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**Down with the flow: public debates shaping the risk framing of artificial groundwater recharge**

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*Abstract*

Securing high-quality potable water is a key challenge for all societies. The question is not only about water availability and quality determined by hydrological, chemical, and biological factors, or technologies and monetary assets, but also about various cultural, social, and political factors that together constitute so-called hydro-social cycles. We focus on risk communication and management, in connection with the debates on planning and construction of an artificial groundwater recharge system in the Virttaankangas esker, aiming to provide potable water for the region of Turku, southwest Finland. Based on print media coverage, online debate, and comments on the environmental impact assessment report, we identify key themes and framings of risk debates and discuss which elements of the hydro-social cycle are prone to be highlighted or omitted. Our results show how different framings of risks and benefits are represented with regard to geography, time span, causative agents, impact types, those exposed, alternative management options, and uncertainties involved. Representations created both by traditional print media and new social media polarise the debate. The adoption of the concept of the hydro-social cycle in planning and communication processes may help in understanding and alleviating polarisation.

*Keywords*

Contaminants; Managed aquifer recharge; Mercury; Newspaper; Social media; Water quality

**Introduction**

Water scarcity emerged as a large-scale problem for human well-being during the 20th century. Over a third of the world's population currently suffer from chronic water shortage, largely because of population growth, urbanisation, and inefficient use of water (Micklin 1996; Kummu et al. 2010). Various water management and conservation schemes have been implemented in order to address the present and future water crises and challenges. Non-conventional water sources such as desalination of seawater, reuse of drainage water for agriculture, recycled effluents for potable water supply, closed industrial water systems, and rain and fog water collection applications have been developed (Klemm et al. 2012; Opare 2012; Meehan et al. 2013). They have been tested and implemented mainly in arid regions suffering from absolute water scarcity. However, availability of high-quality water is an issue affecting other regions as well. Artificially recharged groundwater is a regionally important method to secure the water supply in industrial countries such as Finland (Bouwer 2002; Artimo et al. 2008).

Finland is a land of plenty when it comes to water resources (Kuusisto 2004). This water prosperity is a result of both hydrological and socio-economic factors. Due to climatic and geomorphological conditions, Finland has abundant raw water resources. The long-term investments in water infrastructure have improved the reliability and efficiency of water management (Katko et al. 2006; Lavapuro et al. 2008). Currently, so called clean technology in water management is highlighted as a promising export area for the Finnish economy, as exemplified by the activities of the Finnish Water Forum (http://www.finnishwaterforum.fi/en/home/). However, this framing of advanced technological water know-how as an economic opportunity may overshadow past failures, unresolved or emerging challenges, and social controversies related to water management.

We focus on a case of managed aquifer recharge. Such systems have often been proposed as solutions for securing the water needs of growing urban conglomerations. A community water supply based on managed aquifer recharge can constitute highly complicated systems. Generation of artificial groundwater affects land use and environmental management both at surface level and in subsurface spaces (Evans et al. 2009). It involves various actors and technologies on different spatial, temporal, and functional scales. It also includes various risks, benefits, and impacts.

Here we adopt a holistic perspective of coupled socio-ecological systems and take the notion of the hydro-social cycle as a more specific starting point (Swyngedouw 2009; Barnes 2012; Bouleau 2013). This notion aims to transcend the sharply drawn dichotomy between nature and society and to integrate analysis of hydrological processes with social, cultural, and historical insights. As emphasised by Swyngedouw (2009), hydraulic environments are socio-physical constructions that are actively and historically produced, in terms of both social and physical qualities.

The notion of a hydro-social cycle is a relatively recent one. Studies utilising the concept have focused on water management from the perspectives of political ecology (Budds 2009; Bourblanc and Blanchon 2013), historical development (Brown et al. 2009; Carey et al. 2012), or discourses and co-production of science and technology (Bouleau 2013; Fernandez 2013). Related concepts such as hydro-social balance (Merrett 2004) or hydro-social contract (Meissner and Turton 2003) have also been suggested. These studies have employed different data sources, including results from environmental monitoring and natural sciences, social science insights based on surveys,

interviews, documents, ethnographic observations, and theoretical models, as well as interdisciplinary explorations integrating different approaches and information sources (Barnes 2012; Finewood and Stroup 2012; Norman et al. 2012; Meehan et al. 2013;). However, these studies have not employed media coverage of water issues as a key data source.

We focus on hydro-social cycles from the perspective of risk communication, especially communication about risks from contamination of the potable water production system. We define risk communication as the transmission of information between parties and their deliberation about the significance of health, environmental, or other risks and about their management. Communication aspects of water management are increasingly important, because media representations of various kinds and on many levels prominently reflect and strongly influence public and policy agendas (Cox 2010). Water management issues are brought into people's attention, risks are amplified or attenuated, and controversies and their closures are shaped largely through media coverage and increasingly by social media. Not all risk issues enter the public sphere or media debates, however (Lyytimäki et al. 2011). Better understanding about what issues become topics of heated debate, and how risks are framed in these debates, can advance our ability to manage the risks. Frames are understood here as conceptual devices and ways to select and highlight some aspects of a perceived reality and to intentionally or unintentionally promote a particular problem definition, causal interpretation, moral evaluation. and/or recommendation (Entman 1993).

We aim to answer the call for analysis of the discourses and arguments that are publicly mobilized to defend or legitimate particular strategies (Swyngedouw 2009). A key challenge of such analysis is that environmental and health risks are framed and understood in different ways depending on a variety of factors, such as characteristics of the issue itself, natural conditions, technologies involved, socio-cultural contexts, organisational settings and personal interests, values, and knowledge (Assmuth et al. 2009). Importantly, the ways in which information on risks and related issues is communicated, who communicates it and when, crucially influence the framing, understanding, perception, and response to the information.

Here we focus on the public representations that inform about or aim to advance or oppose the plans for managed aquifer recharge in a prominent case. More specifically, we study the risk representations of newspapers and use social media and planning documents as comparative material.

