Water Resour Manage (2013) 27:75–94
DOI 10.1007/s11269-012-0161-7

Implementing Pollution Source Control—Learning from the Innovation Process in English and Welsh Water Companies

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Received: 22 February 2011 / Accepted: 25 September 2012 /
Published online: 18 October 2012

Abstract Improving the stimulation and management of innovation by water utilities is a key mechanism through which the challenges of securing sustainable water and wastewater services will be achieved. This paper describes the process of adopting source control interventions (SCIs) by water and sewerage companies (WaSCs) in England and Wales. SCIs can be defined as efforts by water suppliers to control agricultural pollution where it arises. To investigate differences in the extent to which SCIs have and are being adopted across all ten WaSCs in England and Wales, Rogers' five stage innovation model is used to structure and interpret results from a series of semi-structured interviews with raw water quality and catchment management personnel. Results suggest that to promote SCI innovation by WaSCs, regulation should be designed in two interdependent ways. First, regulation must generate awareness of a performance gap so as to set an agenda for change and initiate innovation. This can be achieved either through direct regulation or regulation which raises the awareness of an organisations performance gap, for example through additional monitoring. Simultaneously, regulation needs to create possibilities for implementation of innovation through enabling WaSCs to utilise SCIs where appropriate. Evidence from the research suggests that appropriate intermediary organisations can assist in this process by

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providing a resource of relevant and local knowledge and data. Future research should seek to characterise the factors affecting each stage in the WaSC innovation process both to confirm the conclusions of this study and to reveal more detail about various influences on innovation outcomes.

Keywords Innovation · Pollution source control · Water framework directive · Water utilities · Catchment management · Co-operative agreements

Abbreviations

CSFI	England catchment sensitive farming delivery initiative
Defra	Department for food and rural affairs
DOC	Dissolved organic carbon
DWI	Drinking water inspectorate
EU	European Union
EA	Environment agency
NGO	Non Governmental Organisation
Ofwat	Office for water sciences
RWQ	Raw water quality
SCI	Source control Intervention
WaSC	Water and sewerage companies
WFD	Water framework directive

1 Introduction

Delivering affordable water and wastewater services while protecting the aquatic environment is a key challenge for water utilities and governments around the world. In Europe this challenge is represented by the Water Framework Directive (WFD), which aims *inter alia* to achieve good ecological status for all water bodies in the EU (2000). Although achieving this aim will require technological progress as well as innovative ways of delivering water and wastewater services, there is an increasing realisation that the necessary knowledge and technologies largely exist. Rather, the challenge in water and wastewater management is to overcome a set of socio-institutional barriers to implement existing technologies (Daigger 2007; Brown and Farrelly 2009), or, expressed in the language of innovation studies, to stimulate and manage the adoption of practices and technologies which are novel to organisations or other constituencies (Rogers 2003).

The challenge can be viewed as a water sector manifestation of the broader industrial sustainability agenda, where research emphasis has been to understand the management of innovation processes at a company level in the context of achieving cleaner production. More recently, the focus of industrial sustainability innovation research has shifted to the governance or ‘systems’ scale, based on the proposition that it is the wider institutional and technological ‘regime’ or system which must be changed in order to facilitate change at the company level (Berkhout and Green 2002; Rip and Kemp 1998).

Using systems innovation perspectives, analyses of long run (25 years +) changes in water and wastewater systems have been undertaken both in relation to their initial development in the Netherlands (Geels 2006) and their more recent re-orientation towards integrated water resource management (Brugge and Rotmans 2007). The work by Geels (2006) is largely historical, but the work by Brugge and Rotmans (2007) finishes by comparing governance strategies proposed as necessary for successful regime transition management, with the strategies embodied in the implementation of the WFD. The authors conclude that in its current form the WFD is not stimulating innovation sufficiently.

Brown and Farrelly (2009), Cave (2009) and Thomas and Ford (2005) have separately argued that a lack of innovation in water and wastewater is a consequence of institutionalised beliefs and behaviours leading to a preference for traditional, centralised engineering solutions. For the UK in particular Cave (2009) and Thomas and Ford (2005) suggest that a lack of innovation is a result of the system of economic regulation, and a chronic under funding of R&D activities. Their conclusions lend empirical credence to systems innovation claims that the wider institutional context presents both a major barrier to and enabler of change.

Other water and wastewater innovation studies have employed frameworks focussed on understanding change from the perspective of the innovating constituencies. The authors of such studies have argued that the "willingness (or disposition) but also the ability (or capability) in different constituencies (individual, communities, organisations and agencies) to absorb, accept and utilize innovation options" is critical to the successful design and implementation of both water policy instruments (Jeffrey and Seaton 2004), and water technologies characteristic of integrated management approaches such a re-use and recycling (Jeffrey and Jefferson 2003; Brown and Clarke 2006). Moving to the scale of the organisational population, Spiller et al. (2009) have begun to shed light on how the geographical and physical characteristics of water and sewerage company territory influences the choice responses to legislative change such as the WFD. In doing so they have begun to demonstrate that utility specific contextual factors remain important to understanding innovation in water and wastewater, and that physical and engineering factors have enabling and constraining roles in change processes alongside the institutional.

To summarise, whilst the need for appropriate research into innovation processes in the water sector has been recognised (Brown and Farrelly 2009), our understanding of how to best stimulate and manage such innovation for the purposes of improving industrial sustainability is currently patchy and tentative. To inform broader efforts to change water and wastewater systems and to inform efforts to improve the implementation of specific parts of the WFD in Europe, this paper presents an innovation process perspective on change in water utilities. The aim of the research is to identify ways in which innovation in water utilities can be better stimulated and encouraged.

This study investigates the innovation adoption process across all water and sewerage companies (WaSCs) in England and Wales (E&W). While acknowledging that external institutional factors and natural physical conditions play a key role in innovation adoption, an internally focussed perspective is deliberately adopted to shed light on WaSC organisational innovation decision processes. In doing the aim is to provide insight into how governments and regulators can better influence WaSC innovation. The fact that WaSCs ins England and Wales are privatised is of value to better understanding how to govern and manage change, in particular in the light of the growing role of private business in water and wastewater service delivery in Europe (Schouten and Van Dijk 2008). As an exemplar innovation the adoption process for source control interventions (SCIs) is studied.

