2019-07-04

CIRCULAR WATER CHALLENGE

A study of water and wastewater on Örö

Content

1 Summary

Örö is a 2 km^2 island with a whole year resident population of two and few visiting artists. However, during the summer the short tourist season puts a high pressure for Örös infrastructure and natural resources. There are several endangered habitats and species of Örö, for example, the island is well known for its abundance of butterfly and rare beach and pasture plants. By being part of Archipelago National Park, people's recreational opportunity is not allowed to threaten the value of nature.

Even though the residents and some of the summer residents are doing their best to save water, over 2910 m^3 of purified drinking water is produced annually. During the normal period (1981-2010) the annual groundwater recharge was maximum 492 500 m^3. Örö ran out of groundwater in 2018, which is why the island has been dependent on desalination of brackish water from the Baltic sea.

From a water (and energy) saving point of view, Örö is just in the beginning, since most of the water technology is recently changed, unfortunately not into water saving technology. In addition, neither the tourists nor the summer residents are aware of the water scarcity which is why they don't think and act in a water saving manner.

The water reuse proposal includes three different plans with different solutions. The places in Örö, where the water consumption is highest are the public sauna, the restaurant and the toilets. Therefore, the plans are concentrated into them. The toilets could be flushed with the gray water from handwashing or the whole system changed into vacuum toilets. The showerheads at the public sauna should be fixed to use less water. In all the proposals the water scarcity communication to the tourists are considered.

2 Introduction

2.1 Introduction

The purpose of this assignment was to study the water and sewage situation on the island of Örö in Finland in the spring of 2019 by using the Circular Water Challenge projects framework and write a report on it. As an outcome of the research results three suggestions for water circulation possibilities in Örö will be addressed. These outcomes can be found in the end of the report.

In the Circular Water Challenge Project, in addition to Örö, islands Korpo, Oaxen, Möja, Sandhalmen, Kökar and Brändö are participating. The project is financed by Region of Stockholm (Sweden), the municipalities of Södertälje (Sweden), Värmdö (Sweden), Kökar (Finland), Brändö (Finland), Forststyrelsen (Finland) and the Nordic Archipelago Cooperation. KTH Royal institute of technology leads the workflow.

2.2 The three levels of an island

The freshwater system of an island can be described as three superimposed levels:

The water of the island

This is the basic geophysical level which encompasses the physical geographical conditions on the islands no matter if people live there or not: geology, oceans, skies, hydrology, climatology, flora and fauna. This is the physical landscape.

The water of the islanders

At the next level, humans move in and make their human footprints: they build houses and villages, use the soil and water, eat, drink, walk, arrange their social life with children, schools, elderly care, health care and security. This is the cultural landscape.

The water of the community

At the top level, the humans build a common infrastructure of roads, water, sewer, telephone, broadband, fossil and renewable energy sources, ports and ships. Water is produced, distributed, managed, financed and administrated. This is the technical landscape.

2.3 Methodoly

Background data is collected by desktop studies from February to June. Two weeks field studies including semi-structured interviews, observation and field walks are carried out during June. The interviews include representatives from Forststyrelsen, technicians working with the water plants, residents, summer residents and different type of tourists including sailors, overnight tourists. The research results are analyzed, and results presented in this paper. In addition to

previous water related fieldwork period, the three-layer framework and methods were studied in a circular water course in KTH in order to be able to carry out the study of Örö.

During the field studies the analyses were done by using existing maps, such as geological maps and topographical maps and researcher's observation in order to draw the catchment areas and map the water supplies, pumping stations, pipes, reservoirs and sewage systems. The consumption figures were studied during the field trip to Örö with help of the local entrepreneurs and water work managers. The compilation of observation, calculation and suggestions can be found in this report.

The second stage of this project will include analyses and conclusions based on this report. These will be done in local and joint workshops with politicians and officials from all the islands which are participating in the Circular Water Challenge project. Later the representatives of the islands have open dialogue and learn from one another, reflect on their situation and set goals for their own circular water development.

3 Örö as a research context

Örö is a 2km^2 island (figure 1) in the southwest outskirts of the Finnish archipelago in the Baltic Sea. The coordinates for the island are 59°48.7'N, 22°19.4'E. Örös archipelago covers an area of 779 hectare of which 509 hectares is water (figure 2). All together the islets cover 69 hectares. The main island of Örö is 197 hectares. In addition, some 5 hectares are shore meadows. From the main island of Örö 157 hectares of land is part of Natura Network. (Skärgårdskompaniet 2018.)

Örö is part of municipality of Kemiönsaari. The post code of Örö is 25930 and the post office is in Kasnäs in the municipality of Kemiönsaari. Örö is part of the Eastern European summer-time zone, which is GMT +3. (Visitoro.)

