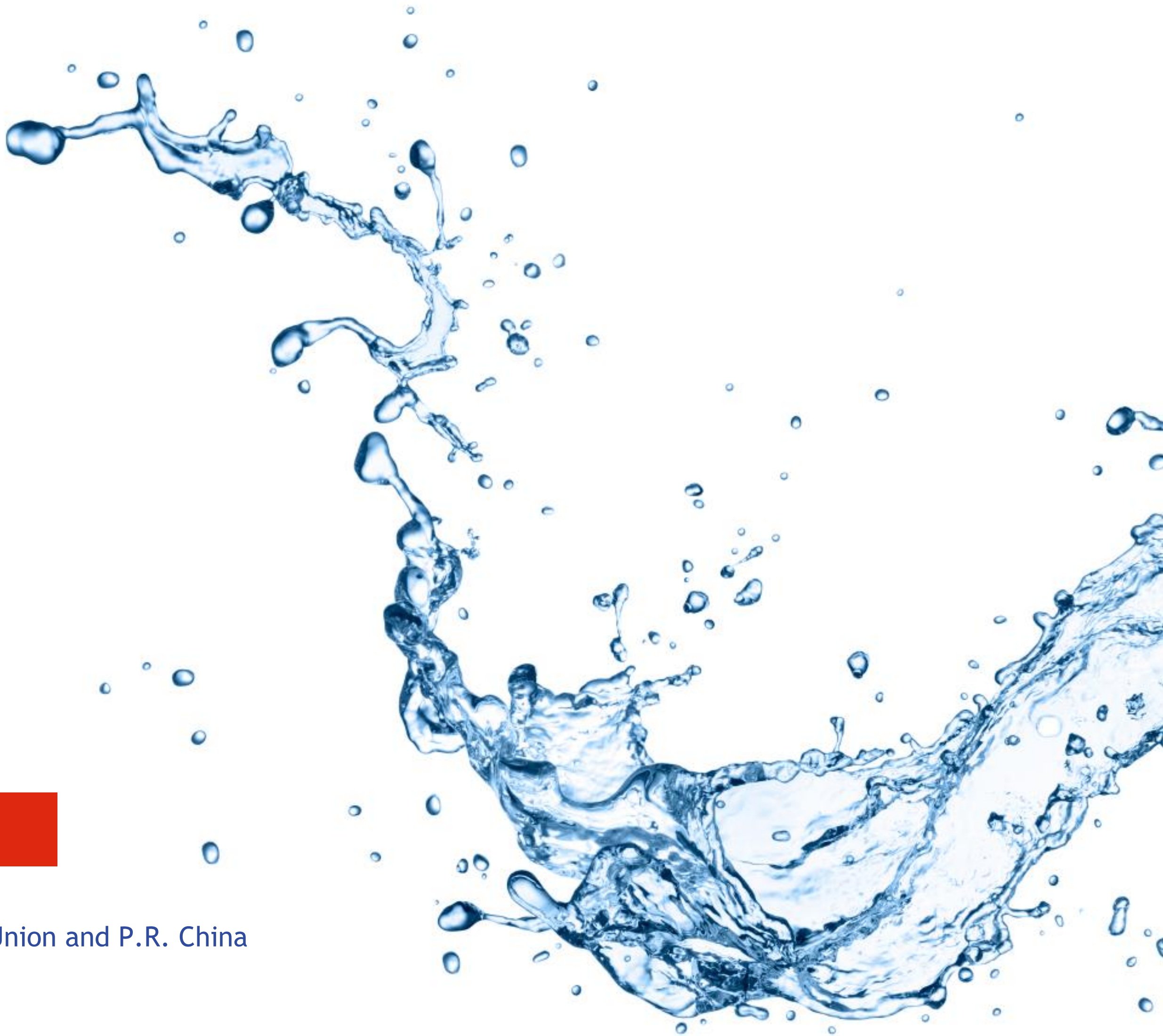
CHINA EUROPE Water Platform

# Small-scale Water Supply and Sanitation in Rural Areas

White Paper



Co-funded by
the European Union and P.R. China

Project ID: 23703265

Versions

| | | | | | |
|---|---|---|---|---|---|
| | 10.5.2022 | FIJAUP | FITIAH/ FIJAUP | FITIAH/ FIJAUP | READY |
| | 3.5.2022 | FIJAUP | FITIAH/ FIJAUP | FITIAH/ FIJAUP | DRAFT |
| | 25.4.2022 | FIJAUP | FITIAH | FITIAH/ FIJAUP | WORK TEMPLATE |
| **Notes** | **Date** | **Accepted** | **Checked** | **Made by** | **Version** |

Centre for Economic Development, Transport and the Environment

SWECO

# Table of contents

## 1 Introduction

The white paper discusses the circular economy technologies of small-scale water supply and sanitation in Europe. It identifies and highlights their practices and technologies in use or under development.

The white paper is a part of China Europe Water Platform’s (CEWP) plans create a base for discussion on the future of a circular economy of water. The paper will be presented as a part of webinar series in the spring of 2022.

The paper includes a short overview of past developments and current situation, with a focus on technologies which are likely to be widely applied in the future. The paper covers only Europe and considers the general situation on the continent. It includes examples from the European countries and examples of possible emerging technologies.

