

THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Factors influencing actors at the interface between the socio-technical
and the ecological systems
The case of on-site sewage systems and eutrophication

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ABSTRACT

Eutrophication, caused by nutrient loading, is a global environmental problem, particularly severe for the Baltic Sea. Long-term solutions rely on the ability of society to respond effectively. This involves, for example, instigating actors who have the capability to directly influence nutrient loads to take action. In Sweden, one of the substantial sources of nutrients is on-site sewage systems (OSS), that is, wastewater treatment systems for one or a few households. The aim of this thesis is to increase the knowledge about factors influencing actors that directly and indirectly influence nutrient loads from Swedish OSS by (1) Identify factors influencing homeowners' to change OSS, and (2) Investigate the relative strength of these factors.

Semi-structured interviews with homeowners and authority inspectors were used to elicit tentative conceptualizations of influencing factors. The results together with literature on pro-environmental and compliance behavior were used in the construction of a questionnaire, directed at Swedish homeowners with OSS. The analysis involved statistical methods, including principal components analysis to identify underlying motivational factors, and regression analysis to investigate the relative strength of these factors, while controlling for government and authority interventions.

The result shows that authority interventions are needed to make homeowners change OSS. Informal means, such as information, will not likely lead to a large-scale transformation of OSS. They may, however, be effective in combination with more deterrent means of regulatory enforcement, such as injunctions. Such interventions are needed because of the high costs and no, or very low, benefits of changing OSS from the homeowner point of view. Furthermore, the awareness about the need to change OSS from an environmental point of view seems to be low. In this situation, homeowners are most inclined to defend their self-interest and do not act based on environmental concerns. Homeowners are more inclined to change OSS under the condition that other homeowners are cooperating.

Keywords: Eutrophication; homeowners; on-site sewage systems; regulatory compliance; goal-framing theory; social dilemma

LIST OF PUBLICATIONS

Papers included in the thesis

Paper I

Wallin, Are, Lars-Olof Johansson and Sverker Molander. "Achieving nutrient load reductions: What makes homeowners install new on-site sewage systems?"

Manuscript

Paper II

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Manuscript

Other publications by the author

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Zannakis, Mathias and Are Wallin. "What factors can influence house-owners' willingness to invest in environmentally improved on-site sewage systems?"

Paper presented at the SWEPSA conference in Gothenburg, 30 September-1 October 2010

Wallin, Are and Sverker Molander. "Factors influencing homeowners to adopt environmentally improved on-site sewage systems".

Poster presented at the International Society for Industrial Ecology 2011 Conference, June 7-10, 2011 University of California, Berkeley

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1 INTRODUCTION

Marine eutrophication, caused by nutrient loading, is a global environmental problem for which the environmental status is beyond a “safe operating space for humanity” (Rockström et al., 2009). Signs of eutrophication are noticed in many of the inland seas of the world as well as in coastal zones, with severe consequences on the ecosystems and repercussions on the human society through, for example, diminishing and even disappearing fish stocks (Diaz and Rosenberg, 2008).

In the Baltic Sea, the first signs of eutrophication were observed as early as in the 1930's (Diaz and Rosenberg, 2008). Today large parts of the Baltic Sea are affected by yearly algal blooms and deep basins are experiencing hypoxic condition (Diaz and Rosenberg, 2008; Conley et al., 2009; HELCOM, 2009). The negative trend of eutrophication in the Baltic Sea can partly be attributed to an increasing population in the catchment area. However it is also explained by large-scale land-use changes, such as draining of lakes and wetlands, and increased use of fertilizers, increased combustion in the transport and energy sectors, and the widespread use of water and wastewater systems, all contributing to increasing loads of nutrients (Conley et al., 2009; HELCOM, 2009). The largest sources today are agriculture, combustion processes, and urban wastewater treatment plants (WWTPs) (HELCOM, 2009). However, in Sweden, a substantial contributor of nutrients is *on-site sewage systems*¹ (OSS), accounting for 15% of total phosphorous loads and 5% of total nitrogen loads (SEPA, 2009b; Ek et al., 2011). The OSS sector is lagging behind other sectors, foremost urban WWTP, in terms of having achieved nutrient load reductions (SEPA, 2009c).

Seen in retrospect, the nutrient loads from OSS drastically increased when dry toilets were replaced with water closets and water-based treatment technologies were introduced. Between 1945 and 1960, about 250 000 countryside homes were retrofitted with water and wastewater pipes and 200 000 got a WC installed (Socialstyrelsen, 1952; Bostadsstyrelsen, 1965). By the end of the 1970's nearly all homes had a WC (SCB, 1978). For dry toilets, the nutrient-rich urine and feces fraction was spread on agricultural land. This practice meant that a large share of the nutrients was cycled at the farms and that emissions of nutrients to waters were low. This was in stark contrast to the early OSS which consisted of, at best, a simple sludge separator and pipes transferring the wastewater to the nearest watercourse (Egnahemsstyrelse, 1942; SOU,

¹ On-site sewage systems are in this thesis defined as systems treating wastewater from kitchen, washing machines and bathrooms, and the urine and feces fraction of household waste, whether water-based or “dry” means of treating this waste fraction are applied. On-site sewage systems handle sewage from one or a few households.

1955). The limited *nutrient capture capability*² of these early treatment technologies, illustrated through Figure 1, led to drastically decreasing overall nutrient capture capability of Swedish OSS.

