THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Actors at the interface between socio-technical and ecological systems

Analytical starting point for identifying mitigation possibilities in the case of on-site sewage systems

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Gothenburg, Sweden 2014

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ISBN 978-91-7597-095-0

Doktorsavhandlingar vid Chalmers Tekniska Högskola

Ny serie Nr 3776

ISSN 0346-718X

Environmental Systems Analysis

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www.chalmers.se

Chalmers Reproservice

Göteborg, Sweden 2014

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ABSTRACT

The thesis addresses several issues related to factors influencing actors around environmental problems to decrease the environmental pressures. Systems treating sewage at the scale of one to a few households (on-site sewage systems, OSSs) comprise a Swedish case study. In Sweden, OSSs contribute substantially to overall nutrient load and there is clearly not enough action taken, despite the fact that the problem has been known for several decades. The overall assumption is that there is, for environmental problems in general as well as in the case of Swedish OSSs, a need for conceptualizations and knowledge development supporting environmental problem-definitions. This regards in particular identification of the actors controlling pressures and factors influencing their decisions. The concept of an interface between the socio-technical and ecological systems is introduced and applied, supporting identification of actors specific to nutrient loading from OSSs. The application of the concepts enables the development of networks of actors influencing homeowners, being the interface-actor for nutrient loading from OSSs, to improve their systems. The network construction is informed by interviews with practitioners (Paper IV). A historical perspective on the case shows that the relatively high nutrient loads from Swedish OSSs can be traced to how institutions and technology have co-evolved during several decades. Society has become locked to using certain types of treatment technologies which, inter alia, has to do with how institutional arrangements have developed and enacted in the past (Paper I). Contrasting these studies at the system level, knowledge is developed about what motivates homeowners with OSSs, i.e., the interface-actor in the case, to change their OSSs. A questionnaire survey is used to investigate a set of motivational factors among Swedish homeowners with OSSs. The results suggest that gain motives are the strongest motive, concerns about fair outcomes are relatively important, and environmental motives are less important (Paper II). Further, the legitimacy of current policies is investigated since every policy instrument needs to be accepted by those affected by them. Using a questionnaire survey, factors explaining acceptance of OSS regulations among Swedish homeowners are investigated. The result suggests a positive relationship between political trust and policy acceptability and, furthermore, that political trust is positively related to perceptions of effectiveness and procedural fairness (Paper III). The thesis suggests a number of implications from the results for policy and management in the OSS sector.

Keywords: eutrophication; homeowners; wastewater treatment systems; interface-actors; problem-structuring

LIST OF PUBLICATIONS

This thesis is based on the work contained in the following papers

Paper I

Wallin, Are, Mathias Zannakis, and Sverker Molander. 2013. ‘’On-Site Sewage Systems from Good to Bad to? Swedish Experiences with Institutional Change and Technological Dependencies 1900 to 2010’’. *Published in Sustainability.*

Paper II

Wallin, Are, Mathias Zannakis, Lars-Olof Johansson and Sverker Molander. 2013. “Influence of interventions and internal motivation on Swedish homeowners’ change of on-site sewage systems”. *Published in Resources, Conservation, and Recycling.*

Paper III

Zannakis, Mathias, Are Wallin, and Lars-Olof Johansson. “Political trust and perceptions of the quality of institutional arrangements – how do they influence rule acceptance?” *Manuscript submitted to Environmental Policy and Governance (in review).*

Paper IV

Wallin, Are and Sverker Molander. “Structuring the mitigation of environmental problems using the concept of interface-actors: The case of nutrient loads from on-site sewage systems”. *Manuscript.*

Other contributions (not included in thesis)

Conference papers

Wallin, A. and M. Zannakis. 2010. What factors can influence house-owners' willingness to invest in environmentally improved on-site sewage systems? In *Swedish Political Science Association conference in Gothenburg, 30 September-1 October 2010. Working group: Environmental problems and lack of cooperation.*

Wallin, A. and M. Zannakis. 2012. Drivers and barriers to decreasing environmental pressures from decentralized large technical systems – institutional changes and technological dependencies in the case of Swedish on-site sewage systems 1930-2010. In *The 3rd International Conference on Sustainability Transitions, August 29-31, 2012. Copenhagen, Denmark.*

Zannakis, M. and A. Wallin. 2012. Political Trust and Perceptions of Environmental Effectiveness – Explaining Homeowners’ Acceptance of Government Regulations of On-site Sewage Systems. In

American Political Science Association 2012 Annual Meeting. August 30–September 2, 2012, New Orleans, LA.

Technical reports

Wallin, Are, Sverker Molander, and Lars-Olof Johansson. 2011. ”Faktorer som påverkar hushåll att minska enskilda avlopps miljöbelastning: resultat från intervjuer med hushåll, gräventreprenörer och miljöskyddsinspektörer” (In Swedish). Göteborg: Chalmers University of Technology. ESA Report 2011:4.

Sundblad, Eva-Lotta, Are Wallin, Anders Grimvall, Lena Gipperth, Sverker Molander. 2014. ”Utveckling av indikatorer för samhällsfenomen som påverkar utsläpp av näringsämnen till havet” (In Swedish). Swedish Institute for the Marine Environment Report 2014:1.

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1 INTRODUCTION

Effective solutions to environmental problems should imply that many individual actors causing pressures on the environment take actions. This is clearly the case for homeowners with on-site sewage systems[1] (OSSs) contributing to eutrophication through nutrient load emissions. Signs of eutrophication are observed in inland seas and coastal zones across the globe, with severe consequences on the ecosystems and repercussions on the human society (Diaz and Rosenberg 2008, Rockström, Steffen et al. 2009). The Baltic Sea is a particularly vulnerable example, being an enclosed inland sea (Diaz and Rosenberg 2008, Conley, Bjorck et al. 2009, HELCOM 2009). Major factors explaining the poor state in the Baltic Sea and elsewhere include a fast increasing population in the catchment area over the past century, an intensified agriculture, which have caused draining of lakes and wetlands, and increased use of fertilizers (Conley, Bjorck et al. 2009, HELCOM 2009). However, important factors are also increased combustion in the transport and energy sectors, and a widespread use of water and wastewater systems. In Sweden, OSSs are important sources of nutrients, contributing 15% of total phosphorous loads and 5% of total nitrogen loads (SEPA 2009, Ek, Junestedt et al. 2011). About one-sixth of the Swedish population, or 700 000 households, are served by an OSS. For OSSs, it is known that the dominant technologies of the past[2] do not treat nutrients as well as it was believed previously, particularly regarding phosphorus (Eveborn 2012, Eveborn, Kong et al. 2012, Paper I). Therefore, the majority of the installed systems need to be updated or completely rebuilt using treatment technologies with higher nutrient capture potential[3]. The problem of malfunctioning OSSs have been discussed at least since the early 1990'ies (SEPA 1993). However, despite the long recognition measures have not yet been effective. In terms of having achieved nutrient load reductions the OSS sector is lagging behind other sectors (SEPA 2009).

One way to enhance opportunities to solve persistent problems such as that of malfunctioning OSSs may be to apply methods to structure the problem as a way of informing intervention attempts. However, current structuring approaches, such as the DPSIR approach (Harremoës 1998, Smeets and Wetering 1999), are only well developed to describe causes and effects in the environment and less suited to reveal actors around environmental problems. It has previously been argued that new approaches are needed to clarify "diffuse governance linkages" for specific environmental problems (Ness, Anderberg et al. 2010). Approaches that can support identification of key actors who should be

[1] On-site sewage systems are sewage treatment systems serving one up to a few households.

[2] Sludge separators or sludge separators combined with a subsequent treatment step, normally some kind of infiltration bed.

[3] An example of an updated OSS could be a sludge separator with a recently constructed infiltration bed an effective measure could be to install a chemical filter before the sludge separator to chemically bind the phosphorus which is then sedimenting as sludge.

involved in the mitigation of environmental problems could possibly contribute to a governance towards improved environmental outcomes.

To improve the governance of environmental problems there is also need to understand the mechanisms underlying the behaviour of actors. At the individual level there are many impediments to environmentally benign actions, including a poor incentive structure and difficulties to perceive the environmental consequences occurring on much larger tempo-spatial scales (cf. Hardin 1968, Platt 1973, Gifford 2011). In addition, there are often large uncertainties regarding whether others are taking action with implications for the value of contributing, and uncertainties related to which of a whole range of actions that resolve the environmental problem at hand. Knowledge about what motivates individuals is one basis for making more informed choices about how to intervene to change behaviours, since motives describes what individuals perceive and consider when they take decisions and act (Lindenberg and Steg 2007, Steg and Vlek 2009). Further, reaching environmentally benign outcomes requires that individuals accept policy interventions when needed from an environmental point of view. Individuals must trust governments to take decisions which have consequences for them (Levi and Stoker 2000). Such trust is built on perceptions on how well governments are succeeding in their endeavour. Whether governments are found worthy of trust is based on judgments of both the procedures by which policies are made and implemented, and whether outcomes are reached or not (ibid.). It is possible that questions of policy acceptance and trust are particularly important in the environmental policy area because of the often poor incentive structure for affected actors and the risk that many individuals therefore would prefer inaction, making it difficult to achieve effective policies.

The research in the thesis seeks to combine the two perspectives in the case of Swedish OSSs. The thesis deals with structuring methods that could reveal the actors who are involved and should be involved in mitigation attempts. Second, the thesis deals with enhancing the understanding the factors underpinning the decisions and actions of the many individual actors affected by environmental policy and management.

1.1 Aims and scope

The thesis aims to contribute with a novel conceptualization to capture human-environment interactions exemplified by the case of Swedish OSSs. This conceptualization comprises an interface between the socio-technical and ecological systems and actors that, at the interface, control pressures on the ecosystem. Applying the conceptualization narrows the analysis and knowledge development to these interface-actors and actors that in turn influence them. The further aim of the thesis is to improve understanding of,

- factors motivating individual homeowners with OSSs to take action that decreases pressures on the ecosystem

- factors contributing to the legitimacy of environmental policy instruments in the case of OSSs
- the activities in society that led to changes in on-site sewage technology and the associated nutrient load changes in the past
- concepts and methods to delineate systems of actors contributing to the governance of specific environmental problems

By introducing and applying the concept of an interface between the socio-technical and ecological systems the thesis contributes to discussions on how to structure environmental problems in ways that can hopefully improve policy interventions.

The thesis applies the conceptualization and develops knowledge using the case of nutrient loads from Swedish OSSs as an example. OSSs are defined as sewage treatment systems serving one or a few households. These households are not connected by pipe to the municipal wastewater treatment plant. The thesis operates both retrospectively and prospectively, studying the period from 1900 to 2010, as well as the situation in 2009-2014, and having near-future implications for the policy and management of the sector.

1.2 Research process

The research process (see Figure 1) comprised a number of steps, starting with studies focusing the Swedish homeowners with OSS, being the interface-actor in the case (the concept of the interface is described in Section 2.1.3.). A first point of departure was a pilot study investigating factors influencing Swedish homeowners with OSS. The study also included municipality inspectors and contractors, which were identified as two actors with relatively much interaction with the homeowner (Wallin, Molander et al. 2011). Besides gaining a first understanding of the views of these actors, the study contributed to the development of questionnaire items described in Paper II and III. The pilot study resulted in preliminary ideas of the relationship between two influencing actors, inspectors and construction contractors, and the actors at the interface – homeowners.

A second point of departure was a historical perspective on the case (Paper I). This can roughly be described as an investigation of linkages between changes in society, changes of OSS, and environmental outcomes. Paper I also serves a broader purpose providing context for the findings of Paper II-IV.

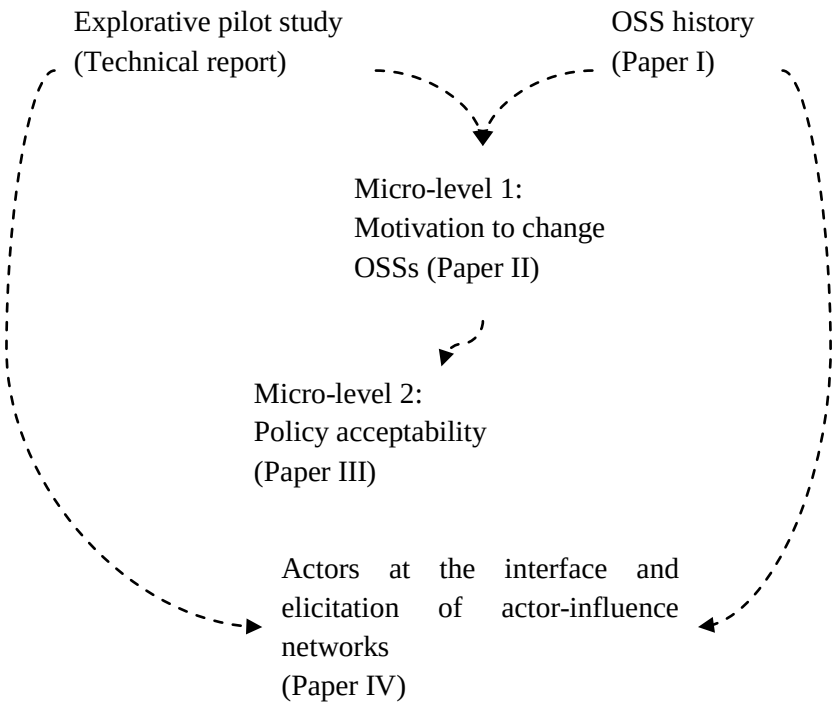

Figure 1 The research process.

In the two following steps, the research focused entirely on the micro-level, investigating the motives underlying homeowners' motives for *changing or refurbishing their OSS* and the factors related to trust and acceptance of OSS regulations (Paper II-III). These studies focus on the underlying mechanisms of environmental behaviors in two ways. First, the behavior to change or refurbish an OSSs is investigated, as an example of a behavior that is tightly connected to specific environmental pressures. Second, acceptance of policy instruments aimed to mitigate nutrient loads of OSS is investigated. Acceptance of policy instruments is assumed to be important for introducing and implementing policy instruments and is indirectly linked to the environmentally benign actions that are causing changes in pressures on the ecosystem.

The fourth step concerns the introduction to and application of the concept of an interface between the socio-technical and ecological system (Paper IV). The main focus of the study was to identify and describe the relationships between actors that are relevant to the problem of malfunctioning OSSs in Sweden.

2 RESEARCH AREA

The principal research approach in the thesis is systems analysis aiming at constructing models as a way of informing interventions. One kind of systems analysis is problem-structuring approaches with roots in operational research (Rosenhead 1989, Newell 2012). In such approaches constructing models, often with the involved actors in cooperation with analysts, is an important part. They are seen as means enabling communication between involved actors and make it possible to arrive at common understanding of problem definitions. Structuring methods have been used during model construction and can include sets of concepts, which enable dialogue about a problem using a common language, and participatory methods (Newell 2012).

2.1 Concepts to identify key actors of specific environmental problems

An example of a method that is commonly used to describe human-environment linkages is the Driving forces-Pressure-State-Impact-Response (DPSIR) framework. The DPSIR framework can be seen as a conceptual aid to structure information (i.e. environmental indicators) in an influence diagram delineating causes and effects related to environmental problems and associated societal responses (Harremoës 1998, Smeets and Wetering 1999, Bell 2012). Societal activities are captured by the term Driving forces and is not described with much detail.

