SAVONIA
University of Applied Sciences

THESIS – BACHELOR'S DEGREE PROGRAMME
TECHNOLOGY, COMMUNICATION AND TRANSPORT

CURRENT STATE OF WATER TREATMENT IN COSTA RICA AND POTENTIAL COOPERATION WITH FINNISH WATER TECHNOLOGY

AUTHOR Lauri Hoffrén

SAVONIA UNIVERSITY OF APPLIED SCIENCES

THESIS
Abstract

Field of Study Technology, Communication and Transport			
Degree Programme Degree Programme in Environmental Technology			
Author(s) Lauri Hoffrén			
Title of Thesis Current State of Water Treatment in Costa Rica and Potential Cooperation with Finnish Water Technology			
Date	24.5.2023	Pages/Number of appendices	33/2
Client Organisation /Partners			

Abstract

The topic of this thesis was to find out current state of water treatment in Costa Rica and potential cooperation with Finnish water technology. The purpose of the thesis was to discover processes used in potable water and wastewater treatment plants, and detecting potential development targets.

The target treatment plants were studied by visiting them and interviewing the personnel responsible for the processes. Also, receiving bodies of waters were visited and observed. Results and efficiencies of the treatment processes were achieved by water laboratory analyses and the results were compared to the Costa Rican legal framework.

The result of the thesis was a description of the processes for three potable water treatment plants and five wastewater treatment plants. The treatment of potable water is very much similar to plants in Finland. Efficiencies of the wastewater treatment processes were evaluated and noticed to have a need for development. How to develop the processes would require more study on site.

Keywords
Potable water, wastewater, treatment process

CONTENTS

LIST OF FIGURES

1 INTRODUCTION

Fresh water is becoming scarce in many places around the world. In the worst case, larger areas including big coastal cities where millions of people are living, could become uninhabitable due to lack of the fresh water. Hundreds of million people are lacking proper source of potable water, and safely organized sanitary facilities number goes to over two billion people. Over 80 % of world's wastewaters are still led to rivers, lakes and oceans without any treatment, which endangers human welfare and environment.

Potable and wastewater treatments are essential parts of water supply. Municipal and private treatment plants consists of unit processes that are individual to the plants. The unit processes are selected depending on qualities of the water and flow rates for example. Development of the treatment processes is essential part of sustainable development's goals.

Topic has been formed from a personal experience and point of interest in the water treatment in Finland. Implementation of work is done by visits to both waters treatment plants, industrial wastewater treatment plants and receiving body of waters, asking questions related to physical-chemical parameters and unit processes. Aim of this thesis is to have an overview of Costa Rica's water treatment processes and qualities of both waste and potable water. Possible development ideas utilizing help of Finnish water technology are pondered after having the general overview of the processes. Research questions related to this thesis are what is the efficiency of wastewater treatment, what kind of treatment is used on potable water and which kind of unit processes are used?

2 RAW WATER SOURCES

2.1 Raw water sources in Finland

Raw water is from groundwater or surface water source that waterworks utilize in the production of potable water. Usually, it has to be treated before appliable to industrial or domestic use. (Vesi.fi s.a.) Groundwater is water filling open spaces in soil and bedrock, formed by absorption of rain or surface water through strata, or flow into gaps of the bedrock. A groundwater basin is defined by geological basis as limitable area of soil formation or zone of the bedrock that enables a significant flow of the groundwater or water intake. These groundwater basins are classified into two types, the first class includes important groundwater basin for water supply utilized more than 10 m^3 per day, the second class includes other kind of use of water supply. (Britschgi, Rintala & Puharinen 2018, 17.)

In Finland, groundwater is formed a tenfold more than consumption rate and the quality of water is naturally good. Although the groundwater situation is good nationwide, there can be scarcity locally. (Finnish Environment Institute 2022) Approximately 75 % of potable water is produced from the groundwater or artificial groundwater, surface water absorbed to soil and filtered through strata. The rest is covered by the surface water. (Finnish Water Utilities Association s.a.)