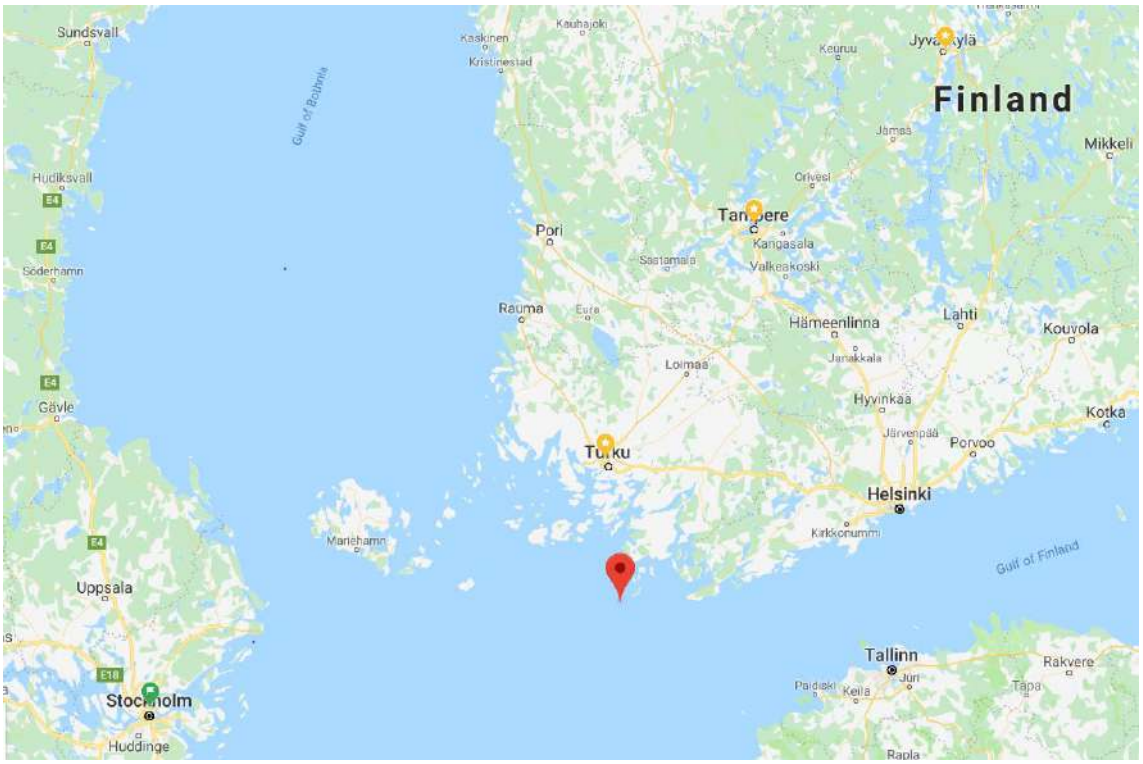

Figure 1. Örö is located in South- West Coast of Finland. Location of Örö. (image:www.maps.google.com)

Used as a closed military fortress from the early 1900s until the end of 2014, the island has since been opened to the general public, developing into a popular travel destination. Örö is part of the Archipelago National Park, administered by the state of Finland via Forststyrelsen. The idea in Örö is not only to develop the tourism industry but also develop the island in a sustainable manner. Örö is also part of Natura Network of European Union. (Metsähallitus, 2014.)

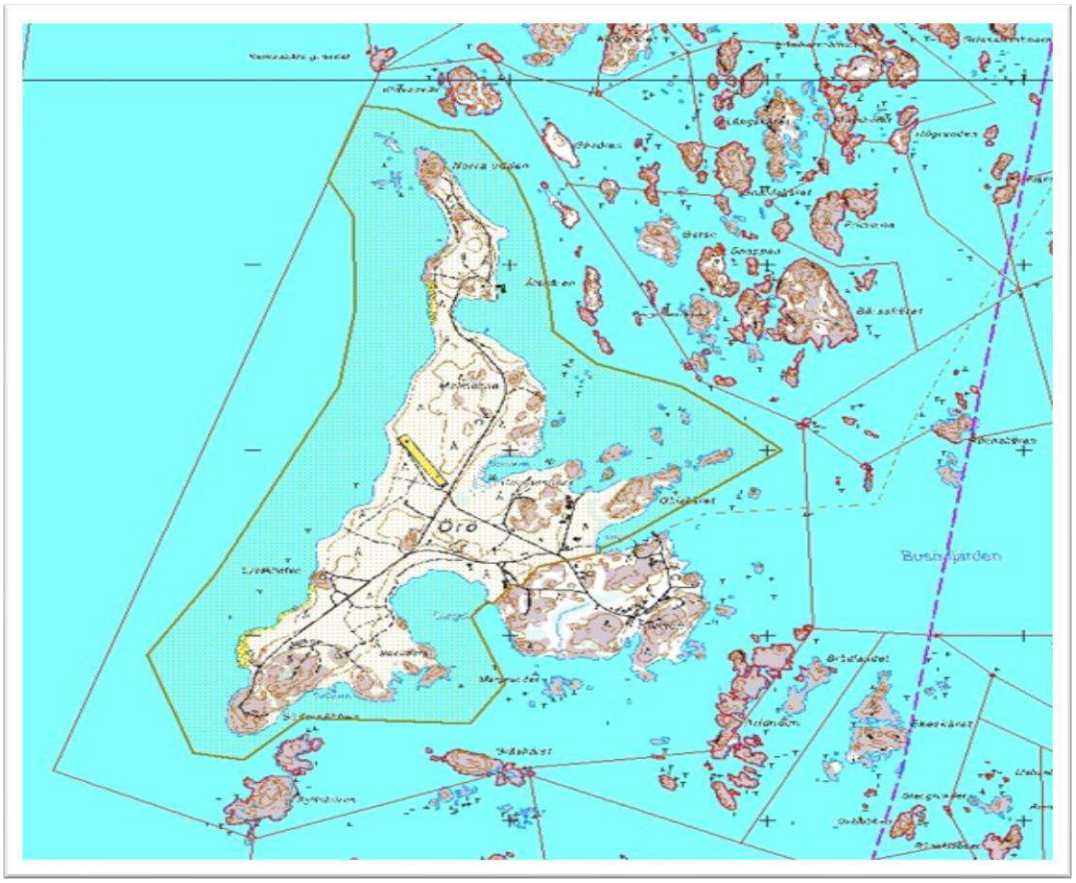

Figure 2 Örös archipelago is presented within the outer borders and the Natura Network as a green area on the map.

The capes (Figure 2) on the island include Norra udden in the north, Södernäbbet in the south, Golskäret and Holmen in the East. The west side of the island doesn't have capes. The tallest hill in Örö is 16 meters above sea level and it is located in the Södernäbbet. Bays include Balget in the south, Solkuro in the southwest and Storviken and Gölen in the east side of the island. (Metsähallitus, 2014.)

4 The Natural Landscape

4.1 Geology

The name Örö is a compound word which means ör-'gravel' and ö-'an island'. Therefore, the word Örö refers to the gravel on the island. (Tuovinen Tapani. 2014). The island lies on the southeastern border of the Gullkrona Basin in the place where a north-south esker is joined with the Second Salpausselkä end moraine. The last Ice Age ended here 11 600 years ago. Moraine and sand were layered on the edge of melting glacier forming the ridge. (Skärgårdskompaniet 2018). According to Koskinen 2018, due to the fact that Örö is located on second Salpausselkä, the soil type is largely sand and gravel (figure 3). The coarseness of sand varies as well as the order of soil type layers. The soil depth varies in different parts of the island. However, the soil depth has not been accurately studied yet. In year 2015 there were three test drills carried out in the central part of the island. The depth of the drillings were 9m and 6m. In the 9 m the soil type was sand and in the other drilling place the soil type was moraine. (Onnila, 2015.)

Figure 3 The soil type in Örö is largely sand and gravel. (Picture: Lotta Eriksson 2019).

The South-West, North-East and North side of the island are rocky. In between the rocks there are low-lying flat, sandy heatlands and boreal forests. In several places can be found different size of round boulders. The bedrock type in the area is granite (figuere 4.) On the East side of the island there exists also granodiorite.