## 2 A Short Introduction to The Circular Economy

In general, the circular economy is a systemic approach in which the waste is minimized, and the life-cycle value of natural resources and products is maximized. The aim is to respond to global and local sustainability challenges. Most crucial topics are related to the supply of water, energy and food for the future population that is expected to achieve 10 billion by 2050. The concepts and technological solutions related to water and sanitation play an important role when adapting to the population growth and the climate change. On contrary to the linear “take-make-waste” model, the circular economy approach is based on a principle of “Reduce-Reuse-Recycle-Restore-Recover, (5R)” (see Figure 1). Many resources like energy, water, materials, data, know-how, and value creation can be circulated. Less waste is produced in the production and consumption phases in the circular economy. The smaller amount of produced waste is seen as a resource for production. The aim is to create sustainable economic value, cost savings, new opportunities and innovation while ensuring the availability of resources. [1, 2, 3]

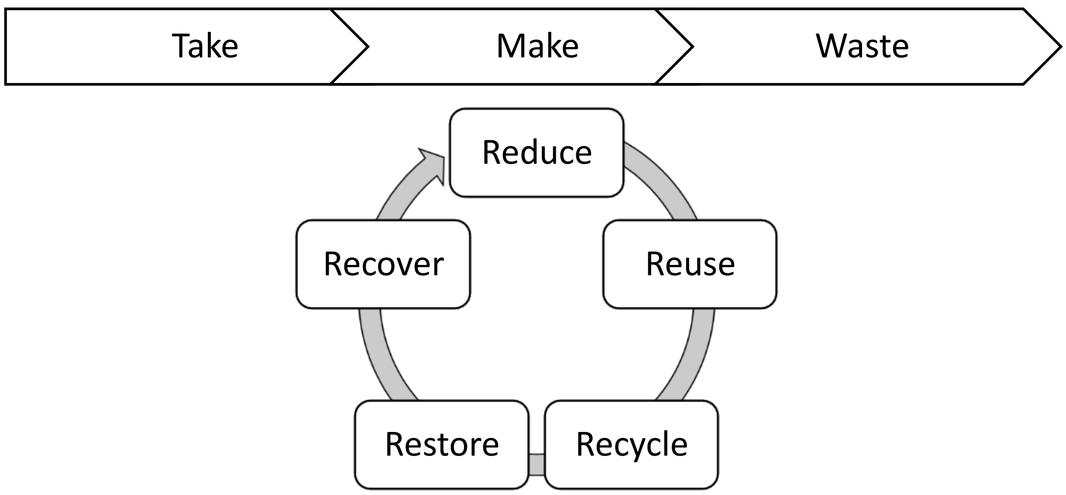



*Figure 1 The principles of the traditional and the circular economy [1] [2] [3]*

Water has a global natural hydrological cycle. The circular economy of drinking water production and sanitation is in fact the circular economy of water which can be seen as the global natural hydrological cycle. [1, 2, 3]

In the circular economy, water is used efficiently minimizing its loss. Substances dissolved and energy bound to the water are recovered and returned to the circulation. Less fresh water is needed to produce drinking water, as the production is more efficient. [1, 2, 3]

Sewage, and substances or energy bound to it during the use of water, can be recovered and returned to the circulation in the upstream. This lowers the amount of fresh water needed. From more concentrated sewage, nutrients and materials can be recovered, and the needed sewage treatment plants are smaller. After collecting the valuables from the sewage, it can be reused as industrial or even drinking water. The energy recovered from the sewage can be used in the treatment process and the surplus can be used locally. [1, 2, 3]

# 3 Past developments

The need for water supply relates closely to the beginning of agriculture and the need for food. The first recorded evidence of water management comes from the time of Scorpion King in the ancient Egypt. The civilizations were flourishing on modern-day Crete and the Indus valley during the Bronze Age. They had developed various of water systems such as aqueducts, cisterns, filtering systems, sedimentation basins, rainwater harvesting systems, terracotta pipes for water supply and sewage, and the sewerage systems. The Romans inherited these techniques and despite being cultural heritage they are also underpinning modern achievements in water engineering and management practices. [4]

Using sewage sludge as a fertilizer has been common from the beginning of time [5]. However, after stricter European Union regulations the circular usage was hindered. For example, in 1998, the European Union set limits on the amount of phosphorus applied to fields, which reduced the use of sewage sludge. From 2006 one should prove the hygiene of the sewage sludge prior to its usage. It has thus been used increasingly for landscaping and energy production. [6]

# 4 The Current Situation in Europe

The chapter discusses the current situation of the circular economy of small-scale water supply and sanitation in Europe. The circular economy practices and technologies in use are identified.

Circular economy is built on business models and broad ecosystems where operators are interlinked to supply the most sustainable and value creating solution for the societies and industry. In rural areas water supply and sanitation can be organized either locally or in collaboration. Small-scale water supplies can be categorized for example by the group of people who are responsible for the administrative, management and operational characteristics and the group of users they supply. WHO and UN lists in the release “Small-scale water supplies in the pan-European region” the small-scale water supplies as below:

- *Private or individual wells* are point sources, such as boreholes, dug wells, springs or rainwater collection, potentially piped into the dwelling or yard, which typically serve a single family or few households (farms, hamlets), and which are usually operated by the users themselves.
- *Community-managed supplies* are systems administered and managed by the community members who are also the users of the water. Community-managed water supplies range from point sources from which community members carry water home, to more sophisticated systems that may involve treatment, storage and piped distribution into dwellings and yards.
- *Public supplies* are systems administered and managed by distinct public entity (such as municipality or water board association) responsible for the provision of drinking-water to the public in a spatially limited area (a small municipality or town) [7]

## 4.1 Drinking water treatment techniques

Drinking water can be made from groundwater, fresh water, brackish water, or salt water. The treatment method chosen depends on how the water quality needs to be improved. The need for water treatment can be determined by laboratory tests indicating the impurities in the water and possible harmful substances. A variety of used treatment methods in Europe are presented in the following chapters.