SCIs are an approach by water utilities to deal with raw water pollution from agriculture at source. Interventions are typically based on co-operation between water utilities and farmers or land managers, potentially through interaction with intermediaries (i.e. individuals or organisations facilitating change in agricultural practice—(Spiller et al. 2012a). SCIs were selected as an exemplar innovation for the following reasons:

- SCIs were being adopted by WaSCs in E&W at the time of the study and so offered an opportunity to investigate processes of change. Recent modifications to the economic and environmental regulation of WaSCs have been a key enabler for this emergence of SCIs. Specifically the changes include a less strict interpretation of the polluter pays principle (Spiller et al. 2012b) and the adoption of drinking water safety plans (section 5).

- SCIs are an example of an integrated approach to water management built on the concepts of pollution prevention and ecological thinking and therefore can be treated as an example of the kind of new, integrated approach to water management advocated as being necessary worldwide.
- SCIs have the potential to meet some of the aims of the WFD (Heinz 2008), such as avoidance of deterioration of water bodies, pollution prevention, involvement of interested parties in the implementation process and catchment scale management.
- SCIs are likely to require change in institutional arrangements (roles and regulations) as well as technologies, and so offer an appropriately rich focus for investigating a range of innovation issues.

In this paper we adopt a broader definition of SCIs than that used by Brouwer et al. (2003a), who investigated only co-operative agreements. Co-operative agreements do not involve intermediary organisations and as a result Brouwer et al. (2003b) did not investigate water resource protection interventions in England and France, because most of them fell outside of the co-operative agreements focussed definition of SCIs they adopted.

By examining the adoption of SCIs across the population of WaSCs in E&W the specific objectives of this study are to:

1 Characterise the extent to which SCIs have been adopted by WaSCs in E&W;
2 Identify the reasons for adoption and non-adoption of SCIs by WaSCs;
3 Assess how the process of SCI adoption and innovation can be better stimulated and guided in privatised WaSCs, and;
4 Identify what can be learned more generally about water utility innovation processes from the SCI-WaSC case study.

2 Conceptual Framework

A modified model of Rogers (2003) five stage organisational innovation adoption process was used as a conceptual framework to analyse the data gathered and to structure the reporting of results (Fig. 1). Rogers' process model has been used to structure and interpret over 30 investigations into water management (data from Web of Science 'cited reference search' executed on 23/06/11).

To provide some detail—Rogers' (2003) model of the innovation process is divided into five sequential stages, beginning with Agenda Setting. The outcome of this first stage is recognition of the need for change as a consequence of having identified one or more "problems". The underlying mechanism for Agenda Setting has been described as the recognition of a performance gap or the deviation of a current state in relation to a desired objective or aspiration level (Cohen and Levinthal 1990; Simon 1997). The notion of a performance gap was first proposed by March and Simon (1958) and subsequently further developed and applied by a number of authors (Cohen and Levinthal 1990; Simon 1997; Mintzberg and Raisinghani 1976). A valid criticism of this depiction of agenda setting is that it is static rather than evolutionary as a consequence of employing an underlying 'control model' i.e. problems are viewed as deviations from some norm, rationally tackled. Such a

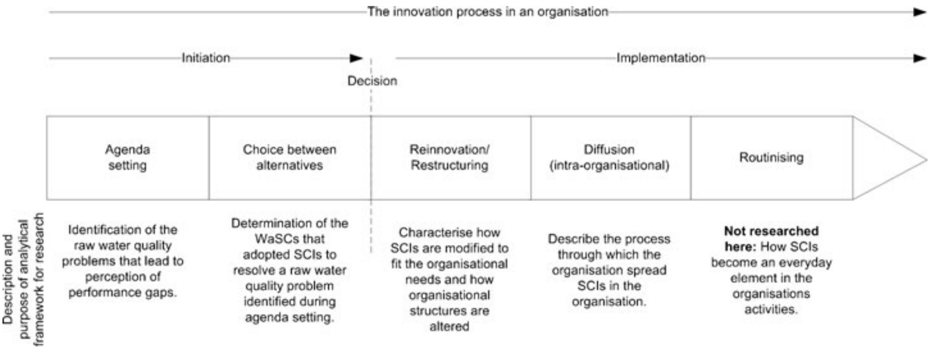


Fig. 1 The innovation process in organisations and purpose of each stage for this research (adapted from Rogers (2003); for the purpose of this research the original names of the second (Matching) and third (Clarifying) process stage of Rogers model have been altered. The rationale for this is explained in the text)

depiction cannot easily represent creative processes where new objectives are formulated or opportunities identified, the model is therefore potentially impoverished (see the critique of rational decision making models by Langley *et al.* 1995).

Having identified a need for change, an organisation then enters into the Choice Between Alternatives process, where alternative ways of resolving the problem are identified and preferred alternatives are selected. Rogers terms this the Matching phase, where the key issues identified during Agenda Setting are matched to alternatives that can close the performance gap. In this research the term Choice between Alternatives is used to emphasise that at this point in the conceptual model response options are accepted or rejected. The Agenda setting and Choice between Alternatives stages result in a decision by the organisation to change in a particular way. Subsequently, actual implementation begins with the process of Re-innovation/Restructuring, where the characteristics of the innovation and the organisation are mutually adapted to accommodate each other. At this stage the innovation is often only implemented in one part of the organisation, to trial and test its performance. More widespread application of an innovation (e.g. SCI) may take place after such trials and experimentation when relevant knowledge has been acquired leading to a re-framing of the innovation, so that it is more tuned to the organisation. This Clarifying stage, as it was labeled by Rogers (2003), is thus linked to the intra-organisational spread, or internal Diffusion of an innovation. Routinisation has been achieved when the innovation is no longer considered novel, but rather becomes part of 'the way things are done in an organisation' i.e. a standard approach.