By focusing both on print and online media debate, we aim to fill in a gap in environmental and risk communication studies, which typically focus on a single medium, particularly newspapers (Cox 2010; Lyytimäki 2011). The importance of printed newspapers has gradually declined during the past decade. However, in Finland, they are still the second most important source of environmental information (Kiljunen 2013). Furthermore, web versions of newspapers serve as important focal points of discussion in electronic spaces. Here we use the archive of a regional newspaper to generate a long-term overview of the debate, while discussions in social media forums provide snapshots of selected debates. Both these approaches to risk discourse are complemented by empirical information on the debates in the context of an environmental impact assessment (EIA) process.

Most previous studies of environmental and risk communication have focused on English-speaking countries or English-language media in other countries. Only a few studies focusing on the media coverage of water issues in Finland have been published in international peer-reviewed journals (Peuhkuri 2002; Lahtinen and Vuorisalo 2004, 2005; Lyytimäki 2007, 2012), and relatively few examples can be found elsewhere (e.g. Schmid et al. 2007; Jönsson 2011; Hurlimann and Dolnicar 2012). Studies focusing on vernacular language samples from countries such as Finland can deepen the understanding of the similarities and differences of risk communication across linguistic and cultural borders.

**Groundwater recharge as a hydro-social system: case Virttaankangas**

The use of groundwater for water supply in Finnish communities has increased continuously since the 1950s (Katko et al. 2006). During the 1990s and early 2000s, the share of artificially recharged groundwater was slightly more than 10 % of all water delivered by water utilities in the country (Isomäki et al. 2007). Currently, the share is about 15 % and it has been projected to increase to 25 % by 2030 (Isomäki et al. 2007; Kitti 2013). People using the water are generally satisfied with the quality of the water. However, particularly the plans for large-scale groundwater recharge sites and schemes have induced public criticism. An intensive debate was sparked by the planning and implementation of the managed aquifer recharge in the Virttaankangas esker area, aimed at securing potable water for the Turku region in southwest Finland (Fig. 1).

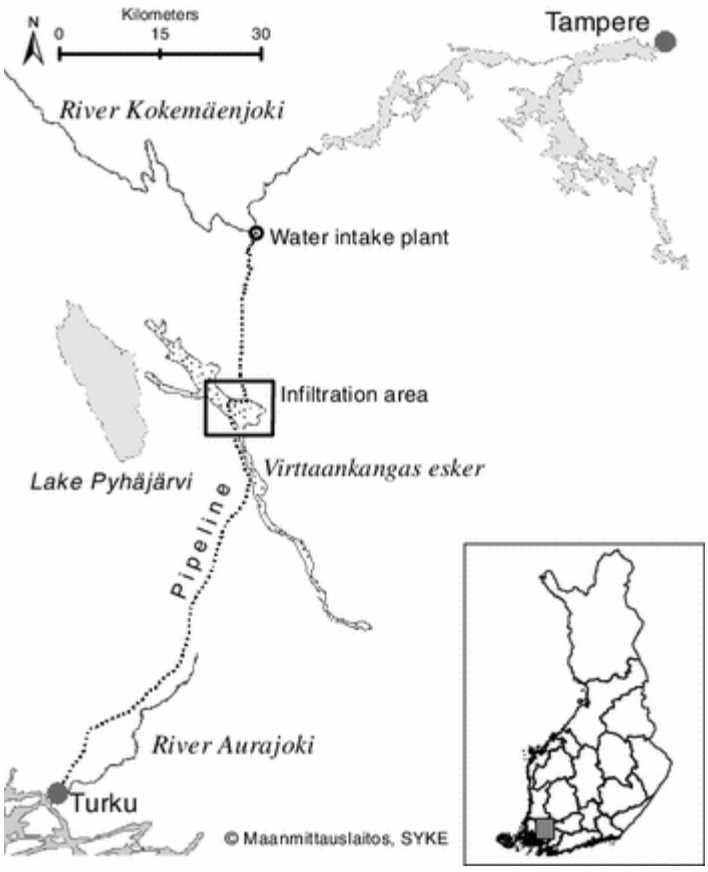


Figure 1. Location of the case area

The water supply for the city of Turku and the surrounding region (currently about 285,000 inhabitants) has been based on local water sources. The water issues have been debated for a century (Stenroos and Rajalin 1999; Lahtinen and Vuorisalo 2005). In order to solve increasing problems of hygiene and water supply, water pipes were installed in the city area at the start of

the 20th century. Around 1910, it became evident that the local groundwater supply was inadequate for the needs of the growing city (Lahtinen and Vuorisalo 2005). Particularly because of summertime water shortages, use of purified water from the river Aurajoki flowing through the city was started in 1923. The public found the taste, smell, and look of the water unappealing. The quality of the river water remained poor during the rapid industrialisation and urbanisation after World War II (Lahtinen and Vuorisalo 2004). The river was strongly influenced by agricultural runoff and flooding, together with pig-farm waste and municipal and industrial wastewater. The water quality was poor particularly during the low flows (Vallin 1999).

The per capita consumption of water provided by the Turku water utility increased rapidly during the 20th century and reached a peak of 400 l per day in the early 1970s (Katko 2000). Because of better leakage control and improved pipe materials, better water fixtures, and consumers' increased awareness of water saving prompted by the oil crisis of 1973, the consumption levelled off and started to decrease (Katko 2000). The quality of the water in the river Aurajoki improved considerably during the last decades of the century, and the quality of the potable water improved, also due to better water treatment methods and more efficient storage and distribution networks. Although the tap water was safe to drink, the smell, taste, and visual problems remained as a source of continuous complaints and public critique. Episodes of significantly impoverished water quality occurred especially during low-flow periods, after spring runoff and floods from the catchment area of the river Aurajoki, and when the principal water-supply systems were dysfunctional. Such episodes caused particularly intense public debates and criticisms.