One way of focusing the analysis of causes is to specify the actor who more than other actors are taking actions that "cause" the problem. For example, Geist and Lambin (2002) identify the key actors as those *proximately causing* change, that is, their immediate actions at the local level are directly determining whether an environmental impact will occur. An actor of proximate cause should be understood as an actor who has decisive influence on a pressure but is not necessarily the person that in a physical sense causes the environmental change. Niemeijer and De Groot (2008) elaborated the Driving forces of the DPSIR framework and identified human activities situated at the *pressure interface*, that is, the place where human activities are translated to pressures on the ecosystem. Sundblad, Grimvall et al. (2014) specify *direct actors* as those "involved in activities causing physical, chemical, or biological disturbances in the environment". As *indirect actors* they distinguish those affecting the environment through their use of products or services and thereby they are responsible by association to the companies or other actors whose activities in turn give rise to physical, chemical, or biological disturbances when producing products and providing services.

The Environmental Protection Process (EPP) framework integrate knowledge about human-nature interactions and extend the analysis to describe the human and societal factors (Tapio and Willamo 2008). In the EPP framework *human actions* influence the ecological environment through intakes and outputs. For example, outputs cause changes, such as increased concentrations of a substance in the

environment which have subsequent impacts when processes in the environment are disturbed. This framework further distinguishes between individual, societal, and ecological factors that directly influence human action. Existing infrastructures act as "filters" and constrain human action, rendering other influencing factors less influential. Feedbacks exist between framework levels when, for example, institutional actors monitor and follow-up measures taken for a certain environmental problem and might, in response, decide on mitigation measures.

The application of this kind of structuring approaches could be particularly important for environmental problems since they often involves conflicting views on precisely how the problem should be framed and thereby also what thinkable solutions are.

2.2 Actors and influences at the interface between the socio-technical and ecological systems[4]

In the case of eutrophication of the Baltic Sea, the problem is well-described when it comes to sources of nutrients, the flows of nutrients to water, and the subsequent effects in the ecosystem – the natural science part of the problem (HELCOM 2009). This has enabled researchers to make detailed descriptions about the pressures, states, and impacts for eutrophication of the Baltic Sea (Lundberg 2005). However, corresponding descriptions of "causes and effects" related to the human actions are largely missing. Previous concepts to distinguish make it possible to identify the actors whose actions directly lead to pressures on the ecosystem (Tapio and Willamo 2008, Sundblad, Grimvall et al. 2014). However, the approaches do less well in making distinctions that enable identification of the further actors in turn taking action that influence these key actors.

In response, this thesis suggests that by constructing an interface between the socio-technical and ecological system it is possible to identify both key actors situated at the interface and further actors influencing them (see Figure 2-3**Error! Reference source not found.**).

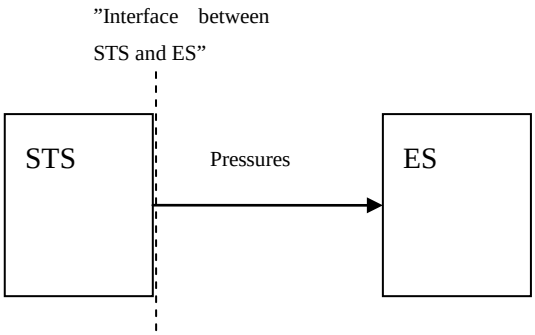

Figure 2 A first distinction: An interface between the socio-technical and ecological system.

[4] This section draws from Paper IV.

Making this distinction means that the human controlled socio-technical factors (e.g., technology, institutions, surrounding infrastructures) are separated from non-controllable ecological factors (e.g., topography, hydrology). Pressures on the ecosystems follow from actions of specific actors, the interface-actors, and cause further effects in the ecosystems. Pressures could be a substance flow emitted from a technical system, such as nutrients in the treated water leaving an on-site sewage system to enter ground or surface waters. Pressures could also be other than material flows. Traffic producing noise or changing land use from forest to road are also examples of human actions putting pressure on the ecosystem.

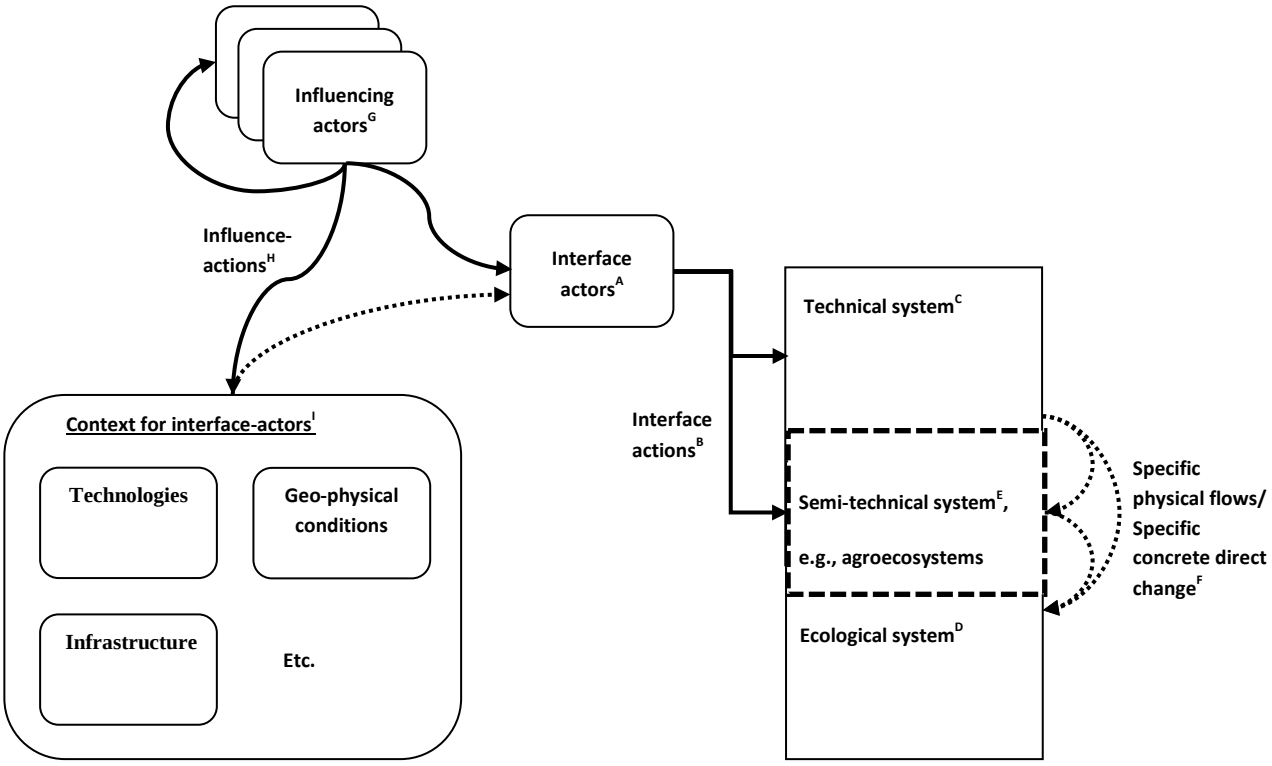

Figure 3 A set of distinctions made to identify interface-actors and –actions, influencing actors and influence-actions connected to specific environmental flows and subsequent change in the environment. 'Monitoring' covers that the changes in the environment that are discovered and focused by societal actors might guide mitigation attempts.

The concept of an *interface-actor* is used to identify actors having a near exclusive ability to directly and physically influence specific pressures on the ecosystem. In the case of OSSs, the homeowner is an actor who can control the nutrient loads leaving the OSS by applying new treatment technologies. Other examples of interface-actors include farmers managing nutrients at the farm, a consumer driving a car fueled by gasoline emitting nitrogen oxide, or the producer of electricity. Contrasting these examples, consumers of food are not interface-actors for the eutrophication problem since they are not directly managing nutrients, nor are drivers interface-actors for the eutrophication problem if their cars run on electricity.

The actions of interface-actors are occurring through the use of technical systems. Technical systems magnify the consequences of human actions, by setting in motion larger energy and material flows than would otherwise be possible. A simple example may illustrate this point, comparing walking to putting on a pair of shoes to ease the walk, then biking using a bicycle, and finally car-driving using a fossil-fuelled car. The consequences in terms of energy and material flows (e.g. metal and non-metal goods and emissions in production and use phase) to perform the activity is increasing multi-fold through the use of more complex and large-scale technical systems. Furthermore, if the infrastructures associated with these technical systems are considered, the consequences will be even larger from their differing energy and material flows during construction, operation, and maintenance phases.

Whether interface-actors' actions turn to an environmental change also depend on whether any transformation of the environmental pressure occurs after its release. For example, a substance emitted to soil may be affected by soil processes. When soil processes affecting specific environmental pressures are manipulated by interface-actors, such manipulating actions are also interface-actions. An example in the case of nutrient loads is when farmers construct wetlands to capture nutrients. Such a measure would also affect nutrients entering the stream from homeowners OSSs.

The concept of interface-actors is used to demarcate an analytical starting point for identifying influences on the interface-actors. Actors in the position to exert an environmentally significant influence on interface-actors are termed *influence-actors*. The environmentally significant actions that they are taking are termed *influence-actions*. Influence-actors are positioned in networks and can be situated one or several steps (or actors) away from the interface and directly (i.e., one step away) or indirectly (i.e., several steps away) influence the interface-actor. The term *tier* is used to categorize actors and influences according to their position in relation to the interface-actor. The more actors between the influence-actors and the interface the higher is the tier. Influencing the interface-actor *indirectly* means that the influence-action is propagated via other influence-actors and suggests that an influence-action may not result in the interface-action that was intended by the influence-actor. Influence-actors can be associated to more than one specific tier, depending on the connections to other influence-actors, and the constituency of the chains of actors and influences between a certain influence-actor and the interface-actor. Actors on higher tiers have an indirect influence and their influence on the interface-actor is associated with propagation cross a higher number of actors. Actors situated at higher tiers do not necessarily have less influence on the interface-actors. Having such position means however that there may be many steps of interpretation in the sequences of actions that follows. Influence-actors can also have linkages with many other influence-actors. However, having many linkages do not necessarily have implication in terms of how much influence an influence-actor has on the interface-actors.

So far, influencing factors have concerned influence-actions affecting interface-actors. Furthermore, interface-actors are also affected by *contextual factors* that constrain what these actors are able to do.

Contextual factors include available technical alternatives and available soil and downstream hydrological conditions of particular sites. These are examples of physical aspects of a situation that can be more or less controllable by interface- and influence-actors. For example, the properties of the soil to capture phosphate in wastewater entering an infiltration bed could vary a lot between sites and constrain the choice of treatment technology for homeowners. This kind of treatment system can however be manipulated. For example the soil can be exchanged at the site to improve infiltration properties of the soil. Examples of other more controllable factors include technical options and price regimes. Other controllable factors are technology. For example, influence-actors in the socio-technical system may strive towards developing, e.g., environmentally improved and user-friendly alternatives, thereby enhancing the possibilities of homeowners to adopt improved systems.

Using the concept of an interface between the socio-technical and ecological system in the case of OSS system it seems thus possible to identify and describe specific actors and actions that are important in mitigation attempts.

2.3 Behavioural explanations to environmental problems

Solving environmental problem is also a problem of governing "commons"(Hardin 1968, Ostrom 1990). Governing commons is non-trivial since it has to do with how individuals act when their actions have a low degree of coordination. In such situations, when individuals can act in their self-interest with low risk of being seen, or "get caught", they may fall short in face of the temptation to do what is best in the short-term. Individuals do so in spite of the fact that they would gain more if they cooperated. A further characteristic of environmental problems is that the negative consequences of individuals' actions are often only experienced on larger tempo-spatial scales. This brings uncertainties related to how others will act and whether the outcome of the individual contribution will matter in the end. Individuals becomes therefore "socially trapped", and the result is that they act in accord with their self-interest (Platt 1973). This stylized view of the causes to environmental problems suggests that the roots to environmental problems are to a certain extent related to behavioural factors.

When investigating variability in behaviour the sources of variability are in principal two. Variability can be traced to the person and relate more to personal characteristics, or to the situational aspects that a person encounters (Fleeson 2004, Funder 2006). Factors can be stable across situations, that is, explain why persons act relatively similar across situations. Factors can also relate more to situation and instead offer explanations to why the same person can act differently across situations. Hence, explanations to behavior need to account for this duality – explanations of behavior need to consider both personal and situational factors. While personal factors include both more changeable factors such as value orientations they include also personal traits. In a similar manner, situational factors could involve subtle aspects of the situation, such as the weather a particular day, or more tangible

factors, such as costs and smells. However, personal factors such as traits and subtle situational aspects will be left out in the following account.

The theory used in this thesis to explain behavior is goal-framing theory, in which cognition play an important role (Lindenberg and Steg 2007). Goals, or motives are assumed to guide a person's cognition and frame how a person orients him- or her-self in situations, as Figure 4 roughly illustrates. Motives are neither entirely stable between situations nor completely changing. Goal-framing theory suggests that multiple goals, or motives, are present in each situation and guide individuals by influencing how information is perceived, considered, and acted upon. Lindenberg and Steg (2007) finds three overall categories of goals; the hedonic goal "to feel better right now"; the gain goal "to guard and improve one's resources"; and the normative goal "to act appropriately". Precisely which motive structure that pertains to different behaviors, including pro-environmental behaviors, is still a question for further research. For example, Barbalopoulos (2012) suggested seven motives underpinning consumer behaviors: Value for money, Quality; Stimulation, Convenience, Ethics, Social Acceptance, and Safety.

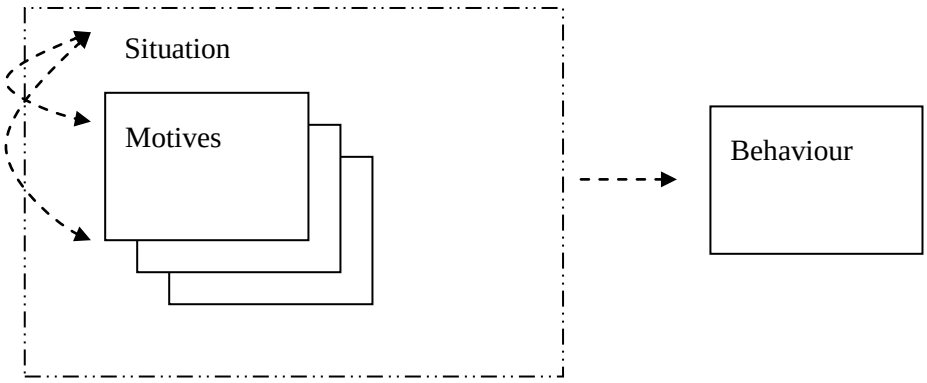

Figure 4 Multiple motives frame how a person perceives and considers aspects such as alternatives, their features, and consequences in particular situations. It is assumed that the strength of motives can change as situational aspects change. The resulting behaviour is therefore related to both motive strength and situational factors. The dashed line between the motives and the situation indicates these dependencies.