In a study by Spiller et al. (2012), Rogers innovation model is compared to other conceptualisations of organisational innovation. All models reviewed in their study, consist of a process that moves from the realisation of a need for change to its final use and exploitation (implementation). In particular the conceptualisations of agenda setting, performance gap identification and choice between alternatives are similar across different models (Mintzberg and Raisinghani 1976; Christensen 1997; Cohen and Levinthal 1990; Tidd et al. 2005; Trott 2005; Gallouj et al. 2002). For the remaining stages of the innovation process, different models start to diverge in terms of the number of stages, sequence and the labels given. The authors suggest that these differences are found in part because of the different perspectives adopted. For instance, authors with a technology transfer perspective (e.g. Trott 2005 and Jeffrey and Seaton 2004) associate knowledge with specific opportunities for application which are subsequently exploited through implementation; while, innovation management scholars (Tidd et al. 2005) emphasise the design and redesign of the innovation and the ‘Restructuring’ of the organisation. The majority of authors propose that routines are established as a final outcome of innovation, a term which was coined by Nelson & Winter (1982) to describe behaviours that are engrained into organisational activity.

Accepting that Rogers model, whilst widely used and cited, has descriptive and explanatory limitations, we selected the model because (i) it is simple and (ii) represents the main process stages which a range of models include in their description of organisational innovation. Our intended use of Rogers model was to provide a degree of minimum structure to our interview analysis and interpretation—we assumed that there would be evidence of each of Rogers’ process stages, but did not make any assumptions about the nature of overall innovation process we would observe (whether stages would be linear or iterative), about the functioning of each stage or about the kinds of factors which would play a role in influencing WaSC innovation. We entered the research prepared to either simply populate Rogers’ model with empirical detail or to propose revisions to the model if the data suggested a need to do so.

3 UK Water and Sewerage Companies and Regulation

WaSCs in England and Wales are fully privatised commercial businesses, they have the following statutory duties (UK Government 2003):

- to develop and maintain efficient and economical systems of water and sewerage service provision;
- to ensure a secure service of water in a sufficient quality;
- to adhere to the prescribed discharge consents;
- to comply with abstraction licenses;
- to draw up 25 year water resource plans and drought management plans;
- to ensure health protection, equity, efficiency and environmental protection WaSCs are regulated by the Environment Agency (EA), Office for Water Services (Ofwat) and the Drinking Water Inspectorate (DWI).

The EA is responsible for the enforcement of environmental regulations such as discharge consents and abstraction licences. As the responsible authority for implementing the WFD the EA has the duty to specify environmental objectives and carry out river basin management planning.

Ofwat is responsible for economic regulation of all WaSCs. Using water company information Ofwat conducts a comparative assessment through which it determines what each water company can charge customers and how capital can be invested (Allan 2006).

The English Catchment Sensitive Farming Delivery Initiative (CSFI) is part of the UK Government’s response to meet the requirements of the Water Framework Directive (Defra 2009) and conservation objectives under other EU policies (e.g. Habitats Directive). The CSFI operates on priority catchments, which are sensitive to pollution from nitrates, phosphorous and sediments (pesticide is covered in collaboration with the Voluntary Initiative) and has the following objectives (Defra 2009):

- to encourage changes in behaviours and practices by engaging with farmers through workshops, seminars, farm demonstrations, self-help groups and undertaking 1:1 farm visits delivered by CSFI Officers;
- to undertake communications and publicity;
- to signpost agri-environment schemes and other incentives, and;
- to assist farmers with CSFI Capital Grant applications.

In Sections 5 and 6 the role of CSFI as an important intermediary for the adoption of SCIs by WaSCs will be discussed.

4 Method

4.1 Research Strategy and Design

An abductive research strategy was used in this study. In other words, the interpretation of events by social actors (i.e. WaSC representatives) was treated as being appropriate evidence to explain decisions about the adoption of SCIs. Abductive designs have been noted as being particularly suitable for describing and understanding change processes (Blaikie 2000).

The research was designed to be a mixed method, comparative case study of the innovation adoption behaviour of the entire population of WaSCs in England and Wales (10 in total). A variance design was selected rather than a longitudinal process design primarily for reasons of resource and access to WaSC personnel. The consequence of this decision was to exclude Routinisation, the final process in Rogers' (2003) innovation adoption model, from the study. Interview data collected was not sufficient to allow conclusions about this process. This would require a detailed process based research.

Semi-structured interviews with 21 individuals in 10 English and Welsh WaSCs were used to gather data. Each individual was selected purposively through a mixture of existing contacts and snowballing. The precondition for being selected for interview was that the individual had to be responsible for raw water quality or catchment management. At least two people from each WaSC were interviewed to provide intra-WaSC triangulation.

4.2 Data Analysis

All interviews were recorded on a digital voice recorder and full transcripts were prepared prior to thematic and content analyses. Each company was anonymously analysed and presented using an alphabetical coding system—A through to J. The data presented per WaSC are the aggregated results for all interviews within that company.

Interview data was subjected to analysis using an inductive, or open coding approach. Rogers' model was used to relate interviewee response fragments to the Agenda Setting, Choice Between Alternatives, Reinnovation/Restructuring or Diffusion stages. In other words whether interviewees were discussing the nature of the raw water quality performance gap they perceived and why they perceived it to exist; how they generated response options, their character and the reasons why they selected particular ones; how they went about designing the actual form of response option (SCIs in particular) and what changes were required organisationally to implement the option, and; how they then went about diffusing selected options more widely across their business. Within each stage an open coding approach was employed as described under 4.2.1 and 4.2.2 below.

4.2.1 Thematic Analysis

The primary analytical tool employed in this study was thematic analysis (Brown and Clarke 2006). It is a method used to identify patterns or themes in transcribed interviews. The Thematic Analysis employed coding of the transcriptions which is defined as (Strauss and Corbin 1998): "*the analytical process through which concepts are identified and their properties and dimensions are discovered in the data*". In simple terms coding breaks up the text in discreet parts such as events or decisions and subsequently collates related concepts in broader categories.