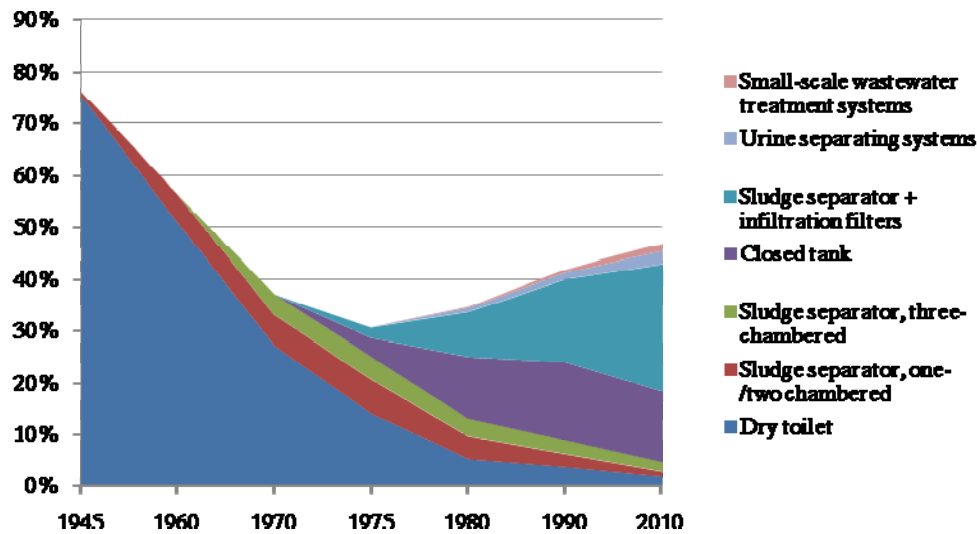


Figure 1 Estimated overall nutrient capture capability of Swedish OSS between 1945 and 2010 as a result of an increasing use of water-based treatment and differences in applied treatment technologies over time³. The figure illustrates the case of phosphorous.

The application of gradually improved infiltration-filters led to somewhat increasing nutrient capture capability of Swedish OSS, foremost from the 1970's and onwards (SOU, 1955; SNV, 1974; SEPA, 1987; Christensen, 2003; SEPA, 2003). However, the nutrient capture capability of infiltration filters decay with time. Moreover, few homeowners have in the past maintained or improved the function of their OSS. Therefore, the nutrient capture capability of older OSS, in particular those installed more than 30 years ago, are estimated to be poor (Ek et al., 2011). The introduction of closed tanks, where the sewage is treated at the municipal wastewater treatment plant, contributed to a higher nutrient capture capability, since the nutrient removal rates of urban WWTPs are high compared to, e.g., infiltration (SEPA, 2009c). Also the urine separation and composting toilet systems and the increasingly common small-scale wastewater

² Nutrient capture refers to the inherent property of an OSS to capture nutrients, that is, avoid nutrient loading of ground or surface waters. Nutrient capture is determined by the OSS components at the level of the property. In some cases other system boundaries should be applied when calculating nutrient capture capability, for example, when sewage from closed tank is treated at the municipal WWTP, or when urine and feces fractions are spread on agricultural land (Lundin, et al., 2000).

³ Following data were used: statistics on installed dry toilets and WCs (Socialstyrelsen, 1952; Bostadsstyrelsen, 1965; SCB, 1974; 1978), currently used technologies and estimates of nutrient capture for currently used technologies (Ek, et al., 2011), phosphorous leakage from open storage of urine and feces and spreading on agricultural land (Miljöskyddsutredningen, 1983), nutrient capture capability of urban WWTP (SEPA, 2009c). Important assumptions: for “disappearing” dry toilets and new OSS, the technology as specified in regulations of the time is used, closed tanks are assumed to be applied mostly during the 1970's and 1980's, and urine separating systems and small-scale WWTP are assumed to be applied from the 80's.

treatment plants (Sw. “minireningsverk”) are contributing to higher nutrient capture capabilities, the latter as long as they are properly maintained (Ek et al., 2011). The technologies applied historically have therefore led to the current situation with relatively low nutrient capture capability, compared to the levels of the 1940’s.

The large-scale transformation to WCs and piped water and wastewater, starting in the 1940’s, can be seen as a successful transformation of a large socio-technical system, initiated and largely driven by governmental interventions. The government aimed for improved living standards in the countryside, in terms of hygiene, and intervened through substantial subsidies to homeowners that covered a major share of the installation cost (Statens Egnahemsstyrelse, 1942). With time it is very likely that homeowners saw the benefits of the WC, for example, the increasing convenience. When this coincided with governmental interventions a strong momentum for technical change was very likely created.

However, with the discovery of eutrophication and a growing insight that OSS are increasingly important contributing sources of nutrients, the unintended environmental consequences of this transformation have become problematic. Actions have since the 1960’s been taken by policy and management actors to improve OSS to meet environmental protection goals, e.g., through the first environmental protection legislation that was introduced in 1969 (MoE, 1969). Since then, regulations for increasing nutrient capture of OSS have been developed and implied stricter requirements. However, this has not implied that many homeowners with existing OSS have changed their OSS. In 2004, up to 60% of Swedish OSS was estimated to be insufficient compared to current regulatory standards (Ejhed et al., 2004)

More recently, environmental legislation and regulations of OSS have been strengthened and the local health and environmental protection authorities have more opportunities to control the function of OSS than in the past (Christensen, 2003). Regulations, supposed to guide the enforcing authorities and ultimately implying rules for how individual homeowners should behave are stricter than before (SEPA, 2006; 2008a; 2008b). Furthermore, other policy instruments aiming to motivate and inform homeowners to improve OSS exist, including a tax reduction applicable to OSS (MoF, 2008) and a national information campaign (SEPA, 2009a). These institutional changes and applied policy instruments may imply that there is now a higher pressure on homeowners to change OSS. However, it is uncertain whether these efforts are sufficient to match the scale of the environmental problem, that is, if the nutrient capture capability of Swedish OSS will become sufficiently high in the long-term. Technically, this will depend on, for example, the rate by which existing old OSS are substituted by technologies

with higher potential for nutrient capture, the extent that infiltration-based technologies are prevailing and the rate at which these are maintained.