The stipulated interactions between motives and situations imply that it is possible to make interventions and that interventions can have different kinds of effects. An introduction of rules and strong sanctions signal appropriateness (activating and strengthening normative motives) but could also generate bad feelings (activate and strengthening hedonic motives) or provide information about effort and costs (activating gain motives).

It is also suggested that the relative strength of motives is connected to particular aspects of the situation. For example, goal-framing theory postulates that when there is much to gain or lose a strong gain goal frame is dominant, while normative motives play a background role (Lindenberg and Steg 2007). For behaviours with environmental consequences this is often the case.

Importantly, taking action can also be constrained by contextual factors such as physical conditions (Steg and Vlek 2009). For example, if poor infrastructures limit action, individuals may not be motivated to act because of the high effort needed to engage in a behaviour. An example is when there is too long distance to the recycling station or to the bus stop (ibid.).

However, there may be further barriers to engage in environmental behaviors as well. For instance, whether or not individuals perceive a behavior to be effective in reducing environmental impact this would influence their motivation (Lindenberg and Steg, 2007). Such perceptions are suggested to be important for the activation of environmental norms, though more so in low-cost than high-cost situations. For engaging in a behavior it can also be important to people that they perceive themselves to have the ability to perform and to have control over the consequences related to a particular behavior (Ajzen 1991, Lindenberg and Steg 2007). This control depends on preconditions such as availability of resources and opportunities to act. Regarding the effect of perceptions of effectiveness on behavior, Gärling and Schuitema (2007) showed that awareness about positive consequences of road fees (i.e., less congestion, better environment) was a prerequisite for their acceptance.

2.4 Trust and environmental policy acceptance

Governments need support from citizens in order to introduce and implement the policies and instruments needed to deliver intended outcomes, such as environmental protection (Easton 1965, Levi and Stoker 2000). This "support" is captured by the concept of trust, by which is meant that individuals make themselves vulnerable to another person or organisation whose actions might have negative consequences for them (Levi and Stoker 2000). The reason for an individual to still trust another in spite of the risk of, e.g., being disfavoured, is expectations of future positive consequences on the personal or collective level that outweighs such risk. Trusting someone else might imply to sacrifice short-term gains to make way for collectively benign outcomes, such as paying taxes or accepting costs associated with being up-to-code. Whether actors trust each other have therefore profound implications for achieving collective goods (ibid; originally de Tocqueville 1990). A distinction can be made between a more general trust from citizens directed at the broader political system or fellow citizens in general, and a more specific support directed at sub-groups. The related but narrower concept of trustworthiness capture instead a more reasoned judgement about specific sub-groups (e.g., environmental protection authorities, local government, neighbours), based on the attributes of an actor, resulting in a trustworthiness judgement (Levi and Stoker 2000). Trust evaluations orient individuals in how they act as citizens. Figure 5 illustrates the dependencies between trust and collective action.

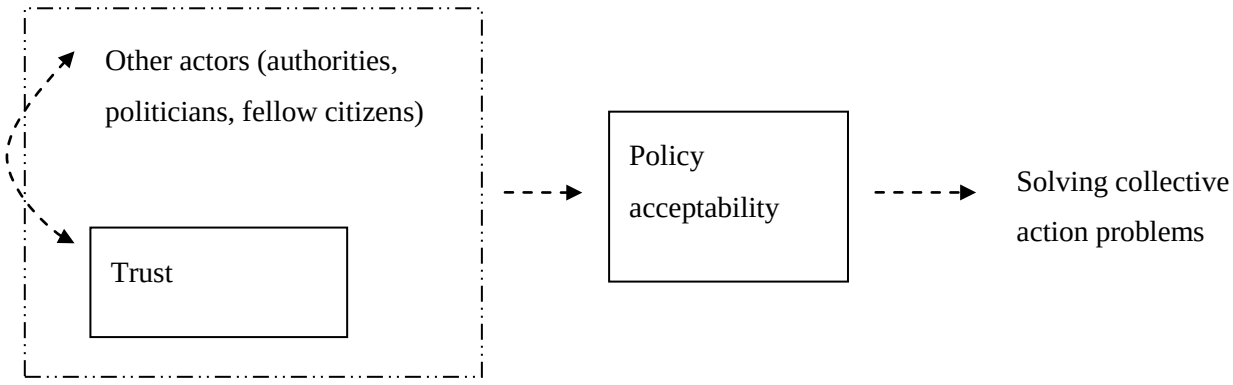

Figure 5 The level of trust is important for achieving outcomes in society, i.e. increasing the opportunities for effective environmental policy-making and implementation.

It is possible to distinguish behaviours for which trust is important in different ways. On the one hand there are *compliance* behaviours and on the other broader *cooperative* behaviours (Levi and Stoker 2000). Regarding compliance behaviours the literature suggests that both trust in governments and trustworthiness judgements explain compliance. Trust is used heuristically and results in a more automated response to comply, while trustworthiness judgements are rather part of the processing underpinning reasoned actions. Trustworthiness is judged on the basis of attributes such as competence, effectiveness in achieving outcomes, and fairness in applied procedures (Levi and Stoker 2000, Tyler 2000, Rothstein and Teorell 2008). In other words, trustworthiness is about the desirability of the means by which authority is exercised as well as the extent that intended outcomes are reached. In addition, it is suggested that showing trust in the other party can invoke trustworthiness, thus reciprocity is important in trustworthiness judgements (Ayres and Braithwaite 1992). The suggested implication is that enforcement methods should focus on communication and means of persuasion before moving on to formal means such as penalties (ibid.). Cooperation is similarly invoked when the government is judged as trustworthy. But, in some contrast, what a trustworthy government ensures is that it increases the predictability of fellow citizens' behaviours. In turn, social bonds are strengthened which lead to increased trust between citizens and, in turn, higher levels of cooperation (Levi and Stoker 2000).

2.5 Socio-technical change processes

The theoretical perspectives explaining technological transitions in society has grown out of the recognition that technical artefacts are deeply intertwined with social elements, hence the term *socio-technical* (Hughes 1983). Socio-technical systems comprise of heterogeneous elements such as actors using, regulating, or developing technologies, institutions (*i.e.*, regulative, normative, cognitive) coordinating actors, and more tangible elements of the socio-technical system, such as artefacts (Geels 2002, Geels 2006). Socio-technical change processes can be found at three levels of analysis, the

landscape, regime and niche levels (Rip and Kemp 1998, Geels 2002). At the level of the socio-technical *landscape*, fixed or slowly changing technology-external processes are operating that are beyond the direct influence of the regime actors, at least in a short-term perspective. These can be exemplified by cultural values, economic growth, and infrastructures. Processes at the landscape level provide the context for lower levels. The level of the socio-technical *regime* highlights the importance of intra- and intergroup coordination that occurs around the dominant technologies. A regime consists of such elements as technology, know-how among engineers and technicians, rule-sets and user preferences. The coordination is played out with the present technologies, know-how and rule-sets as constraints that are the rules for actors. Because these constraints are shared across various groups and the social and technical systems become intertwined. The interconnectedness of relatively slow-changing factors at the regime level can therefore explain periods of stable socio-technical systems. Finally, at the *niche* level novelties may emerge, *i.e.*, new configurations of actors, institutions, and socio-technical system components which are more or less in conflict with current configurations at the regime level (Rip and Kemp 1998, Geels 2002).

Some limitations of this multi-level perspective are that it is less suited for capturing agency (at the niche-level actors strategies and actions are important) and for handling issues of power (Smith, Stirling et al. 2005, Smith, Voß et al. 2010, Grin, Rotmans et al. 2011). In this regard, Mahoney and Thelen (2010) in their power-distributional approach to explaining institutions change (utilized in Paper I) complements the multi-level perspective. Their point of departure is related to the fact that rules are very seldom free from interpretation during implementation and are therefore seldom fully enforced (Mahoney and Thelen 2010). Hence, there will always be a gap between the intentions formulated in rules and the outcomes in reality due to vagaries of interpretation and enforcement, leading to unintended outcomes and, over time, ignored and replaced rules. The character of the institution, how it either in a clear way or more ambiguously distributes roles, resources, and tools among actors, is one source of change since that puts certain actors in the position to exert power over other actors. The fact that institutions have such outcomes is a source of conflict, because the result is unequal constraints imposed on different actors. The other source of change is the political context, that is, which actors are managing to act strongly and defend the "status quo" (Mahoney and Thelen 2010) in terms of existing rule systems and how rules shall be interpreted. Over time, the ability of different actors to defend the status quo varies. In the perspective of Mahoney and Thelen (2010) institutional stability is explained by periods of lasting "compromises", or in other words, that dominant actors are able to maintain their position or adjust the institutions in line with their interests. The situation is the result of a favourable "status quo" (Pierson 2000, Pierson 2004, Capoccia and Kelemen 2007). The stability of processes at the regime level is in this perspective illusory. Periods of slow technological change, or incremental change along one path of development (i.e., only involving one kind of technology), could in this perspective be related to long periods of lasting compromises.

But when there is room for rule interpretation and compromises are questioned, this perspective might also show how the socio-technical system change “from within”.

3 SUMMARIES OF PAPERS: METHODS AND MAIN RESULTS

3.1 Paper I: The historical transitions underlying the malfunctioning OSSs

3.1.1 Purpose

The case of Swedish OSSs is an example of a large technical system that provides households in scattered dwellings with a basic service – they treat wastewater produced by individual households. As with other technical systems the use of OSSs causes environmental problems and most importantly OSSs contribute with nutrient loads causing eutrophication. The purpose of Paper I is firstly to show the scope of the problem of malfunctioning OSS by modelling nutrient loads over time. Then, the changing load trend is analysed and linked to changes in the socio-technical system. The multi-level perspective (Rip and Kemp 1998, Geels 2002, Geels 2006) is used to identify and structure the narrative of historical change processes in the case and we use the theory of incremental institutional change (Mahoney and Thelen 2010) to make actors more visible in processes that lead to institutional change. These perspectives are further described in the theoretical section of the thesis and in Paper I.

3.1.2 Method

The nutrient load modelling was based on assumptions regarding applied technologies in different time periods and the available data on, e.g. installed systems in different time-periods. Information sources included Swedish official statistics of OSS developments, official inquiries, information about applied technologies in different time periods, and expert judgements on different technical systems nutrient removal capability.

The next step of the analysis was to explain the socio-technical changes underlying the modelled nutrient load trend. The sources used to describe the development of Swedish OSSs included primary sources such as official statistics, government agency inquiries, and technical reports. Other historical descriptions of rural and urban living have been used as well although these sources often covered only partially Swedish OSSs.

3.1.3 Results[5]

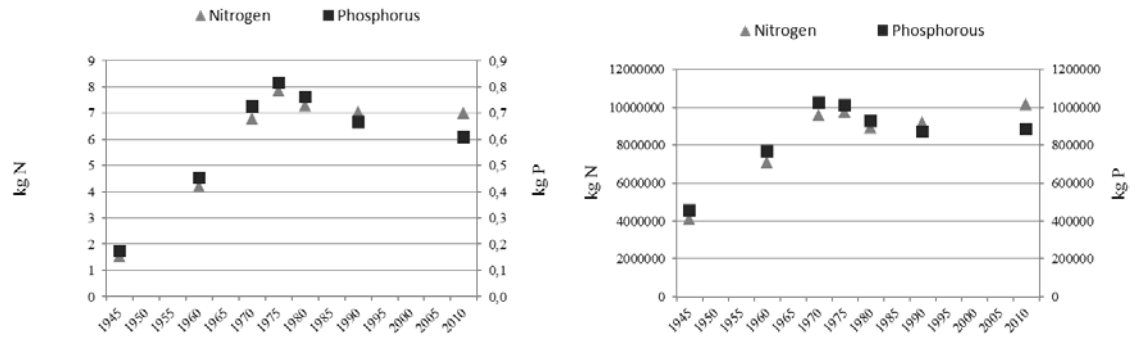

Figure 6 shows the resulting nutrient loads (per capita) from 1940'ies to 2010. When the technology changed on a large-scale in the 1940'ies the nutrient loads increased quite rapidly and did not start to decrease until the early 1970'ies. The nutrient loads then decreased slowly in the following decades. However, from the 90'ies and onwards, the nutrient loads show signs of a stagnating trend. In 2010 the loads still exceed those of the 1940'ies.

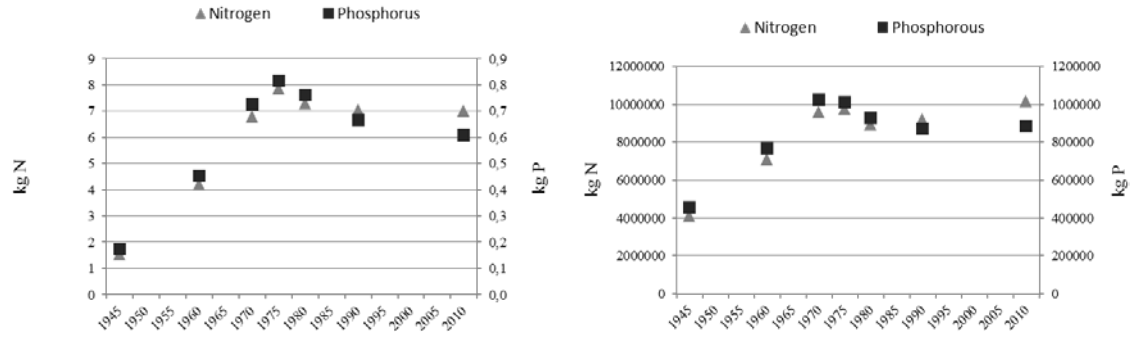

Figure 6 Estimated per capita (left) and total (right) loads of phosphorous and nitrogen from Swedish on-site sewage systems 1945–2010 (Paper I).

The increasing nutrient loads in the 1940'ies and during the two following decades was caused by a quite rapid technological change. During the time period the large majority of the population installed WCs and some kind of wastewater handling system, i.e., pipes to nearest ditch possibly combined with sludge separators (Figure 7). It is worthy to note that this change implied the birth of water-based treatment of wastewater and in principle the abandoning of the dry handling methods – such as production of "poudrettes", pits, and co-handling the human and animal excreta for subsequent use as fertilizers. The large majority of dry handling OSS is today found in summer homes.

[5] The section draws on Paper I, Section 3.

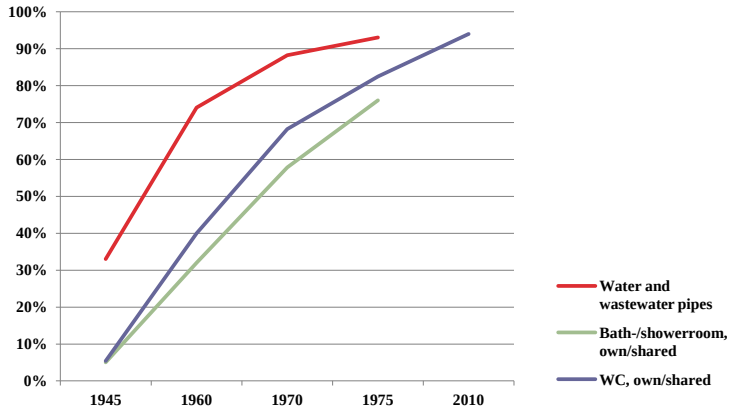

Figure 7 The expansion of piped water and wastewater systems, baths/showers and WCs into Swedish countryside permanent homes 1945–2010 (Paper I).