Long-distance water transfer has been discussed as a potential solution for the Turku area water problems for decades. The plans for transferring water from the lake Pyhäjärvi, located about 70 km north of Turku, were ready for implementation in the early 1990s, but the plans were discarded by Turku city council in 1993, due largely to opposition by the users of the lake, including fishermen and local inhabitants, supported by researchers concerned about the ecology of the lake and by regional and national authorities. The intensive debate started again after the exceptional water-quality problems of the summer of 1999. Because of dry weather conditions, the amount water in the river Aurajoki was low and water quality was poor. The water supply for neighbouring municipalities of Turku was restricted. Furthermore, the potable water plant, using ozone purification instead of the traditional strong chlorination causing smell problems and even health risks, faced temporary technical problems. Risks related to the use of river as a raw water source were also highlighted by oil accidents during the summer (Andersson 2010, p. 289). The debate was influenced by the intense news coverage of water eutrophication and blue-green algae risks, sparked by exceptionally large algal blooms in the summer of 1998 (Lyytimäki 2007, 2012).

Groundwater in Finland is generally of good quality and can be used as drinking water with little or no treatment (Lavapuro et al. 2008). However, the availability and quality of groundwater is variable, and additional water has to be imported particularly to coastal cities such as Turku. Groundwater obtained from the Virttaankangas esker aquifer, located 66 km north of Turku, was suggested as a source of additional water for Turku region already in the 1960s. The availability of natural groundwater was, however, a limiting factor. Managed aquifer recharge was suggested as a potential solution in the 1990s. The first modern recharge plant in the country was constructed in Lappeenranta, southeast Finland, in 1970, and experiences were available from other domestic cases as well (Kivimäki 1992). In autumn 1999, a new plan based on long-distance transfer of artificially recharged groundwater was released by the regional water company (Turku Region Water Ltd.). The plan was to extract water from the river Kokemäenjoki, located 28 km north of

Virttaankangas. The raw water would be pre-treated and infiltrated via sprinkler systems into Virttaankangas aquifer. This artificially recharged groundwater would then be pumped to the Turku region for final treatment and consumption (Artimo et al. 2008). The proposed amount of water required for the recharge was 105,000 m3/day, making the facility the biggest in Finland.

The proposed groundwater recharge system created a novel hydro-social cycle connecting two separate watersheds of the rivers Kokemäenjoki and Aurajoki. Furthermore, a connection was created between the city of Turku and the city of Tampere, which is the largest inland city in Finland (Fig. 2). The hydro-social cycle of the Virttaankangas artificial groundwater scheme includes not only urban and natural areas, but also socio-economic issues such as different histories of water use in different regions and different expectations related to future water use.

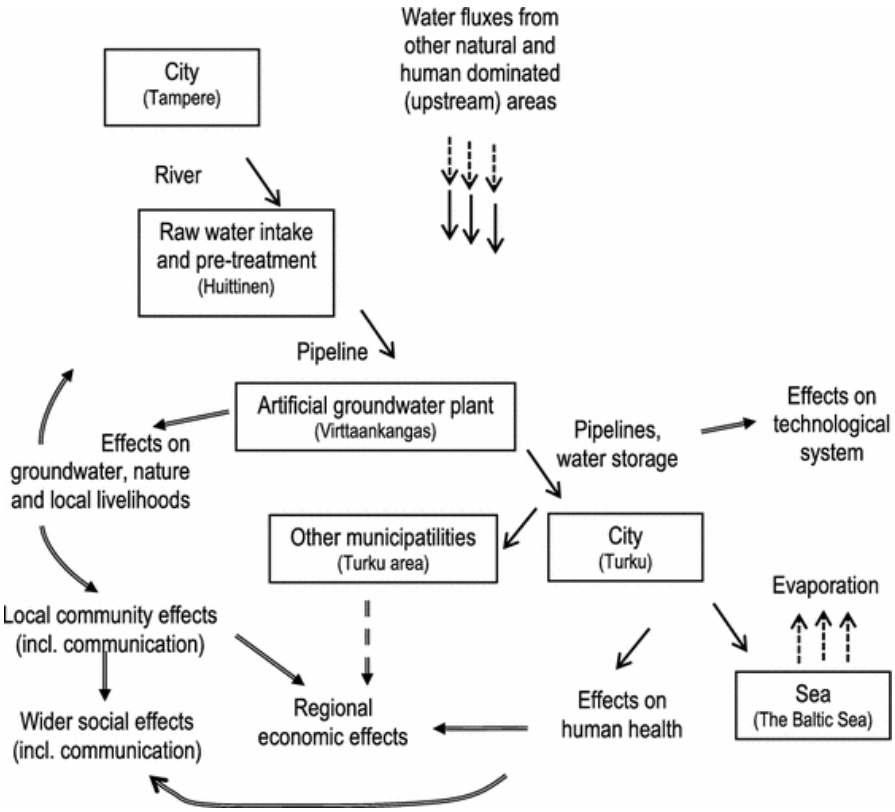


Figure 2. Hydro-social cycle related to the artificial groundwater scheme of Virttaankangas. Water fluxes, biophysical effects on health, and technological effects are shown by simple arrows; social and economic effects by double arrows. Note the occurrence and interrelations of effects (beneficial and adverse) and of risks and of communication about them on several levels and in various stages of the water and social cycles.

**Materials and methods**

The electronic news archive of the newspaper Turun Sanomat (TS) was searched for contents dealing with the Virttaankangas groundwater recharge scheme. With a circulation of 168,000 printed copies and 92,000 online subscribers, TS is the third most widely read daily newspaper in Finland and the leading newspaper in the Turku region (Levikintarkastus 2013). The newspaper has declared independence from any political orientation and can be considered as a mainstream quality newspaper aimed at a large audience.

Different search strategies were tested in order to find keywords that would produce a sample illustrating the key phases and themes of the debate comprehensively enough. Most of the news items were found with search strings including the keywords “Virttaankangas” or “artificial groundwater” (“tekopohjavesi” or “keinopohjavesi” in Finnish). Searches with other suitable keywords (i.e. not producing excessive numbers of irrelevant hits) were tested until the material was saturated and no new hits were found. The search engine did not allow the use of Boolean operators or other detailed search strategies. It is possible that some news items related to the case but not containing the keywords tested here remained outside the sample. However, we consider the sample adequate to identify the key themes of the debate on the artificial groundwater recharge scheme.

The results from the search engine included the text of the news articles, columns, editorials, and letters to the editor. Announcements, advertisements, and cartoons were not included. Information on the author, the time of publication, and the section in the newspaper were provided by the search engine. After removing hits not related to the case (most often about outdoor recreation and cross-country skiing in the Virttaankangas area), 277 news items were included in the sample.