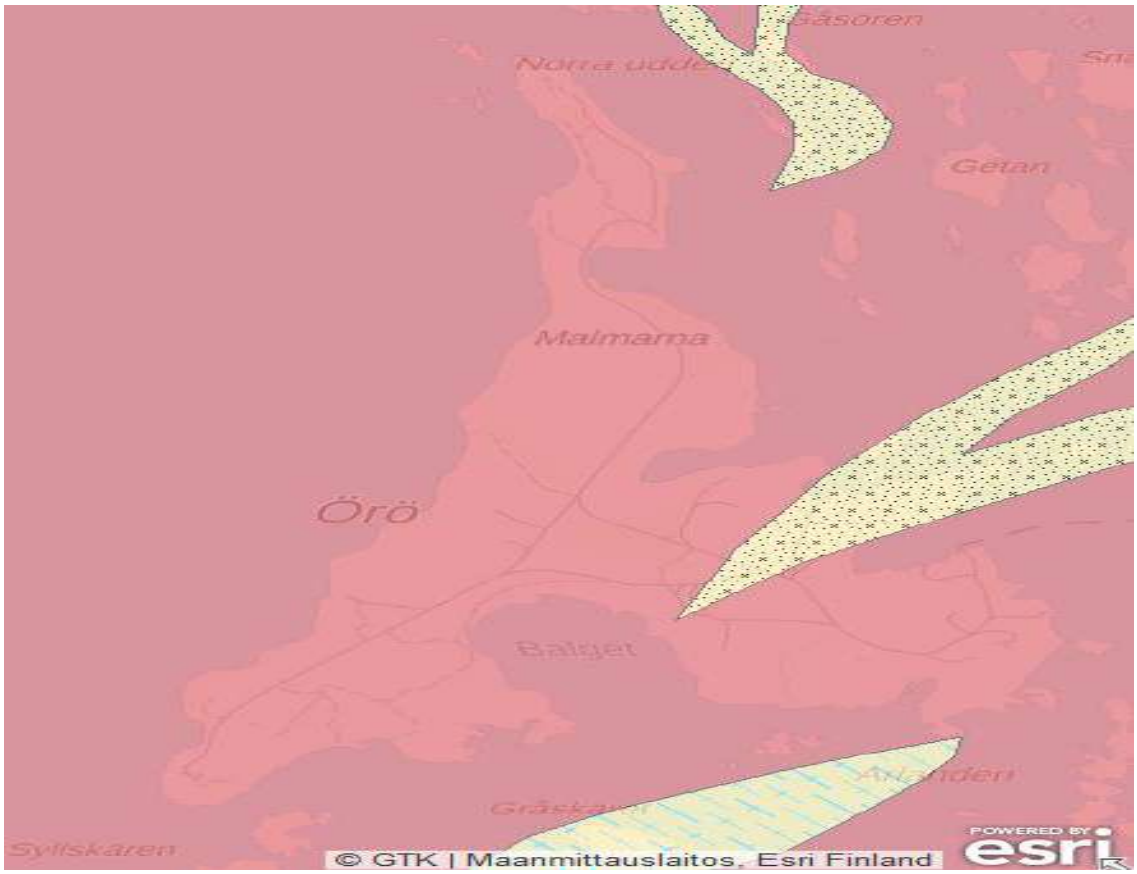

Figure 4. The bedrock type in Örö. The red color refers to granite and the dotted yellow to granodiorite. (Image from geologian tutkimuskesus).

4.2 Hydrology and Climate

According to Köppen climate classification the southern coast of Finland belongs to the Dfb group, which means humid continental mild summers and it is wet all year around. The westerly winds bring the warm air currents into the Baltic areas. This moderates the winter temperatures and keeps the mean annual temperature is 5.5°C. The 2018 was 1-2 degrees warmer than an average year in Finland. (Finnish Meteorological Institute.)

During the normal period (1981-2010) the average annual precipitation in Örö was 650-700mm. This is also an average precipitation in other parts of South Western Finland. However, year 2018 was drier than an average year in Finland and the Finnish Archipelago got only 400 mm of annual precipitation. (Finnish Metorological Institute.) As mentioned during the normal period the average annual rainfall in Örö was around 650 mm, and according to Leppäranta (2017) the

evapotranspiration during the same period was 400mm. This means that annually 250mm water percolates down into the groundwater.

As table 1 show the precipitation during spring and summer months are smaller than other parts of the year. In addition, during summer months the evapotranspiration is higher than in other times of the year. At same time of the year the infiltrated water is used by the vegetation and does not built new groundwater. (Sen 2015.) As table 1 shows, the precipitation increased from August to September as well as from December to January. During the normal period, there were 165-180 rainy days (≥ 0,1 mm) in the South West part of Finland, including Örö. (Finnish Meteorological Institute).

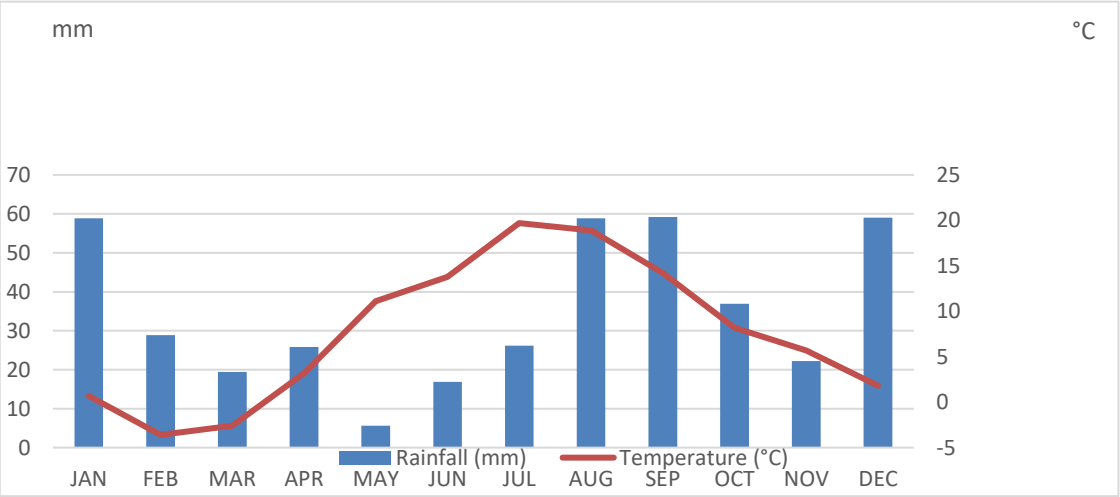

Table 1. The average rainfall and air temperature in Örö in 1981-2010. Monthly mean rainfall (mm) and monthly mean temperatures (°C).