3.1.3.1 OSS development from the 1940'ies to 1960'ies

A number of factors contributed to the large-scale transformation that comprised installation of WCs and the first water-based treatment systems. Before the 1950s, handling of sewage, as well as wastewater in general, was formally a largely unregulated area in the countryside. Tradition and local knowledge were used when building farm-level systems for handling water and latrines. The processes of changing the handling of water and sewage in the cities preceded a similar transformation in the countryside. Hygiene concerns, increased convenience for homeowners, and changed expectations regarding toilets, made the WC a desirable solution in the broader society and with time also in the countryside. The unspecific rules of the 1940s and 1950s created a space for action for individual homeowners and other actors having knowledge of how to install the systems. Further, in the absence of specific rules and enforcement capacity, it was possible for individual homeowners to install WCs, without much notice taken by the authorities.

Further actors took action as well, including actors from the established, primarily urban, sphere such as the media, middle-class citizens and others who had already experienced improved material welfare and governmental agencies who were in favour of making the countryside follow the example of the cities. At first, this was in conflict with the interest of the homeowners who did not seem to have seen the benefits. Homeowners could however not resist the thrusts, which came from many directions. However, homeowners must soon have realized the convenience that an indoor WC brought. Returnees, guests and others from the cities must have exerted pressure on the countryside residents and been an important carrier of technology expectations and norms from the cities. Once the rural homeowners adopted the new ideas, tensions were resolved and instead there was a relatively high coordination and alignment between activities and agendas of rural homeowners, governments, authorities, and established spheres.

The government introduced rules prescribing homeowners to have basic treatment in the form of a sludge separator when installing a WC. Local health protection committees were given the task of

overseeing the implementation of these rules and an obligation for homeowners to apply for a permit to install an OSS gave the committees a means to do so. That way the role of local knowledge and traditions was replaced by the authorities' knowledge and rules for structuring homeowners' actions. The technology was also fairly rudimentary and while the installation of pipes required labour, the installation could be handled locally, without much assistance from trained contractors.

During this era, the decades after World War II, the government became a relatively stronger player, not least because of industrialization and the increasing tax revenues that followed. Due to a combination of the political climate and the increased economic capacity, governmental interventions were possible. Importantly, the government intervened and subsidized the construction of water and sewage handling systems in rural areas, giving homeowners the economic capacity to embrace the new technology. Homeowners and others in the countryside who may have objected to this development were not sufficiently large in number to bend the development path, e.g., the use of other technologies. Thus, when using Mahoney and Thelen's theory of incremental change (Mahoney and Thelen 2010) we interpret the quite abrupt technological-institutional change as being rooted in activities starting several decades before. Several actors used change strategies that served their own differing interests but despite this they all acted in ways that resulted in a coherent development of OSS. It was a combination of an enabling political context at the landscape level, self-motivated homeowners, and government interventions that led to the expansion of piped water, WCs, and the use of sludge separators as the principal treatment process in Swedish countryside homes. This implied the birth of the new socio-technical configuration from the 1940s with piped water and WCs as dominant technologies. However, as WCs replaced latrines and only rudimentary technologies were applied, the nutrient capture capacity of OSSs decreased and nutrient loads increased drastically, as illustrated in

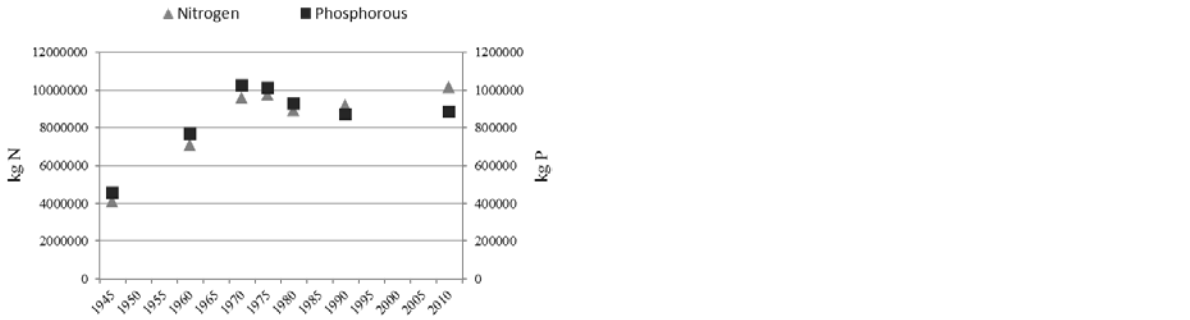

Figure 6.

3.1.3.2 OSS developments from the 1960'ies to 1990'ies

The 1960s and 1970s were marked by growing environmental concerns that translated into governmental action and further institutional arrangements and regulation of wastewater. The rules regarding the application of especially new OSSs came to embrace both health and

environmental concerns. From a technical and environmental perspective these changes explain the break around 1975 of the negative trend for nutrient removal capacity. An important technical factor is also that municipal WWTPs have shown increasing nutrient capture rates since the 1970s. It became relatively common that sewage collected from closed tanks was treated at the municipal WWTPs. This influenced the overall nutrient capture capability of Swedish OSSs, even if on-site treatment systems as such were not improved.

However, several circumstances made the long-term environmental gains rather small. Homeowners could continue to use more rudimentary treatment technologies since they were not subjected to inspection. The technical lifetime of the dominant technology (sludge separator combined with an infiltration bed or compact filter) was unknown at the time of installation and has been shown to be limited. Further, WCs replaced latrines in rural and in summer home areas on an increasing scale, creating conditions that were difficult for municipalities and environmental protection authorities to address. Changing user demands and the broad transformation of summer homes to permanent homes, gave rise to changes in some of the elements at the regime level even though the result was not a complete change of existing OSSs, nor did the new technologies diffuse beyond their initial niches. For instance, closed tanks did not replace existing OSSs. Further, even though urine separation technologies became common in summer homes, this technology has not diffused beyond this niche.

The origin of the technology-specific rules was the increasing knowledge about environmental impacts, discoveries of water quality problems, and rising environmental concerns when scientific knowledge became accepted on a broader scale. The 1960s to the 1990s was a period where national government strengthened environmental institutions, introduced more specific laws, and strengthened enforcement capacity by creating local public health and environmental protection authorities. The technology-specific rules gave certain actors, e.g., those producing components and installing sludge separators, a position to act while restricting the room for action of other potential suppliers. For most users the change in treatment technology did not create any tensions with their expectations or daily routines involving the technology. The “interface” (the tap, the WC etc.) to the sewage handling system remained essentially the same, at least in the cases of newly constructed houses. In cases where the change of technology implied a changed “user interface”, most prominently when latrines were turned into WCs, this was in line with users’ expectations of the new technology and implied, as desired, more convenient systems. In both cases it was in the interest of homeowners to install these specific technologies, that is, piped water, WC, and further means of getting rid of the wastewater from the lot. From this perspective it is also logical that there was no major state aid aimed at easing investments in OSSs similar to the previous decades—it was not needed because of strong user desires for WCs.

Compared to the previous period, which was marked by reconfiguration of many system elements and much activity on several administrative levels, the period from the 1960s and onwards is marked by

stability. Technological changes occurred not on the large-scale but in pockets, *i.e.*, when summer homes were built or when summer homes were transformed to permanent homes. Though environmental concerns grew in society this did not lead to major technological changes. The treatment technologies applied remained essentially the same, based on the WC and sludge separators, and were not changing very much during the period besides slight changes in the dimensioning of treatment system components. The socio-technical system therefore followed a path defined by the application of certain types of treatment technologies, which were embedded in a configuration including users' expectations and routines, and formal rules and guidance that defined appropriate treatment technologies. The institutions that were built-up during the period and the rules that were applied were continuously built on the previous ones—new structures were layered (Mahoney and Thelen 2010) on previous ones and did not imply tensions between, e.g., actors or other aspects of the socio-technical system. Also, the institution-building activities were directed at other sources to the nutrient load problem, unintentionally reducing the interest in OSS and not focusing on efforts such as enforcement capacity-building that could have altered the development path for OSS. Therefore, despite a growing concern for the environmental impact of wastewater and incremental institutional changes, environmental outcomes did not improve correspondingly.

3.1.3.3 OSS developments after the 1990'ies

In the 1980s and the 1990s concerns for the environment increased, e.g., as resource and pollution problems were increasingly discussed. Despite some initiatives to increase the scale of enforcement of primarily the old malfunctioning OSS the result on the large scale was limited. A new environmental legislation – the Environmental Code, changed the prerequisites for enforcing old and malfunctioning OSS. With the regulation 'Allmänna Råden' in 2006 there was a shift from imposing requirements in form of a specified technical standard (i.e., at least a three-chambered sludge separator combined with a subsequent treatment step) to requirements specifying the function of the installed system.

The emphasis on the technology-neutral "function" of OSS instead of specifying a minimum required technology is important since this shift opens up for a variety of technical solutions that fulfil the specified function. However, if rules can be flexibly interpreted this gives actors more room to act, both in line with, and beyond, the original intentions of the rules.

The initiative from the state to intervene was likely related to the limited success of previous legislation in terms of improved OSSs, which was apparent since at least the late 1970s but certainly in the early 1990s. Because of the limited success it is also likely that the initiative was a response from the government to make a change in the regulations "to try something new"[6]. The emphasis on

[6] According to interviews the idea of functional requirements was picked up from the project 'Bra Små Avlopp', which primarily was focusing on testing and demonstrating a number of different treatment technologies, but collected also a number of ideas for how to increase inspection of existing OSSs.

technology-neutrality was also certainly aligned with an ideological move towards a preference for market solutions, relying more on private initiatives and less on state interference. Importantly, the emphasis on function can be seen as aligned with one of the institutional building blocks of the European Union, the EU Single Market Act, which came into force in 1993. Such changes in market institutions (e.g., EU Single Market Act and associated national adaptations) make it possible for actors who operate across national boundaries to attract resources and use their position on one market when entering another market. This is certainly the case for many treatment system manufacturers for which Sweden is not their biggest market. This institutional change, which was external to the OSS regime, reduced the possibility of keeping the previous technology-specific rules. By merging functional requirements with previous legislation and using the existing health and environmental protection committees (in Swe. "Miljö- och hälsoskyddsnämnd") to enforce the new legislation, the government could avoid the tension implied by the new market institutions and still keep, in principle, a high ambition level concerning environmental sustainability. Thus, in principle, the rule changes gave the HEPAs power to judge the legality of the growing number of technologies on the market and to check that all homeowners continuously have well-functioning OSS. However, the legislation was not accompanied with more resources given to the HEPAs. Thus, the enforcing authorities were in a sense given the tools to enforce OSS regulations to a larger extent than before but since no corresponding decision were made by municipalities to increase inspections and increase inspection personnel, the enforcement actions were relatively limited in scale[7].

3.1.3.4 Summary remark

Overall, the development of nutrient loads over time shows an increasingly problematic situation of malfunctioning OSS and increasing nutrient loads. The problem was acknowledged and remediating actions had the effect that the increasing trend broke in the beginning of the 70'ies. Since then the nutrient loads have not decreased much, despite several attempts to regulate OSS towards decreasing loads. From the 40'ies until present days the actor structure around OSS and the institutional arrangements governing actor interactions have grown increasingly complex. However, this has only implied effective nutrient load management up to a certain level, which is today known to be insufficient.

It is noteworthy that there is an "unintendedness" associated with human actions, which seems difficult to cope with. One kind of "unintendedness" is insufficient knowledge, exemplified by the growing nutrient loads that were not seen as an urgent issue in the 40'ies and 50'ies. The awareness about environmental problems, its causes, and the need for protective measures came later. A second kind is a more or less conscious ignorance due to prioritization of other nutrient sources. For example,

[7] The recent official inquiry into OSS claims that the inspection rate needs to increase five-fold compared to the current rate.

OSSs as sources of nutrient loads were not focused from the 70'ies until the 90'ies while there were much attention and resources directed to municipal wastewater treatment plants. Some activity was certainly directed at OSS in the form of incrementally stricter rules regarding the dimensioning of OSSs. However, there was a lack of inspection of the old OSSs and on the ground there were not sufficient actions taken by homeowners. The incrementally strict OSSs rules contributed to a situation of lock-in to certain water-based treatment technologies, such as infiltration beds, that grew strong in this time-period. The lock-in was also located in technology preferences of actors around OSS such as inspectors, contractors, and regular homeowners as well as in the large number of such systems installed during the time-period. A third kind of "unintendedness" lies in the difficulty to foresee which human actions that will become large-scale. For example, the general perception in the 40'ies was that people in the countryside would not install WCs and regulation was therefore not needed. History shows that WCs were precisely what became desired and soon the norm also in the countryside.

The third kind of "unintendedness" relates to a kind of sustainability challenge that is possibly pervading environmental problems generally – namely that solutions that are not in line the preferences of individuals are much less likely to succeed. It has previously been argued that solutions chosen in the past to fulfil functions in society were chosen because they were convenient, and sustainable solutions are not necessarily that (Kemp and Van Lente 2011). Therefore, one should not hope for solutions to work unless the discrepancy between individual preference and overall societal goals are addressed. In the case of OSSs, homeowners choosing WCs was in essence an action to achieve convenience and the same is true for installing a simple well or pipe "to get rid of" the wastewater. It was possible to deal with this relatively simple problem and the result was indeed a large-scale transition in which people abandoned dry toilets in favour of WCs. Multiple factors was at play including changes in behaviours, norms, regulations, and in treatment technology. It is important to note that eutrophication is not necessarily aligned with homeowners' preferences. Further, the eutrophication problem caused by malfunctioning WCs have less evident causes and consequences than poor hygiene, which make problem definition even harder.

3.2 Paper II: Motive structure underpinning readiness to change OSS

3.2.1 Purpose

Looking back on the early OSS transformations in Sweden, that resulted in the introduction of WC in 250 000 Swedish homes during a period of 20 years (Wallin, Zannakis et al. 2013), they had at first hygiene as an overall purpose (Paper I). This transformation may be seen as a highly successful transformation that solved a huge social issue. The urge of the time to solve the hygiene problem might in some sense be comparable to current environmental problems. An important difference is, however, that it was in the individuals' own interest to contribute to solving the problem. Having a

WC was both a convenient solution, socially accepted, and perhaps even the norm. This alignment was likely an important circumstance that made the large-scale change possible. The eutrophication issue is not similar in this regard, since OSSs do not seem to be associated with similar incentives to act among homeowners – there is certainly not much private benefit from changing an OSS in the short-term. The case of environmentally improving OSSs is an example of technological change that needs large efforts and investments from individuals and that require interventions to encourage them.

The behavioural roots to environmental problems deserve therefore to be scrutinized, also in the case of Swedish OSSs. In this case, homeowners can improve the function of their OSSs and thereby contribute to decreased nutrient loads and less eutrophication. The improvement action could be to re-furbish existing OSSs or to change to a new treatment technology. Therefore, making homeowners motivated to take these actions would contribute to solving the eutrophication problem. If homeowners are more motivated to change OSSs this would, if not make them change systems, at least ease enforcement of the regulations of OSSs. Related to motivation is also the support that is needed for political organisations to govern effectively including enforcing rules imposed on actors on the ground (Easton 1965, Levi and Stoker 2000). Political trust captures this support of politicians. Trust need to be deserved, and politicians or political organisations can therefore be found "worthy of trust" given how they act towards the citizens and how they fulfil their tasks (Levi and Stoker 2000). Such factors have been shown to explain why individuals comply with regulations and might be important also in the case of OSS.