The collection of treatment methods in relation to water source and the factor to be deleted are presented in Table 1. [8, 9, 10]

*Table 1 Drinking water treatment methods in relation to water source and the factor to be deleted*

| Treatment method | Ground water | Fresh water | Salt water* | Factor to be deleted |
|---|---|---|---|---|
| **Chlorination** | X | X | X | Microbes |
| **UV disinfection** | X | X | X | Microbes |
| **Alkalization** | X | | | Raising the pH<br>Capturing free $CO_2$ |
| **Coagulation-flocculation** | X | X | | Suspended solids and natural organic matter (gravel, sand, algae, clay, iron, protozoa) |
| **Aeration / Oxidation** | X | | | Rn, $H_2S$, together with sand filtration also Fe and Mn |
| **Sand filtration** | X | X | | Solid particles, organisms and together with oxidation also Fe and Mn |
| **Activated carbon adsorption** | X | X | | Rn, color, pesticides, unwanted smell, and taste |
| **Membrane filtration** | | X | X | $NH_4^+$, bacteria, $Cl^-$, $F^-$, humus and color, micro-organisms, Ni, $NO_2^-$, pesticides, unwanted odor, and taste |
| **Ozonation** | X | | | Bacteria, algae, biofilms, micro-organisms |

* Methods used for salt water can also be used for brackish water

### 4.1.1 Disinfection

The purpose of disinfection is to eliminate pathogens. In a small-scale water treatment, the methods used are chlorination and/or UV-disinfection. For chlorination, the chemical is usually sodium hypochlorite which is added to water just before pressure tank using a simple diaphragm pump. [11]

In UV-disinfection water is exposed to UV radiation. In the UV device water flows through a tubular chamber which contains one or more longitudinal ultraviolet lamps. Properly handled UV disinfection is very effective, but it does not protect water from later contamination. If wanted to ensure hygiene in distribution, it is necessary to add a bit of chlorine to water. [11]

These disinfection methods can be used despite the water source.

### 4.1.2 Alkalization

The purpose of alkalization is to reduce the acidity of the water i.e., to raise the pH. It also increases the buffer capacity of the water (the ability to resist pH change). Alkalization binds the free corrosive carbon dioxide in the water. The purpose of alkalization is to adjust the pH level of the water, so it does not cause harmful corrosion. Generally, the pH is set between 7.5-8.5 depending on the water hardness. The harder the water, the closer to pH 7.5 is intended. [11]

### 4.1.3 Coagulation-flocculation

Coagulation-flocculation is a chemical water treatment technique which is typically applied before sedimentation and filtration (rapid sand filtration for example) to improve the ability of a treatment process to remove particles. In coagulation process charges are neutralized and a gelatinous mass traps or bridges particles to form a mass large enough to settle or trap particles in the filter. Flocculation means gentle stirring or agitation to get the particles formed to agglomerate into larger masses to settle or be filtered from solution. [12]

### 4.1.4 Oxidation

In oxidation air is fed to water. Oxidation aims to oxidize a compound with the oxygen in the air, or to remove dissolved gases such as carbon dioxide, radon, or hydrogen sulphide from the water. Some volatile compounds causing odour or taste can also be removed by oxidation. [11]

### 4.1.5 Sand filtration

Sand filtration is used together with oxidation to remove iron and manganese. In freshwater treatment plants sand filtration is used to remove the flocks which emerged in chemical coagulation and got through sedimentation. There are diverse of sand filters, flow can happen with the help of the gravity (open system), or it can happen by the pressure of a pump (closed system). Regular backwash is usually part of the maintenance. To ensure the safeness of drinking water sand filtration requires an adequate pre-treatment (usually coagulation-flocculation) and post-treatment (usually disinfection). [13, 11]

### 4.1.6 Slow sand filtration

Slow sand filtration reminds sand filtration, but the purification process is mainly biological not physical. With slow sand filtration it is possible to remove many impurities such as compounds causing smell or taste, ammonium, iron, manganese and partly humus. [11] A well-designed and properly maintained slow sand filter removes turbidity and pathogenic organisms through various biological, physical and chemical processes in a single treatment step. [14]

### 4.1.7 Activated Carbon Adsorption

Activated carbon filtration is based on the adsorption of contaminants onto the surface of an active carbon. Activated carbon adsorption is an effective method of removing organic compounds such as unwanted taste and odours and pesticides. It is also effective against chlorine, fluorine, and radon. The adsorption efficiency depends on the nature of the used activated carbon and on the raw water composition, so the carbon used should be chosen on a case-by-case basis. [15, 11]

### 4.1.8 Membrane filtration

Membrane filtration refers to methods where water is compressed through a thin film. Based on the pore size of the membrane, membrane filtration can be divided into micro-, ultra-, nanofiltration and reverse osmosis. Each type of filter can remove particles of different sizes or even molecules and ions. Membrane processes are used to remove bacteria and other micro-organisms, particulate material, micropollutants, and natural organic material causing unwanted colour, taste, and odour to the water. Pretreatment before membrane filtration is necessary to prevent pores from clogging. [11, 16]

Reverse osmosis is used particularly for the desalination of salt or brackish water. Because nanofiltration and reverse osmosis also removes the water hardness salts, it is necessary to adjust water hardness and alkalinity after filtration (mineralization). [16, 11]

Examples of different kind of membrane filters and processes are introduced in chapter 4.3.