The newspaper material was coded in order to provide an overall picture of whether the Virttaankangas case was the main topic of the news item, and whether the overall framing towards the artificial recharge scheme was positive, neutral, or negative. News items focusing mainly on issues other than artificial groundwater were included, because such news coverage can give important insights into the framings and connections of an issue with other issues (Lyytimäki 2011). After this initial quantitative survey, the key frames of concern and associated claims and counter-claims were identified (Entman 1993; Krippendorff 2004). These qualitative characterisations were based on interpretations by two researchers, who first worked independently and then combined their interpretations after several rounds of readings.

Selected documents and online discussions were used as comparative material illustrating different types of debate. The documents included comments given on the report of the obligatory environmental impact assessment (EIA) of the plan for the Virttaankangas artificial groundwater recharge system. The material consists of the publicly available summaries of statements by 43 municipal or expert organisations, and summaries of opinions by 35 private persons or non-governmental organisations, as compiled by the EIA authority (Regional Environmental Centre of Häme). The purpose of this material is to show the diversity of views presented in the context of the formal planning process and ex ante assessment. The EIA process was conducted during the initiation phase of the recharge scheme (2000–2001).

Other comparative material aiming to illuminate the debates in informal contexts was selected from the online discussion forum “Suomi24”. This is a popular Internet-based Finnish-language discussion forum, open to everyone. It covers all issues and includes both national-level and locally oriented discussions. Over a hundred discussion threads at least partially related to the Virttaankangas case were found in the forum. Almost all of them occurred in the context of local or regional discussions. A sample of four discussion threads was selected for this study (Table 1). The key selection criterion was that the starting comment of the discussion was directly related to the key themes identified from newspaper material (see Table 2).

Table 1 Description of the sample of online discussions (as of May 22 2013) from discussion forum www.suomi.24.fi

| Title of discussion (In Finnish) | Starting date | Date of the last comment | Number of comments | Number of visits to the discussion |
|---|---|---|---|---|
| Virttaan vesihomma (Virttaankangas water stuff) | October 12 2007 | October 19 2007 | 17 | 1221 |
| Virttaan soraharjun maanvaihto (land swap in the esker) | February 12 2008 | February 19 2008 | 16 | 365 |
| Pukkinen ei vastannut! (Pukkinen didn't answer!) | February 19 2008 | February 25 2008 | 16 | 423 |
| Itkeä vai nauraako? (to cry or laugh?) | April 21 2011 | April 27 2011 | 50 | 196 |

Table 2. Concerns and claims regarding risks and impacts of the artificial groundwater recharge scheme at Virttaankangas esker, based on newspaper representations, online debate, and comments on the EIA report

| Theme | Frame of concern | Key claim | Counter claims |
|---|---|---|---|
| *Health* | | | |
| Mercury (Hg) pollution | Release of Hg from sediment to raw water | Hg will accumulate to esker, methyl mercury poses a health risk | Health concerns non-relevant as mercury is insoluble to water |
| Other contaminants | Chemical quality of raw water | Risks are caused by contaminants stored in river sediments and various current impurities of the water | Risks are identified and under control |
| *Environmental* | | | |
| Biodiversity of the esker area | Fragile nature and threatened species | Ecosystem will be irreversibly spoiled | Adverse impacts are limited; critique not answered |
| Groundwater pollution | Non-treated groundwater as a vulnerable resource | Natural groundwater will be polluted | Esker area will produce clean drinking water |
| *Economic* | | | |
| Project costs | Local economy (increase of water fees and municipal taxes) | Excessive or completely unnecessary investment and running costs | Costs of alternative water supply systems probably much higher |
| Cost-benefit distribution | Justness between people and municipalities | Benefits are reaped elsewhere, costs locally | Society as a whole benefits |
| *Social* | | | |
| Citizen rights in planning process | Lack of real influence by local people | System represents outsider intrusion | Critique is unjustified, legal obligations are fulfilled |
| Recreation | Usability of esker area | Recreation opportunities in esker nature will be lost | Critique not answered |
| *Technological* | | | |
| Water technologies | Use of appropriate technology | Artificial groundwater is expensive and risky, alternative technologies exist | Artificial groundwater is the only feasible technology available |
| System vulnerability, interruptions of raw water availability | Uncontrollable consequences of unexpected incidents | Water production may be hit by natural or man-made disasters, e.g. chemical accidents or algal problems influence raw water quality | Potential risk situations are assessed and risks can be managed |
| *Knowledge base* | | | |
| Availability of research data | Unknown risks | Chemical measurements are inadequate, lack of data | Adequate data already exists |
| Utilization of research results | Neglected risks | Relevant results are not taken into account | All relevant information is included |

Six key themes were identified. Each theme is illustrated with two examples of frames of concern and associated key claims and counterclaims. The themes are partially overlapping

## Results

### Ups and downs of the debate

The release of the plans for the artificial groundwater recharge facilities in 1999 did not cause a major public debate (Fig. 3). However, some critical letters to the editor were published related to the potential risks to the ecologically vulnerable esker ecosystem of Virttaankangas. This recurrent theme of the debate did not focus on risks (mainly to human health) downstream, but on potential damage to local nature. The intensity of the debate started to increase during 2003. Key topics included the technical methods for pre-treatment of raw water and the environmental permit that was applied for by the Turku Region Water Ltd. The EIA procedure received only minor attention.