The principal aim in Paper II was therefore to investigate factors explaining homeowners' readiness to change their OSSs. The investigated factors were of two principal kinds. First, they related to the role of motives for pro-environmental behaviours (cf. Wilke 1991, Lindenberg and Steg 2007, Steg and Vlek 2009). Secondly, the factors related to the role of trust and trust-related factors (cf. Levi and Stoker 2000). A secondary aim was to investigate the importance and influence on homeowners' actions of different influence-actors and their actions.

3.2.2 Methods

The methodology for the study was to explore tentative explanations through interviews and to test a broad set of factors through using questionnaires (Djurfeldt and Barmark 2009, Esaiasson, Gilljam et al. 2009, Djurfeldt, Larsson et al. 2010). As a first step semi-structured interviews (Kvale 1997, Esaiasson, Gilljam et al. 2009) with 12 homeowners was made to explore potential factors[8]. The factors identified in the interviews were developed using previous research about factors explaining why people engage in pro-environmental behaviours (cf. Wilke 1991, Lindenberg and Steg 2007, Johansson and Svedsäter 2009, Barbopoulos 2012), and about trust-related factors (cf. Levi and Stoker

[8] The results of the interviews were reported in Wallin (2011).

2000, Tyler 2000). Based on the interviews and the previous research questionnaire items was developed. The questionnaire was tested on a pilot sample of homeowners and the final questionnaire was sent to 3615 Swedish homeowners with OSS, randomly sampled from homeowners with OSS in the Real Property Register, with a response rate of 46% (N=1615). After cleaning the data set 1481 responses remained (42%).

Generally, the first step of the data analysis was to investigate the dimensionality of the dataset by means of principal component analysis (PCA) (Costello A. B. 2005, Eriksson, Johansson et al. 2006, Djurfeldt and Barmark 2009), which analyses the dimensionality of the data set (i.e. which clusters of questionnaire items give rise to variance among homeowners). The process of finding principal components was iterative, investigating several principal component models choosing the model providing best fit and (within-sample) predictability. The naming of components was made by finding the common meaning of the items "building up" the principal component and when suitable basing the naming on existing theoretical constructs in previous research. Since the PCA approach implies that questionnaire items may be eliminated because they coincidentally correlate with other items, or because items are too few to form stable principal components, correlation patterns was checked to identify such patterns. In a second step, the resulting factors were tested as explanations to readiness to change OSS using regression analysis (see method section in Paper II for further details).

3.2.3 Results

Applying PCA to the questionnaire items resulted in 10 factors that are candidates to explain readiness to change OSS. A further factor, *Fair outcomes,* was added after checking correlational patterns for items with high correlation with the dependent variable and low correlations with the variables in the principle component models. The resulting 11 factors are described in the following.

The factor *To benefit* comprises aspects such as costs of change and operation of the system. *To avoid inconvenience* consists of relatively diverse items related to feelings of discomfort, including having an unlawful OSS and the risk of illness due to a malfunctioning OSS. *Political trust* is about trust in OSS matters. This factor includes actors in the public administration. *Trust in actors at the action-level*[9] instead comprises actors at the local level such as construction contractors, relatives, neighbors, and other close acquaintances, and OSS suppliers. Related to the work of enforcing authorities, the factor *Disbelief in effectiveness of regulation* gathered statements about how effective enforcing authorities are in ensuring homeowners change their OSS. A number of items with statements reflecting both personal (i.e. related to moral obligation) and social norms (i.e. related to others expectations) (Lindenberg and Steg 2007) regarding environmental consequences of OSSs form the factor *Environmental concerns*. Two factors concerned fairness. First, *Qualified fairness* comprises

[9] I.e., actors that homeowners may interact with during the process of change, such as close associates and construction contractors.

statements about principles for distributing costs and benefits, that is, who should bear the costs and on what grounds should people be exempted from taking action. The PCA did not distinguish between the different principles described in literature – equality, equity, and need (Deutsch 1975). Qualified fairness gathers items having in common that exemptions from equality can be allowed but need to be grounded, therefore the term qualified. The second kind of fairness, *Fair outcomes*, implies that homeowners are ready to change OSS conditional on others changing their OSS. Last, three factors gathered different kinds of perceptions about control of consequences of current and future OSS. *Efficacy with current OSS* and *Efficacy if OSS is changed* are about the perceived capability of controlling consequences with the current and a future OSS. *Ability to change OSS* comprises instead items about perceived barriers to perform a change of system.

The 11 factors found through the PCA imply that homeowners differ along a number of scales. In order to find out which factors were relevant for homeowners' change of OSSs, the factors where tested as explanations of readiness to change OSSs. The result shows five factors that consistently contributed to explain variance in the dependent variable in the two time horizons that were tested. The factors are: *To benefit*, *Fair outcomes*, *Efficacy if OSS is changed*, *Efficacy with current OSS*, and *Ability to change OSS*. The regression model showed that a higher readiness to change OSS was related to positive benefits of system change and that outcomes were fair. A higher readiness was also related to the perceptions that nutrient loads would decrease with a changed OSS, nutrient loads with the current system were low, and that homeowners felt they were able to change their systems. Hence, the importance of the To benefit, a gain-related motive, is problematic since it might be difficult to make economic subsidies a positive incentive because of the high cost of investment. In contrast, if homeowners could be convinced that outcomes are fair this is a possible way of influencing their decisions. For short-term readiness adding *Environmental concern* contributed to explained variance. This means that a normative motive related to acting environmentally friendly (it is important for me to act/that others act environmentally friendly) is active when homeowners change OSS. For long-term readiness further contribution to explained variance resulted from adding *Qualified fairness* and *Avoid inconvenience*. The negative correlation between Qualified fairness and readiness to change system implies that homeowners having the opinion that no category of homeowners can be exempted from taking action, are more ready to act. In both time horizons, the factors related to perceived behavioural control and barriers to improve systems explained readiness to change OSS. Not surprisingly, homeowners perceiving the current OSS to perform better are less ready to change OSS. At the same time, homeowners perceiving that a new OSS with improved environmental performance and that they were able to change system were more ready to change OSS. Since homeowners on average seem to exaggerate the performance of their systems (Descriptive statistics, Results section of Paper II) this means that convincing argumentation about systems performance could convince at least some homeowners.

Partly contrasting the result of the regression analysis, there was some evidence of an influence of personal norms (i.e., to feel morally obliged to change OSS) among homeowners who had changed OSS (Paper II). Other studies on compliance behaviour have shown that moral obligation can be an important explanatory factor of regulatory compliance (e.g., Winter and May 2001). However, among homeowners in general, the PCA did not result in any factor corresponding to personal norms. It is possible that personal norms are most strongly present among homeowners who have changed OSS because of post-justification processes (Festinger 1976, Kunda 1990). In studies like this one, it is however difficult to distinguish between the activation of personal norms due to authority interventions that might have preceded change, and post-decision adjustments. It is therefore possible that personal norms should be seen as one of the factors positively related to change of OSS along with the factors in the regression models.

Furthermore, Paper II also suggests that three actor categories are more important than others as sources of influence. The actor categories are the municipality, construction contractors, and close acquaintances. Further, the data suggests that injunctions are more likely associated with homeowners who have changed OSS than with those who have merely been reached by an inspection or an advice.

3.3 Paper III: Quality of institutional arrangements and political trust as explanations to acceptance of governmental regulations

3.3.1 Purpose

In the case of OSS, the rules stipulating functional requirements for OSSs are important regulations that homeowners need to obey. A majority of homeowners have most likely systems that at some point, possibly up to 50-60 years ago, were up-to-code. However, the code and the rules decided by the agencies have changed several times. Since the legislative changes in 1969 the most rudimentary OSSs have by definition not been up-to-code, that is, the OSSs that at best are equipped with sludge separators without any subsequent treatment step. Later, when the function requirement entered into force in 2006 (SEPA 2006), this implied that more recently installed systems (i.e., sludge separators with a subsequent infiltration step), might be deemed unlawful by the local environmental authority. In 2013, a large majority of homeowners were thought to have OSSs with insufficient function compared to the function requirements (SwAM 2013). This implies a challenge for the enforcing authorities. On the one hand, they have the tools (the code and the functional requirements) required for enforcement. On the other, the implementation gap that has grown for several decades makes it non-trivial to "just enforce" because of the possibly sensitive decisions to prioritize OSS that are needed at the local level. In Finland, where there had been a similar lack of measures to improve OSSs historically, the requirements on homeowners to improve their OSSs were alleviated after heavy debate and protests by the people (Zannakis manuscript). Thus, factors related to legitimacy of the governance system might be important to achieve political outcomes (Levi and Stoker 2000). Such factors include that local

politicians and local environmental protection authorities need to be trusted by homeowners in order to gain acceptance for the increasing enforcement of the OSS regulations.

The previous Paper II treated trust-related factors as if they were related to homeowners' readiness to change their OSSs. However, no relationship was found. Paper III instead uses trust and trust-related factors as explanatory factors of acceptance of governmental regulations among homeowners with OSSs, assuming that these factors are important for implementing OSS regulations and can only be indirectly associated with readiness to change OSSs. As described above, trust is one factor that should be expected to be related to acceptance of governmental regulations. Paper III aims firstly to investigate whether political trust, i.e. trust in the local environmental authorities that enforce the OSS rules, might explain the acceptance of the rules. A number of other factors were also analysed including the quality of institutional arrangements and the role of others behaviours. Secondly, the paper investigates whether quality of institutional arrangements is related to political trust, since there should be a positive relationship between the two according to the literature.

3.3.2 Method

A number of hypotheses were developed building on previous research on the role of trust for acceptance of regulations, and the role of institutional arrangements (see Chapter 2 of the thesis and Paper III). The first hypothesis tested whether there is a relationship between trust in particular authorities and acceptance of government regulations. The second set of hypotheses tested instead whether quality of institutional arrangements, measures as perceptions of authority impartiality, effectiveness of procedures might be related to acceptance of government regulations on the one hand and the trust in the particular authorities on the other. Thus, if there are effects of the perceived quality of institutional arrangements both on trust in particular authorities and on acceptance of governmental regulations, some of the effect on the latter could be mediated by trust in particular authorities. Such relationships are important to investigate since they could support claims regarding the means by which authorities could increase acceptance among homeowners. A further hypothesis tested for a positive relationship between adhering to an equality principle and acceptance of government regulations and trust in the particular authorities. The last hypothesis concerned instead the relationship between others' behaviours, trust in the particular authorities, and acceptance of governmental regulations. Thus, this factor is similar to quality of the institutional arrangements, but works through either normative motivation, or, because of concerns whether it is worthwhile to contribute given the extent that others contribute.

Data was gathered through the questionnaire sent to Swedish homeowners with OSS in 2010 (same as in Paper II). Trust was measured in two ways. Trust was directed at societal institutions in general and the trust in the environmental protection inspectors at the local environmental authorities inspecting OSSs. The effect of perceptions of the quality of institutional arrangements on acceptance of

regulations was anticipated to be mediated by trust in particular authorities. The developed hypotheses on the relationships between the variables were tested using regression analysis (this step is reported in Paper III).

3.3.3 Results

The results of Paper III suggest that homeowners accept OSS regulations (Descriptive statistics, Paper III). Homeowners tend to trust both societal institutions in general and the environmental protection inspectors. Further, homeowners also perceive environmental protection authorities to act impartially more than partially and that if complying to the regulations the eutrophication would decrease. Thus, based on the descriptive statistics one could suggest that the regulatory system is legitimate. Further, there seems to be a support for enforcing regulations since individuals tend to have the view that authorities do their job and that regulation is both needed and improves the environmental state. The fact that the responses of OSS changers, those who have improved their OSS, are more supportive than those of non-changers, might suggest that positive consequences of complying are outweighing negative ones. In all, the results do at least not contradict that experiences with an OSS makes homeowners more positively oriented towards the current regulatory system.

The next step in the analysis was the tests of hypotheses regarding the relationships between the acceptance, trust, and perceptions related to the quality of institutional arrangements (Figure 8). The analysis of acceptance of OSS regulations shows, as hypothesized, a significant positive relationship between homeowners trust in local environmental authority inspectors and acceptance of regulations, controlling for all other variables in the analysis including trust in societal institutions in general. It is therefore possible to state that homeowners that tend to trust local environmental authorities also tend to accept regulations. The effect is importantly independent from the more diffuse trust in societal institutions in general and supports the literature suggesting that relationships between trust and acceptance are found at the level of particular matters, as in this case enforcement measures to improve OSS (Levi and Stoker 2000). This also means that a path towards increased acceptance of regulations is to develop trust between authorities and regulated persons.

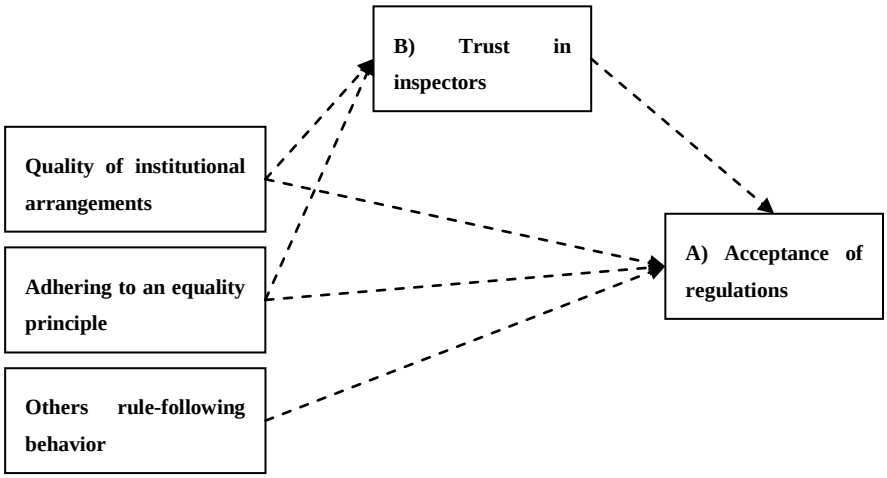

Figure 8 Factors significantly correlating with A) acceptance of regulations and B) trust in local environmental authority inspectors.

Further, the results suggest that there is a significant positive relationship between perceived effectiveness of meeting authority requirements, the perception that other homeowners are up-to-code, and the acceptance of regulations. The positive relationship between adherence to an equality principle and acceptance was also confirmed. Thus, accepting regulations seems to be related to not only trust in the local environmental authority, but also to whether homeowners perceive that outcomes are achieved when they act in line with the requirements. Further, the behaviours of other homeowners are important for acceptance. For homeowners that tend to accept regulations it is important that all homeowners that need to change their OSS are reached by enforcement activities and that they change their systems.

