OPPORTUNITIES FOR WASTEWATER REUSE IN SWEDEN
MÖJLIGHETER FÖR ÅTERANVÄNDNING AV AVLOPPSVATTEN I SVERIGE

Maria Takman
Water and Environmental Engineering, Lund University, Box 118, 221 00 Lund, Sweden, maria.takman@chemeng.lth.se

Abstract
The summer of 2018 was extraordinarily dry, and the groundwater levels and water flows are still low at some places in Sweden. Changes in water use, a growing population, higher living standards and climate change are factors that increase the significance of these issues nationally and globally. Water scarcity affects different aspects of society, and there are also different approaches to the situation. One method to handle scarce water resources is wastewater reuse. Wastewater could be reused for different applications, for example groundwater recharge, irrigation, industrial processes, or for drinking water production. For the different applications, different water quality would be required, and thus different treatment technologies. Wastewater reuse is already applied in countries with longer and more frequent periods of drought, but is not as common in Sweden. There is no legislation specifically regulating this in Sweden. The issue of legislation is one thing that needs to be addressed in order to implement the technology in a safe way. It can also be important in order to gain acceptance for the system, which is another crucial issue. In order to achieve a successful implementation, both questions regarding technology, legislation and social acceptance need to be addressed.

Sammanfattning
Sommaren 2018 var extremt torr, och grundvattennivåer och vattenflöden är fortfarande låga på vissa håll i Sverige. En växande befolkning, högre levnadsstandard och klimatförändringar är faktorer som kan förstärka dessa problem både nationellt och globalt. Vattenbrist påverkar olika delar av samhället, och det finns också olika metoder för att bemöta problemet, varav en är återanvändning av avloppsvatten. Avloppsvatten kan återanvändas för olika ändamål, exempelvis infiltration av grundvatten, bevattning, i industriella processer, eller för dricksvattenproduktion. För de olika tillämpningarna krävs olika vattenkvalitet, och därmed olika reningstekniker. Återanvändning av avloppsvatten förekommer redan i länder med fler och längre torrperioder, men är relativt nytt i Sverige. Det finns därför ingen lagstiftning som specifikt reglerar detta. Frågan om lagstiftning är central för att säkert kunna implementera tekniken. Lagstiftning kan också fylla en viktig funktion för att nå tillit och acceptans för systemet, vilket är en annan viktig fråga. För att säkert och effektivt kunna återanvända avloppsvatten är både teknik, lagstiftning och social acceptans är avgörande.

Keywords: Wastewater reuse, 2030 Agenda, Advanced wastewater treatment.

Introduction

The summer of 2018 was extraordinarily dry, and the groundwater levels and water flows are still low at some places in Sweden: at the south east coast, and at Öland and Gotland (SMHI, 2019). Problems related to lack of water have existed in all times, but a changed water use, a growing population, higher living standards and climate change are factors that increase these issues nationally and globally.

Lack of water affects different aspects of society, for example drinking water supply, industries and agriculture. There are also different ways to approach the situation. Municipal water authorities can encourage households to save water in different ways, seawater can be desalinated for drinking water purposes, water saving measures and optimization at industries can be applied, and wastewater can be reused, to mention a few.

Other environmental challenges also connect to the question of wastewater reuse, such as the treatment of micro-pollutants in wastewater. To separate for example pharmaceutical residues from wastewater, advanced methods are used, which leads to a very clean water. The question has thus been raised if this water can be used for something more, rather than being released to the recipient.

Different questions arise on the subject of reusing the treated wastewater. For what should the water be used, and what water quality requirements are there in the specific application? What techniques can be used to reach the quality requirements, and are there other challenges connected to the question of water reuse?

In 2015, all United Nations member states adopted the 2030 Agenda, to which the 17 Sustainable Development Goals (SDGs) form a basis (Sustainable development goals, 2019a). The goals include for example "No poverty", "Zero hunger", "Clean water and sanitation", "Sustainable cities", "Responsible consumption and production", "Climate action" and "Life below water", and each of them has specified targets related to it. Both water management in general, and wastewater reuse in particular, relates clearly to the goal "Clean water and sanitation" (goal number 6), but is also related to the goals about food production and health, sustainable cities, responsible production, climate action and life below water. Some of the targets, specified for goal number 6, that I would like to point out are: To, by 2030, achieve universal and equitable access to safe and affordable drinking water for all, increase water-use efficiency across all sectors, protect and restore water-related ecosystems, and to expand international cooperation in water- and sanitation-related activities, including wastewater treatment, recycling and reuse technologies (Sustainable development goals, 2019b). It is clear that wastewater reuse has potential to contribute to the sustainability work sought in the 2030 Agenda. It is although important to remember that it is not the only solution, and not always necessarily the best solution, and that there are also risks related to usage of treated wastewater.