The transformation of OSS towards decreasing nutrient loads depends ultimately on whether homeowners change OSS so that higher nutrient capture potentials of higher performing treatment technologies are realized. However, to install an OSS brings with it high costs that have to be paid by the individual homeowners. At the same time, there is little to gain for individual homeowners from changing their OSS. Furthermore, the benefits such as a cleaner sea are largely collective and may be difficult for homeowners to perceive. From an individual homeowner's point of view it may therefore be completely rational not to change OSS, at least in a short time horizon. Therefore, a transformation of OSS is dependent on, at least partly, the presence and effectiveness of institutions, e.g., through regulatory enforcement (by the local environmental protection authorities). If homeowners followed existing rules, nutrient loads would be substantially lower. This is, however, far from being the case at the moment.

1.1 Research idea

The research presented in this thesis builds on the rationale that if the environmental problems are caused by the actions of societal actors, then societal interventions aiming for mitigation of the same environmental problems must be based on knowledge about what influence the behaviors of societal actors. Elaborating on this rationale it is possible to describe a system of connected actors, influencing factors, actions and the resulting environmental pressures. There will always be one action that directly causes the environmental pressure, an action that most often implies the use, or change, of a technical system. Actions are proximately caused (Geist and Lambin, 2002) by an actor situated at the interface between the socio-technical and the ecological system. Combinations of proximate causes and underlying drivers influence actors' behaviors, in turn influencing environmental pressures. Importantly, the actions taken by actors at the interface can be influenced by other actors, which thereby influence, indirectly, the environmental pressures of the technical system.

Here, the actor of proximate cause is defined as the homeowner and the action with environmental pressure as the change of OSS. Influencing factors are investigated in a multi-level perspective which implies, for example, that the authority inspector, an actor with indirect influence on environmental pressure from OSS, is also included in the analysis.

1.2 Research aims and approach

The aim of the research is to:

- identify factors influencing homeowners' to change OSS
- investigate the relative strength of these factors

A sub-aim is also to investigate the effect of interactions between the homeowner and current government and authority interventions, including regulatory enforcement actions. Through the investigation of factors that make homeowners change OSS, it is possible to reason about the effectiveness of different interventions.

The research approach (illustrated in Figure 2) can be described as being initially explorative and less influenced by theory in the first round of observations, leading to a first tentative conceptualization of influencing factors (Paper I). The tentative conceptualization is then expanded, using theory, and tested in a second round of observation and analysis (Paper II).

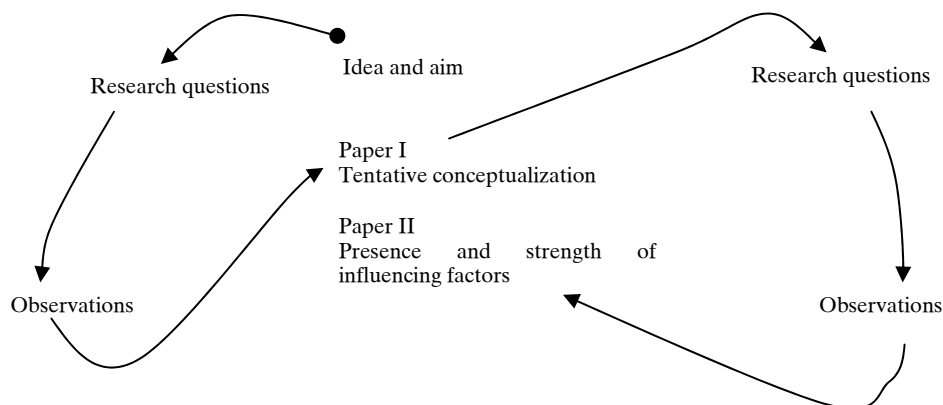


Figure 2 The research process described as two iterations, leading to a first conceptualization of influencing factors in Paper I, and a reworked conceptualization and quantification of relative strength of influencing factors, in Paper II.

Paper I uses interviews with homeowners and inspectors to identify factors influencing homeowners to change OSS. The paper discusses the perceptions and the reasons related to taking action, of homeowners and inspectors. Furthermore, the influences between homeowners and local regulatory authorities are investigated.

Paper II used the findings from Paper I to develop a questionnaire that surveyed Swedish homeowners using OSS. The paper investigates the role of different government and authority interventions and a broad set of motivational factors that may explain homeowners' behaviors. A theoretical framework was developed, expanding on the findings in Paper I, and was used to develop measurement scales. Statistical methods were applied to identify and investigate the relative strength of the influencing factors.

1.3 Thesis outline

The organization of the thesis is as follows. Chapter 2 introduces previous research into influencing factors, and the main concepts and theories utilized in the thesis. Chapter 3 describes the methods used in Paper I and Paper II. Chapter 4 summarizes the main findings from Paper I and Paper II and discusses these findings in relation to previous research. Chapter 5 presents the conclusions while Chapter 6 proposes further research. Finally, Chapter 7 discusses the implications for policy and management of OSS.

Paper I and Paper II are appended to the thesis.

2 THEORETICAL BACKGROUND

Many environmental problems and challenges that society face can be seen as social dilemmas (Hardin, 1968; Ostrom, 1990). A fact that increases the complexity of management of environmental resources is that social dilemmas often include a temporal component. They can, therefore, be regarded as social traps (Platt, 1973) where the gain derived from a particular behaviour, i.e., action or inaction, is experienced immediately by the individual. At the same time the negative consequences for the collective are occurring at much larger tempo-spatial scales. In the context studied in this thesis the individual homeowners gain from choosing not to change OSS, i.e., avoid costs by inaction, while the consequences of increased nutrient loads that cause marine eutrophication is shared by many over a long period of time.