2.2 Raw water sources in Costa Rica

Groundwater and surface water resources are wide in Costa Rica with 34 watersheds and a volume of more than 113 km^3 approximately per year. 73 km^3 is equivalent to the surface source and the rest 40 km^3 to natural aquifers recharging. With the addition of 7 % national territory being covered by wetlands, each Costa Rican has approximately 23,405 m^3 of water per year. (The Water and Sanitation Observatory for Latin America and the Caribbean s.a.)

Generally, the use of water divides to many sectors nationwide. When examining the total water intake in Costa Rica including human consumption and industry, only 20.2 % of total volume is used. Most of this percentage is formed by hydroelectric generation, irrigation and water supply. 75-80 % of total electricity is generated by the hydroelectric, 9 % of GDP (gross domestic product) is covered by national agriculture, 22 % of GDP is covered by industry and agribusiness, and tourism covers approximately 8 % of GDP. Therefore, national goals have an inseparable relationship with water resources and key to achieve aspirations related on these goals is adequate water management. (Costa Rican Ministry of Environment, Energy and Telecommunications 2008)

3 POTABLE AND WASTEWATER MANAGEMENT IN FINLAND

3.1 Typical potable water treatment process

Potable water needs to be treated before leading it to human consumption. The treatment process is formed of unit processes individual to a treatment plant because of differences in the quality of water. The source of the treated water can be groundwater or surface water that includes lakes and rivers. The surface water has always at least disinfection in Finland to destroy microbes that are dangerous for the health of human. (Finnish Institute for Health and Welfare 2023)

Groundwater can be drinkable without a treatment but usually has alkalization to raise the pH-value that increases the age of pipelines. A typical surface water treatment process (see Figure 1) consists of chemical precipitation, filtration, alkalization and disinfection. The chemical precipitation includes a chemical added to water creating flocs that are removed either from bottom or surface. This unit process removes iron, microbes, organic matter and soil from the water. The filtration removes small particles left to the water from the chemical precipitation commonly through sand. Another method is an active-carbon filter that removes bad taste or smell causing compositions. The alkalization has the same purpose as with the groundwater, to raise pH-value of the water led to distribution. This unit process can be done by feeding lime or lye to the water or by filtrating the water through limestone. The disinfection aims to destroy microbes and viruses that cause danger for health, usually stomach disease. This can be done by chlorination, ozonization, UV light or mix of these. Chlorine will move along in the distribution network ensuring hygienical quality of the water. (Pelto-Huikko & Vieno 2009, 8-11)

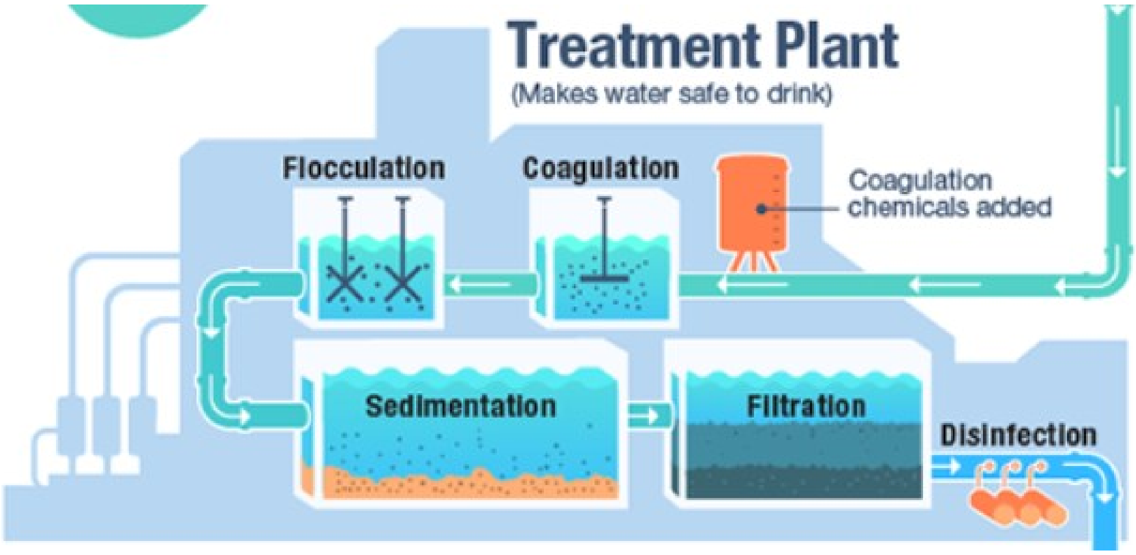

FIGURE 1. Clip from CDC’s website Water treatment (Centers for Disease Control and Prevention 2022)

3.2 Water quality and control

Potable water is safe to use and quality is excellent in Finland. Health protection authority supervises the quality of domestic water regularly and takes responsibility of water sample collection as well as examinations by the law. (Finnish Institute for Health and Welfare 2023).