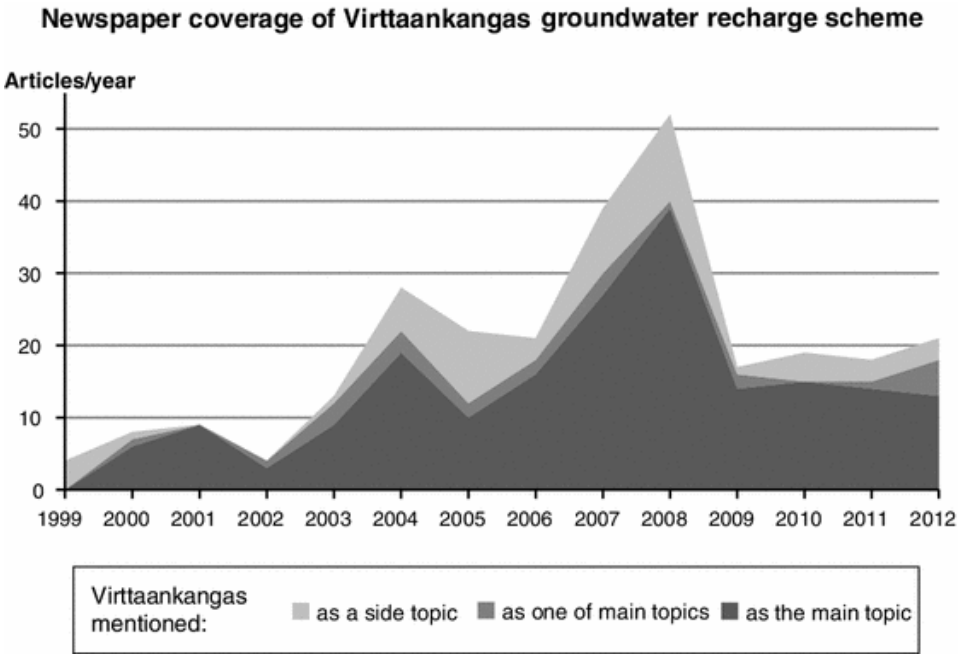


Figure 3. Coverage of Virttaankangas groundwater recharge by the regional newspaper Turun Sanomat

Easily observable changes in nature can become widely discussed “media events” that are represented as symptoms of a particular human activity or environmental problem (Anderson 1997, p. 148). The dramatic drop in the water level in the small lake Kankaanjärvi in the Virttaankangas area drew major attention in 2003. Suspected reasons included the groundwater abstraction from the area and the test activities related to the planned managed aquifer recharge system. However, according to groundwater measurements and information gathered by the Turku Region Water Ltd., the reason was the unusually dry weather of 2002–2003 (see Vienonen et al. 2012). Additional criticism was sparked in the autumn of 2003 when the National Broadcast Company aired a television documentary very critical of the planned artificial groundwater recharge facilities in Virttaankangas, as well as in the Tampere region, upstream from the point of water extraction to Virttaankangas (YLE 2003).

During 2004–2006, the media coverage of the scheme remained at a relatively high level. Several critical letters to the editor were published. The environmental permit process generated about 200 complaints, but the permit was granted in 2005. The debate continued because several

additional complaints about this permit decision were made. The peak years of the coverage were 2007 and 2008. Concerns about the high costs of the recharge scheme and implications for the price of the tap water were raised. The economic efficiency of the water-supply scheme in relation to alternatives was thus questioned only at this relatively late stage. The final decision from the Supreme Administrative Court, ending the environmental permit process and allowing the construction, was strongly criticised. The initiation of the actual construction work started to generate newspaper stories with a neutral tone.

The intensive phase of the debate ended in 2009. Some news attention was generated by vandalism directed at the construction of facilities. At the end of the period, technical problems in the construction work received some attention. The news coverage also framed Turku Region Water Ltd. as reluctant to follow the very detailed instructions for the intensity and coverage of environmental compliance monitoring given by the regional environmental authorities. The potential increase in the price of the water, because of high investment costs, remained a key public concern.

**Critical public tone**

The majority of the coverage (56.7 %) was negative towards the artificial groundwater scheme (Fig. 4). This is largely explained by the letters to the editor, of which 85.3 % were written with a negative tone. All the letters to the editor with a clearly positive tone towards the recharge scheme were written by the representatives of Turku Region Water Ltd. A third (33.2 %) of all newspaper material had a neutral position and only a tenth (11.1 %) a positive position towards the recharge scheme.

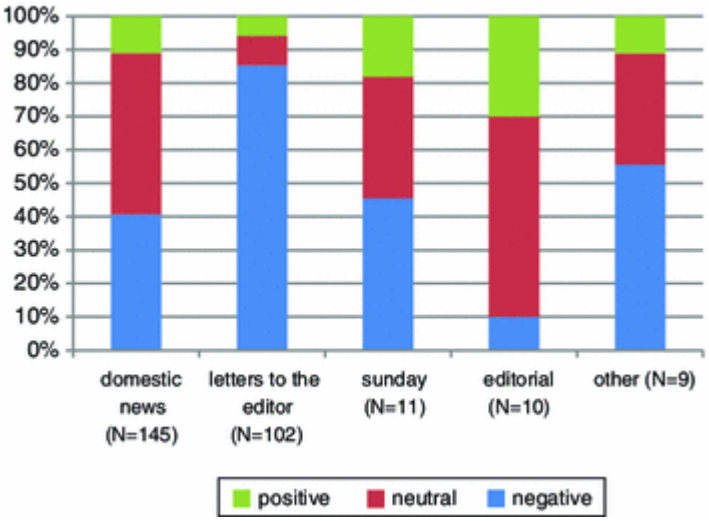


Figure 4. Positive, negative, and neutral framings of the coverage

Most of the coverage was published as letters to the editor or domestic news (83.0 % of all items). About half of the domestic news (48.3 %) showed a neutral tone. These news items typically described rather technical issues such as construction activities. Editorials were most often written with a neutral or positive tone. Only one editorial piece (March 9 2007), focusing on the costs of the project, took a clearly negative and critical stance. In editorials, the topic was discussed mainly in the context of the water consumption of the city of Turku. The urgent need to secure sufficient availability of high-quality water was highlighted, and the timeframe of planning and building an

extensive and complex new artificial groundwater system relying on surface water transfer and treatment was considered as too long.

All comments on the EIA report given by private persons and NGOs were critical towards the proposed artificial groundwater recharge facility. The tone in the statements by municipal and expert organisations was more variable, ranging from short notices stating no major concerns towards the plan, to critiques of various inadequacies in the EIA report. The key inadequacies noted were the limited assessment of the potential impacts of planned pipelines on land use (including traffic, agriculture, and forestry) and of the potential effects on the cultural and historical values and nationally valuable landscapes of the recharge area. The lack of proper treatment of alternatives to managed aquifer recharge in the EIA report was also commonly criticised. The adequacy of the plan to use only mechanical pre-treatment (sand infiltration) was questioned, particularly in the comments of municipal organisations. Chemical treatment was considered a better option.