The next step of the analysis can be seen as an investigation of possible factors that could be utilized to increase the trust in local environmental authority inspectors (B in Figure 8) and thereby also increase acceptance of OSS regulations. The result shows a significant positive relationship between trust in inspectors and perceptions of authorities being impartial and that requirements have their intended environmental outcomes. There was also a significant positive relationship between adhering to an equality principle and trust in inspectors. In other words, homeowners who perceive that inspectors treat homeowners equally during enforcement and perceive that by meeting the requirements of the authority the environmental impact decreases, will tend to trust inspectors. Further, if homeowners think that homeowners should be treated equally and that no exemptions should be made based on factors such as income and age, this is also related to increased trust.

These results might suggest that a possible pathway to increased acceptance of regulations among homeowners is to increase the level of trust. This is in turn possibly linked to ensuring that all homeowners are reached by the enforcing authorities and that, if the circumstances are the same, the imposed requirements on a homeowner will be the same. Another way of increasing trust in the

enforcing authorities is to impose requirements in ways that secure positive environmental outcomes. This should be possible to do by only accepting systems that unquestionably lead to less environmental impact and to develop knowledge in the cases where the treatment function can be questioned (e.g., soil infiltrations). However, the results are based on correlational analysis and it is therefore not possible to draw strong conclusions about the direction of the relationships. For instance, it is possible that high-trusters perceive authorities to be more impartial than low-trusters.

3.4 Paper IV: A novel conceptualization of human-environment interactions and resulting actor-influence networks

3.4.1 Purpose

In the search for possible solutions to environmental problems actors need to reach a common ground about the environmental problem definitions. To enable discussions about how environmental problems are structured, that is, what are their causes or contributing factors, concepts and models can create shared meaning among involved actors. Environmental problems are difficult to solve for several reasons, including the many actors and perspectives involved and the separation in time and space between actions and environmental change. Problem structuring methods may therefore be particularly useful for environmental problem solving.

In the case of OSSs, one aspect of the problem relate to issues of governance. On the one hand, it is "simply" a question of implementing the existing legislation of OSSs which already in the 60'ies made a large share of the OSSs unlawful (Paper I). However, many homeowners of these OSSs have not improved their systems since then. Further, the number of homeowners that are not up-to-code have very likely grown since the introduction of the environmental code (MoE 1998) and the rule changes that came into force in 2006 (Sve. 'Allmänna Råden'; (SEPA 2006)). The lack of an automatic response among homeowners to comply when new rules were introduced, and the lack of enforcement activities by the local environmental protection authorities make it non-trivial to "just implement" the legislation. For example, the implementation can easily become politicized at the local level. Therefore it is not as simple as just use the judicial means available and force homeowners to change their OSSs. There are also a growing number of actors around OSS, including more suppliers of technical systems, branch organisations, and knowledge brokers (Paper I). The issue of how to intervene to improve the function of OSSs have therefore grown more complex. More actors act to influence the development and they may or may not have common goals, and may or may therefore not contribute to an environmentally effective governance of Swedish OSSs.

The purpose of Paper IV is to go some way towards capturing the structure of the governance system aiming for decreased nutrient loads from Swedish OSSs. The paper introduces the concepts of an interface between the socio-technical and ecological systems, interface- and influence-actors, and

interface- and influence-actions as a conceptual framework that could guide environmental problem-structuring activities (further detailed in chapter 2.2 of the thesis and Paper IV). The set of concepts are put to use in the case of OSS to identify important actors and relationships.

3.4.2 Method

The approach chosen to construct the model of actors and influences was through the use of practitioners' perspectives. Six practitioners were asked to participate in interviews to give their views of the system of actors that take actions that are of relevance because they directly or indirectly influence homeowners to change, or refurbish, their OSSs. Contextual aspects were covered to a lesser extent (Figure 9).

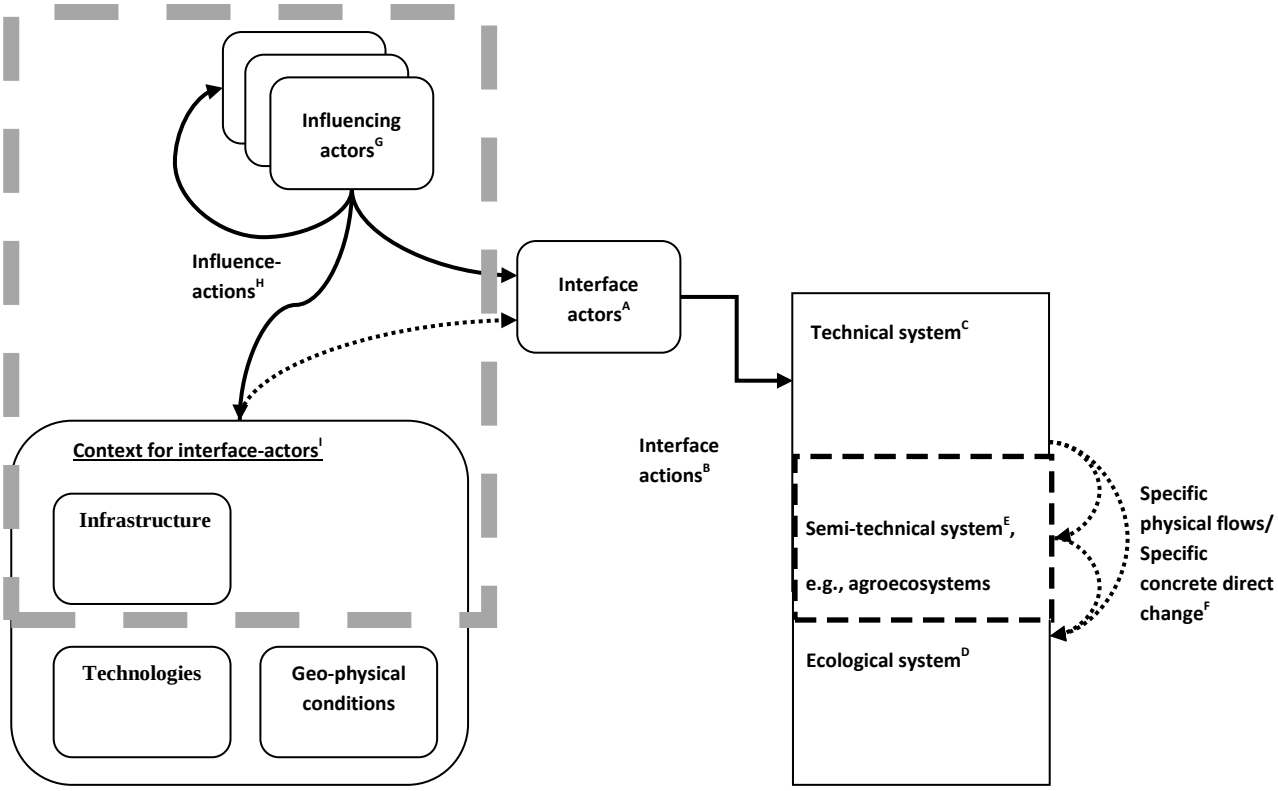

Figure 9 The paper is limited to identifying influence-actors and influence-actions. To some extent contextual factors are also covered.

The informants was invited to draw diagrams with nodes representing actors and arrows representing influences, to depict their worldviews (cf. Newell 2012)[10]. During the interviews influence diagrams (Rosenhead 1989) of identified actors and influences were specified. The concept of an interface was guiding the interviewer when facilitating the process of constructing diagrams. The interviews were

[10] In two cases, as the interview unfolded, complete influence diagrams covering the actors identified during the interviews were not drawn during the interview, but was instead completed by the interviewer afterwards.

also recorded. In the analysis of the interview outputs, the different actors' contributions were synthesised and we could extract six partly overlapping sub-networks.

3.4.3 Results

Based on the interviews it was possible to distinguish at least six co-existing and partly overlapping networks of interdependent actors directly and indirectly influencing homeowners' action "to change or refurbish their OSS". The six networks are; the public administration network; the infrasystem provision network; the OSS change facilitator network; the WFD network; the CE-labelling network; and the local level network. While we call only the first one "public administration" network, the other networks are as well connected to the public administration influence-actors. The list of networks is not exhaustive but comprises the prominently appearing networks. Two networks will be presented here as examples.

Example 1: The public administration network

The influence-actors of the public administration network are the Government, the governmental agencies that are most relevant in the case of OSS, and the authorities at the county and local (municipal) levels (Figure 10). The relationships are first of all of formal nature with the Government (and the Parliament) defining roles and responsibilities for administrative actors from national to local level through, e.g., laws, regulations, and yearly amendments. These actors and relationships are illustrated as chains of administrative actors and influence-actions in Figure 10.

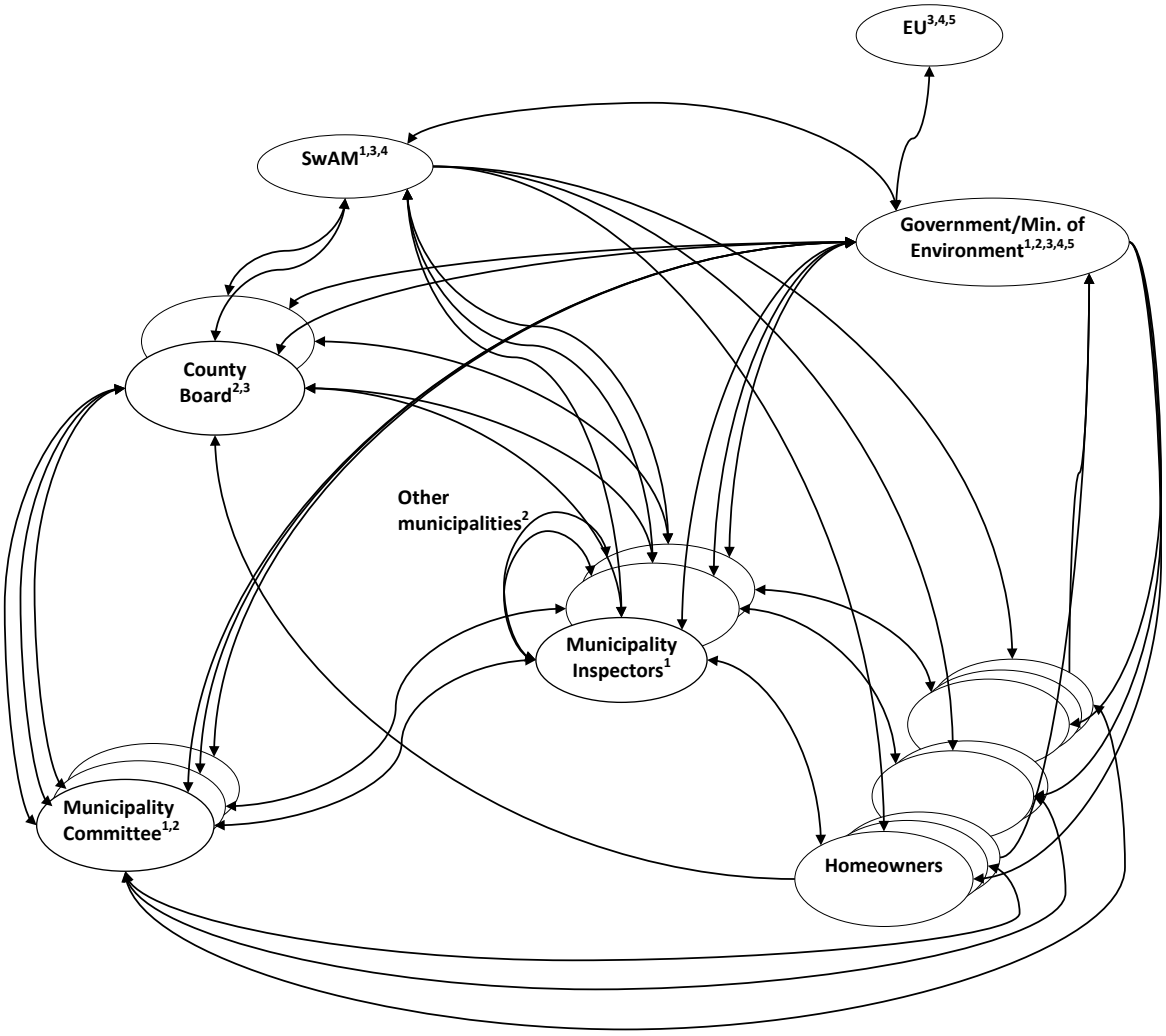

Figure 10 The network of public administration actors associated with implementation of the environmental protection legislation. The Government/ministries, the municipal committees, and the municipal inspectors take influence-actions since they influence homeowners to change their OSSs. The county boards in turn influence the municipality committee and inspectors through providing inspection guidance.

At the local level the municipality has some freedom in how to organize the environmental protection processes, but most commonly the enforcement activities are directed by special "environmental and health protection committees" (In Swe. "Miljö- och hälsoskyddsnämnd") and the operational enforcement activities are delegated to local environmental authority inspectors. Decisions of this committee have a decisive influence on whether a homeowner will change their OSS or not. The municipal parliament decides on budget for enforcement activities in the municipality and influence that way also the amount of work done by the local authority working with the enforcement of regulations. For instance, a policy to inspect a specific number of households per year together with a budget and personnel sufficient to perform the intentions of the policy are examples of influence-actions that could increase the number of inspections, in turn making more homeowners improve their systems. It is, however, the municipal inspectors who have most contact with the homeowner and

prepare the decision of the municipal committee. When it comes to interpreting national legislation in particular situations the work of municipal inspectors is key. The influence from the Government (i.e., the Ministry of Environment) on interface-actors is therefore relying on decisions made at the local level, by the committees and municipal parliaments. In much the same way, governmental agencies have intentions to support the administrative actors at local levels but their priorities, tasks, and budget are decided by The Governments yearly amendments and the resources assigned to fulfil the amendment. For instance, the interviewee at SwAM noted that there is currently no national goal directly focusing on increased enforcement rates. The view of the interviewee was that inaction from the Government impeded them to play any decisive role, albeit their role is mainly to produce guidance and they have no capacity to place any sanctions on municipalities that have low inspection rates.

According to the interviews it is relatively common with informal interactions that cut across administrative levels. For example, inspectors try to get advice from the national agency - Swedish Agency for Marine and Water Management (SwAM), implying that communication can jump the "county level". Municipality inspectors try to get clarifying information from the national agency, and there can be experience-sharing and coordination activities. There are also collaboration activities between inspectors of different municipalities and between counties, which is further discussed in the subsequent section.

Example 2: The OSS change facilitator network

Associated with the implementation of national policies into practices at the local level, facilitating actors have emerged as a response to coordination and interpretation problems at the county and municipal levels (Figure 11). In the OSS change facilitator network, the public administration network is complemented with two actors, Avloppsguiden and Miljösamverkan, which are actors working with knowledge brokerage, guidance in interpreting legislation and rules, and tools that aid inspectors in their enforcement (mostly Miljösamverkan). Avloppsguiden also have the intention to inform and guide homeowners in their change process.