Majority of the groundwater in Örö flows slowly to the Baltic sea. On south east part of the island there can be found a wetland. According to the interviews, this wetland has been formed as a pass by water from the drinking water purification plant. There is a river from the wetland to the sea. The precipitated surface water from the rocky areas on the island (South, North and South-East) flows directly into the sea.

There are 4 main catchment areas in Örö (figure 5). The border of each catchment is also a water divide. The catchment areas are identified by understanding the topography. Without soil depth information it's hard to know how much groundwater is found in the soil. The catchment area number 1 is 52.6 hectares, the catchment number 2 is 37.3 hectares, catchment number 3 is 76 hectares and the catchment area number 4 is 31,1 hectares. The groundwater well is located in the catchment area number 3.

Annually the maximum groundwater recharge in Örö is around 492 500 m^3. However, it is unknown how much groundwater can be stored in the soil and bedrock. Sometimes there can be found runoff from bedrock to the sea, especially in areas close to the sea.

Figure 5. The main catchment areas (1-4) in Örö where the groundwater recharge can be found.

4.3 Sea: surface, depth, flora and fauna

The coast of Örö is shallow. The East coast is only around 1,4m deep, South Coast 2,1m and West coast 4,3m. The temperature of the water varieties from 0°C to 20 °C. The grey seal and ringed seal can be spotted on the islets of Örö. The fish stocks used to be large, however they have decreased. The fish species include for example, baltic herring, european perch and northern pike. The coast of Örö suffers from Eutrophication. (Syke, 2019.)

4.4 Land: landscape, flora and fauna

Due to the rather large size, the location in the southern outer archipelago, the geological history and the historical use of the island, Örös nature is extraordinarily rich. Örö's natural environment is unique, it includes some of Southern Finland's most important concentrations of threatened species (figure 6) and habitats. There are 236 species which are classified either under supervision or endangered. Especially the butterfly-fauna is rich and for many plant species Örö is either the only or one of few possible habitats. (Ryömä, 2015.)

Figure 6. Some unique plant species in Örö. (Picture Lotta Eriksson 2019)

In addition to having a typical island ecosystem, Örö is home to some unique habitats and 48% of the islands surface belongs to 17 Natura habitats on the island. Six of these are prioritized or classified as high priority. The main habitat of Örö is escer-island which covers most of the island and the surrounding waters. The most precious of these are the invaluable scorched heathlands and sandy beaches that have remained virtually untouched for over 100 years, during which time the island has been a closed fortress. The abolishment of the defense forces on the island has led to the progressive overgrowth of many traditional biotopes. (Lindgren 2015.)

The landscape varies from natural open beaches to archipelago and hot sunny meadows on the islands inner area. The impact of the harsh winds is also seen in the inland's trees. The pine trees for example grow more branched and lower than in inland (Lindgren 2015). As a result, from the interviews the landscape was described as following: South and West side of the island opens the horizon to the open sea from where the landscape changes slowly through the interface in between the sea and land to sculpturally beautiful archipelago forest. Towards the north there are beautifully sheltered inner bays with beach meadows which changes to grazing land for high-land cattle and sheep. Every side of Örö contains a different atmosphere. Atmosphere not only changes within the spatial dimension but it also changes within the seasons. Even though the atmosphere was generally described relaxing and welcoming, it was also described being serious due to the army background.

4.5 Drinking water resources

Based on the interviews with- Forststyrelsen all the drinking water throughout the army times and until June 2018 was taken from the drilled well which is located in the middle of the island.

Figure 7 The iron in groundwater colors the rocks on the outflow area. (Picture Lotta Eriksson 2019)

In general, the groundwater from the well meets the requirements of the Ministry of Social Affairs and Health No 401/2001 concerning the quality standards and recommendations for household water excluding iron, manganese, COD-value, turbidity and color. Iron (figure 7) is commonly found in Finnish groundwater and can also be dissolved from the waterpipes. Iron reduces the usability of the groundwater, but it is not dangerous for health. The COD value describes the amount of organic matter in the water. Hummus in the water is not dangerous for health. The turbidity of water is often due to iron or clay and the turbidity does not cause negative health effects. The color of water is generally due to colored organic compounds such as humic acids. Also, iron and manganese cause a change in watercolor (Appendix 1 and 2). (Lounais-Suomen vesi-ja ympäristötutkimus Oy, 2015 and 2018.)

The groundwater storage in the 4 catchment areas, with the annual 250mm groundwater recharge, was during normal period at the most 492 500 m^3.

4.6 Summary

The island has varied scenery which include some of Southern Finland's most important concentration of threatened species and habitats. The precipitation percolates into groundwater mainly in between October and April. There are four catchment areas in Örö, which can be analyzed from above the ground. The maximum groundwater recharge in all catchment areas is 492 500 m^3 /year. The groundwater is slowly flowing towards the sea from each catchment. The groundwater quality was tested in 2018 and it contains high amount of iron, manganese, COD-value, turbidity and color.

5 The Cultural Landscape

5.1 Population

According to interviews there are only two whole year residents in Örö. However, there is an artist residence which accommodates simultaneously two visiting artists from one week up to a month throughout the year. During the winter months the technicians, as well as people working for army are visiting the island.

During the summer months the human pressure multiplies. In the summer 2019 there are 17 summer residents working for the West Coast Sea Service company. According to the representative from West Coast Sea Service, the company takes care of the accommodation, guest harbor and the restaurant on the island. Majority of the workers are staying on the island from June to August, but some of them only for 5 weeks.

5.2 Settlements

Since Örö used to be a fortress island, majority of the buildings are built during army times. Nowadays, apart from few single buildings, such as a radar station, all the buildings on the island are governed, owned and maintained by Forststyrelsen. (Pakola, 2008.) West Coast SeaService is renting all the buildings from Forststyrelsen including saunas, restaurants and accommodation buildings for tourists and employees.

The only paved road is the road from the harbor to the main village (figure 8). However, old cobblestone roads still exist. Along the roads there are trenches, which are partly overgrown.

5.3 Agriculture, animal husbandry and fishing

During summertime, there is a small pack of highland cattle and a pack of sheep. The animals are grazing in different parts of the island (figure 9), in order to prevent the overgrowth of the different cultural landscapes and maintain the different habitats in Örö. (Raatikainen, 2018.)

5.5 Tourism

The tourism season in Örö is from June to end of August. However, 80 % of the tourists visits from mid- June to end of August. From tourism point of view, the month of May and beginning of June as well as September are normally very quiet. In 2018, 25 500 people visited Örö and in 2017 up to 30 000 people visited the island. The long-term plan is to get 60 000 tourists annually visiting the island (Metsähallitus, 2014.)