Miles and Huberman (1994) suggest that this coding begins with descriptive codes, which require little interpretation, but are rather using labels directly derived from the language used by the respondents. This closeness to the respondent's language facilitates, to some extent, a more direct reflection of their perceptions. Later in the process, when the researcher has gained knowledge about the data, codes become more interpretive and inferential, for instance by coding along an analytical framework or determining common characteristics of codes.

4.2.2 Content Analysis

Content analysis is a method for making replicable and valid inferences from text by condensing the data into categories (Krippendorff 2004; Busch et al. 2005). Content analysis is thus similar to thematic analysis, but contrary to thematic analysis, has a tradition of quantitative data analysis. In this study the term content analysis was used as an umbrella term to cover all quantitative categorical data analysis techniques.

Content analysis was used to assess (i) how frequently a theme occurs in the interview (recurrence counts) and (ii) the amount of 'space' it occupies in the text i.e. its coverage. Technique (i) was applied to determine the recurrence of SCI types and specific water source (i.e. groundwater and surface water), and technique (ii) was employed to determine the coverage of specific raw water quality problems.

5 Results

The presentation of research results has been structured according to the first four stages of Rogers' five stage innovation model (Fig. 1). The final stage (Routinisation) will not be covered for reasons described in 4.1. The section on:

- *Agenda Setting* will address the process of problem identification and the raw water quality problems WaSCs perceived,
- *Choice Between Alternatives* will characterise the relationships between perceived raw water quality problems and SCI adoption across the population of WaSCs, the reasons why SCIs were or were not selected and the types of SCI design utilised by WaSCs,
- *Re-innovation and Restructuring* will explain the ways in which activities from two specific SCI types were designed to meet organisational needs, and the way in which WaSCs organisationally changed to accommodate different SCI types,
- *Diffusion* will describe the process by which SCIs were adopted at multiple sites.

5.1 Agenda-setting

The process of agenda setting was affected by organisational characteristics, regulatory institutional factors and specific site conditions. Most frequently, drinking water quality standards were found to have served as an aspiration level or a minimum value to be attained. The state of the raw water marked the deviation from the aspiration level, while asset characteristics moderated the perception of declining water quality raw water quality and seasonal pollution peaks. In other words, where existing treatment assets could not treat to the drinking water quality standard, a problem was perceived. This was most likely where extrapolation of present water quality trends showed a decline and where seasonal pollution peaks occurred, rather than where deteriorated raw water quality had persisted for some time. This was the case simply because deterioration in water quality required a response from WaSCs to maintain potable water quality standards, while sites with historically poor raw water quality were likely to have treatment processes in place.

Another way in which Agenda Setting was found to occur involved the influence of land ownership and environmental quality standards. WaSCs were obliged to ensure adequate status for their land holdings under environmental/conservation legislation (i.e. Habitats Directive EC 1992; WFD EC 2000). In this situation, the same key elements as above can be identified; namely an aspiration level (i.e. the prescribed legislative objective), the deviation or threat of deviation from this aspiration level (e.g. environmental status) and the responsibility of land ownership.

Yet another pathway to ‘Agenda Setting’ was related to the introduction of Drinking Water Safety Plans. Drinking Water Safety Plans required WaSCs to map and assess the risks to raw water quality from the catchment. As a result, WaSCs built up an awareness of potential water quality risks, understood as the deviation (or anticipated deviation) from an aspiration level.

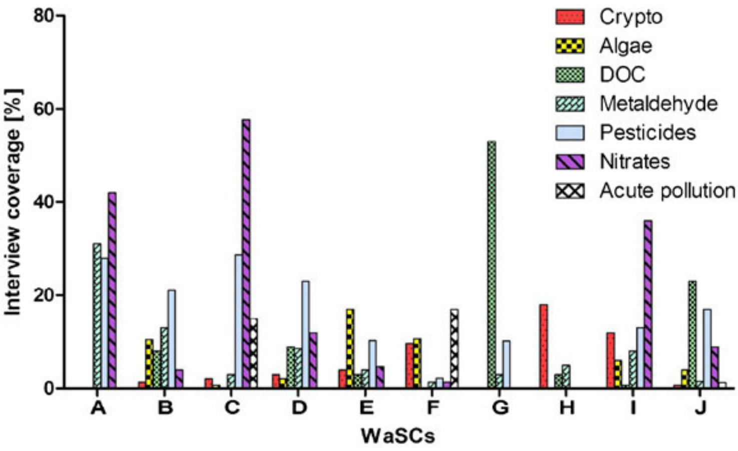
Cryptosporidium, Dissolved Organic Carbon (DOC), pesticide pollution, algae, nitrates and acute pollution incidence were the raw water quality (RWQ) issues perceived by the WaSCs interviewed (Fig. 2). On average nitrates and pesticides were the most frequently mentioned RWQ issues. Pesticides showed a low standard deviation, while the standard deviation for nitrate pollution issues was the highest in the sample. In other words pesticides were a concern for most interviewees, while the perception of nitrate issues varied more widely between interviews. The average coverage for the remaining issues was lower and of those DOC showed the highest average and a high standard deviation. In particular, interviews with G and J emphasised DOC issues. Cryptosporidium was not a major topic in most interviews, with the exception of interviews with H, I and F. Interviews with WaSC A and B showed comparatively frequent references to Metaldehyde issues (note: that Metaldehyde issues also comprise Clopyralid issues as the were commonly perceived to be similar, see also (Spiller et al. 2012b), followed by interviews with D and I. Algae was no major concern with the exception of interviews with B and E. Finally, acute pollution was not specifically referred to by most interviewees, other than representatives of F and C.