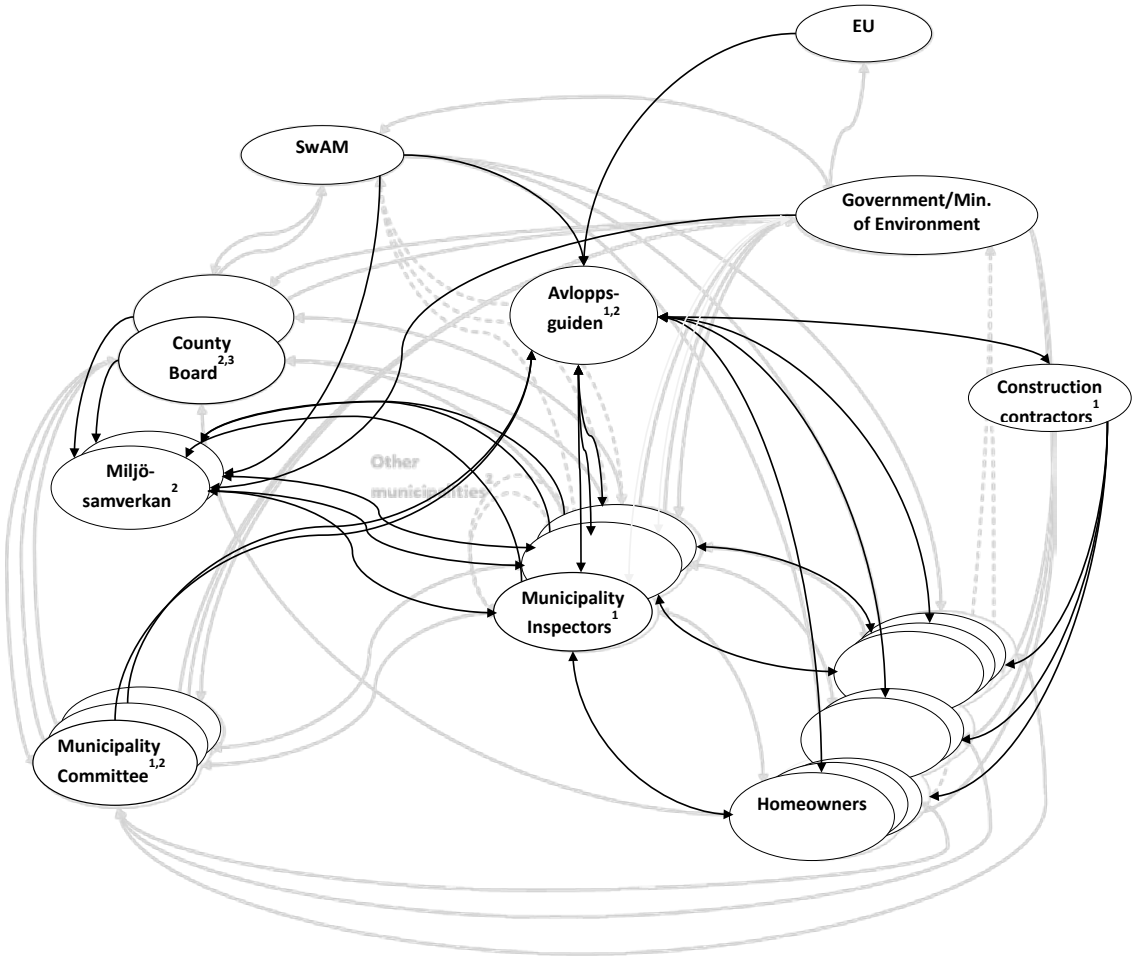

Figure 11 The actors and influences related to the OSS change facilitators. Influence-actors networks are partly overlapping through actors positioned in the "intersections", which is exemplified by the public administration network kept in the background.

One central actor is "Avloppsguiden" which was created by an initiative of some individual municipality inspectors who saw the need for coordination between local authorities and support from fellow inspectors to facilitate inspections. The influence of Avloppsguiden is mostly directed at the level of inspectors including guidance through a discussion forum, education programmes, and yearly national OSS conferences. Avloppsguiden offer also education programmes to politicians (e.g., municipal committees), estate agents, and contractors. According to the interviews, the existence of Avloppsguiden having a role similar to the county boards can be seen as an indication of weak guidance from the regional and national level authorities.

Another example of a facilitating actor is Miljösamverkan (in Eng. *'Environmental collaboration'*) which is a collaboration at the national level between national agencies in order to coordinate and enhance the inspection guidance among Swedish counties. At the regional level the collaboration

occurs instead between the county board and the municipalities of the county to improve inspections. For example, projects of Miljösamverkan have developed document templates to use in inspections.

Problem-structuring in the case of OSS: influence networks related to OSS improvements

The public administration network illustrates the function of government, where the Governments decisions are intended to be implemented by responsible actors on the ground, in the case of OSS the homeowners. A hierarchy of influence-actors from national agencies, to county administrations and municipalities has been built up in order to support the implementation. The influence-actions of these actors include interventions to ensure a coordinated implementation and that intended outcomes are achieved. In the case of OSS intended outcomes are environmental and health protection, but also outcomes pertaining to consequences of legislation in general, such as reasonability of costs for the individual and legal certainty.

In stark contrast with the public administration network, the change facilitator network illustrates a response from administrative actors to implementation challenges that is outside of their "normal" operations (i.e., perform inspections). Change facilitators such as Avloppsguiden support implementation processes in several ways, such as offering discussion forums to inspectors to get assistance in their judgment of the performance of OSSs in individual cases. This can be seen as a form of inspection guidance that "should" be offered by the counties and the SwAM, but because the perception among inspectors is that their guidance was insufficient a new actor, Avloppsguiden, was created to provide this function. In turn, inspections are influence-actions that are important to make homeowners improve their OSS. Without inspections and a more or less explicit-made requirement to improve the OSS, few homeowners change their systems (Wallin, Molander et al. 2011; Paper II). The addition of the OSS change facilitator network complements the view of "who is involved" in policy implementation processes, and the diagram helps to clarify and maybe also to facilitate communication about what the additional actors contribute and what that means for implementation processes.

Other networks show yet other complimentary views. For example, the infrasystem provision network illustrates the more or less unintended consequences that a law intended to provide drinking water and wastewater treatment in areas of municipal operation (in Sve. "kommunalt verksamhetsområde"). This law seems to have influence on the nearby policy area of on-site wastewater treatment (which normally takes place in the rural areas that are not areas of municipal operation and therefore would not be connected to the municipal grid). Although the influence-actions taken in this network are not primarily intended to solve nutrient loading from all OSS, this is what happens in at least a subset of Swedish municipalities. Together, the set of influence networks illustrate the multi-dimensional character of the governance system. The networks shows that it is certainly more actors involved than those formally connected to the Government and implementation of OSS regulations.

In our account of actors and influences we did not place much emphasis on influences in the direction *from* the interface-actor back to influence-actors that affect their future decisions. Incorporating such feedbacks would result in a more complex but also more comprehensive view of the system of actors and influences. The very reason for influence-actors to take action to protect the environment is feedback through observing first of all, the impacts on environment, and secondly that actions taken by certain interface-actors are insufficient. The feedback from interface-actors could also impede further influence-actions. The interviewees contributed with knowledge on this type of influences even though it was not the principal focus area of the interviews. For instance, the fear of receiving complaints from homeowners and a non-supportive local opinion may make local politicians unwilling to take decisions, for instance, to increase resources needed for inspecting more homeowners OSSs. On the same grounds, inspectors (formally the committees) may choose to impose requirements on OSSs nutrient treatment performance corresponding to a normal instead of a high level of protection, which are the two protection levels introduced by the SEPA in 2006 (SEPA 2006). Another case of feedback influences is the formal reporting occurring between influence-actors at different levels in the administration and from countries to the EU. This is an example of an influence in the opposite direction (from interface-actors to influence-actors) that may cause adaptation based on the result of a previous influence-action. For instance, the Water authorities report back to the government and the EU about progress towards WFD goals, who in response could take further measures towards the countries unless the WFD binding water quality standards are met by 2015. Such feedbacks are also part of the picture since they relate to how influence-actors act in "the next time step".

3.5 Reflections on the applied methods

The application of multiple methods to the case of OSS might be necessary to identify solutions matching the different kinds of difficulties that environmental policy-makers may encounter, and, to have reasonable expectations on policy outcomes. Having knowledge about motivation mechanisms of individuals (Paper II) may make policy-makers believe that the problem reside at the individual level. However, adding the socio-technical-environmental perspective (Paper I) indicate that the problem of nutrient loads OSS is deeply rooted in society, connected not only to individual homeowners' preferences but also to institutional arrangements of different time-periods and prevailing knowledge. Further, the views of practitioners regarding which actors are determining outcomes (improved OSS), and which interactions are important, can reflect actual circumstances and give yet other views on the system to intervene in (Paper IV). Different methods give different answers to "what the problem core is" and will suggest, thereby, multiple solutions.

When performing the research this way, concepts and theory was borrowed from different disciplines. Paper II models mental processes underpinning homeowners' behaviours and used recent theoretical developments in environmental psychology. Paper III focused the individual but regarded instead the

relationship between individuals and government. The subject of support of governments' actions from citizens is important for policies and regulations needed to improve environmental outcomes and is studied foremost in political science and psychology. Paper I and IV instead aims at studying systems comprising multiple actors and further also technological and institutional dimensions of system change. Hence, approaches and methods in systems analysis were applied.

Applying multiple focal points on the case necessitated a broad set of information sources, ranging from "snap-shot" studies (questionnaire surveys) to get data on individuals' behaviour, historical data (documents and statistics) on OSS developments in Sweden, and engaging actors of the system to elicit the actor structure of the same system (interviews and influence diagram modeling). A few examples can be made regarding difficulties in obtaining data and strategies to improve validity. The first study aiming for descriptions of historical change processes was constrained by scarce information and varying quality of the information used. For instance, the early Housing statistics that was used when modeling historical nutrient loads from OSS is based on measurements in populated areas that at the time of measurement were chosen because they were deemed typical of Swedish conditions. Hence, there is a risk that the measurements might not represent the population of Swedes with OSS in general. The more recent statistics are based on measurements capturing much larger shares of the populations can be considered more valid. Other sources were official inquiries which were used to trace intentions and views on directions of change of governmental agencies in different time periods. However, the statements about the preferences of ordinary people of the time are not as underpinned, being based on third-party-reporting. The analysis strategy was therefore to triangulate, striving for several information sources to confirm important arguments and finding a narrative that fitted as much of the gathered material as possible and with few, if any, contradictions. The construction of the narrative was also framed by theoretical perspectives on socio-technical change processes which are in turn based on case studies.

The second study dealt with the challenge of modeling mental processes underpinning homeowners' behaviours, which cannot be readily observed. At the outset it was only expected that gain-related motives should be important for homeowners changing OSS, because of the general characteristics of the situation with high costs and practically no private benefits (Lindenberg and Steg 2007). However, since multiple-motive models are quite recent developments in environmental psychology, few studies exist to generalize from. It was therefore reasonable to take on a relatively exploratory approach when investigating which motives where present and their relative importance. The elicitation of items was therefore informed by a pilot study (Wallin, Molander et al. 2011) and previous research found to be relevant to the action to change an OSS. The first step in the analysis tested the dimensionality of the items, which led to both confirmations of theoretical constructs and construction of partly new constructs (called candidates to motivational factors in Paper II). The regression analysis gave the

relative importance of the motivational factors. This means also that the resulting motive structure of Paper II is developed primarily to hold within the case.

Paper IV concerned, in some contrast to the previous papers, with the question of delineating the current system of actors involved in the governance towards decreasing nutrient load from OSS. A main challenge here is to judge the boundaries of the system, regarding which actors should be included because they have a "significant" influence and which actions should count as influences. The chosen strategy on the matter was to use the views of the interviewees to distinguish the influence-actions and -actors that should be part of the networks. The interviewees were deemed to be "information-rich" and representing relatively diverse views, making it reasonable to assume that the main distinctions would remain if further actors would be involved. This might be suitable since the main purpose of the study was to introduce and illustrate a possible application of the interface concepts.

Applying multiple methods impose a kind of challenges on the researcher that likely pertain to interdisciplinary research more generally. Challenges include to accommodate and build on previous research in a scientifically sound way and to apply different methods that each one requires a number of iterations to get the feel for all the choices that has to be made. There are both risks of performing to shallow research because of limited understanding of the state of the art in specific disciplines and of going to deep in the process of analysing and thereby miss broader perspectives. On the other hand, the reward of applying multiple methods on a case is that it enables investigating several aspects encountered in environmental problem solving. As Paper I showed, environmental problems have roots stretching several decades back and are the result of actions taken by many actors in the past. Society are locked to using certain technologies and the factors contributing to this lock-in need to be considered. Paper II and III investigated instead the root causes as if they related to individuals' behaviours, assuming that every environmental problem-solving attempt will have to deal with individuals' choices and reactions to the application of policy instruments, which do not necessarily go hand in hand with individuals' wills. Paper IV broadens the scope again and maps the sources of influence on homeowners' change of OSSs. The paper is an attempt to depict the multiple actors involved in governing OSS towards decreasing nutrient loads and enable more informed OSS policy-making. Perhaps, and hopefully, when the understanding of the potential contributions of different research disciplines sits in individual researchers this is a kind of competence that can enhance environmental problem-solving attempts.

4 CONTRIBUTIONS AND CONCLUSIONS

4.1 Conceptual development and problem-structuring method: Developing and using the concept of an interface between the socio-technical and ecological systems

The first contribution of the thesis is related to conceptualizations of human-environment interactions and modelling that guide policy-makers towards more effective environmental policies. The main assumption adopted in the thesis is that specific actors are causing environmental problems and problem-solving approaches that identify and describe specific actors' actions are therefore needed as well as knowledge about the mechanisms underlying their behaviours. Knowing more about actors and what might influence them to take mitigating actions will result in a more informed and hopefully more effective environmentally policy-making.

At a conceptual level, there seems to be relatively few approaches available that aid actor identification and further actors related to specific environmental problems. For example, the DPSIR approach is well developed to describe the environmental effects once a pressure have occurred but societal activities is summarized as Driving Forces and Responses (Harremoës 1998, Smeets and Wetering 1999). Tapio and Willamo (2008) make a set of distinctions that might make it possible to identify actors connected to the specific human actions causing intakes from and outputs to ecological systems. This would be actors connected to infrastructural and other factors that are the context to the human actions causing intakes and outputs. The set of concepts related to an interface between socio-technical and ecological systems, which enable identification of actors controlling specific environmental pressures and the actors influencing them, are relatively close to the latter conceptualisation. However, by identifying interface-actors and -actions and influence-actors and -actions we go one step further in order to delineate a system of actors and actions connected to specific environmental pressures, that in turn are connected to specific problems such as eutrophication or climate change. In the investigated case, the actors at the interface are homeowners using on-site sewage systems and thereby causing nutrient flows to surface and groundwater, which in turn contribute to eutrophication of Sweden's coastal zones.

Interface-actors are influenced by a multitude of influence-actions of which some play more decisive roles than others. Naturally, as is shown in the case of OSSs, factors such as Government legislation and agency regulation are important factors influencing what homeowners do about their OSSs. Though legislation may be seen as imposing quite hard constraints on homeowners' behaviours, homeowners do not act in line with the intentions of legislation unless local authorities require them to do so. The case shows that influencing actions that reach and place quite structuring constraints on interface-actors might be important to solve specific environmental problems.

The mapping of important actors and influence and construction of influence networks in the last study (Paper IV) is an attempt to perform a problem-structuring activity in collaboration with practitioners, being guided by the interface concept. In the case of OSSs, the chosen approach to use practitioners' views and focus on identifying relevant actors and relationships resulted in six networks. More work can certainly be done to develop the process of model elicitation, e.g., how to facilitate model construction processes and performing validation. There is certainly room for more work when it comes to describing actors and actions connected to specific environmental problems, both conceptual development and empirical contributions.