In this thesis a broad view is applied on factors influencing individuals' behavior in general and environmental behavior in particular. Theoretically, factors constituting the sources of variability regarding individuals' environmental behaviors are of two kinds (Fleeson, 2004; Funder, 2006). Factors can, e.g., relate more to person and be stable across situations and 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. That said, in this research, individual differences will not be studied in specific detail with respect to, e.g., traits, or with respect to subtle situational aspects.

Factors of interest can partly be found in previous research on homeowners' environmental behaviors. There are, for example, quite a number of studies investigating homeowners' investments in heating systems and energy-efficiency measures (e.g., recent studies by Mahapatra and Gustavsson, 2010; Nair et al., 2010; Sopha et al., 2010; Christie et al., 2011; Nair et al., 2012). These studies relies foremost on Ajzen's (1991) Theory of Planned behavior or other theories based on rational choice (e.g., Rogers, 2003). However, since the behavioral context is of great importance for how individuals will behave (Lindenberg and Steg, 2007; Steg and Vlek, 2009), the transferability of findings from these cases to the case of OSS can be questioned. In the case of energy-related behaviors, choosing an environmentally benign behavior almost always imply a return on investment that balances the cost. Homeowners also have the freedom to choose whether to invest in a new energy system or not. In contrast, in the case of changing OSS, the behavioral context is defined by high costs and no, or very low, personal benefits. Furthermore, legislation, regulations and regulatory enforcement are likely important contextual factors in the case of OSS. Certainly, homeowners may choose to voluntarily change OSS, but this has not occurred to any significant extent.

Thus, factors showed to be important in previous research on homeowners' energy-related environmental behavior may not be applicable in the case of homeowners' changing OSS. Therefore, a broader view on influencing factors is taken, using a recent theory of environmental behavior. This theory – goal-framing theory – suggests that multiple goals influence human behavior. The theory is suggested useful to explain environmental behaviors (Lindenberg and Steg, 2007; Steg and Vlek, 2009; Huijts et al., 2012), but also to explain compliance behaviors (Etienne, 2011). As evident from the fact that less, or no, private benefits may exist in the case of OSS, this study also included factors of importance for compliance and cooperation.

2.1 Goal-framing theory, influence of multiple motives, and interactions of motive and context

Goal-framing theory (Lindenberg and Steg, 2007) suggests that multiple goals, or motives, guide individuals by influencing how information is perceived, considered and acted upon. Individuals may enter a situation with a certain goal-frame, that is, one goal will be the strongest and be in the foreground, and will guide individuals more than other goals. Goals may also play a background role, weakening the influence of the foreground goal. However, goals can change roles and strength depending on, e.g., changes in incentive structures or of physical barriers. There are, according to Lindenberg and Steg (2007), three overall categories of goals:

- hedonic, “to feel better right now”
- gain, “to guard and improve one’s resources”
- normative, “to act appropriately”.

Lindenberg and Steg (2007) suggest that environmentally detrimental behaviors originate from acting in line with hedonic and gain goal-frames. Pro-environmental behavior often depends on some degree of activation of normative motives, but may need strong external support in the form of, e.g., institutions (i.e. legal structures, regulations etc), to influence behavior. In high-cost situations, the expectation is that gain goal frames are the strongest, while normative motives play a background role. In such situations, interventions can support both gain and normative motivation through introducing, e.g., sanctions. Sanctions may simultaneously weaken the gain goal through introducing costs and strengthen normative goals through indicating appropriate behavior. 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 behavior. Interventions can then aim to encourage taking action by improving infrastructures, taxing current behavior or introducing rules. However, while heavy

constraints may be effective and increase predictability of behavior, they can also lead to resistance to act and to denial strategies (Lindenberg and Steg, 2007).

Engaging in environmental behaviors can also depend on whether individuals perceive a behavior to be effective in reducing environmental impact (Lindenberg and Steg, 2007), or in other words, if they are efficacious. Such perceptions are suggested to be important for the activation of environmental norms, though more so in low-cost than high-cost situations. Efficacy can more over relate to the degree that people perceive that they have control over their 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. In other words, it is important for the individual that regulations have their intended effects, even in cases where these may not be directly perceivable by the individual. Lindenberg and Steg (2007) suggested that a strong gain frame, in particular in high cost situations, can be manifested through self-serving argumentation, that is, individuals will try to find arguments that support acting in line with their self-interest. That way, for example, environmental norms may be weakened through a more or less active ignorance of environmental consequences, or, through diminishing the possibility of averting these consequences. It is therefore an empirical question whether perceptions related to effectiveness of behaviors, reflect a defensive strategy to maintain a goal frame, or, reflect actual perceptions.

2.2 Trust, trustworthiness judgments and fairness – factors influencing compliance and cooperation

The influence of government and authority interventions may depend on various aspects of the relation and interaction between regulators and regulated persons (May and Winter, 1999; Levi and Stoker, 2000; Winter and May, 2001). The extent that individuals trust, in other words, make themselves “vulnerable to another individual, group or institution that has the capacity to do [them] harm or to betray [them]” (Levi and Stoker, 2000), influences their willingness to comply with regulations. Trustworthiness, that is, a more specific judgment of a trusted person’s “commitment to act in the interest of the truster” and the competence to act so can also be influential (Levi and Stoker, 2000). Judgments of trustworthiness are based on perceptions of whether procedures are fair, including authorities acting in a fair and consistent way. Considerations of fairness can furthermore relate to whether others comply with regulations (Levi and Stoker, 2000; Winter and May, 2001). This is similar to fairness as a condition for taking action (Johansson and Svedsäter, 2009).