According to a discussion with Forststyrelsen in 2018, 10 000 people visited the island by using the daily charter boats. Around 7 000 people stayed overnight in the hotel or apartments. There were 3 500 boats staying overnight in the quest harbor with an average of 2,8 people staying on each boat (all together 10 000 people). There are no available records how many days the tourists stay in Örö, therefore their stay was estimated to be one night. Neither there were existing records for the number of campers staying at the camping site.

5.6 Water demand. The consumption perspective

The human pressure on the island's infrastructure including freshwater, energy and sewage multiplies during the summer months. There are only two water meters on the island; one at the water purification plant and the other one at the sewage treatment plant. Therefore, it is hard to know the exact amounts of water consumption in different parts of the island.

In Finland, the average daily water consumption rate per capita is 140l/p/d (Motiva, 2019). Based on interviews with the different categories on Örö, the following suggestions of different water consumption categories rose.

5.6.1 Residents

The water consumption of residents in Örö is remarkably lower than the average water consumption on mainland. This is due to the fact that the residents in Örö are using water as little as they can and they are practicing different water recycling methods, which lowers the water consumption. This group was calling for action for reusing of water in Örö.

5.6.2 Summer residents

The summer residences use 140 l/p/d, which include their daily meals at the restaurant, collectively washed dishes, laundry, showers, sauna and drinking water. Majority of the summer residence were not aware of the water situation in Örö in 2018, neither were they aware of the general water scarcity on the archipelago. All of the respondents pointed out that the only way to use less water is to close the water tap. They eat all their meals at the restaurant and every respondent pointed out that they wash laundry only when the laundry machine is full. Since majority of the summer residence use sauna several times in a week, it increases their water consumption. The summer residents were positive for reusing of graywater.

5.6.3 Restaurant

The restaurants (figure 10) in Örö were unsure how they could be using less water than they do now. All the vegetables which are possible to order prewashed are bought prewashed. Other water minimizing techniques used in the kitchen are washing the dishes only when the dishwasher is full and minimizing the water usage while cleaning. Kitchen staff were positive in general for reusing water; although they were not sure how the hygiene standards would allow it.

5.6.4 Day visitors

Majority of the day visitors visited the restaurant in Örö and used the toilet twice, which increased their average water usage to 50 l/p/d. None of the daily visitors were aware of the water situation in Örö and they were shocked by the information that the island can run out of groundwater and were pointing out that tourists should be informed. However, 50 % of the respondents thought that method which is used to produce drinking water (reverse osmosis) should not be mentioned. This is due to their negative preconception that the desalinated water would not be healthy to drink. The day visitors were positive for reusing gray water, but negative for reusing of black water.

5.6.5 Overnight visitors

The overnight visitors used in average 100l/p/d. This include one shower, restaurant meal and flushing the toilet 6 times. Only few of the overnight visitors were aware of the islands water scarcity. However, few of them thought that their high-water consumption habits were acknowledged since they paid their accommodation and are therefore allowed to use as much water as they will. In addition, few respondents pointed out that their water consumption would not affect the water situation in Örö. However majority thought that it would be important to inform the tourists about the water situation, so they could have a change to decrease their water consumption. Over half of the respondents said that the water scarcity feels scary and something that that they are not used to. The graywater reuse was accepted within the overnight visitors.

5.6.6 The yachtsmen

The yachtsmen use 75 l/p/d water in Örö. This include a shower, dishes and flushing toilet 6 times. The yachtsmen are not directly forbidden to wash their boats in Örö, but the water tap (Figure 11) at the harbor is far from the docks. Instead of having water pipes on the decks at the harbor, there is only one short water pipe for filling up drinking water bottles. This was taken as a hint of water scarcity on the island by the sailors. The yachtsmen were most aware of the water scarcity in the archipelago and few of them had visited Örö during the water crisis in June 2018. This group pointed out the fact, that in some islands on the Finnish Archipelago the water is not for free; the yachtsmen has to pay for shower and pay for drinking water. The general opinion was that the reuse of graywater would be preferable way of water use.

figure 10 The water tap at the harbor in Örö

Based on results of the interviews the table 2 below is created which shows the water consumption by each category.

Quantity	Category		l/p/d	Number of Days	Sum m^3
2+2	Residents		40	300	48
17+3	Summer residence		140	90	252
25 000	Tourists	Day visitors 8000	50	8000	400
		Overnight 7000	100	14 000	1400
		Yachtsmen 10 000	75	10 000	750
Sum			405	32 390	2850

Table2. Human pressure on freshwater in Örö in 2019.

5.8 Summary

Human are the only water consuming actors in Örö, since the highland cattle and lambs are getting their water needs either from the sea or from the vegetation. The annual water consumption in Örö is 2850 $m^{3.}$ On a personal level the overnight visitors use the highest amount of water, which is 100 l/p /d. Since the sailors are the biggest visitor group they use as a group the highest amount of water, which is 700m^3. The residents are using small amount of water, only 40l /d/p. All categories together consume 2850m^3 water in year 2019.

In 2018 there were 25 000 people visiting Örö. Very few of the tourists are aware of the water scarcity in Örö. It is evident from the data, that the visitors are interested on the water situation on the Archipelago and the attitude towards reuse of gray water was generally positive. Although, only few of the respondents would be willing to recycle the black water. The visitors pointed out that since there are no signs of water scarcity, they don't think about their water usage, but if there were notes to remind them to close the taps, they would do so. Majority of the tourists were shocked after hearing the previous year's groundwater situation and they found it as an extremely scary threat to their wellbeing.

6 Technological landscape

6.1 Energy, waste, transport, electricity and telecommunications

Energy is brought from mainland through cables from army time. Solid waste is managed in two different places in Örö. (1) the recycling station at the harbor is mainly used by the yachtsmen. Glass, metal, paper, biowaste and bottles are collected at the harbor. (2)The waste from the restaurant, hotel and stuff are managed separately.

The waste management as whole is managed by the entrepreneur. During the peak season in summer 2016 the waste was transported to Kasnäs twice a week. At the main restaurant there is a test compression compost from University of Turku, which composts the biowaste quicker in situ. Due to the fact that it is not allowed to grow anything on the island, the composted soil which is produced cannot be used for agricultural purposes. (Metsähallitus. 2016.)

6.2 Water production: covers, waterworks, reservoirs and pipelines

According to interviews with representatives from Forststyrelsen in Örö there are two different water purification methods used; reverse osmosis and chemical purification of groundwater. During the wintertime the old method of chemical purification is used, and during summertime reverse osmosis is used. The whole island is part of the drinking waternetwork, except Ahtisaari cottage on the northern part of the island. The plastic piping system was renewed in 1990 and it is believed to be in a good state. Though, no tests are done to prove this.

