran et al., 2008; Baxter, 1985a, 1985b; Chilton et al., 2005; Foster et al., 1991; Stuart et al., 2014).

The fissured, and in places karstic, nature of the Chalk means that this aquifer can be particularly vulnerable to the rapid vertical and horizontal migration of contaminants (Baran et al., 2008; Gooddy et al., 2002; Johnson et al., 2001; Katz et al., 2009; Lapworth and Gooddy, 2006; Morasch, 2013). The unsaturated zone thickness can be considerable (>80 m) in areas of higher elevation which can lead to pollution attenuation in the unsaturated zone through dispersion and diffusion into the matrix (Foster et al., 1991; Gooddy et al., 2007; Stuart et al., 2011). Once organic contaminants move from the soil to the unsaturated zone the potential for degradation and attenuation is significantly diminished (Johnson et al., 1998). The relationship between the Chalk and the overlying drift deposits are important in controlling hydrogeology and prevailing geochemical conditions (Edmunds et al., 1987; Edmunds and Shand, 2008; Kloppmann et al., 1998; Lloyd and

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