5.2 Choice Between Alternatives—Conditions for SCI Selection

5.2.1 The Conditions for SCI Selection

SCIs were implemented or considered for implementation for most RWQ problems that attained a high coverage (Table 1). The exceptions were the Metaldehyde RWQ issue of WaSC B, the Algae RWQ issue of WaSC F and the Nitrate RWQ issue of WaSC D and J. Further exceptions were the RWQ issues Cryptosporidium and Acute pollution, for which SCIs were considered unsuitable by all WaSCs (Spiller et al. 2012b).

The majority of WaSCs considered SCIs for pesticide raw water quality problems. Only three organizations proposed SCIs for nitrate and two for algae raw water quality problems. SCIs for DOC were mentioned three times; which represents all those WaSCs that perceived a DOC raw water quality problem. For acute pollution no SCI was employed. Since most of these raw water quality issues are associated with surface waters, the majority of SCIs were implemented (or planned) in surface water catchments. Exceptions to this were SCIs for nitrate issues, since nitrate pollution was associated with groundwater, and the SCI for pesticide issues of WaSC I.



	Crypto	Algae	DOC	Metaldehyde	Pesticides	Nitrates	Acute pollution
AVG	6.3	7.3	12.5	7.8	17.0	18.5	4.7
STDEV	6.2	5.8	18.0	8.9	8.9	21.1	7.7

Fig. 2 Variation of raw water quality problem perception between WaSCs expressed as interview coverage. (AVG—average, STDEV—standard deviation, Crypto—Cryptosporidium Oocyst)

5.2.2 WaSC Reasons for Selecting Source Control Interventions (SCIs)

It appears that multiple factors were aligned when WaSCs made a choice to adopt SCIs. For example, it was found that WaSCs chose SCIs when catchments were small and their hydrogeology was suitable. However, WaSCs only did so when these conditions were matched with the 'right' customer preferences, managerial attitudes (such as towards notions of sustainability), asset characteristics (such as investment needs to meet the drinking water quality standard) or land ownership. Furthermore, an enabling environment in terms of regulation and other institutional factors was required to facilitate the choice of SCIs (Section 5.3).

Table 1 SCIs adopted for surface waters (SW) and for groundwater (GW) catchments and the interview coverage in % of each Raw Water Quality (RWQ) problem by company

	Crypto	Algae	DOC	Metaldehyde	Pesticides	Nitrates	Acute pollution
A				31/SW	28/SW	42/GW	
B	1.3	10.5/SW	8/SW	13	21/SW	4	0
C	2	0.7	0	3	28.7/SW	57.6/GW	15
D	3	2	9/SW	8.5/SW	23/SW	12	0
E	4	17/SW	3	4	10.3/SW	4.7	
F	9.7	10.7		1.3	2.1	1.3	17
G			53/SW	3	10.2/SW	0	0
H	18		3	5			
I	12	6	0.7	8/SW	13/GW	36/GW	0
J	0.7	4	23/SW	1.5	17/SW	9	1.2

During the Choice between Alternatives processes the primary objective of WaSCs was that the problem identified in the Agenda Setting process could be resolved by the innovation to be chosen e.g. by SCI. In the present case this entailed achieving statutory drinking water objectives and in some instances conservation targets (where WaSCs owned land). If the chosen alternative (here specifically SCIs) was assessed as being capable of achieving these ‘primary’ objectives, second order objectives were used to further distinguish and evaluate alternatives. These second order objectives were about reduction of CO_2 emissions, reduction of operational costs (for example longer regeneration cycles of Granulated Activated Carbon), avoidance of asset investment and long term improvements of raw water quality. This finding could be interpreted as a situation where WaSCs first aimed to satisfy their basic statutory duties, here the supply of potable water, and only then would they consider long term goals and environmental objectives.

5.2.3 Typology of Source Control Interventions Selected

SCIs may be distinguished based on the scale at which they operate and the knowledge demands they make on WaSCs. Using these two dimension Spiller et al. (2012b) identified four notional types or categories of SCI activities—‘Lobbying’, ‘Liaison’, ‘Education’ and ‘Advice and Support’ (Fig. 3). Of relevance to this study are the ‘Liaison’ and ‘Advice & Support’ SCI activities only, since they were sufficiently widespread to reveal key information about their adoption process and because insufficient information was available on ‘Lobbying’ and ‘Education’ activities.

Figure 4 shows which WaSCs planned or had implemented the different SCI designs. With the exception of WaSC H and F, all organisations employed ‘Liaison’ for Metaldehyde, Pesticide and Nitrate RWQ issues. Five WaSCs used ‘Educational’ approaches (mainly for Metaldehyde and Pesticides) or showed evidence of ‘Advice & Support’ activities. In two

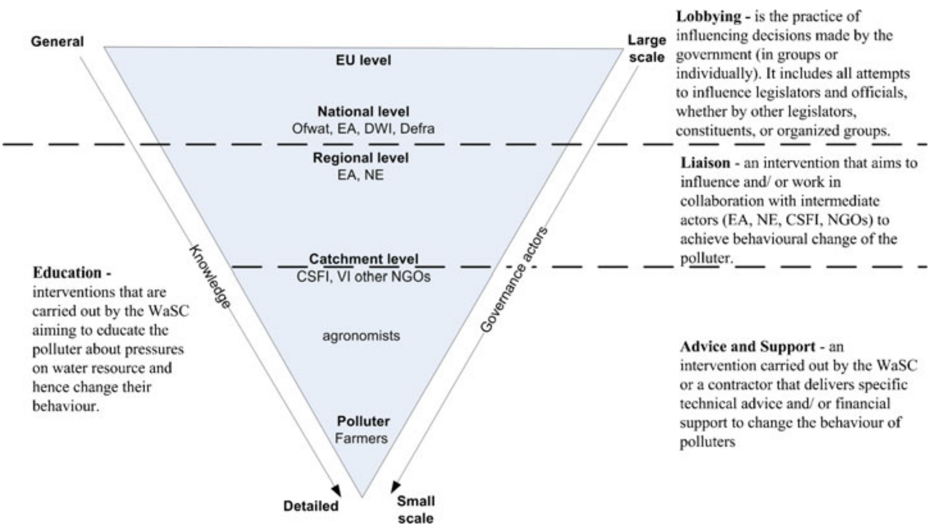
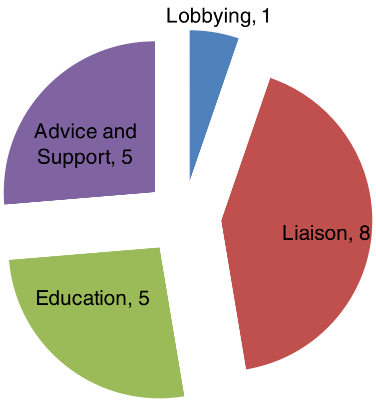