Figure 12. The water purification plant in Örö.(Picture: Lotta Eriksson 2019)

Both purification methods are carried out in a same rather old looking building (figure 12). Nevertheless, the visit on the purification plant gave the impression that it functions well for its purpose. The capacity of

the water purification plant is 2,7 m^3 /day and the size of the container for purified water is 77m^3. The water containers are from 1980s There is two men from company of Juha Pekan Kiinteistösiivous working with the water purification plant throughout the year.

6.2.2 Reverse osmosis

The reverse osmosis is from Afflux Water Ab and the water purification model name is RoBUST 1000 (figure 13), which makes 1000l drinking water in an hour. Worldwide reverse osmosis is most widely used desalination technology. Reverse osmosis is the process driven by an applied pressure, which makes water transport through the membrane in the direction opposite to that osmosis. (Juomavesi, 2019.)

Figure13. The RoBUST 1000 Reverse Osmosis Desalination Plant. (Picture: Lotta Eriksson 2019.)

There is a pre-filtration which removes mechanical impurities, active chlorine, organochlorine compounds, as well as natural organic substances. The membrane removes up to 99.8% of dissolved impurities, micro-organism. The post-process includes activated carbon, which improves the taste and smell of purified water. The system can be in stand-by position throughout the winter, because the sea water intake location is on the surface which freezes during wintertime. (Juomavesi, 2019.)

An additional reverse osmosis water treatment system will be built during the autumn 2019. The provider and the model for the new technology will be the same as the current one. Instead of taking the water from the surface of the sea, there will be drilled well on a bedrock near the sea, which filters the coarse material away. When the second reverse osmosis will be installed the desalinated seawater will cover the whole islands water needs throughout the year. According to the interviews, it is unsure if these two reverse osmoses plants will be able to provide water for the planned 60 000 visitors.

Normally, desalination is an energy hog which has been one of the main barriers to extend desalination more widely (Zarzo & Prats 2018). During the field study it was unclear how much energy is used in desalination processes. However, in the interviews it was stated that it is not too expensive compared to the old method.

6.2.3 The chemical drinking water treatment plant

The chemical treatment plant (figure 14) is Farmo-technology and it is used since late 1970. The type of chemical used in the purification process is PAX and Soda. The groundwater is taken from 8 m deep well (figure 15). The quality of the groundwater meets the requirements

Figure 14. The chemical treatment plant in Örö. (Picture: Lotta Eriksson 2019.)

In July 2018, the quality of drinking water after the purification, was according to standards of the Ministry of Social Affairs and Health No 401/2001 concerning the quality standards and recommendations (Appendix 1 and 2). This regulation states that in every three years comprehensive test is carried out and every year lighter tests are done for the drinking water. The laboratory tests are taken by the employees of Juha Pekan Kiinteistösiivous and are sent to be analyzed to Lounais-Suomen vesi- ja ympäristötutkimus. (Lounais-Suomen vesi- ja ympäristötutkimus Oy. 2018.)

6.3 Water demand (production perspective), seasonal variation

During the summer 2018 Örö run out of groundwater. In the beginning, it was in doubt that the problem was the wells pumping system (figure 15). However, according to the interviews with Forststyrelsen and the technicians, after examining the pumping system it was discovered that the groundwater level was so low, that it was impossible to use the groundwater for consumption.

Figure 15. The groundwater well in Örö. (Picture: Lotta Eriksson 2019).

As shown in the table below (table 2) the seasonal differences in water production are high in Örö. The first period from January to April the water production was around 220m3. During wintertime there has been few visiting groups and during April there has been construction workers staying on the island, which rises the water usage. The second period from

May to August is the peak season and the water production sum was 1580m^3. The third period is from September to December, when the amount of water produced was 340m^3. All together in year 2017 the water purification plant produced 2910 m^3.

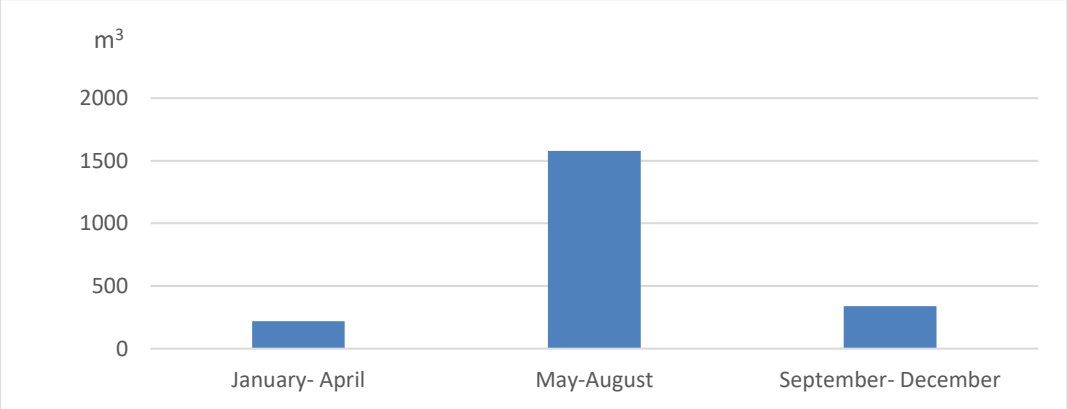

Table 2. Water production in 4-month periods in Örö in 2017 (m3/4kk)

According to the interview with the technicians, the current reverse osmosis plant is not exed to produce enough water to cover the water demand during the high season, the old chemical water purification system will be used as a backup service.

6.4 Sewage: network, piping and sewage treatment plants

Örö has a sewage network built by the Defense Forces. The wastewater treatment plant (figure 16) is located into South East side of Göle Bay. The wastewater treatment plant was built during spring 2016 and wastewater treatment plant was ordered from Clever Technology. The purification plant consists of four carrier bioreactors. The treatment processes (figure 17) include flotation and UV-

Figure 16. The wastewater treatment plant in Örö. (picture Lotta Eriksson 2019)

Disinfection before discharge into the sea. All the wastewater from the hotel, hostels, apartments, saunas and restaurants goes to the sewage treatment plant. The old wastewater treatment plant was soil infiltration, which still works as a backup service during the bypass. So far, there has been no bypasses since the new treatment plant was built. (Aluehallintovirasto 2016.)

