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Source apportionment of on-site domestic wastewater contamination impacts on springs in rural karst catchments

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On a global scale the main wastewater treatment options for rural and suburban communities which lack access to centralised wastewater treatment are split between septic tanks, latrines and other improved on-site wastewater treatment systems (DWTSs) – estimated to be used by at least 2.8 billion people. In Ireland, more than one third of the population (approximately 500,000 dwellings) use DWTSs, of which more than 87% are septic tanks. Previous studies have found that the effectiveness of DWTSs in treating domestic wastewater varies widely, depending on local soil attenuation capabilities, system design, installation and maintenance. Consequently, the potential impacts of such on-site effluent, especially in cases of inadequate DWTS performance, are microbial and chemical pollution of groundwater and / or surface water.
Karst aquifer systems are exceptionally vulnerable to pollution from such potential contamination sources as a result of predominantly rapid recharge of water from the surface and strong aquifer heterogeneity in these regions. These karst network characteristics and multiple pollution sources make it complex to trace the origins of pollution using conventional methods whereby targeted pollutants in groundwater can be linked to their specific sources and quantified at the same time. This is particularly important in karst aquifer systems where numerical modelling of the fate and transport of pollutants from prevailing contamination origins is extremely challenging and yet increasingly necessary for the implementation of appropriate management strategies at a catchment scale.
To overcome these challenges, this paper presents the results of research being conducted using a wide range of novel, non-conventional and traditional methodologies capable of detecting low concentrations of contaminants in order to determine and quantify human faecal pollution impacts on karst springs. A variety of microbial and chemical source apportionment methodologies are being tested across several Irish rural catchment areas with high densities of DWTSs. The catchments have been selected to compare contrasting groundwater vulnerabilities, different sizes and types of karst systems. A thorough analysis of the results obtained so far using a multiple-tracer approach has been conducted and methods have been evaluated in terms of applicability, sensitivity and accuracy.
The results show that detection and quantification of source specific chemicals such as fluorescent whitening compounds (FWCs), fluorescence-based investigations of organic matter using the excitation-emission matrix (EEM) and PARAFAC analysis, specific anion ratio signatures, faecal sterol and stanol profiles and ratios, and several microbial fingerprinting methodologies in parallel can provide sufficient information for decision making processes and adaptive management strategies. Notably, whilst some of the techniques tested are not capable of being able to link pollutants directly with any particular pollution source, they can still quantify specific pollutants, in some cases to a very high accuracy, thereby determining the overall impacts of contaminants on groundwater quality at karst springs. Furthermore, it has been found that techniques for advanced investigation of microbial populations may be exceptionally advantageous for numerical modelling of the fate and transport of contaminants of DWTSs effluent origin through karst aquifer systems.