It is according to Levi and Stoker (2000) particularly trustworthiness judgments of specific authorities that matter for compliance, rather than more general trust judgments. In addition, in the specific interactions between regulators and regulated persons, if mutual trust is achieved this may increase the level of compliance. In practice, mutual trust can be promoted if regulators convince the regulated that they trust them to comply, and even more so in situations where there is little to gain for the regulated person. This is one of the reasons why informal and persuasive approaches can potentially achieve more positive responses from individuals than more formal and coercive enforcement approaches. Winter and May (2001) and May and Winter (1999) showed that informal approaches do have influence on the levels of compliance and may be as influential as more formal approaches. Thus, there is reason to study the actual enforcement activities in terms of informal and formal means of enforcement, as differences in enforcement approach may matter for compliance.

3 METHODS USED IN PAPER I AND PAPER II

3.1 Paper I

The objective in Paper I was to explore homeowner decision processes for categories of factors influencing change of OSS. Further, the inspector-homeowner interactions were explored to some depth, since regulations and regulatory enforcement actions was expected to be an important influencing factor.

The study included 12 homeowners and five environmental protection authority inspectors in three municipalities. The municipalities were chosen to gain a variation in the geographical location (west coast, east coast), OSS policy, size, and the extent to which they had worked or were currently working actively with inspections of existing OSS. Homeowners were taken, in order of appearance, from lists provided by local environmental authority inspectors to include homeowners who had changed OSS recently (i.e. the past two years) or were possibly about to change OSS (i.e. had been informed by an inspection campaign within the past two years). After 12 interviews had been made it was perceived that saturation was reached, that is, the last interviews did not contribute with essentially new aspects.

The interviews were semi-structured (Kvale, 1997), using open-ended questions and letting the informants influence the direction of the conversation. However, the informants were also guided using topics decided on beforehand. For homeowners, topics included open questions about the reasons to why homeowners had changed OSS or were going to change OSS, their experience of and reactions to different policy and management actions that had reached them. Further questions related to alternative OSS; if they had considered changing OSS, and if so, how they had gone about finding out about alternatives, what their opinions were about alternatives, and what had been important in forming an opinion about different alternatives. For authority inspectors, interview topics included open questions about their choice and implementation of enforcement strategies, and barriers and opportunities to enforce regulations. Prior to the interviews, interviewees were informed about the research and the participation via a letter, and were then contacted by phone and asked to participate. About half of the homeowners who were contacted by phone accepted to participate. Homeowners participated anonymously. All contacted inspectors accepted to participate. The interviews were recorded and transcribed before further analysis. During two interviews with homeowners, the recorder failed to start. Notes were in those cases taken immediately after the interview. The interviews with the homeowners were held in their homes, or workplaces, while the inspectors' were interviewed at their workplaces.

The analysis of data can simplistically be described as a process where the thematic structure was built from data, but was also inspiring the search for concepts and theory in literature. The found concepts and theories inspired further analysis and led to adjustments of the thematic structure. Thus, the thematic structure was emerging from data, but was also influenced by theory.

3.2 Paper II

In Paper II, a set of candidate factors influencing the intention to change OSS and the actual change of OSS was developed and tested, using questionnaires (Esaiasson et al., 2009). The development of questionnaire items was based on the initial understanding of influencing factors developed in Paper I and a minor review of previous research on pro-environmental behavior and compliance behavior (presented in Chapter 2 of this thesis).

The questionnaire was sent to Swedish homeowners with OSS on their property (N=3630), randomly sampled from the Real Property Register (Sw. Fastighetsregistret). No rewards were given to respondents. The response rate after two reminders was 42%, after cleaning the dataset from homeowners who appeared to have connection to the municipal WWTP and had built a new house and therefore installed a new OSS (N=1481). In terms of represented technologies, the sample was similar to available estimates on currently used technologies (Ek et al., 2011), implying that the sample can be considered representative of the population.

The analyses of data were done iteratively by first exploring patterns in data and then establish a strategy of analysis. Descriptive statistics, cross-tabulations, correlation analyses, comparison of means and their associated test statistics was used, as well as principal component analysis (PCA) (Costello A. B., 2005; Eriksson et al., 2006; Djurfeldt and Barmark, 2009).

A few remarks can be made regarding the use of PCA and the connection between the results of the PCA and the following regression analysis. In PCA, latent structures in data are given by the principal components. Here, PCA was applied on the questionnaire items that corresponded, more or less directly, to different motives. The principal components that resulted from applying PCA, was used to form “new” motivational factors. These factors were developed to be similar in content, internally consistent (Cronbach’s Alpha 0.6-0.9) and to only include items that had large contributions to the principal components (factor loadings > 0.5). Items that did not contribute to any principal component were eliminated and are not included in the results. The validity of the principal component models was tested by first developing a principal component model on half of the sample (based on a random split) and confirming the model components on the other half. Through this process of analysis, the motivational factors

used in further analysis were partly defined by the prior theoretical concepts, but were also adapted to actual patterns in data.

The approach implies that questionnaire items may be eliminated because they coincidentally correlate with other items, or when items are too few to become stable components. The latter can occur because errors such as imprecise measurements and noise can suppress “singular” items (i.e., items that have little in common with many other items). Therefore, the correlations between the eliminated items that were conceptually different from the “new” motivational factors and intention to change OSS were checked before excluding the eliminated items from further analysis. Items that had high correlation but were conceptually different from the motivational factors were therefore included in further analysis (one of about ten was added).

The motivational factors resulting from the PCA were used to explain variation in intentions to change OSS, using regression analysis. Items measuring presence of interventions (e.g., inspections and tax reductions), past change of OSS, and homeowner characteristics (i.e., age, income) were used as control variables in the regression analysis.

4 RESULTS AND DISCUSSION

4.1 Influence of authorities and other actors

Regulatory enforcement, as experienced by homeowners, can be both informal (i.e., awareness-raising information, recurring communication, recommendations to change OSS) and more formal (i.e., injunctions and sanctions) (Paper I).