Fig. 3 Definitions of SCIs types and their associated scale of intervention and required level of knowledge (CSFI—English Catchment Sensitive Farming Delivery Initiative, Defra—Department for Food and Rural Affairs, DWI—Drinking Water Inspectorate, EA—Environment Agency, NE—Natural England, NGO—Non Governmental Organisation, Ofwat—Office for water services, VI—Voluntary Initiative)



	Crypto	Algae	DOC	Metaldehyde	Pesticides	Nitrates	Acute pollution
Lobbying	Generic for G (was not specifically investigated)						
Liaison		B*, E	B, G, J, D*	A*, B*, D*, I	A*, B*, C*, E, G, J	A*, E*, C*, D*	
Education			J	A*, B*, I	A*, B*, G, J	A*	
A&S			B, D*, G, J,	I, J	I, J	I	

Fig. 4 Number of WaSCs that adopted or planned to adopt the four SCI types for specific raw water quality problems (* planned implementation at time of interviewing, Crypto—Cryptosporidium Oocyst)

instances 'Advice & Support' activities were restricted to DOC raw water quality issues (B, D), while the remaining two WaSCs applied 'Advice & Support' also for Metaldehyde and Pesticide RWQ problems. WaSCs I was the only organisation to apply 'Advice & Support' for nitrates.

5.3 Re-innovation

In this sections results are presented which show how WaSCs designed SCIs in response to site conditions and according to organisational needs. In other words, this section investigates re-innovation (adaptation of innovations) as described in section 2.

5.3.1 Liaison SCIs

WaSCs used 'Liaison' SCIs to influence or work together with intermediaries such as the EA, Natural England and green NGOs to facilitate source control. Rather than being simply a lobbying effort the distinguishing feature of this SCI type was that it involved the mutual co-operation and support between the WaSCs and intermediaries. This comprised data sharing or collaborative work (e.g. joint events) through Catchment Officers. Furthermore, WaSCs may have communicated directly with the polluter, but the intermediaries were crucial in facilitating this. Frequently, WaSCs used the CSFI events as a platform to communicate raw water quality problems to farmers. In all instances this process relied on local, catchment specific knowledge and data, including knowledge of stakeholders (i.e. farmers), hydrogeology and land use. 'Liaison' activities operated at the regional (>5 km^2) to local scale (about 1 km^2) to make use of influence and collaboration with regional and local actors such as CSFI, EA and NGOs to deliver source control (see section 5.3).

Data gathering was a key element of Liaison designs. For instance, representatives of two WaSCs (A; J) argued that modelling and data sharing with the EA was a crucial part of their approach to Liaison. In other words rather than collecting data this WaSC wanted to generate knowledge of the catchment through mining existing data sources. Using this data, this WaSC aimed to develop pollution pathway models to prioritise areas for intervention and then use this knowledge to guide the activities of intermediaries. A number of WaSCs (3/10) emphasised that they did not intend to develop agricultural skills themselves for instance by employing Catchment Officers: "*...we don't believe that it's a water company's role to be talking directly to farmers or whatever, there are other people that are more skilled, that have more knowledge than us, so it's really trying to identify what are we good at as a water company and then how can we make that better.*"

Other approaches to Liaison included the provision of start up capital for environmental and agricultural NGOs that worked in the interest of the WaSCs (E); or the collaboration (incl. financial support) of the EA (Spiller et al. 2012b).

5.3.2 Advice and Support SCIs

The distinguishing attributes of 'Advice & Support' activities such as crop management plans, soil management plans and on farm infrastructure investment was that they required specific knowledge of the problem situation and direct engagement with the polluter. Catchment Officers employed by the WaSC facilitated this higher demand for knowledge and direct involvement at a local scale (sub-catchments and individual water sources between 20 and 80 ha). 'Advice & Support' activities were also based on formal agreements between WaSCs and the polluters. In all cases the aim of 'Advice & Support' was to make agri-environmental grants available to farmers, and thus cross-finance activities which are thought to lead to environmental and water quality improvements.

The potential magnitude of success of 'Advice & Support' was demonstrated in one catchment of WaSC I (Spiller et al. 2012b). In this area the EA limited its regulatory activities as a result of the 'Advice & Support' intervention implemented. The catchment Officers employed by the WaSC visited 40 local farmers frequently, facilitating advice on a range of subjects (e.g. nutrient and pesticide management). This generated trust of the farmers, which in turn resulted in a relationship where information could be accessed that would otherwise have been challenging to obtain (e.g. spraying records, fertiliser application, observation boreholes). Since there were concerns that the EA could adversely affect this relationship, a mutual agreement was reached which reduce the policing involvement of the EA to a minimum.

5.4 Restructuring WaSCs to Accommodate SCIs

To accommodate SCIs seven WaSCs (A, B, D, E, G, I, J) were found to have recently (between 2004 and 2009) developed specific departments or employed individuals that held catchment and agricultural knowledge. WaSCs undertook this restructuring to overcome knowledge deficits with regards to hydrogeology, pollution pathways and agriculture practice. The function of the individual or department appeared to be either associated with development and testing (A, D, J) or with the delivery of SCIs (B, E, G, I). In five instances WaSCs were also found to employ or plan to employ Catchment Officers to conduct one-to-one farm visits. No reference to staff designated to catchment management or source control functions was made by three companies (C, F, H). The exact configurations of departments were difficult to compare based on the information from the interviews. However, the key point is that seven WaSCs (A, B, D, E, G, I, J) maintained specific departments or employed individuals that held or generated knowledge relevant (i.e. catchment and agricultural) for the implementation of SCIs. This implied that seven out of the eight WaSCs which were found to plan or have implemented SCIs showed evidence for 'Restructuring' of their organisation. Likewise, all WaSCs which employed or planned to employ Catchment Officers had implemented 'Advice & Support' activities.