4.2 The multiple motives underlying behaviour

The second contribution of the thesis is related to understanding mechanisms underlying individuals' behaviours with environmental repercussions. The thesis started out describing a stylized view of individuals' behaviours as the roots to environmental problems, describing environmental problems as "social dilemmas" (Hardin 1968, Dawes 1980, Ostrom 1990). In the presented view, the basic problem is that individuals act in line with their (short-term) self-interest and do not consider collective costs and benefits. In fact, they do not even perceive the consequences, much because these occurs on larger tempo-spatial scales (Platt 1973). The approach chosen in the thesis was to take the analysis in the case further by viewing the problem as a problem of motivation at the individual level. A relatively recent theory, goal-framing theory, suggests that individuals are guided by multiple motives, or goals (Lindenberg and Steg 2007). The theory bridges between two strands in literature on the roots of behavioural differences between persons and between situations; behaviours can result from differing personal characteristics (e.g. traits, values) and from differing situational aspects (e.g. others behaviour, infrastructure) (Fleeson 2004, Funder 2006). According to goal-framing theory individuals are guided by three master motives, which gathers a further number of sub-ordinated motives, and these simultaneously guide individuals as they gather and process information and then act (Lindenberg and Steg 2007). One motive can have precedence over another when individuals enter a particular situation, but aspects of the situation may also change which motive precedes another. From this reasoning follows two general intervention possibilities. First, knowing the motive structure policy-makers can adapt interventions to match primary, secondary etc. motives. Second, knowing that situational aspects may influence the presence and structure of motives the intervention strategies must be much carefully tailored to send signals that might activate and strengthen certain motives in a way that favours intended outcomes.

This thesis contributes by developing a motive structure for homeowners changing or refurbishing their OSSs (Paper II). Having knowledge about which motives are related to this behaviour can inform the design of interventions directed at homeowners with OSSs. The thesis suggests that the strongest motives guiding homeowners are *To benefit* and *Fair outcomes*. These motives consistently explain

readiness to change OSS, both when a short and a long time horizon for the decision to change OSS were applied. First, the presence of the motive *To benefit* suggests that homeowners are first of all sensitive to the consequences of change that can be measured economically or imply noticeable improvement, such as a more convenient system (which may or may not be explicitly associated with an economic value). The importance of this motive is consistent with the predictions of goal-framing theory, since situations characterized by high costs and low benefits should activate foremost gain goals (Lindenberg and Steg 2007). Second, the presence of the motive *Fair outcomes* suggests that homeowners tend to be ready to change OSS under the condition that other change OSS. Put differently, people want outcomes to be equal and will not try to get away if others are cooperating (Wilke 1991)[11]. Such considerations have previously been shown to be highly influential in resource dilemma situations (Wilke 1991, Fehr and Schmidt 1999, Johansson and Svedsäter 2009). The presence of this motive is important since it can be used to make homeowners more motivated to change OSS. It is for example difficult to get around the fact that it is costly to change OSS. However, the presence of this fairness motive suggests that homeowners could become more positively oriented to changing of OSS if they see that other homeowners improve their OSS.

Three further motives appear in the analysis. *Environmental concern* was found to be a relatively weak motive and appeared when analyzing short-term readiness to change OSS. The weakness of this motive is expected, particularly since a change of an OSS is an example of a decision characterized by high costs and low benefits (Lindenberg and Steg, 2007). From an environmental policy point of view this finding is however problematic, since environmental protection is one of the main purposes of the OSS legislation and regulations. The relative weakness of this motive suggests that environmental information would not convince the majority of homeowners to change systems. The presence of the motive *Qualified fairness* implies that the more homeowners think that no one should be exempted from contributing equally, the more ready were they to change their systems. *Avoid inconvenience* was found to be a further factor explaining readiness. Thus, homeowners are sensitive to information related to the risk of getting caught or smells and odours related to their OSSs. Thus, “not feeling good“ about the current system is a factor affecting homeowners, but likely not as much as concerns about costs and concern about others behaviours.

A set of variables related to perceived behavioural control (Ajzen 1991) were also explaining the level of readiness: *Efficacy if OSS is changed*, *Efficacy with current OSS*, and *Ability to change OSS*. Such barriers to taking action have been suggested to be important for environmental behaviours in previous research (Gifford 2011).

Overall, it is therefore reason to believe that homeowners will not, without any intervention, change their OSS. Homeowners are, however, sensitive to different kinds of signals from their surroundings,

[11] Wilke (1991) termed such consideration ”aversion to inequality in outcomes”.

including economic information, the behaviour of others, and any inconvenience a current or new system would bring. Data strengthen this argument since the large majority of homeowners changed their OSS only after a contact with the local environmental authority. In the large majority of cases resulting in a change of system this contact was in the form of an injunction (Paper II). In all, the enforcement actions of the local environmental authority are important influences on homeowners' decisions regarding their OSSs.

4.3 Quality of institutional arrangements and political trust as explanations to acceptance of governmental regulations

The third contribution of the thesis relates to the issue of how governments get support from its citizens in order to govern to achieve environmental outcomes. Such support is a factor underpinning legitimacy of governments, or in other words, concerns the consent among citizens that the government have the "right to govern" (Coicaud and Curtis 2002). Such support is described and measured as the trust that individuals have in governments (Levi and Stoker 2000). To strive for high levels of trust is possibly particularly important for environmental issues since these are associated with, e.g., large uncertainties and causes and consequences can be contested. Factors underpinning trust include the competence of authorities in particular matters, the impartiality of enforcement, and whether the regulations have their intended outcomes (Levi and Stoker 2000).

The thesis investigated the relationships between acceptance of OSS regulations, political trust and the perceived quality of institutional arrangements. It was found that acceptance of regulations was explained by trust in HEPA inspectors and by perceptions of impartiality in authority procedure and effectiveness of meeting the authority requirement. In the case of OSS, homeowners who tend to accept regulations are high-trusters, perceive authorities to be impartial during enforcement, and believe that eutrophication decrease if they improve their OSSs. These findings supports statements regarding the role of trust for acceptability of specific regulations and in turn for the legitimacy of the regulatory system (cf., Levi and Stoker 2000, Tyler 2006, Matti 2010, Schmöcker, Pettersson et al. 2012).

In some contrast to the findings of paper II environmental information is important for political trust and for acceptance of regulations. The specific information that is important concerns effectiveness of following the imposed requirements, and whether the authorities treat different homeowners equally in their judgements. The communications that authorities have with homeowners are opportunities to inform homeowners. It is furthermore important that rules are not only existing but are actually implemented. In the case, this means that inspections are made on a scale that corresponds to the needs, that is, that homeowners with OSSs that are not up-to-code are identified and enforcement actions are sufficient to make homeowners comply. The findings of the paper further suggest that an enforcement on an appropriate scale would also be legitimate as long as authorities can ensure the

intended environmental outcomes are reached. However, the capture potential of systems with one point of emission are relatively foreseeable and stable over time given that they are correctly installed and maintained, while the performance of systems with diffuse outflows is fundamentally difficult to control. Therefore, it might be difficult to convincingly argue that the imposed requirements have environmentally benign outcomes. Possibly, communication to make homeowners understand the possible benefits of allowing these systems anyway (robustness, allowance given only in less environmentally sensitive areas) could resolve the issue.

4.4 Historical nutrient loads from OSS and associated socio-technical changes

The thesis showed that the nutrient loads from OSSs increased radically from the 1940'ies to the 1970'ies. Since the 1970'ies the loads have decreased to some extent but are high compared to the 1940'ies and given the nutrient capture potential of the treatment technologies that exist today. This load trend is caused by a large-scale introduction of WCs in combination with poorly treating sewage treatment systems. Since few OSS have been improved in the time-period and treatment systems whose nutrient capture capacities decay with time have been adopted, there has only been a very slow decrease in nutrient loads from the 70'ies to 2010.

The thesis contributes with several insights regarding the socio-technical changes underpinning the load trend. As in other cases of sewage system expansions there were a hygiene movement driving water and sewage system developments (cf. Geels 2006). The overall remark made in the thesis is that a strong drive for adopting WCs must have been the combined effect of great promises of increased convenience, the strong hygiene movement, and state subsidisation of the water and wastewater treatment improvements. The consequences in terms of increasing environmental impacts were discovered only a few decades later. The rules pertaining to OSSs were for a long time focused on water-based treatment using infiltration beds as the subsequent treatment step in addition to sludge separators. This contributed to a lock-in to on-site water-based treatment systems. The outreach to homeowners with malfunctioning OSS was limited, and the situation did not change until the 90'ies. This was likely due to a more or less conscious ignorance in light of mitigation actions directed at the larger point sources such as municipal wastewater treatment plants. The limited outreach was possibly also related to fear of receiving complaints from homeowners and perceived difficulties to create acceptance for prioritizing OSS at the local level. The turn to relatively flexibly interpretable rules (i.e. function requirements) is both a possibility to increase enforcement but leaves also considerable interpretative work and demands appropriate resources for local environmental authorities.

5 IMPLICATIONS FOR POLICY MAKING AND MANAGEMENT

The thesis argues for an increased focus during environmental policy-making and management on specific actors controlling the pressure on the ecosystem. In the thesis the actors having this particular capability were called interface-actors. Further, it is possible to identify not only interface-actors but also the actors influencing them to take action that decrease pressures. Identifying actors that contribute to mitigating environmental problems might be important when developing mitigation measures. Importantly, the identification of actions at the interface as causes to pressures on the ecological system contrasts the commonly identified consumption as the key behaviour that need to be changed in more sustainable direction. The point is not that consumption is unimportant, but that consumption is in most cases only indirectly linked to specific environmental pressures. One function that the concept of the interface-actor might serve is to increase the focus on actors that are directly linked to, and controls, environmental pressures.

A good understanding of the system is a basis for identifying and directing measures during interventions. The method developed in the thesis, to identify actors and actions tied to specific pressures on the ecological systems, is a possible method to develop such understanding. This method consists of three main components. The first component is the set of concepts related to an interface between the socio-technical system and the ecological system. These concepts operate on a general level and can be used to guide problem-structuring activities involving actors in the practice (policy-makers and managers). In the thesis they were kept in the background guiding the person acting as facilitator during the problem-structuring activity (i.e., the interview). The second component is the use of influence diagrams which are simple and intuitive tools forcing involved persons and analysts to describe the reality in terms of “boxes” and “arrows” that can be discussed by facilitator and analysts. The third component is the information collection needed to construct the influence diagram. In the thesis the information was gathered by involving the actors who were to be nodes in the influence diagrams, which is reasonable because they are the actors receiving and acting on influences. The thesis did not go very far in testing the method but showed that it is at least one possible approach to identify and structure the actors and their relationships that are relevant to understand which actors are involved and what they currently do to influence the direction of change.

Another basis for making successful interventions is to enhance the understanding of the influences making individuals engage in the actions that decrease pressures on the ecological system. The thesis addressed inducements in two ways. First of all, homeowners are importantly guided by more than private economic benefits. Homeowners are also guided by concerns related to “what others do” and what is a fair share of the mitigation burden. Homeowners want to see that other homeowners take action in order to take action themselves. Because of the long technical lifetimes of OSSs homeowners do not make many system improvements during a life time. It might therefore never be evident to

homeowners when the situation is such that many homeowners do their fair share. The risk of being a "sucker" might prevail. For regulators, this means that it is important to tell homeowners who have poorly functioning systems and are not up-to-code that all other homeowners in the same situation will be required to act. It is further important to ensure that this is actually the situation, which is not really possible in Sweden as of today when a majority of homeowners has poorly functioning OSSs and inspection rates are low (SwAM 2013). Further, while concerns of environmental consequences are not unimportant it does not play an overwhelmingly important part in the decision to change an OSS. However, as will be discussed, homeowners will accept authorities' requirements when they have their intended outcomes, that is, when the required technical changes lead to less eutrophication.

Secondly, implementing policy instruments, such as legal ones aiming for environmentally benign behaviours, requires acceptance among actors in the affected population. In the thesis, the OSS regulations and enforcement actions by the local environmental authorities in the Swedish municipalities (in Swe. 'Miljö- och hälsoskyddsnämnden') was investigated. The thesis showed that homeowners who trust the local environmental authority tend to accept the OSS rules to a larger extent. Thus, local environmental authorities should work towards increased trust. This can be done in at least two ways. First, it is important to ensure a fair treatment of homeowners and communicate clearly the reasons for differing outcomes between homeowners. Second, since the intention of the rules is environmental protection, it is important that imposed requirements, when these translate to changed OSSs, lead to less loads and improved environmental status. However, the local environmental authorities can only partially control these conditions for improved trust. For example, the possibility to ensure fair treatment relies on judgements of performance of different technologies. Individual municipalities cannot ensure that individual technologies are judged similarly in all municipalities which points to the need for coordination and guidance from national agencies. Another example is the relatively poor scientific knowledge about how well technology performs, i.e., what statements are possible to make about the performance of treatment technologies utilizing natural processes in soil given the current state of knowledge. This leaves inspectors with difficult judgements of performance of individual homeowners OSSs and opens up for homeowners to question whether the imposed requirements are legally certain. The possibly most important factor for ensuring fair treatment at the local level is however that local politicians must be determined and both prioritize and direct resources to improve OSS locally in the municipalities.

6 ACKNOWLEDGEMENTS

The dissertation was made possible through the contributions of a number of persons. First of all, I want to thank my main supervisor Sverker Molander and co-supervisor Lars-Olof Johansson for discussions and feedback all the way from the beginning to the end. In the closest group I count also Mathias Zannakis who I am grateful to for great cooperation in the first three papers of the thesis, and who took on some supervising tasks in the second half of the studies. I also highly appreciate comments on the work from examiner Anne-Marie Tillman. In the process I also got the opportunity to work a couple of months with Eva-Lotta Sundblad, Anders Grimwall and Lena Gipperth at the Swedish Institute for Marine Environment where some of the ideas elaborated in the thesis were discussed – thanks for taking me on board! A big thanks goes also to all persons I have shared office with, worked more or less close with, or been there as fellow colleagues before and during my doctoral studies at ESA (my ESA era started back in 2006).

I am also grateful for the grants from the Swedish Research Council FORMAS and the Bank of Sweden Tercentenary Foundation (Stiftelsen Riksbankens Jubileumsfond) which financed most of the research in the thesis.

Persons in the field of practice have contributed in several ways. I appreciate discussions in meetings, conferences and other discussion forums and the opportunities we have got to present and discuss findings. I also got valuable information during interviews with persons, e.g. authority officials in municipalities, contractors. No names mentioned, but I thank you all the same. Last but not least, I want to thank all homeowners anonymously participating in the questionnaire surveys – I don't know who you are, but getting your contributions are necessary for scientific progress!

Last, I am happy to have a great family and friends. Kajsa who is the person having to bear with mood changes, for cheering and keeping me in a relatively good mental state. Then of course the big family who are always there, for a talk about how things go or life at large. Thank you friends for chats, training sessions, dinners, and being there. Not least for reminding me about things I like to do in the spare time.

Over and Out!

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