As expected, authority interventions, in the form of injunctions, were highly associated with change of OSS (Paper II). Information alone (i.e., without receiving an injunction) was weakly, but significantly, associated with change of OSS. Further, in the regression analysis, interventions explained quite a large share of the variability among homeowners with respect to readiness to change OSS. The influence of informal enforcement on compliance has been shown to be influential in other studies (Winter and May, 2001), and has in previous research been attributed to the activation of personal norms (Winter and May, 2001; Lindenberg and Steg, 2007). As will be discussed in next section (4.2), these findings imply some evidence for the activation of personal norms among homeowners who have changed OSS, but not among homeowners in general.

The enforcement approach chosen by inspectors may cause both positive and negative reactions from homeowners. Confronted with inspections and more or less explicit-made demands to change OSS, homeowners may perceive themselves threatened to take action, but also that there is some possibility to influence the process of change (Paper I). As discussed, by Ölander and Thøgersen (1995), homeowners feeling coerced to behave in a certain way, will probably lead to lower readiness to take action. On the other hand, if homeowners feel they can influence the process of change they are probably more positively oriented towards changing OSS. Such reactions are also influenced by the perceptions, and the awareness, of the consequences of their behavior (Winter and May, 2001). If homeowners do not perceive that there are any problems with the current function of OSS, they will likely perceive deterrent means of enforcement as threats and question the authorities' demands for action. A fine-tuned analysis of differences in enforcement approaches on homeowners' intention has not been done here and is an issue for further research.

Levi and Stoker (2000) suggested that by showing regulated persons that they are entrusted, levels of compliance may increase. Current enforcement, as reported by the interviewed inspectors (Paper I), aims for a transfer of the responsibility to take action to homeowners. This approach may be of the entrusting kind that increases the chances for compliance and

maintains sound relations between authorities and homeowners. Thus, homeowners' responses to enforcement actions are not only influenced by the instrumental flows of information, but also by how such messages are communicated. Also these preliminary findings suggest that current enforcement approaches should be studied in more detail than what is done in this thesis.

So far, the influence of inspectors' actions on homeowners' behavior is discussed, but homeowners' responses may also influence inspectors' decisions. Homeowners' responses to regulatory enforcement actions may influence how strict requirements are posed by inspectors (Paper I). As Paper I indicates, inspectors may not always enforce the strictest requirements that are possible given current legislation and OSS regulations. The general influence of regulated persons on regulators' actions have been highlighted before, e.g., that complaints may influence enforcement (May and Winter, 1999). Such feedback loops may be of particular importance here, where there is considerable room for authorities to interpret and to choose how to enforce regulations (Bengtsson, 2004). Differences in enforcement can be attributed to local physical-environmental conditions (i.e., sensitivity of environment and soils), individuals requisite resources and opportunities, and the availability of enforcement resources (Paper I). The evidence for this kind of adaptation is not strong in this thesis, but the results indicate a possible negative feedback that should be considered when judging the effect of changes in legislation and regulations.

Other policy instruments having the purpose to instigate homeowners to change OSS exist, including tax reduction, a national information campaign and the OSS knowledge bank *Avloppsguiden* (directed to OSS sector actors, including homeowners). These policy and management actions were tested in Paper II but could not explain homeowners' intentions and actions. Tax reductions, for example, can be suggested to act as "carrots" that stimulate homeowners to change OSS. However, this does not seem to occur in this thesis. This may be explained by the relatively small reduction in investment costs of about 10-30%. Thus, the cost-benefit ratio is still low after the tax reduction and may explain the weak influence on homeowners in general. Possibly, tax reductions will instigate change only in combination with regulatory enforcement. Then, the reduced costs by tax reductions may act to make gain-motivated homeowners more positively oriented to change OSS (the strong influence of gain-goals is discussed in section 4.2).

Besides the local environmental authorities, construction contractors and close acquaintances are important sources of influence when homeowners change OSS (Paper II). Not surprisingly, environmental authorities are stated to be the most important, followed by construction

contractors and close acquaintances. Notably, the importance of these information sources varies between homeowners. The influence of these types of actors have been shown important in studies of homeowners' investments in energy technologies (Mahapatra et al., 2011) and studies of farmer behavior (Edwards-Jones, 2006). These source of influences are largely ignored by the literature on pro-environmental and compliance (e.g., Winter and May, 2001; Steg and Vlek, 2009).

4.2 Influence of motives

In the regression analysis of the readiness to change OSS (Paper II) it was found that the most important motive was gain (cf. goal-framing theory in Chapter 2.2) followed by fairness concerns (i.e., homeowners change OSS if others do so as well). Environmental concerns had only weak effects on readiness to change OSS, while the effects of political trust, and trust in actors "at the action level"⁴ were insignificant.

The importance of the gain 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). The results of the regression analysis showed that a factor describes as benefits (interpreted broadly) had a strong effect on homeowners readiness to change OSS. Furthermore, when people are in a strong gain goal frame they will spend much effort to find arguments for not behaving environmentally-friendly (Lindenberg and Steg, 2007; Steg and Vlek, 2009). For example, homeowners may not acknowledge arguments supporting a change of OSS. Such tendencies were found in the results. First, the more homeowners perceived themselves to be efficacious in relation to the environmental load, the less ready to change OSS were the homeowners. Second, the more the homeowners perceived themselves to be more efficacious with a changed OSS in relation to the environmental load, the more they were ready to change their OSS. However, the effect of the perceived increase in efficacy with a changed OSS was relatively weak. These results regarding capabilities to control environmental consequences indicate that homeowners exaggerate the treatment function of current OSS, and underrate the potential of a changed OSS. This would support the idea of a more or less conscious process of creating self-serving arguments to engage, or not engage, in a behavior, particularly important when the gain goal is strong (Kunda, 1990; Lindenberg and Steg, 2007).