### 4.1.9 Ozonation

Ozonation or ozonization is a chemical water treatment technique which is based on the infusion of ozone into water. Ozone ($O_3$) gas in one of the most powerful oxidants so ozonation is an advanced oxidation process, in which very reactive oxygen species are produced and able to attack a wide range of organic compounds and micro-organisms. Ozonation is efficient for the disinfection and degradation of organic and inorganic pollutants. In ozone production oxygen ($O_2$) is subjected to high energy voltage or UV radiation to make ozone ($O_3$) so it requires a lot of energy although it can be done at the point of use. [17]

## 4.2 Sanitation

The chapter discusses small-scale treatment technologies and more specifically their closed system technologies and local utilization.

The sewage can be separated to grey and black waters. Grey water is domestic wastewater which is produced from the recycling of laundry, shower, and hand basin water. Black water is sewage which also contains the discharge from the toilets. Black water contains more organic loading than grey water.

Even though the chapter discusses the treatment of sewage, it is getting more popular to use dry toilets and treat the grey water fraction separately. Europe's largest permanent dry toilet solution in Tampere Hiedanranta produces biologically soil improver from dry waste. Digi Toilet Systems Oy has a plant located there in the event centre. They utilize microbes in optimal conditions. The microbes degrade the carbon compounds of the faeces and produce nutrient minerals. It is a closed system thus the $CO_2$ generated can be utilized for example in a greenhouse. [18]

There are multiple technologies to treat sewage in rural areas (see Table 2). The scale of the applications may vary from a single house treatment plant to a village treatment plant.

*Table 2 Small-scale treatment technologies for sewage [11]*

| Technology | Black waters | Grey waters |
|---|---|---|
| **Ground absorption** | Yes (+enhanced dephosphorization) | Yes |
| **Ground filtration** | Yes (+enhanced dephosphorization) | Yes |
| **Seepage pit** | No | Yes |
| **Grey water filter** | No | Yes |
| **Small-scale treatment plant** | Yes | No |
| **Reed fields/wetlands** | Yes | Yes |

### 4.2.1 Small-scale treatment technologies

**All small-scale treatment technologies** have some sort of septic tank as a first stage of treatment. In it, the solids are deposited, and grease is separated from the sewage.

**Subsurface disposal systems** are based on either ground absorption or filtration. The sewage is either absorbed or filtrated to the ground depending on the used technology. In ground absorption the natural or artificial soil purifies the sewage, and the treated sewage ends up in the groundwater. In ground filtration, the treated sewage is collected and discarded to a water body. Various filter modules can also be used. Over the years, the natural phosphorus removal capacity of the ground decreases. In areas with stricter cleaning requirements, the ground treatment plant requires enhanced phosphorus removal if black waters are treated. There is no need for separate phosphorus removal if only the grey water is treated. Enhancement of phosphorus removal can be accomplished through different options:

- A chemical dispenser can be installed inside the property, in a septic tank, or in a phosphorus removal well
- A phosphorus removal mass can be placed in the field structure or in a phosphorus removal well. [19]

**A seepage pit** should be used only in specific cases, and it can be used only for small amounts of grey water. It is a pit that is dug vertically into the ground and is lined with a porous material (concrete and rocks). The porous material lets grey water percolate into the ground.

An electrically free **grey water filter** may use either filter bag or a lime filter and sedimentation to remove phosphorus, nitrogen, and bacteria from the water biologically. The filter module can be built above or underground. There are multiple grey water filters in the market.

**Small-scale treatment plants**

Small-scale treatment plants are electrical devices based on biological and/or chemical treatment. The plants require regular maintenance. The most common maintenance measures are slurry draining and the addition of a phosphorus precipitation chemical. They need to be done to almost all small-scale treatment plants. There are plenty of devices on the market. [20]

Biological treatment relies on bacteria, which break down the waste. The process technology may rely on batch treatment, trickling filters or continuous activated sludge treatment. In the chemical treatment, the added chemicals precipitate for example phosphorus. [10]

Examples of the biological treatment are SBR and MBR processes. The SBR process is a form of activated sludge process where all components of a conventional aeration plant are implemented in phases within the same tank. The MBR process is a hybrid of a conventional biological treatment system and physical liquid–solid separation using membrane filtration in one system. [10]

Constructed reed fields or other wetlands are also a form of biological treatment. The sewage is treated by bacteria. The bacteria form biofilm on plant roots and clay granules. Oxygen rich and oxygen poor zones are formed, which enhances the spectrum of bacteria. The wide spectrum of bacteria can treat pathogens and substances that are otherwise difficult to degrade. [10, 21, 22]

The small-scale treatment plants can be made into closed systems. The easiest option it to use treated sewage in secondary processes that don't need drinking water quality. [10]