In order to determine if wastewater reuse is a suitable method to handle the water sources and to successfully implement it, more disciplinary backgrounds and perspectives are needed than those of engineers. In 2019, Lund University started a graduate school related to the sustainable development goals within the 2030 Agenda, with the aim to increase interdisciplinary research among the participating PhD students. PhD students from different departments and disciplinary backgrounds are participating. I am one of two PhD students from the faculty of engineering at Lund University, and wastewater reuse will be the focus of my thesis. In this text I have discussed a few perspectives on challenges and opportunities related to wastewater reuse, as an introduction to the subject and a basis for further discussions.

Applications

Three possible applications for wastewater reuse, studied by Baresel et al. (2015), are irrigation, industrial processes, and ground water recharge. In the study, the irrigation application included mainly agricultural purposes, but it can also include recreational use, for example irrigation in parks. The industry application included water used for cooling, boiler make-up, industrial process water in pulp and paper, chemical, petrochemical, and coal

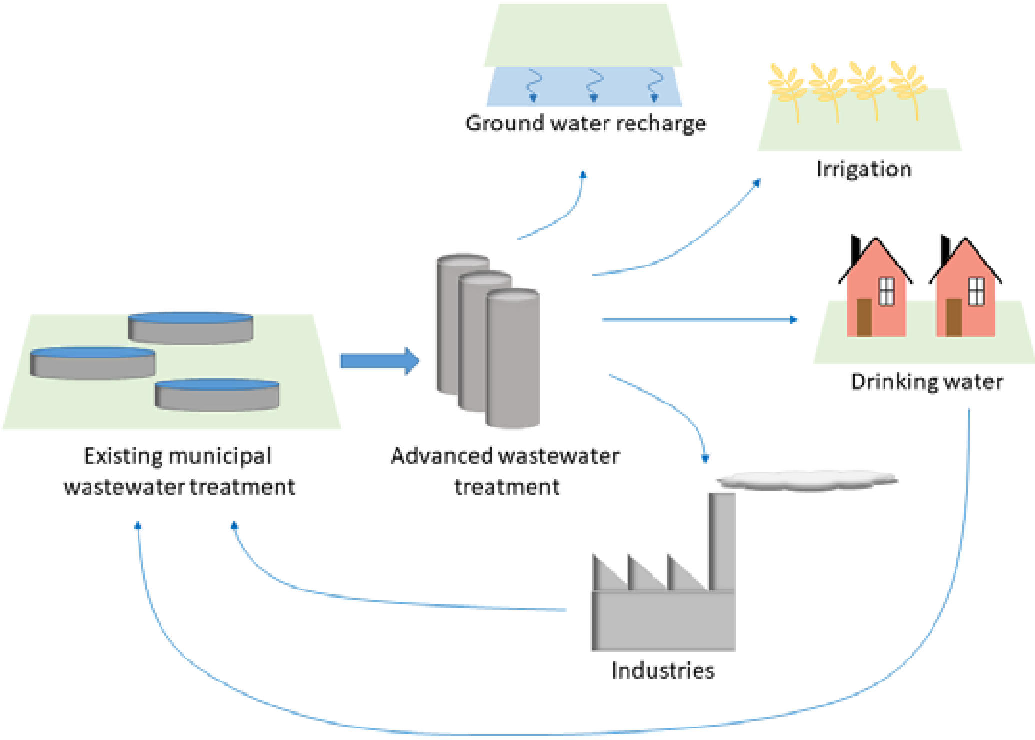

Figure 1. *Schematic overview of possible wastewater reuse applications. Different treatment steps will be required for different applications, and it is possible that industries add additional treatment steps for applications that require a higher water quality. One can also differentiate between direct reuse and indirect reuse. If the treated wastewater passes a natural buffer, like a lake or an aquifer, before being used as drinking water or in an industry, it would be considered indirect reuse.*

and cement industries. The application groundwater recharge was focused on augmentation of aquifers, but also infiltration basins, percolation ponds or augmentation of other natural water bodies can be included. The conclusion was that there are available combinations of techniques that have potential to provide a sufficient water quality for different reuse applications. One problem which is often mentioned when talking about wastewater reuse in agricultural irrigation is the distance between the wastewater source and the fields that are going to be irrigated. Long distance piping is costly, and solutions could focus on reusing wastewater locally, or on developing more cost efficient means of transportation.