Several observations strengthen this interpretation. Since a recent change of OSS was controlled for the overestimation is not simply explained by homeowners that have changed

⁴ I.e., actors that homeowners may interact with during the process of change, such as close associates and construction contractors.

OSS and are not willing to change again. Furthermore, the results shows that homeowners are very satisfied with the performance of current OSS, and do not perceive that a change of current OSS lead to increases in effectiveness, e.g., that environmental impacts are reduced. This is at odds with the knowledge about currently used OSS. The survey by Ek et al. (2011) shows that the function of a majority of currently used OSS technologies are poor. Furthermore, it is known that for a majority of the current OSS the performance decrease over time (SEPA, 2003; Ek et al., 2011). It is thus very likely that homeowners overestimate the function of their OSS and to some extent, underestimate the function when their OSS is improved. Alternatively, homeowners may simply have a low awareness about the consequences of using OSS. The latter interpretation offers more hope concerning the potential of persuasive means of enforcement to make homeowners change OSS, e.g., by raising awareness about environmental and other consequences.

Fairness motives can be highly influential in resource dilemma situations. Such motives showed to be important in this thesis. Previous research describes distributive fairness as aversion against inequalities (Wilke, 1991; Fehr and Schmidt, 1999; Johansson and Svedsäter, 2009). Three distinct motives emerge; advantageous inequality aversion (i.e., aversion against getting more than others), disadvantageous inequality aversion (i.e., aversion against getting less than others), and third-party inequality aversion, (i.e., aversion against differences in outcomes between others). The results showed the first two kinds of fairness motives. First, fairness was important in the sense that homeowners tend to be ready to change OSS under the condition that other change OSS. This kind of fairness can be understood as if people are constrained in their decision-making and do not only want to maximize their own outcomes, but also achieve fair outcomes (Wilke, 1991). In other words, since people want outcomes to be fair they will not try to get away if others are cooperating. This fairness motive had a relatively strong effect on readiness to change OSS.

Second, a different fairness motive emerged. This motive can be described as the adherence to a principle of no exceptions from equality, no matter the circumstances (e.g., quantity of emissions or ability to pay). This kind of fairness motive is similar to what has been discussed as disadvantageous inequality aversion (Fehr and Schmidt, 1999), in other words, individuals cooperate when they perceive that others are not getting away, and do not cooperate when they perceive that others get away, no matter the circumstances. This type of fairness had, however, only a weak influence on readiness to change OSS.

Environmental concerns were among the motives that were only weakly correlated to readiness to change OSS. While it is expected that norms should not be the most important

motive, it is somewhat surprising that the influence of environmental concerns is weak and barely significant. Literature on pro-environmental behavior often stipulate that pro-environmental behavior relies on the activation of norms, including environmental concerns, even though the influence should be expected to be relatively weak, particularly in situations of high costs and low benefits (Lindenberg and Steg, 2007). From an environmental policy point of view this finding may be problematic, since environmental protection is one of the main purposes of the OSS legislation and regulations.

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 behavior have shown that moral obligation can be an important explanatory factor of regulatory compliance (Winter and May, 2001). However, among homeowners in general, the PCA did not result in any factor corresponding to personal norms. The weak influence of personal norms can be explained by the strong gain frame that makes homeowners explain away the influence of personal norms. The perceptions that would be noted by homeowners, if personal norms were influencing behavior, are precisely those that homeowners seem to be reluctant to acknowledge. That is (as was discussed earlier in this section), homeowners tend to overestimate the performance of their current OSS and underestimate the improved performance if the OSS is changed. Possibly, the weak influence of norms has also to do with the fact that transformation of OSS towards decreasing nutrient loads is still in its infancy, and more homeowners need to change OSS in order for OSS-specific norms to increase in importance.

The fact that personal norms was only present among homeowners who had changed OSS, can also be attributed to post-justification of the made decision to change OSS (Festinger, 1976; Kunda, 1990). That is, homeowners may choose to find justifications that suit the conclusions they want to arrive at. If this is the case, this would strengthen the interpretation that personal norms are not strongly influencing behavior in this thesis. In studies like this one, it is however difficult to distinguish between the activation of personal norms, e.g., due to authority interventions preceding change, and post-decision adjustments.

5 CONCLUSIONS

The thesis has identified and also quantified factors influencing homeowners to change OSS. It was concluded from both interview and survey data that authority interventions, most likely inspections, are needed to make homeowners change OSS. Homeowners who have been affected by inspections have to a large extent changed OSS, while homeowners who have not been affected by inspections, have to a very small extent changed OSS. Information means may instigate change, but will not likely lead to a large-scale transformation of OSS. They may, however, be useful in combination with more deterrent means of regulatory enforcement, such as injunctions.

It was found that the most influential goal of homeowners was the gain goal. Homeowners in other words act to defend their self-interest and this frames how homeowners perceive, interpret and act upon information. The strength of this motive is manifested in an attention to costs and benefits and in homeowners' judgments of their capability to achieve low environmental impacts with their current OSS and with a changed OSS. In addition, a fairness motive appeared to be relatively strong. This fairness motive implies that homeowners will not try to get away when they perceive that others are cooperating. Environmental concerns have only a weak influence on homeowners' behavior. Because of the strong gain-goal, interventions become important to make homeowners take actions that can lead to higher the nutrient capture rates.