#### 4.2.2 Local utilization

**Organizing the local utilization**

From smaller units, sludge is usually transported to bigger plants for processing [10]. In the coastal area of Finland, individual septic tanks are emptied by a local contractor who transports the sludge to regional treatment plants. The transport, the pre and main treatment of the sludge and a possible productization are controlled by a regional waste management service company. The company is owned by 18 municipalities. [23]

Small-scale treatment facilities may get benefit from joining a larger circular economy ecosystem. For example, Pirkanmaa biogas ecosystem in Finland enables the diverse utilization of local resources. It is a regional biogas cooperative -model in development. Local biogas production is networked to local and regional actors. Owners of the ecosystem are the local farmers producing raw materials. They don't need to operate a biogas plant themselves. The operators could be other actors in the ecosystem, such as energy distribution or biogas refinery facilities. Local actors such as farms, plant producers, and industry feed their waste and sewage fractions to a biogas plant. The plant offers them for example energy, fertilizers, and raw materials. The efficiency is better compared to multiple small biogas plants, but the ecosystem is controlled locally. [24, 25, 26]

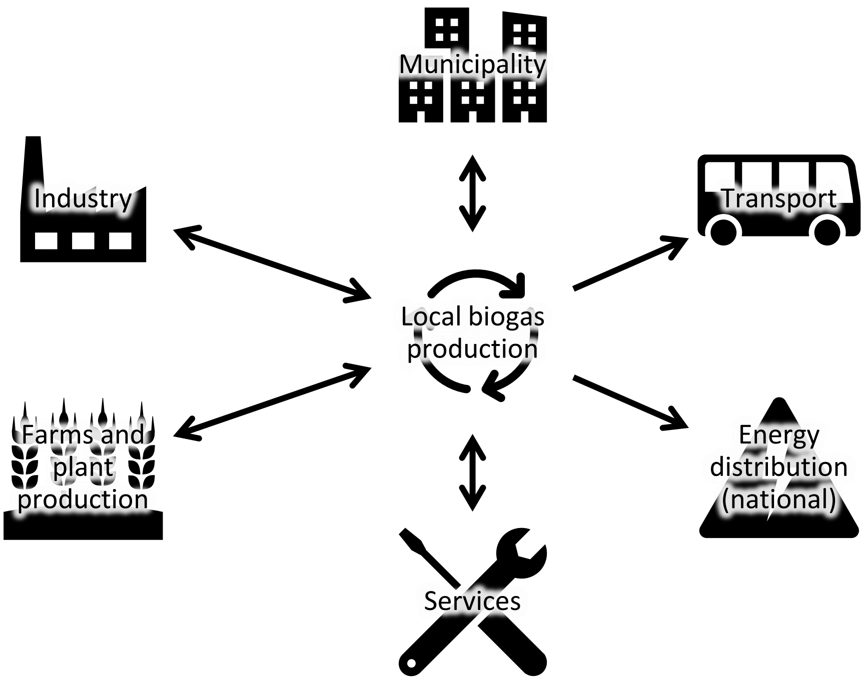



Figure 2 Pirkanmaa's biogas ecosystem [26].

A Braunschweig model combines urban sewage and rural bioenergy to form a water-nutrient-energy cycle. First the sewage from municipalities is mechanically and biologically purified in the Steinhof sewage treatment plant. The treated sewage is then used for irrigation in the fields of their association members. This gives the plants both water and nutrients. Both food and energy crops are produced. The latter is used in the Braunschweig biogas plant, which generates electricity and heat for households. [27]

**Fractions to utilize**

Sewage concentrates are used as mineral source for agriculture. Resources recovered from the small-scale treatment are for example nutrients such as phosphorus and nitrogen. Also, water can be reused even as drinking water [10].

Sewage sludge processed in a biogas plant and/or a compost are further utilized in the agriculture, especially in the Nordic countries [28]. Separated solids are further processed into a fertilizer or used in the fields as such. The liquid fraction is further processed into nutrient-rich concentrate which can be used as an industrial raw material in addition to its usage as a fertilizer. However, organic fertilizer products produced in the biogas plant process are not exempted from REACH registration by the European Chemicals Agency unlike fertilizer preparations produced by composting which hinder the utilization. [29]

To promote market creation, an obligation to use recycled phosphorus as part of products (blending obligation) should be placed. A state's support for farmers using recycled nutrients could also be considered. The use of recycled fertilizer products could be favoured for tax purposes, for example by imposing a tax on mineral-based fertilizers or with a carbon compensation fee paid to farmers. [29]

Even though the reuse of purified sewage is not widely applied, there are some examples in Europe. For example, in Spain drinking water sources aren't abundant. Holmen paper mill reuses its white water from the paper machine after ultrafiltration to paper machine showers. European actors see that the future lies in the recycling of water for industrial operators, gardening or infiltration to boost groundwater formation [29, 28].