Decree of the Ministry of Social Affairs and Health Relating to the Quality and Control of Domestic Water and the Risk Management of Water Installations in Buildings controls the quality of potable water with certain upper and lower limits. For example, quality demands and recommendations in Appendix 1. (Quality and Control of Domestic Water and the Risk Management of Water Installations in Buildings 1352/2015, 4§). In addition, waterworks must be aware of risks relating to the quality and quantity of raw water they use and a condition of equipment, meaning observation of the above-mentioned affairs (Water Services Act 119/2001, 15§).

3.3 Typical wastewater treatment process

Wastewaters are led to sewerage in urban areas, which flows to a municipal treatment plant. Typical process (see Figure 2) consists of mechanical, biological and chemical treatment, which guarantee removal of solid materials, nitrogen, phosphorus and organic matter. The process creates sludge as a by-product that can be utilized as fertilizing product in agriculture and landscaping once treated properly. (Finnish Water Utilities Association s.a.)

Mechanical treatment, also called as a preliminary treatment, typically includes screening, sand extraction, preliminary sedimentation and pre-aeration in Finland. The screens remove bigger particles such as leftovers and other things not belonging to a sewer. The sand extraction aims to remove sand and other heavy material. The pre-aeration blends the wastewater and separates fat and other matter lighter than the water. The preliminary sedimentation separates heavy solid particles from the wastewater by settling them to the bottom. (Laitinen, Nieminen, Saarinen & Toivikko 2014, 46-47.)

The most common biological-chemical treatment is an activated sludge process, which removes nitrogen, phosphorus and organic matter. The activated sludge process requires an aerobic section for nitrification and removal of organic matter. The nitrification is oxidation of ammoniacal nitrogen to nitrite that transforms to nitrate nitrogen in aerobic circumstances (Laitinen et al. 2014, 71.). For denitrification, an anoxic section is required and for possible removal of phosphorus the anaerobic section as well. The denitrification is reduction of nitrate to nitrogen gas in the anoxic circumstances, anoxic means condition where oxygen is only bounded to nitrate-ions (Laitinen et al. 2014, 70.). Section order has many variations in the activated sludge process but the denitrification comes before the nitrification usually, that influent's organic carbon can be practically used in the denitrification. Aeration to the process comes from holes at the bottom of basin. Chemical treatment of the process is done by feeding a chemical coagulant after preliminary treatment, or before and after secondary treatment. Typical chemicals used to remove phosphorus are aluminium and iron salts. (Laitinen et al. 2014, 47-49.)

Other method used as biological treatment can be carrier process, which includes a biorotor, a biological filter or a trickling filter. The method improves nitrification but is not widely used in Finland. Adding a carrier to process increases area of sludge's reaction thus volume of aeration can be designed smaller. Discs, where a biofilm attaches, form the carrier in the biorotor. The discs are placed to a basin where partly in purifiable water. Rotation of the discs gives oxygen to microbes on the biofilm enabling nitrification. The biological filter is filled with the carrier through which wastewater flows either up or down. Filtration cells can be nitrifying or denitrifying, which means the nitrification needs aeration to have aerobic circumstances, and denitrification needs anoxic circumstances. The trickling filter has similar method as the biological filter. Purifiable water is led to a top part of reactor that is broadly filled with pieces of the carrier. The water is sprinkled on the carrier and flows down forming the biofilm on surface of the carrier. The microbes receive oxygen by void between the carrier. (Laitinen et al. 2014, 48.)