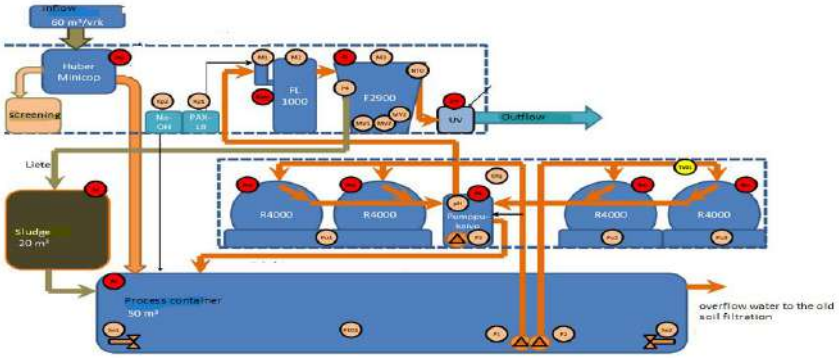

Figure 17. The process flow at the wastewater treatment plant. (picture: Clever Oy)

According to information from Clever the treatment plant is planned for 60m^3 wastewater/day. However, the quantity of treated wastewater varies from season to season (table 3). During the peak season the daily quantity of wastewater can reach up to 40m^3. Whereas during winter times the amount of wastewater is very small. During the winter season the wastewater treatment plant is in a power saving mode and only one out of four bioreactors is functioning.

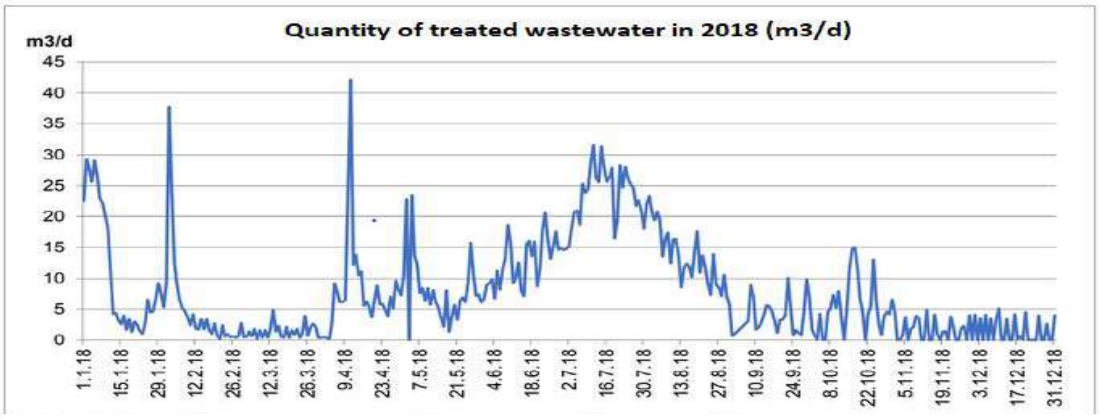

Table 3. The quantity of treated wastewater in Örö in 2018. (table from Lounais-Suomen vesi-ja ympäristötutkimus Oy.

In 2018, there was 40 m^3 of sedimented sludge produced at the wastewater treatment plant and brought to the mainland to Tyskaholm wastewater treatment plant with a lorry, which can

take 10 m^3 of sludge at the time. (Lounais-Suomen vesi-ja ympäristötutkimus Oy, 2019). Consequently, the sludge consumes energy as it needs a lorry and the lorry needs a ferry.

The water quality tests are taken with the automatic tests. The incoming wastewater quality tests are taken before screening and the outgoing water quality after UV-treatment. In 2018, the wastewater treatment plant in Örö was functioning according to standards of the environmental permit (Etelä-Suomen aluehallintovirasto 14.6.2016 nro 121/2016/2) except the phosphorus concentration which didn't meet the purification requirements. (Lounais-Suomen vesi-ja ympäristötutkimus Oy, 20*19*.)

During the summer 2019 the septic tank for the wastewater from the boats was not working and it was unsure whether it will be taken into use anymore. (Örön puhdistamon Ympäristöluvasta, 2016.) The discussions are ongoing in between the entrepreneur from West Coast SeaService and Forststyrelsen.

6.5 Private wells, private wastewater treatment plants and dry toilets

There are no private drinking water wells in Örö except for the cottage Ahtisaari where is a saltwater well and the withdrawn water is used only for showers.

According to the interview with the representatives from Forststyrelsen there is one private wastewater system in Örö which is in an area called 6th inches, just outside from the artist residence house and it is used to manage the resident's wastewater (black and gray together). The current wastewater treatment system is unknown but there are at least two septic tanks. This system will be changed as soon as Forststyrelsen gets funding for it. The plan is to collect the black water to a separate tank, which will be transported to the mainland to Kasnäs wastewater treatment plant. The grey water will be infiltrated to the ground through an infiltration bed.

According to the interviews with the representative with Forststyrelsen there are five dry toilets (figure 18) on the island. One at the camping area, one at Ahtisaari, one almost at Norra Udden, and two at the 6th inches area. Once the chambers are full in the dry toilets, the chambers are changed, and the composting process is started on the closed chambers. Later the compost is brought to an area where composting takes place (figure 19)There is no existing plan yet what the compost will be used for once it's done and it's not known if someone is turning the compost mass around as it should be done.

Figure 18 One of the dry toilets in Örö. (picture Lotta Eriksson 2018)

Figure 19 The composting of the excreta from dry toilets in Örö. (picture Lotta Eriksson 2019)

6.6 Government exercise, cost structure and pricing

Forststyrelsen owns both the drinking water purification plant and the wastewater treatment plant. Juha Pekan Kiinteistösiivous maintains and takes care of both plants and the company is contracted by Forststyrelsen. Normally, there are two men working with the plants. (Lounais-Suomen vesi-ja ympäristötutkimus Oy, 2019.)

According to the interview with the West Coast SeaService they pay around 8€/m^3 for water. The waster cost is quite expensive in Örö compared with other islands in the Circular Water studies. In Möja the water cost is 2,5 euro/m^3 and Korppoo is 6 euro/m^3. This covers both the drinking water and the sewage water treatment. For the permanent residents the monthly payment for water is fixed. The summer residents do not pay for water and neither do the yachtsmen.

6.7 Summary

The water is rather expensive for the entrepreneur in Örö and reverse osmosis consumes high amount of electricity. These facts in addition to the environmentally friendly attitude are the main motivation factors for the West Coast SeaService to be interested in possibilities in circular water.

Forststyrelsen has invested in reverse osmosis as well as in other water related technology. This saves the groundwater; still on low level and with rather poor quality. With the increasing number of tourists, the reverse osmosis will provide a more sustainable water solution. The second reverse osmosis plant ensures the water need also during the wintertime. A water related technology; such as toilets, taps etc. comes of age they should be changed to more water saving technology such as vacuum toilets or toilets, which are flushed with gray water.