## 4.3 Water supply in Finnish archipelago town called Pargas

Pargas is a small town in south-western Finland. From the water distribution point of view, the municipality consists of a centre on the mainland and three rural islands. Drinking water for the town centre is bought from a wholesale water company called Turku Region Water Ltd and owned by nine Turku region municipalities. Water purchased from Turku Region Water Ltd. is routed via 100-kilometer-long line with a diameter of 1,200 mm. Pargas town centre has its own biochemical sewage treatment plant in the mainland, and the municipality also owns and takes care of the water and sewage treatment plants in islands. The treatment plants on the rural islands are described in the following paragraphs. [30]

### 4.3.1 Nauvo

On the largest island called Nauvo there are approximately 250 properties joined to the water supply network, and drinking water is made from groundwater in two water treatment plants from which the water is led to waterworks on the centre of the island. In the waterworks of the centre, there is a 200 $m^3$ water tank and two frequency-controlled pumps maintaining a stabilized pressure of four bars. All the water goes through UV-disinfection before leaving the plant. The waterworks of the centre is visited daily by personnel for operational control and the average flow is 102 $m^3/d$. [30]

One of the water treatment plants in Nauvo is built in 2005 and its purification technique is based on NatWat's method which does not require an addition of chemicals. The water is finely distributed and aerated with a fan in containers containing a biological filter. This process breaks down the manganese into manganese dioxide. At the same time, the oxygen supply raises the pH of the water and converts the divalent iron into trivalent, solid iron. The water is then filtered with sand and lime mass to filter out iron and manganese. A stable water with a pH value of 8 is obtained without chemical pH control. The water is then collected in a basin holding 50 $m^3$, from where it is pumped via UV-filters to the plant in centre as needed. The filters are backwashed manually when necessary. The maximum filtration rate is 12 $m^3/h$. On the other water treatment plant water is treated with a contact filter which is a continuously working sand filtration solution. After filtering the pH of the water is adjusted and the last treatment on-site is UV-disinfection. [30, 31]

The sewage is treated in a small plant with an average flow of 210 $m^3/d$ and design flow 18 $m^3/h$. The plant is using a rotating biochemical filter as a treatment method. Phosphorus is removed by post-precipitation with poly aluminium chloride. The sludge is collected from the bottom of the pre- and post-clarification tanks to the sludge compaction tank and dried with a screw dryer. [30]

### 4.3.2 Korppoo

On the second island called Korppoo there are approximately 150 properties joined to the water network, and the water is made from fresh water coming from a marshland to a small pond and from the brackish water. The fresh water contains a lot of humus and iron. First the freshwater is passed through a softening filter (cation filter) then it is aerated inside an aeration column. Finally, the water passes through a limestone filter, so the alkalinity and pH level become appropriate. The water is then led to a 60 $m^3$ storage tank and from there through the UV-disinfection to the islands network. Drinking water made from the brackish water is first pumped to a container from which it is led to three sand filters. After sand filtration, the water is refined in two ionization filters which are regenerated with NaCl when needed. Then water is led to two bag filters having two different pore sizes to go through. After membrane filtration it is time for reverse osmosis. From reverse osmosis, the water goes to two containers of size four $m^3$. From these containers, the water is pumped through a neutralization filter to adjust the pH. The filter mass has a brand name MagnoDol. Finally, the water goes through UV-disinfection and to the distribution network. The average flow from both water treatment plants together is 55 $m^3/d$. [30]

In Korppoo island, the sewage is treated with a rotating biochemical filter and a post-precipitation of phosphorus with poly aluminium chloride. The sludge is collected from the bottom of the pre- and post-clarification tanks. The design flow is 8 $m^3/h$ with a maximum of 15 $m^3/h$. [30]

### 4.3.3 Houtskär

On the smallest island called Houtskär there are approximately 50 properties, and the water is made from ground and brackish water. The ground water is first aerated and then led through plastic briquettes with favourable microbial growth to remove iron and manganese. After this, the water is treated with sand filtering to remove remaining humus, manganese, and iron. From sand filtering the water is led through a lime filter to raise pH and alkalinity. The brackish water is first pumped to basins and then led to a bag filter with the roughest pore size. Then water goes through rapid sand filtration. The sand filters are rinsed automatically. After sand filtration, the water is led to another bag filter which has smaller pore size than the first one. Before reverse osmosis, the water goes through a cartridge filter. After reverse osmosis waters pH is adjusted with the same lime filters used for ground water. Treated water from both resources is led to storage basins where the water is constantly on the move. From storage basins, the water is pumped to a distribution network via UV-disinfection. The average flow from the plant is 17 $m^3$/d. [30]

In Houstkär island, the sewage is also treated with a rotating biochemical filter and a post-precipitation of phosphorus with poly aluminium chloride. The sludge is collected from the bottom of the pre- and post-clarification tanks. The design flow is 6 $m^3$/h with a maximum of 9 $m^3$/h. [30]

# 5 Future

The chapter highlights the most interesting new technologies in small-scale drinking water production as well as in sewage treatment. Also, a future scenario is created.

## 5.1 Promising drinking water technologies

One option to purify drinking water is to use a modular on-site system. For example, a Belgian company Bosaq has developed a modular drinking water purification system which purifies fresh water, brackish water or salt water into drinking water using solar energy. The system called SolarAq has pre-filtration to remove suspended solids and organics and membrane filtration for more sophisticated purification. The membrane filtration is based on ultrafiltration, nanofiltration and reverse osmosis. The final disinfection is made with LED-UV technology. The system has a battery pack so it can be used easily also in the areas where electricity is not available although there is also a possibility to plug the system via electricity grid. [32]

The atmospheric water generators (AWG) are a promising technology. For example, Italian company Veragon produces technology which replicates the natural cycle of water. The humidity condenses from the atmosphere onto the ground and percolates into the soil. The soil then enriches the water by minerals. The machines of Veragon do the same and treat them with ozone and UV light to ensure sterilization. Then the water is mineralized. [33] There are multiple other companies located in Europe that produce AWG-machines too, especially from Italy and Spain [34].