Water reuse is already implemented in some applications and locations in Sweden. In pulp- and paper industry, it is common to recirculate process water in different ways, for example in the so called short and long circulation (Skogssverige, 2019; Fatta-Kassinos et al., 2016). Moslehi (2017) did lab experiments, combining different reverse osmosis-membranes with a number of pre-treatment methods, to evaluate the possibility to reuse process water at a Swedish paper mill. In Mörbylånga municipality, at Öland, there is a full scale plant where wastewater from a local chicken industry and seawater is treated at the same plant, and then used as drinking water (Ny Teknik, 2019). In figure 1 a schematic overview of the discussed applications is presented.

Treatment alternatives

Depending on application, different water qualities need to be reached. For agricultural irrigation, it might even be an advantage if nutrients are not removed. For industrial use, focus might be on removing substances that cause scaling and encrustations, and also, the required water quality varies depending on how it will be used and for what industry. Water with lower quality might be suitable for example when cleaning filters or tanks, while the requirements on water used in production processes might be stricter, to not risk the quality of the end product.

A number of methods are available for advanced wastewater treatment. Ozonation, activated carbon or a combination of both, following on the biological treatment, have been proven to remove micro-pollutants (Havs- och vattenmyndigheten, 2018). A combination of ultrafiltration (UF) and granular activated carbon, following on a biological treatment, has also been shown to be efficient for removal of micro-pollutants (Edefell et al., 2019). In both reports (Edefell et al., 2019, and Havs och vattenmyndigheten, 2018), reuse of wastewater is mentioned as a possible application for the treated water.

Apart from the combinations mentioned above, there have been a number of treatment combinations tested with the aim of reusing wastewater for agricultural irrigation, industrial processes, and groundwater recharge (Baresel et al., 2015). Biological treatment was combined in different ways with various filters (sand filter, disc filter, biologically active filter, ultrafiltration) and ozonation. The water was then disinfected with UV or chlorination, or a combination of both. Also more selective membranes, such as reverse osmosis (RO) or nanofiltration (NF) can potentially be used to achieve a very clean treated effluent (Fatta-Kassinos et al., 2016).

To separate micro-pollutants, such as pharmaceutical residues or biocides, from municipal wastewater, the methods that today are considered most cost efficient are generally activated carbon, ozonation or a combination of both. However, which technique that would be considered most suitable will depend on the application and the water quality requirements.

Legislation

Legislation defining water quality requirements for different applications for wastewater reuse is needed for the protection of people's health and the protection of the environment. Common water reuse standards are also important in the European Union to avoid creating trade barriers for agricultural goods irrigated with reused wastewater. Without common standards, once a product is on the market, all member states might not accept it because the level of safety might not be considered sufficient (Alcalde-Sanz and Gawlik, 2017).

Countries and regions with longer and more frequent draught periods already have more extensive legislation regarding reuse of wastewater (for example Australia and California) (Alcalde-Sanz and Gawlik (2017), but in Sweden, there is no legislation specifically regulating wastewater reuse. There are however other legislations that might be relevant, for example legislations regulating drinking water quality, environmental legislation, legislation for working environment, management of waste, and management of byproducts.

When trying to figure out what legislation is relevant for the reuse of wastewater, one first question to ask could be "What is treated wastewater?" In the Swedish legislation for waste, there are different rules for waste and for byproducts. So depending on if the reused water would be classified as a waste or as a byproduct, different legislation would apply, and thus there would be a difference in management of the water (Naturvårdsverket, 2019).

On EU level, there has been a proposal written for regulation of water reuse (European Commission, 2018). The proposal includes water reuse for agricultural irrigation and aquifer recharge, and proposes recommended restrictions on E. coli, BOD5, TSS, turbidity, legionella and intestinal nematodes. A number of substances are hence not included, such as salts, pharmaceutical residues, hormones, biocides, or heavy metals.

Alcalde-Sanz and Gawlik (2017), part of the

European Joint Research Centre (a science and knowledge service for the European Commission), wrote a "Science for policy report" where minimum quality requirements are recommended for water reuse in agricultural irrigation and aquifer recharge. Specific levels were suggested for the same parameters as in the proposal for regulation of water reuse (European Commission, 2018) (that is, E. coli, BOD5, TSS, Turbidity, legionella and intestinal nematodes). However, salts, heavy metals, hormones, pharmaceutical residues and other compounds of emerging concern (CECs) are discussed and considered an important factor to study further, as well as the environmental and health concerns related to these substances. Agricultural irrigation and aquifer recharge were chosen as focus areas since those applications were earlier identified having the highest potential for wastewater reuse in the European Union. Among the international regulation and standards there is also an ISO standard (ISO 16075-1:2015) for wastewater reuse for irrigation.