The sample of online debate showed the dominance of critical opinion but also a strong polarisation of views. This debate was characterised by personalisation of arguments and use of expressions ridiculing the opponent. For example, the discussion initiated on April 24 2011, with a comment critically evaluating the rationale behind the plans for the artificial groundwater recharge scheme and arguing for an alternative option to build a direct pipeline from the river Kokemäenjoki to Turku, generated 50 responses (see Table 1). Several of the responses were ironic or humorous, and many were clearly provocative. The main targets of the irony were the planning process, where the influence of public critique was considered minimal, and the online discussion itself, which supposedly serves only as a tool for self-expression. The activists defending the natural values of the esker were marginalised and ridiculed by comments labelling them as “esker elves” and simple-minded country people. Rights and justice issues were provocatively commented on by maintaining that the residents of Turku have the right to use the water resources in the far-away esker as they wish, without any need to consider the rights, needs, or opinions of the local people.

The newspaper sample included news items that mention the artificial groundwater scheme only in passing, as a side topic related to news about some other issue (Fig. 3). The share of these news items was 22.8 % of all coverage. This share is low if compared with Finnish newspaper discussion of water eutrophication or climate change (Lyytimäki 2011, 2012) and suggests that the issues of groundwater resources are more specific and only rarely discussed in connection with other topics. The share of positive framing was relatively high in news items that mentioned the recharge scheme only in passing: 43.1 % of these news items took a neutral and 15.5 % a positive position. A clear majority of the news items focusing on the recharge scheme (60.5 %), and those news items with several topics (62.5 %), showed a negative tone. Notably, even though the newspaper coverage treated the artificial groundwater recharge scheme as an isolated issue, the comments on the EIA report connected it with wider issues of cultural heritage and land use. This indicates that the mandatory EIA process, despite its limitations (including those criticised in the media), was indeed more capable of a broad and systematic treatment of impacts and issues.

**Effluents and contaminants from upstream**

Several potential risks were raised related to the groundwater recharge scheme, particularly in letters to the editor (Table 2). Economic risks related to the chosen technological solutions were a

key concern, as were the risks related to the transport pathways of various contaminants. For example, a letter to the editor signed by a scientist (March 9 2005) asserted that "[t]he artificial water project of Virttaankangas is a scandal. 100 million euros are planned to be sacrificed in order to decrease the quality of the drinking water in Turku region." Notably, the earlier inadequate water supplies for the Turku region were not used here as a point of reference for the new scheme, and economic considerations that include benefits from the new supply were excluded. The author referred to a research report assessing the feasibility of managed aquifer recharge technologies (Helmisaari et al. 2003) and criticised the proposed technologies as inadequate. The author was worried about various impurities of the raw water, including heavy metals such as mercury and cadmium, medical residuals, and harmful microbes. The polemical opinion piece ended with a word play suggesting that the Virttaankangas area will soon be Virtsankangas (Urine heath), an area infected with the impurities of wastewater originating from the city of Tampere.

The connection created between two previously separated watersheds and the impacts resulting from the upstream activities on the downstream water quality were a recurrent theme in the debate: "Residents of Turku will soon drink wastewaters of Tampere" (letter to the editor, December 1 2007). Risks related to the quality of the raw water were thus discussed in the domestic news of the plans to build new wastewater treatment plants for the Tampere region (e.g., February 28 2005). One of the planned sites for the release of treated wastewater was in the river Kokemäenjoki, about 50 km upstream from the place of the intake of raw water to the esker. This caused suspicions of the deterioration of raw water and finally also potable water quality, despite reassuring comments from the representatives of both the Turku and Tampere area water companies.

Risks caused by upstream activities were highlighted in the online debates as well, but they were not raised as a major concern in the comments on the EIA report. This is somewhat surprising considering the discharges in the upstream region due to, for example, flooding and technical problems in treatment plants. Furthermore, the traditionally competitive relationship between Turku and Tampere was visible in online and newspaper debates. These tensions often led to accusations of unfairness and violation of rights between upstream and downstream users of watercourses, which have been noted in many other cases as well (Carey et al. 2012; Fernandez 2013). The existence of major risks was categorically denied in newspaper comments by the representatives of Turku Region Water Ltd. For example, in an interview related to the pre-treatment of raw water, the representative of the company stated that "the quality of the water in the river Kokemäenjoki is so unbelievably good that no chemical treatment is needed" (September 28 2006). This kind of over-confident tone reflects the view of a responsible party focusing only on the current overall physical–chemical composition and on the known and normal-case water quality.

**Mercury scares**

About one tenth of the sample (11.2 %) mentioned mercury (Hg) as a potential environmental or health risk. The risk of the release of Hg from the bottom of the river Kokemäenjoki was discussed particularly during 2007. Through this critique, statistics indicating the reasonably good quality of the river Kokemäenjoki were questioned more generally. The Hg discharges into water were framed as a problem of the past, but with a long-lasting legacy. "The river Kokemäenjoki served for a long time as a sewer of Tampere, the biggest and the most industrialised inland city", stated a letter to the editor (January 31, 2007). This is, in fact, inaccurate and even misleading, as

Tampere was not the main source of Hg in the river, but the chloralkali industry located in a downstream municipality (Äetsä) closer to the point of water intake to the esker. The debate was intense despite the expert knowledge suggesting that the risks related to Hg in this case were not a real concern. For example, in February 3 2008, a long report entitled “Frightening mercury” was published in the Sunday section of the newspaper. The piece included comments by various experts and scientists that the key fears related to mercury were either exaggerated or based on misunderstandings.

The behaviour of Hg in the environment is a complicated issue that easily creates confusion among the public. These fears or claims of risks are interesting in terms of the conceptual framing and other factors influencing perception and debate, as mercury and its main toxic compounds, being insoluble in water, are not of primary concern in the potable water produced compared to water-soluble contaminants. These concerns largely reflected a regionally widespread long-time awareness of methyl mercury pollution in the lower reaches of the raw water supplying the river, due to industrial discharges, that is, a memory carry-over or transference effect that may cause misdirected concerns and claims (Lyytimäki et al. 2011).