5.5 Diffusion of SCIs

The present investigation revealed that WaSCs repeated the process of agenda setting, choice between alternatives and design of SCIs for each catchment to find the most suitable alternatives that best serves their needs and suits the local environmental and institutional circumstance. For instance organisation B used a 'Liaison' design for pesticide issues in one sub-catchment, because CSFI Officers were present in this catchment. Contrary to this it gave preference to 'Advice & Support' designs in other sub-catchments, where no CSFI initiatives existed. In other circumstance knowledge of pollution pathways or the type of the water resource issue affected for each individual catchment which SCIs was adopted. The suggestion from this finding is that the process of diffusion of SCIs within a WaSC is not so much one of diffusion in the normal sense, but one in which the first three stages of Rogers (2003) process may be repeated sequentially at each new site (or catchment/sub-catchment area).

6 Discussion

6.1 Performance of SCIs

Whether SCIs in England and Wales are effective ways for WaSCs to tackle raw water quality problems at source alongside secondary objectives relating to reducing capital costs and carbon emissions is not yet clear. The response time of the natural system to SCIs can be in the order of decades and thus no sufficiently long term data for improvements to the water quality, saving of operational costs or capital expenditure are available yet.

However, evidence published by Spiller et al. (2012b) suggest that in England and Wales at least one successful case exists where SCIs have avoided investment into the construction of new assets. Furthermore, in a modelling analysis of the performance of the English CSFI it was estimated that interventions similar to SCIs can result in a reduction of pollutant loss typically between 5 and 10 %, but potentially up to 36 % (ECSFDI 2011). Evidence from the Europe, the US and Taiwan demonstrate that SCIs or the specific measures associated with them can be a cost effective means to comply with drinking water standards and to protect water resources (Table 2 Chang et al. 2010; Heinz 2004; Postel and Thompson 2005). Contrary to this, a study by Bach et al. (2007) indicates that cost of advice and support activities can exceed the cost for treatment by 346–488€ kg/NO_3-N. However, Bach et al.'s (2007) analysis does not take into account the benefits for decades to come that may arise from improved agricultural practice. Studies that assess the CO_2 emission reduction have not been conducted, but it is likely that the CO_2 footprint of SCIs is lower than end of pipe treatment.

SCIs are however an inherently uncertain approach to achieve water quality targets from the perspective of a water company, as they rely on other actors (i.e. farmers) to adhere to specific practices at all times. Uncertainty in performance was a frequently mentioned

Table 2 Performance of catchment management projects in the USA and Germany (adapted from Heinz 2004 +; Bach et al. 2007#; Postel and Thompson 2005*)

USA: Cities that have avoided construction of treatment plants through implementation of catchment protection		Germany: raw water quality benefits and cost implications	
Metropolitan area	Avoided costs through catchment protection	Farmland area	Benefit of agreement
*New York City	$1.5bn spend on catchment protection over 10 years to avoid at least $6bn capital costs and $300 m annual operating costs	+Viersen/Süchteln (Germany) 600 ha	water quality below limit value; 213,000 Euro per year saved water treatment cost
*Boston, Massachusetts	$180 m avoided cost	#Hessen (Germany)	Nitrate trend reversal in raw water; costs of intervention exceed treatment costs by 346–488€ kg/NO_3-N removed from raw water
*Seattle, Washington	$150–200 m avoided cost		
*Portland, Oregon	$920,000 spend annually to protect catchment is avoiding $200 m capital cost		
*Portland, Maine	$729,000 spend annually to protect catchment has avoided $25 m in capital costs and $725,000 in operating costs		
*Syracuse, New York	$10 m catchment plan is avoiding $45–60 m in capital cost		

concern during the interviews. There it was explained how accidents or mistakes have resulted in significant setbacks for the success of SCIs.

Surveys of farmers' attitudes after attending workshops and one to one visits by catchment officers of the CSFI provide evidence for the challenges of implementation of SCIs (ECSFDI 2010). For example, between 2007 and 2009 the number of farmers in England and Wales who thought that their own farming activities contribute a great deal or fair amount to water pollution remains low, at only 3 %. The percentage of farmers that changed their practice as a result of one to one or event based advice stayed around 50 %, indicating the need for longer and more concerted action to influence a higher proportion of farmers. The need for such effort presents a challenge to WaSCs when seeking to implement SCIs.

6.2 Understanding Innovation Processes in WaSCs

The results of the research show that the first three stages of Rogers (2003) innovation model can usefully represent the process of WaSC SCI innovation, but that some differences exist with regards to the Diffusion stage (see Section 5.5). Having explored the SCI innovation process in WaSCs using this framework, what can be learned about how to better stimulate and manage the process of innovation adoption, both with regards to SCIs and more generally with regards to WaSCs and water and wastewater systems?

Findings suggested that the statutory drinking water standard was a key factor in WaSCs recognition of raw water quality issues. Expressed in the language of innovation studies, it can be said that the statutory drinking water standard was critical for performance gap recognition and Agenda Setting. In environmental policy literature there is evidence that direct regulation that defines and enforces specific standards has been successful in promoting technical change, by setting performance target and thus creating a performance gap (Maria 2005). For water services, such regulations (e.g. drinking water regulations and the UWWTD) have led to improvements in water and sewerage service provision (EC 2007). Whether these improvements have also led to innovations in technologies or other approaches is questionable. The Urban Wastewater Treatment Directive (EC 1991) sets specific standards for infrastructure, for example that all agglomerations above a population equivalent of 2000 need to install a wastewater collection system. Water utilities responded to this requirement by replicating large centralised wastewater systems rather than alternative decentralised and re-use orientated technologies.