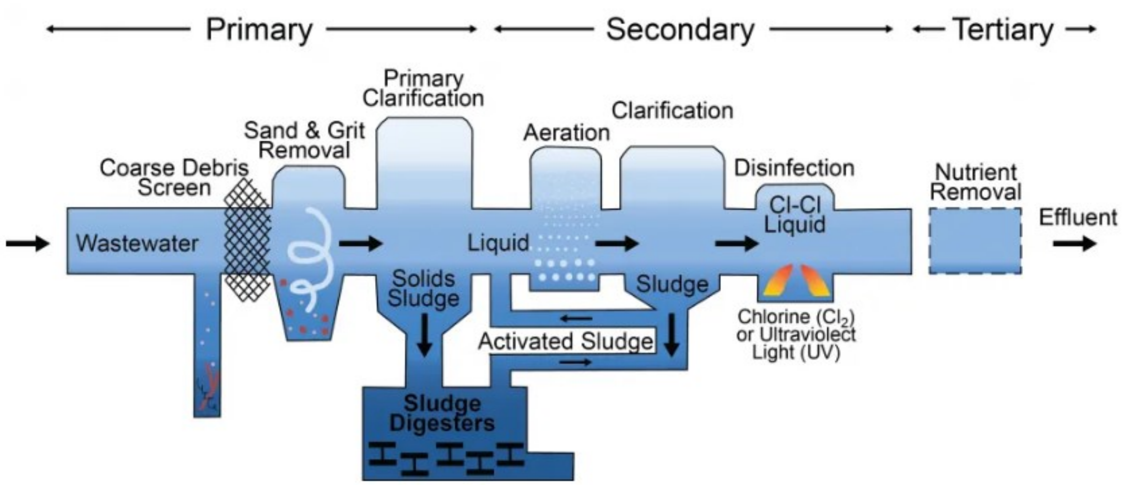

FIGURE 2. Clip from CSS' Website U.S. Wastewater Treatment Factsheet (Center for Sustainable Systems, University of Michigan 2021)

3.4 Wastewater quality and control

Minimum level of the treatment process is determined by an environmental permit that is individual to a treatment plant. Decision on the granting the permit sets frames to the designs of the plant's processes mirroring to condition of a receiving body of water. Volume and quality of influent wastewater determines necessary areas, chemicals and energy consumption of the processes. Quality of the treatment process is observed according to a monitoring scheme, which is also individual to the plant and defined in the environmental permit. (Kuopion Vesi s.a.)

Efficiency of a wastewater treatment plant depends also about evenness of influent and load. Changes in flow rate during a day are appearing commonly but can create problems to the treatment. These problems can be avoided with an equalizing basin or wide sewerage system, which stabilize the flow rate before the process. Other benefit of the equalizing basin is stabilizing the quality of wastewater during storage decreasing effect of load peek. The basins can be located nearby the plant or as a part of the sewerage system and can be for instance, ponds, old or new built basins. (Laitinen et al. 2014, 46.)

Other typical changes appearing in flow rates are glacier waters that creates problems to many wastewater treatment plants during spring. When hydraulic capacity will be exceeded or hardware failure appears, leaks might cause a significant risk for environment and health locally. Even small amount of unpurified wastewater can have a huge impact on the environment. For instance, water catchments and public beaches can be influenced by this kind of environmental or health risk. (Laitinen et al. 2022, 25.)

Environmental Protection Act, Water Services Act and Decree of the Finnish Government Relating to Urban Wastewaters are controlling wastewater treatment in Finland. A property in waterworks' operating region must be connected to a sewerage system (Water Services Act 10§). When designing, building and maintaining the sewerage system, wastewater treatment requirement and use of best available technology have to be taken into account. Especially, paying attention to characteristics and a volume of the wastewater, preventing leaks and restrictions of water pollution caused by a spillover water. (Urban Wastewater Treatment 888/2006, 3§)

There is a general obligation to clean wastewaters in Finland, which relates to properties neither connected to a sewerage system nor required an environmental permit. These properties must treat and lead the wastewaters without a risk of environmental pollution. If other than water closet's wastewaters and quantity is minor along with no danger of the environmental pollution, the wastewaters can be led unpurified to a soil. (Environmental Protection Act 527/2014, 155§)

4 POTABLE AND WASTEWATER MANAGEMENT IN COSTA RICA

4.1 Potable water control

In Costa Rica, there are institutions taking care of protection, extraction, use and management of water resources. These different institutions take responsibility for drinking water and sanitation. Institute of Aqueducts and Sewerage, known as AyA, is a national institution in charge of management of drinking water and sanitation services. Another institution is Water Supply Administration Associations, known as ASADA, which manages rural areas of the country. (Arroyo Fernandez 2022)

Potable water is for human consumption causing no harm for health and follows maximum limits for chemical, physical and microbiological pollutants. Treatment of the water depends on quality of water and source. Treated water, which is either ground or surface water, includes at least disinfection. (Drinking Water Quality 38924-S, Article 4.)