When discussing the application of reuse for irrigation or groundwater recharge, it would probably be wise to also look into the Swedish Environmental Code (Miljöbalken). In the first chapter, it is stated that the Environmental Code should be applied with the aim to protect people's health and the environment, to protect valuable natural and cultural environments, protect the biodiversity, make sure that ground, water and the physical environment in general is used in a way that ensures sustainability, and to promote reuse and recycling of material, raw materials and energy (MB 1998:808, 1 chapter, 1 §). The last aim, about promoting reuse and recycling, goes hand in hand with reuse of wastewater, provided that the first aims are also met. Other Swedish legislation that also might be relevant is the Swedish Work Environment Act (Arbetsmiljölagen), regarding risks related to the content of the treated wastewater used in for example industrial processes or for irrigation.

The proposals and standards mentioned above do not discuss wastewater reuse for drinking water purpose or for industrial use. The required water quality, of course, differs a lot depending on application, and also at a specific industry different water quality might be needed for different applications. The legislation of drinking water quality is extensive (LIVSFS 2017:2) (Livsmedelsverket/Swedish Food Agency), but pharmaceutical residues are not included today. To make sure wastewater reuse is done in a safe way, these substances might need to be included in the future.

Social and communicational aspects

To reach a successful implementation of a technical system, one needs to keep in mind the importance of the user's acceptance. Wastewater reuse can be associated with big social concern, including impact on health and safety and on the environment (Saad et al., 2017). Hallgren and Ljung (2011) argue that the communication with affected parties is of essential value. They emphasize the importance of understanding the different factors that impact the attitudes of the people affected by the project (users, industries, land owners etc.). Also in the case with the chicken industry at Öland, mentioned in the beginning of this text, project leader Peter Asteberg highlight the importance of information to the public to gain acceptance for the reused wastewater (Ny Teknik, 2019).

It is also important to understand the diversity of people in a community. A community is made up of individuals with different backgrounds, different social and economic opportunities, and within a certain group there are often different interest groups. In order to gain acceptance for a specific technological system, it is crucial to involve the public in the process at an early stage. Even if the water is extensively treated using advanced technologies, and health risks are carefully handled, social perception might still be what determines if the project is successful (Saad et al., 2017).

When it comes to reuse of wastewater, the level of acceptance is dependent on the reuse application, and is affected by many factors, such as degree of contact with the water, feelings of disgust, education, water scarcity, availability of different water sources, economic considerations, and environmental attitudes. According to Saad et al.

(2017), the level of education and the degree of physical contact with the water (potable/non potable) are most influential on the attitudes towards reuse of treated wastewater. It is for example easier to gain acceptance for wastewater reused for toilet flushing than for irrigation of edible crops, and for edible crops, it is easier to gain acceptance for irrigation of crops that need to be peeled before being eaten.

Wrapping up

Reuse of wastewater seems to be a complex mix of engineering, law, economy and sociology. Not only should the most efficient and suitable technology be used. Legislature regulating water quality for different applications needs to be in place for the protection of the environment and people's health, but also to avoid the creation of trade barriers for example in the European Union. Without common standards, once a product is on the market, all member states might not accept it because the level of safety might not be considered sufficient. In order to make the implementation successful, it is also crucial to gain acceptance among the users of the system.

In many parts of Sweden, the actual problem has not necessarily been lack of water, but rather lack of capacity at the drinking water plant. When that is the case, wastewater reuse is probably not the most efficient alternative. However, in areas where there is actual lack of water and low groundwater levels, wastewater reuse is often considered being a more energy efficient alternative than desalination of seawater. When discussing wastewater reuse as a way to handle water scarcity, there are questions and challenges in many stages of the planning and implementation process. Below I have summarized the questions that I have discussed in this text:

- What applications can be suitable for reuse of wastewater?
- What treatment alternatives are there, and which ones are most appropriate for different applications?
- What water quality parameters need to be regulated in order to protect people's health and the environment, and what levels are adequate for the different substances?
- What role does social acceptance play, and how can it be addressed?

In order to understand and address these questions, different disciplinary backgrounds are needed. Working technical systems is a necessity, but to achieve a successful implementation, also questions regarding legislation and social acceptance need to be taken into account.

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