## 5.2 Promising sewage treatment technologies

Rietland produces natural treatment systems with plants and their innovations have been mentioned in discussions about promising sewage treatment technologies. Their products include PhytoAir, Phytoparking and Phytocube. They are constructed wetlands/reed beds. They consume low energy, have little malfunctions, need minimal maintenance, and have a long service life. Phyto-series add extra oxygen to the filter bed which increases the filter's treatment efficiency and reduces the required area of the filter. This technology is a combination of aerated reed beds (Forced Bed Aeration (FBA®)) and two-stage system where the sewage flows first through a vertical filter and then through a horizontal one. In addition to the Phyto series Rietland also produces classic reed beds such as horizontal and vertical subsurface flow wetlands as well as surface flow wetlands.

## 5.3 Future scenarios

In discussion about the future of sewage treatment, separating sewage in houses is mentioned. There urine, grey water and rainwater are collected separately and treated each in its own way. Urine can be used as a fertilizer, and both rainwater and grey water for irrigation. The grey water and rainwater can be used for flushing toilets if one has a conventional toilet system. Even a local secondary network for non-drinking water can be used. In any case, the drinking water usage will be reduced. [10]

There is plenty of thermal energy in sewage. In discussion about the future of sewage treatment, it is seen that this potential should be harnessed. For example, Greengineering specialize in harvesting & reusing waste thermal energy. The heat can be captured for example from shower outlet. The heat recovery units are suitable for commercial or domestic installations. [35]

## 6 Conclusions

There is a wealth of expertise in water and wastewater treatment methods in Europe. Drinking water can be made from ground water, fresh water, brackish water or even salt water. The treatment methods used depends on the water source and water quality, so before choosing the method used it is recommended to define the water quality in a laboratory. Some treatment methods are very easy and inexpensive to use and maintain, but some of them requires more professional skills and knowledge. Many of the drinking water treatment methods require a power source. If electricity is not available, there are also solar-powered devices on the market.

The sewage can be separated to grey and black waters. Even though the paper discusses the treatment of sewage, it is getting more popular to use dry toilets and treat the grey water fraction separately. Ground absorption and filtration, small-scale treatment plants and reed fields or wetlands are examples of the sewage treatment technologies used in Europe. Grey waters can also be treated in seepage pits or grey water filters. From smaller units, sludge formed in small-scale treatment is usually transported to bigger plants for processing. The concentrates formed there can be used as a mineral source for agriculture. Also, the water fraction is reused though the reuse of purified sewage is not widely applied.

## 7 Acknowledgements

The paper is written for Centre for Economic Development, Transport, and the Environment of Southwest Finland by M.Sc. (Tech.) Tia Savolainen and M. Eng Jaana Pulkkinen from Sweco Finland. M.Sc. (Tech.) Antti Ryynänen from Sweco Finland acted as a project manager as well as a contributing expert. Pekka Parkkila from Centre for Economic Development, Transport, and the Environment of Southwest Finland acted as a subscriber and contributing expert.

The experts interviewed by a survey are:

- *Steven Raes, Sweco, Belgium*
- *Dr. Heinrich Herbst, Sweco, Germany*
- *Vesa Arvonen, Suomen Vesihuolto-osuuskunnat RY*

The experts interviewed in person:

- *Henrik Roms, Pargas Water Services*

## References

[1] Maa ja Metsätalousministeriö, *Circular Economy in Water Sector work shop 13.5.2020,* 2020.

[2] Sitra, *Kierrolla kärkeen - Suomen tiekartta kiertotalouteen 2016-2025,* 2016.

[3] World business council for sustainable development, *Business guide to circular water management,* 2017.

[4] N. A. Angelakis ja X. Yun Zheng, "Evolution of Water Supply, Sanitation, Wastewater, and Stormwater Technologies Globally," Multidisciplinary Digital Publishing Institute, 2015.

[5] G. Lofrano and J. Brown, "Wastewater management through the ages: A history of mankind," *Science of the Total Environment,* pp. 5254-5264, 2010.

[6] V. Tompuri, "Lietteen kuivausmenetelmät ja hyötykäyttö tehostuvat," *Tekniikka ja Talous,* 2006.

[7] B. Rickert, M. Samwel, E. Shinee ja F. a. S. O. Kozisek, "Status of Small-Scale Water Supplies in the WHO European Region," World Health Organization, , 2016.

[8] Suomen Ympäristökeskus, "Kaivoveden käsittely," 2020. [Online]. Available: https://www.ymparisto.fi/fi-FI/Rakentaminen/Rakennushanke/Talotekniset_jarjestelmat_LVI/Vedenhankinta_kaivosta/Kaivoveden_kasittely.

[9] Socotec, "FAQs Ozone Water Treatment," 2017. [Online]. Available: https://www.socotec.co.uk/media/faqs/faqs-ozone-water-treatment.

[10] T. Savolainen ja J. Pulkkinen, Interviewees, *A survey about small scale water production and sanitation.* [Haastattelu]. 3 2022.

[11] E. Isomäki, M. Valve, A.-L. Kivimäki ja K. Lahti, "Pienten pohjavesilaitosten ylläpito ja valvonta," Suomen Ympäristökeskus, Helsinki, 2006.

[12] F. Mazille ja D. Spuhler, "Coagulation-Flocculation," [Online]. Available: https://sswm.info/sswm-university-course/module-6-disaster-situations-planning-and-preparedness/further-resources-0/coagulation-flocculation. [Haettu 6 April 2022].