Activists opposing the recharge scheme used the Hg as an argument that can evoke strong feelings and fears of irreversible losses and catastrophic consequences. The Minamata poisoning episode in Japan in the 1950s, resulting from long-term release of methyl mercury in the industrial wastewater, was raised as a warning example by letters to the editor (October 31 2006; August 19 2007). This shows that episodic cases of pollution can re-emerge after a long time-lag as symbolic general-level objects of concern. In this case, the anxiety was strengthened because of the previous more specific, localised and strong controversy around Hg contamination in the river and the region as a whole (and even in Finland more generally, due to other prominent regional cases of mercury contamination, especially in the river Kymijoki, also due to chloralkali production), which was a hot topic especially in the 1970s (Lodenius 1985). The preoccupation with Hg also indicates that it may be difficult for laypersons (and even some experts) to refocus their attention from well-known previous risks that are unlikely to be important in a new setting. This lagged perception is connected with the lack of knowledge and the lack of analytical capability in measuring emerging contaminants, and therefore in identifying them as causes of concern in a particular case.

Based on expert knowledge, the Vaasa Administrative Court stated in its decision related to complaints made in the environmental permit process that the sediment contaminated by Hg does not cause a risk to the quality of the artificial groundwater. However, the court decision required that the water use has to be stopped if the level of Hg in the raw water exceeds 0.13 µg/l (domestic news, March 8 2007). This decision also reflects the focus on contaminants that have traditionally been recognised and measured. The public lack of trust towards the expert knowledge was, however, strong, partly because studies of Hg were commissioned by Turku Region Water Ltd., whom people suspected of having a tendency to downplay risks. The laboratory results were generally accepted as trustworthy, but the number of samples was criticised as too low and interpretations as biased.

The views of the newly established association for the protection of the esker were highlighted by the domestic news (March 30 2007), noting the limited number of measurements of Hg and the lack of any measurements of methyl mercury, which indicates some familiarity with Hg risks but not with factors that render it a much less likely threat in this case than many other contaminants.

Thus, while relatively high levels of Hg in the sediment were confirmed by analysis of three additional sediment samples, strong public disagreement prevailed on whether the Hg in sediment could cause any risk to the esker ecosystem or affect the quality of tap water. The representative of Turku Region Water Ltd. considered that the research on the Hg in sediment was unnecessary intimidation of the people (domestic news, April 11 2007). This may have been correct, but simultaneously missed other potential causes of concern in much the same way as those critical of the water-supply project and its impacts.

The issue of Hg and other contaminants to be potentially released from the sediment or water of the river Kokemäenjoki were a major concern in online discussions as well, despite the research results showing low levels of Hg in the water. For example, a comment posted on February 20 2008 referred to the Chernobyl nuclear accident (1986) and to more recent water contamination in the Finnish town of Nokia (Lavento 2009) as warning signs, and suggested that the plans to use the polluted water from the river Kokemäenjoki show a profound inability to learn from previous mistakes. The risks caused by water contaminants nevertheless received only little attention in comments on the EIA report, suggesting a lack of understanding of both the risks and the role they play in people's risk perceptions, which in any case need to be dealt with. Only one municipal organisation mentioned the potential risk of an increase in the levels of Hg (and Al) in tap water.

**Effects on nature**

Disagreement regarding potential ecosystem effects caused by the recharge facilities prevailed particularly during the first years of the study period. The representatives of Turku Region Water Ltd. claimed that the planned facility does not cause a threat to endangered species. A letter to the editor by the research director of Turku Region Water Ltd. (September 9 2002) claimed that the artificial groundwater plant does not threaten the natural values of Virttaankangas, and that the assessments conducted are sufficient to show that no rare or threatened species will suffer because of the activities. Despite this, potential adverse nature effects were repeatedly raised in letters to the editor.

Inadequate or missing assessment of the impacts on endangered and other species was noted as a major concern by several comments on the EIA report. The narrow focus on the most obvious threatened species (and to anthropocentric concerns such as human health and welfare) and the failure to systematically and comprehensively address biodiversity issues and other ecological effects is a common problem of EIA reports in Finland (Söderman 2012).

The deterioration of the recreational value of the esker nature was raised on several occasions. The concept of ecosystem services was not mentioned, even though erosion of various benefits—including cultural ecosystem services such as recreation and education (Plieninger et al. 2013)—provided by the esker ecosystem was a key concern. For example, hikers visiting the esker area, who were interviewed for domestic news (September 25, 2006), suspected that the groundwater plant would irreversibly destroy the esker: "Nature would be used as a filter, but filters do not last forever." This view and technical metaphor, while primarily associated with local impacts, reflects a folk wisdom type of realisation of the imperfections, limitations, and uncertainties of any technological and natural system, even the key notion of limited buffer capacity and limited sustainability of an esker formation, and is in line with the above criticisms of the flaws in the basic framing and assumptions in the EIA. As such, it highlights an intuitive understanding of the importance of sustainability in the use of natural resources, and of the need for a long perspective.

It was also feared that, because of the impurities of the raw water, the fragile esker ecosystem would turn from service producer to a source of disservices. A strong disbelief was expressed towards the claim that the raw water would not blend with the groundwater currently used as water source.

**General discussion: dominant and missing risk framings of the hydro-social cycle**

Two different overall framings could be discerned. First, there was a techno-rationalistic framing of the hydro-social cycle, focusing on the water supply, which included both highly positive and highly negative views of the economic and technological feasibility of the recharge scheme. Second, an ecosystem and human health-oriented framing of the hydro-social cycle focused on the environmental risks and potential health effects. This framing was dominated by negative views of the recharge scheme, with only marginal attention given to the aim of improving the quality of tap water or to potential positive side-effects, such as the impact of reduced water intake from the river Aurajoki. One reason for this is that impact assessment focusing on the project scale is unlikely to capture the cumulative effects and side-effects occurring on watershed scale (Sheelanere et al. 2013).