The wastewater plant could handle the septic wastewater from the boats. In that case the challenge is the increasing amount of sedimented sludge, which has to be brought in to the Tyskaholm wastewater treatment plant with a lorry. The composting of the excreta from dry toilets should be handled better.

7 Circular water

7.1 About circular water

Water circulation is a process where water is used more than once before being returned to nature. Circular water usage has begun to be introduced in many places to conserve the world's freshwater resources, since water scarcity is a common problem in many parts of the world (Cisneros, 2014).

One of the solutions to the increasing need for water is to reuse treated wastewater, which is an example of circular aquaculture. In order to meet future water requirements, the traditional linear resource flow for water, which means that the purified wastewater is discharged to nature without being reused, needs to be challenged. For example, in Sweden there are a couple of local projects that involve recycling water in different ways. (Adelsköld & Ilao Åström 2019.)

7.2 Proposal 1. Public awareness and changes in the toilets

The tourists should be- and they want to be- informed about the freshwater situation in Örö and generally in Archipelago. There could be information boards next to the other information boards on the “village”. Information could also be found from the internet pages and from the sailors’ newspapers. There could be notes close to the water taps to remind people to close the taps to reduce unnecessary water usage. The residence artists showed interests to be part of water awareness campaign through visual art which could be placed in the village as well.

In the public places the current water technology could be replaced with water saving technology. There could be waterless urinals at the men’s toilets. The showers at the public sauna should be fixed. At the moment the water is running too long at the women’s showers and the men’s shower starts running randomly without no-one being under the shower.

7.3 Proposal 2. Ten years plan

Most of the water technology, such as showerheads, toilets, taps etc. is rather new in Örö. With a few exceptions, they are not water saving and at least one of the shower heads at the public sauna leaks. That should be fixed immediately.

System components could be changed gradually: (a) the public toilets should be changed into low water consuming vacuum toilets; (2) there could be urinals for men; (3) during summertime there should be enough water running in the sewage system to make the waste from the vacuum toilets channeled to the wastewater treatment plant; (4) There could be a rainwater harvesting system flushing toilets. All these measures would decrease the water usage in the toilet section. Another option (5) is to change the toilets to use gray water from hand washing or brackish water to flush as is done on Möja (one of the seven islands in the study). And (6) the composting of dry toilets should be controlled better, with (7)a hygienic composting.

The public sauna is one of the main water consuming place on the island. (8) the showerheads should be fixed so that they would use less water than they do now and (9) the gray water could be reused for flushing the toilets at the public sauna.

In addition to this (10) the public awareness on the freshwater issues on the islands should be taken into consideration as mentioned in the proposal 1.

7.4 Proposal 3. Wastewater reuse from the wastewater treatment plant

(1) Both the laundry water and handwashing water could be filtered through course -and fine filter and reused in the toilets as flushing water. (2) The tourists could be challenged to use as little water as possible and given a free drink/dessert in the restaurant if they manage to reach beforehand set target on amount of water consumption. (3) In the restaurant, the water used to wash vegetables could be used in the upcoming greenhouse or the plants on the tables of restaurant. (4) The purified wastewater would be redirected from the wastewater treatment plant back to the accommodation areas as well as into the public toilets to be used as a toilet flushing water.

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Appendix 1. The drinking water quality in July 2018.

Lounais-Suomen vesi-ja ympäristötutkimus Oy

TEST REPORT
Drinking water quality test
27.4.2015

Forststyrelsen
The nature service of southern Finland
Kärsämäntie 8
20300 Turku

Ordernumber 177771 (X/S), arrived 13.4.2015

SAMPLES

Lab.nro	Description of sample
4885	Raw water
4886	Tap water
4888	Filtrate

SAMPLES

Samples	Unit	4885	4886	4888	STM 401
Aluminium, Al*	µg/	33	4	18	<1 (a)
Mangan, Mn *	µg/l	240	160	230	«200 (b)
Iron, Fel *	µg/l	7200	250	4500	«100 (b)
COD(Mn)-value *	mgO2/l	20	4,0	4,3	«50 (b)
pH (25 °C) *		7,3	7,1	6,7	«200 (b)
Turbidity *	FNU	0,3	2,8	1,8	«1 (b)
Color* (visual)	mg/l Pt	E			«5 (b)
Color centrif (visual)	mg/Pt	260			«5 (b)

The definitions: P= the calculation is not finished E= Undone, ~ = Around, < =smaller than, <<=smaller or equal to, > bigger than, >> = bigger than or equal to.
STM 401= Regulation No 401/2001 of the Ministry of Social Affairs and Health
* - marked analyzes are accredited. (a) = quality requirement, (b)= quality recommendation

Jari Pusa
Head of Laboratory

Appendix 2. The drinking water quality in July 2018.

Lounais-Suomen vesi-ja ympäristötutkimus Oy

TEST REPORT
Drinking water quality test
17.7.2018

Foreststyrelsen
The nature service of southern Finland
Petri Hautala
Kärsämäntie 8
20300 Turku

Ordernumber 216689 (WÖRÖ/Outgoing), arrived 11.7.2018, the date of sampling: 11.7.2018 (11:10)
Sampler: LSVYT Oy, Laurikainen

SAMPLES

Lab nro	Discription of sample
10555	Örö water purification plant, outgoing

SAMPLES

Samples	Unit	10555	STM 401
Escherichia coli CL *	MPN/100 ml	0	<1 (a)
Aluminium, Al *	µg/l	<5	«200 (b)
Chloride, Cl *	mg/l	27	«100 (b)
Mangan, Mn *	µg/l	<1	«50 (b)
Iron, Fe *	µg/l	<2	«200 (b)
COD(Mn)-value *	mgO2/l	<0,5	«5 (b)
Coliform bacterium CL *	MPN/100 ml	0	<1 (b)
pH (25 °C) *		8,8	«9,5, »6,5 (b)
Turbidity *	FNU	<0,1	«1 (b)
Color*	mg/l Pt	<1	«5 (b)

The definitions: P= the calculation is not finished E= Undone, ~ = Around, < =smaller than, <<=smaller or equal to, > bigger than, >> = bigger than or equal to.
STM 401= Regulation No 401/2001 of the Ministry of Social Affairs and Health
* - marked analyzes are accredited. (a) = quality requirement, (b)= quality recommendation, (N)= observation of the sampeler

STATEMENT

Tested properties of drinking water fulfills the requirements and -recommendations of the Ministry of Social Affairs and Health Regulation No 401/2001.

Sanna Nurmela
Microbiologist

FOR NOTICE

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