In relation to goal-framing theory this thesis makes two contributions. First, the claims of goal-framing theory have mostly concerned low-cost situations such as electricity use, and high-cost situations such as energy investments. These are situations where there clearly are individual economic benefits of choosing a behavior with positive environmental consequences. In this thesis goal-framing theory was applied in contexts that are characterized by high costs and no, or at least very low, individual benefits, and where the most important interventions are rules and regulatory enforcement actions. Further, goal-framing theory as presented by Lindenberg and Steg (2007) describes persons to be guided by three broad categories of goals and that there may be sub-goals related to these. In addition to the motives as described by Lindenberg and Steg (2007) a relatively strong fairness motive was found. This motive can be described as a willingness to engage when outcomes are fair, that is, when others are cooperating. This fairness motive can be seen as a sub-goal of normative motives.

6 FUTURE RESEARCH

An immediate issue for future research is to study interaction effects between interventions and between interventions and motives. First, there is a need to investigate the effect of interaction between different kinds of interventions on readiness to change OSS. An example is the interaction between authority inspections and tax reductions. This would strengthen the findings regarding the effectiveness of different interventions and the recommendations for policy and management. Second, there is a need to investigate the effect of an interaction between interventions and motives on readiness to change OSS. This regards, for example, the interaction between information interventions and personal norms. In order to study the influence of information and the previously discussed activation of personal norms, further empirical investigations may be needed.

Trust-related factors were only weakly correlated with homeowners' readiness to change OSS. A reason may be that more distal factors will have less influence on behavior in high-cost situations. I speculate that trust, trustworthiness judgments, and perceptions of fair procedures relate more to the acceptance of the regulatory system as such, rather than to readiness to change OSS. In other words, homeowners may accept the regulatory system, but when it comes to personally taking action homeowners may not be willing to comply. It may therefore be fruitful to in more detail investigate the relationships between trust-related factors and acceptance of the regulatory system.

It would be interesting to take further steps towards a formal modeling of influencing factors that enables reasoning about the effects of current, but also future, policy and management actions. The results of the initial studies presented in this thesis can be used for elicitation of model structure and quantification of model relationships.

One possible modeling approach is to use influence diagrams and extensions thereof (Pearl, 2000; Kjaerulff and Madsen, 2008). Influence diagrams may be a useful approach to represent knowledge about causes and effects and explicitly acknowledge the uncertainties related to, e.g., efforts to govern social systems. The explicit consideration of causal relationships and of uncertainties, make this kind of approach suitable for reasoning and decision-making under uncertainty. Many applications are found in resource and environmental management, e.g., assessments of effects of management actions on environmental outcome (Kuikka et al., 1999; Uusitalo, 2007; Barton et al., 2008). There are also examples of applications where actors are included into the models, e.g., land managers' conservation behavior (Bacon et al., 2002;

Aalders, 2008; Ticehurst et al., 2011) and fishers' commitment to restore fish stocks (Haapasaari et al., 2007).

Having established a formal model, there are two principal directions that can follow. First, model validity can be tested by further data collection within the empirical field of OSS. Second, model validity can be tested by investigating other empirical fields where the decision structures are similar but the particular contexts are different.

In conjunction to the above research areas, I perceive a need to further study the factors influencing authority inspectors' actions. One question regards whether the suggested influence from homeowners on inspectors' judgments is valid for municipalities in general. Other factors influencing inspectors' implementation practices can be, for example, the degree of authority and the available resources for enforcement (Eckerberg and Forsberg, 1996). One interesting question is whether other institutional arrangements, such as environmental protection authorities run by several municipalities in cooperation, might strengthen the transformative capacity of authority inspectors, by making them less susceptible to influence from, for example, complaints from homeowners and political pressure.

7 IMPLICATIONS FOR POLICY MAKING AND MANAGEMENT

The results of this thesis show that authority interventions are needed to make the majority of homeowners change OSS. However, given the strength of motives related to self-interest there is a risk that homeowners react negatively to strong deterrent means. It is likely that injunctions and sanctions that are “kept in the background” can serve as means to deter homeowners. This approach is also likely to make homeowners choose to comply “semi-voluntarily” at earlier stages of the inspection process. Information and communication is not sufficient to make homeowners change OSS, but may have a role to keep the change process going and make homeowners realize that there is no other options than to comply and change OSS.

The results regarding motives behind changing OSS have some implications regarding how to approach homeowners during enforcement. Concerning the fairness motive related to equal outcomes, it is important to *ensure* that all homeowners take action and *assure* homeowners that this is indeed the case. A difficulty may reside in the fact that the pace of inspections is low, and homeowners may therefore perceive uncertainty about whether other homeowners are taking, or will take, action. Therefore, there is some uncertainty about the possibilities of utilizing this motive.

The results indicate a tendency that homeowners overestimate the effectiveness of their current OSS and underestimate the effect of changing OSS. This calls for efforts to raise awareness of the problems associated with the current OSS and to make efforts to come to an agreement with homeowners about the merits of changing OSS. The weak influence of environmental concern indicates that there is only some room for persuading homeowners with environmental arguments. Environmental concerns were, however, more important in a longer time perspective. Homeowners may therefore have some insight into the consequences of their OSS, and are possibly open to the possibility that a change of OSS may be needed – at least in a more or less far future. Taken together, these results indicate that the emphasis should be more on information valid to specific homeowners’ OSS, and less on environmental information in general.

The results also showed that the most important sources of information were authority inspectors, contractors and close acquaintances. From the point of view of instigating change through raising awareness, it may therefore be important to raise awareness not only among homeowners, but also more generally in the OSS sector. Of particular importance are the

construction contractors. Thereby the chances for converging worldviews will increase and uncertainties concerning the change of OSS may decrease.

The tax reductions, introduced in 2008, do not seem to have any strong influence on readiness to change OSS among homeowners in general. The potential of this economic instrument to act as a "carrot", can therefore be questioned. There is also a risk that economic instruments act as a cue making homeowners focus even more on the economic aspects of changing OSS. Nevertheless, it is possible that a tax reduction may make homeowners *less reluctant* to change OSS in the situation when their OSS is inspected by the environmental authorities.

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