Representations created both by traditional print media and new social media polarised the debate. Online discussion polarised the debate through stronger personalisation of the arguments than print media. The polarisation was partly induced by the strong commitment of the water utility to implementing the pre-determined plans, and by argumentation focusing on defending the chosen approach. The comments given on the EIA report by municipal organisations, in particular, criticised the lack of proper treatment of alternative options for the recharge plant. This is a common problem of EIA processes (Söderman 2012). Letters to the editor and online debate suggested the option of using pipelines to transport pre-treated raw water from the river Kokemäenjoki for treatment and use in the Turku region, without using artificial recharge technology. This fundamental critique, based on an alternative conception of the hydro-social cycle, was largely left unanswered.

The sensitivity of the water utility to public criticism was poor, with some responses creating the impression of an arrogant attitude. This type of outreach largely followed a one-way model of science communication, instead of two-way communication that is more open and responsive to complementary arguments, differing framings and values, and concerns of citizens (Cox 2010). Interaction acknowledging the importance of lay knowledge based not only on personal experiences of water and nature, but also on argumentation with potential flaws of current expert knowledge, alternative expert knowledge, and background assumptions of the planning, could forestall or alleviate the polarisation and enable social learning for all participants (Leys and Vanclay 2011; Johnson 2012). The notion of a hydro-social cycle provides a conceptual tool to understand and alleviate such unidirectional and simplistic polarisation, to promote genuine dialogues or multilogues between actors.

Emerging pollutants with largely unknown environmental and health consequences pose a particularly difficult problem, not only for water treatment but also for communication and interaction (Lyytimäki et al. 2011; Matamoros and Salvadó 2013). In polarised debates, where risks and certainties are exaggerated and downplayed selectively and tactically, and where the stakes are high for those responsible for the conduct of the technological and economic system implemented, openness and tolerance allowing the introduction and treatment of new

information is a key challenge (Assmuth et al. 2009). New forms of citizen activity, particularly through social media, add to this challenge, but also suggest new ways to tackle them through participatory communication and learning processes.

Potential risks caused by mercury in sediment on the bottom of the river Kokemänjoki emerged as a symbol of uncontrollable risks in print and online debate, transferring and re-enacting previous other concerns to the case of the water-supply system, while in the EIA comments and media comments by experts, it remained as one relatively well-known and controlled factor. The effects of the effluents of the city of Tampere on the quality of the raw water and potentially on the esker nature and groundwater were also discussed through the Hg question, exemplifying the variations and contestations in focusing concern and blame along the risk chain and along upstream and downstream stages of a hydro-social cycle.

Risks—or benefits—related to climate change received relatively little attention, even though climate change was the most widely discussed environmental issue in Finland during the study period (Lyytimäki 2011). Only sporadic attention was given to risks such as increased microbial growth resulting from the warming of water. However, other risks also exist (Vienonen et al. 2012). Increased flooding may introduce new stress factors, increasing risks of contamination (e.g., causing sudden leaks of pathogenic microbes or toxic substances along the hydrological cycle or mobilising accumulated contaminants) and other forms of system malfunctions, such as physical breakdowns due to hydrological and hydraulic loading. Notably, the managed aquifer recharge was not highlighted as a potential tool for climate change adaptation that could help to respond to the increasing hydrological variability.

Distrust of the water utility and policy-makers, and also of authorities and expert knowledge, was evident in the debates. Concerns and distrust were partly explained by historical burden and long-lasting memories of past Hg contamination and other industrial pollution (Lyytimäki et al. 2011). It is possible that this distrust, along with the concerns for the impacts of the scheme, will gradually wane, as often happens after a new system is introduced. However, new concerns and conflicts may also emerge and debates may be intensified again, due to alterations both in the functions or failures of the system, in the attitudes and perceptions of the publics and actors, and in contextual factors such as economics (see Carey et al. 2012) and developments in (electronic) communication and (social) media.

A key issue underlying these debates, but not yet well articulated, was the distribution of risks and benefits among regions (such as the local area around the esker, the downstream area where water is used, and the upstream area impacting both), among the different municipalities based on their contractual and economic relationships with the regional water company, among administrative sectors (such as technical, health, and environmental, and their various combinations depending on the level of governance), among segments of the population including different age groups and water user groups, and among time periods (e.g., the beneficiaries or exposed now or in the distant future). All these variations in the hydro-social cycle are likely to influence the views and responses of actors and the general public to the system, and may thus be of importance for communication, decision-making, and management of risks.

**Conclusions**

The case and analyses presented above show that current risk representations reflect other controversies and concerns. These may be related or unrelated to planning and implementation of actual plans for land use and utilisation of natural resources. The notion of the hydro-social cycle helps to integrate different concerns and to analyse how different risks related to potential contaminant pathways and effects are represented and managed. Memories from past environmental debates that come to the fore in present debates may be opened up and discussed through the hydro-social cycle, which takes into account not only expert knowledge about risks but also the social contexts, histories, and relations influencing the risk framing. Thus, there may also be cycles in the communication about risks, benefits, and impacts of the implemented system of water resource use and potable water provision, with shifts in the intensity, framing, and mode of discourse. Likewise, the notion of the hydro-social cycle can serve as a conceptual device to integrate risk representations related to different regions, environmental issues, and disciplines.

The online debates are particularly prone to lead to polarised communication that narrows the scope of public understanding and often leaves relevant benefits and risks with little attention. The results of our study suggest that active and open public interaction and communication about the key issues of contaminant pathways, risks, and uncertainties eventually reduce the misunderstandings and imbalanced framing inherent to public risk debates and deliberation. However, our results also suggest that opening up the debate may be painful for the core actors, because it may require them to radically rethink plans and management options, and associated valuations and preferences initially considered as the best ones, and to adopt, in general, a new attitude. Communication in controversial schemes such as this is, understandably but unfortunately, often regarded by those in charge of the scheme as a “necessary evil” and a threat to normal operations, instead of seeing it as a potentially valuable complement, serving to identify new threats, issues, and even opportunities that are beyond the radar of those professionally engaged. New ways to cross these divides and meet these challenges in communication and governance are therefore needed.

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