Porter and van der Linde (1995) offered another way in which Agenda Setting can be influenced to initiate innovation processes. They argue that regulation that requires organisations to gather information can result in improved environmental performance by raising companies' awareness of their comparative performance. Indeed, the Drinking Water Safety Plans functioned in this way as it triggered WaSCs to identify risks to drinking water quality in the catchment. This provides evidence that water utility regulators are able to initiate innovation by designing regulation which requires the gathering of environmental information.

The research reported here further showed that the perception of a performance gap alone is insufficient to initiate an SCI innovation process in WaSCs. Rather, the different types of SCIs adopted and the organisational changes initiated by WaSCs underline the fact that innovations are also designed to fit organisational skills as well as local environmental (as in external to the WaSC) circumstances. In Rogers' (2003) words, at the point of choice between alternatives, organisations go through a process of reality testing, where an organisation attempts to anticipate the feasibility and benefits of the innovation. As a result, the organisation will make a decision whether to adopt an innovation or whether to re-design the innovation or to change the organisation. This draws attention to the key importance of the Re-innovation/Restructuring stage of the innovation process. WaSCs might for instance design 'Advice & Support' SCI types in small catchments where chances of success are high, or they might use 'Liaison' SCIs types in areas where the CSFI is operating. Likewise, if WaSCs anticipate the possibility that they might adopt a specific innovation, such as SCIs, they seek to develop the relevant knowledge and skills necessary for adoption.

To promote the development of designs and organisational knowledge, scholars have argued that the role of Government is to provide a place to experiment with potential solutions. This is achieved by creating favourable conditions in 'niches' through short term subsidies and by accepting failure as part of a learning process (Kemp and Rotmans 2004; Nill and Kemp 2009). Another mechanism to facilitate such learning and innovation has been shown in this research, where the findings demonstrate how intermediary organisations can transfer knowledge and facilitate capacity building.

The development of Liaison SCIs by WaSCs created a pathway through which the knowledge and expertise of intermediate organisations (e.g. agronomists, local NGOs) could be exploited. These intermediary organisations can be described as boundary spanning agents, or organisations that stimulate innovation by enabling the exchange of information and by providing new perspectives, knowledge and insights (Guy et al. 2011). For change in water management more specifically, intermediary organisations which hold catchment specific knowledge appear particularly relevant in the context of river basin management, where problems are specifically dependent on local environmental conditions and interaction between local actors.

Based on this insight, policies to promote change and innovation in water management might profitably be developed to support appropriately scaled organisations that can act as intermediaries. Taking the successful boundary spanning activities of the CSFI as an example, it can be suggested that an appropriate scale is the sub-catchment level with a size between 130 and 200 km^2 (the catchment size of the priority catchments ECSFDI (2008). However, WaSCs are mostly focusing on even smaller scale areas in which to implement 'Liaison' SCIs, suggesting that further downscaling of information and knowledge to few km^2 is necessary.

Finally, the results suggest that diffusion or the spread of an innovation and thereby a wider transition to new water management systems will occur through an iteration of the previous innovation adoption stages. This may suggest that all situations were reassessed on an individual basis to determine whether alternatives are suitable. In other words, intra-organisational 'Diffusion' is a re-iteration of 'Agenda Setting', 'Choice between Alternatives' and 'Reinnovation'. This would suggest little potential for governments to promote innovation diffusion between and within water utilities, since local conditions may simply make particular innovations unattractive or not feasible.

7 Conclusions

The results of this study show that governments could develop policy instruments to promote innovation in two interdependent ways. Firstly, policy and direct regulation can be used to generate awareness of a performance gap so as to set an agenda for change and initiate innovation. Secondly, governments have a potential role in facilitating the design of water and wastewater innovations, and the concomitant restructuring of organisations to enable progress from identification of a performance gap towards implementation of innovative responses. Knowledge capacity (skills and expertise) was shown to be a key factor in enabling organisations to design and restructure. The results of this study demonstrate that intermediary organisations can provide a substitute for under-developed knowledge capacity in WaSCs and in doing so that they can facilitate knowledge transfer between WaSCs and agriculture. Further our results suggest that in the context of catchment management specifically, intermediary organisations should possess local knowledge and data to function successfully. It is therefore the role of governments to promote appropriate intermediary organistions.

Finally, it can also be observed that the influence of regulation and policy on inter- and intra-company innovation processes is likely to be restricted to those stages already described, because diffusion appears to occur through a re-iteration of agenda setting, choice between alternatives, and re-innovation/restructuring processes. As a consequence diffusion is open to influence from local contextual factors which may include existing infrastructural asset characteristics (performance, reliability, age, cost etc.), environmental conditions, and the availability, willingness and knowledge of local stakeholders.

The scope of this paper has been limited to describing the extent of an exemplar innovation (SCIs) and how the types of innovation relate to the overall adoption process. Future research should investigate factors of influence on the innovation adoption process in more detail. This should help to substantiate the conclusion about how policy actions can influence innovation and about the possible trade-offs policy makers need to be aware off.

For instance, the effect of command and control regulations in generating a performance gap and subsequent innovation could be examined in relation to SCI innovation outcomes. The role of specific directives and policy like the WFD, economic regulation of WaSCs, elements of the Common Agricultural Policy and possibly Drinking Water Safety Plans could also be investigated. Finally, the literature on SCIs suggests that their implementation is dependent on hydrogeological factors (Brouwer et al. 2003a), raising the question of the extent to which natural environmental factors act to promote or inhibit innovation. Seeking to engineer change in water and wastewater systems without such knowledge risks at best wasted effort, and at worst, lock-in to a new set of ill-fitting technologies and practices.

Acknowledgements The authors would like to acknowledge the support of the EC funded ISBP project (NEST-PATHFINDER-CUL 043199, Integrated Systems and the Boundary Problem), the kind co-operation of all the interviewees. Furthermore, the authors would like to thank the two anonymous reviews for their valuable comments and suggestions.

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