[13] M. Bruni ja D. Spuhler, "Rapid Sand Filtration," [Online]. Available: https://sswm.info/sswm-university-course/module-6-disaster-situations-planning-and-preparedness/further-resources-0/rapid-sand-filtration. [Haettu 6 April 2022].

[14] M. A. Bruni ja D. Spuhler, "Slow Sand Filtration," [Online]. Available: https://sswm.info/sswm-university-course/module-2-centralised-and-decentralised-systems-water-and-sanitation-2/slow-sand-filtration. [Haettu 6 April 2022].

[15] F. Mazille ja D. Spuhler, "Adsorption (Activated Carbon)," [Online]. Available: https://sswm.info/sswm-university-course/module-6-disaster-situations-planning-and-preparedness/further-resources-0/adsorption-(activated-carbon). [Haettu 12 April 2022].

[16] F. Mazille ja D. Spuhler, "Membrane Filtration," [Online]. Available: https://sswm.info/sswm-university-course/module-6-disaster-situations-planning-and-preparedness/further-resources-0/membrane-filtration. [Haettu 12 April 2022].

[17] F. Mazille ja D. Spuhler, "Ozonation," [Online]. Available: https://sswm.info/sswm-university-course/module-6-disaster-situations-planning-and-preparedness/further-resources-0/ozonation. [Haettu 13 April 2022].

[18] Digi Toilet Systems Oy, "Digi Toilet Systems," Digi Toilet Systems Oy, [Online]. Available: www.dtso.fi. [Haettu 22 4 2022].

[19] Muoviteollisuus Ry, "Hajajätevesiopas," Putkijaosto, 2017.

[20] Ympäristöhallinto, "Kiinteistön jätevesien käsittely," Ympäristöhallinto, 20 2 2019. [Online]. Available: https://www.ymparisto.fi/fi-FI/Rakentaminen/Rakennushanke/Talotekniset_jarjestelmat_LVI/Kiinteiston_jatevesien_kasittely. [Haettu 6 4 2022].

[21] Rietland, "Rietland," Rietland, 2017. [Online]. Available: https://rietland.com/en/. [Haettu 6 4 2022].

[22] AGRICULTURAL REQUISITES AND MECHANIZATIONS LIMITED, "Final Report Summary - ARBI (Autonomous Reed Bed Installations)," Cordis EU Research Results, Rugeley, 2015.

[23] Lounais-Suomen Jätehuolto Oy, "Lounais-Suomen Jätehuolto Oy," Lounais-Suomen Jätehuolto Oy, [Online]. Available: https://www.lsjh.fi/en/. [Haettu 22 4 2022].

[24] P. Nissinen, "MIKROSIIVILÖINTI JÄTEVEDENPUHDISTAMON ESIKÄSITTELYVAIHEENA - vaikutusten arviointi staattisen mallin avulla," Tampere University of Technology, Tampere, 2017.

[25] Sweco, "Advanced Treatment Technologies and Asset Optimisation Videoconferenceseminar - Nokia ECO3 Perspective," in *Advanced Treatment Technologies and Asset Optimisation Videoconferenceseminar - Nokia ECO3 Perspective*, Tampere/Online, 2016.

[26] Sweco, Writer, *Pirkanmaan biokaasuekosysteemi -raportin tulokset*. [Performance]. Sweco, 2020.

[27] Abwasserverband Braunschweig, ”Braunschweig model,” Abwasserverband Braunschweig, [Online]. Available: https://www.abwasserverband-bs.de/en/what-we-do/the-braunschweig-model/. [Haettu 2 5 2022].

[28] M. Kierikka, A. Bruunen-van Bergen, D. Antakyali, M. Ejderby, S. Suurla ja T. Haavisto, *A workshop for circular economy of municipal wastewater treatment plants,* Online: Sweco, 2020.

[29] J. Salminen, K. Määttä, K. Noro, J. Raatikainen, M. Maidell, H. Haimi, J. Pohjola, P. Horne, A. Karjalainen and V. Junttila, "Vesiviisaan bio- ja kiertotalouden kannusteet," Valtioneuvoston kanslia, 2020.

[30] H. Roms, Interviewee, [Haastattelu]. 21 April 2022.

[31] Ferroplast Oy, ”NatWat-process,” May 2016. [Online]. Available: https://www.ferroplan.fi/pdf/Ferroplan_NatWat_process_brochure_eng_print.pdf. [Haettu 2 May 2022].

[32] Bosaq, [Online]. Available: https://bosaq.com/.

[33] Veragon, ”Products,” Veragon, [Online]. Available: http://veragon.com/products/. [Haettu 2 5 2022].

[34] Environmental-Expert, ”atmospheric water generator Companies in Europe,” Environmental-Expert, [Online]. Available: https://www.environmental-expert.com/companies/keyword-atmospheric-water-generator-9614/location-europe. [Haettu 2 5 2022].

[35] Greengineering Ltd, ”Greengineering Ltd,” Greengineering Ltd, [Online]. Available: http://www.greengineering.co.uk/. [Haettu 24 4 2022].

CHINA
EUROPE
Water Platform

This action is co-funded by the European Union and P.R. China.
The project partners are solely responsible for the contents, which do not necessarily reflect the views of the funding parties.

Twitter @ChinaEUwater #CEWP