Objective of Regulation for Drinking Water Quality is to ensure maximum limits for chemical, physical and microbiological pollutants in potable water (see Table 1). This regulation applies to all operating entities with water supply throughout national territory. All companies, which have production processes on the potable water, must comply with the maximum permissible limits. (Drinking Water Quality Article 2.)

TABLE 1. Water quality parameters (N1)

PARAMETER	**UNIT**	**ALERT VALUE**	**VALUE MAXIMUM ADMISSIBLE (VMA)**
COLOR	U-pt-Co	< 5	15
CONDUCTIVITY	µS/cm	400	-
COLIFORM BACTERIA	CFU/100 ml	No detectable	No detectable
E. COLI	CFU/100 ml	No detectable	No detectable
FREE RESIDUAL CHLORINE	mg/l	0,3	1,0
COMBINED RESIDUAL CHLORINE	mg/l	1,0	1,8
TURBIDITY	NTU	1,0	5,0
SMELL	-	Acceptable	Acceptable
TEMPERATURE	°C	18	30
pH	pH value	6,0	8,0

4.2 Wastewater control

In Costa Rica, only 30 % of households are connected to a sewerage system, which is far more less compared to Finland. In addition, only 14 % of these households are connected to either a public or a private wastewater treatment plant. (The Water and Sanitation Observatory for Latin America and the Caribbean s.a.) The most common method is a septic tank, buried and watertight tank designed for domestic wastewater. Heavier solids settle to the bottom of the tank and lighter solids along with greases float to the top. (United States Environmental Protection Agency 2022)

Costa Rican government has a regulation for Wastewater Discharge and Reuse, which states every wastewater generating entity must treat it complying with the regulation to avoid damaging environment or human health. The entities have also an obligation to prepare operational reports when effluent is discharged to a water body. The report can be presented by two ways, submitting by email or physical presentation by the entity. (Wastewater Discharge and Reuse 33601, Chapter I) The regulation also states a contamination of the water bodies increases diseases and reduces available resources. In addition, costs of water supply will be increased and endangers flora and fauna (Wastewater Discharge and Reuse 3º). Article 14 in the regulation introduces parameters that are mandatory to be analyzed from the wastewater, which includes flow rate, biological oxygen demand, chemical oxygen demand, pH, fats and oils, settleable and total suspended solids (Wastewater Discharge and Reuse, Article 14).

Additional limits for discharge of special wastewater such as industrial have different maximum limits for three selected parameters. These maximum limits depends on the type of water activity disposed to a receiving water body. General maximum permissible limits are introduced in table 2 of article 18 in the regulation and in Table 2 below. (Wastewater Discharge and Reuse, Chapter III)

TABLE 2. General maximum permissible limits for parameters in wastewater (Wastewater Discharge and Reuse)

PARAMETER	**MAXIMUM LIMIT**
BIOLOGICAL OXYGEN DEMAND (BOD)	300 mg/l
CHEMICAL OXYGEN DEMAND (COD)	750 mg/l
TOTAL SUSPENDED SOLIDS	300 mg/l
SETTLEABLE SOLIDS	5 ml/l
FATS AND OILS	50 mg/l
PH	6 to 9
TEMPERATURE	15 °C ≤ T ≤ 40 °C
METHYLENE BLUE ACTIVE SUBSTANCES	5 mg/l

5 VISITED WATER TREATMENT PLANTS

5.1 AyA Tres Ríos

The potable water treatment plant AyA Tres Ríos is located in province of Cartago, canton of Tres Ríos. It is the biggest potable water treatment plant in Costa Rica and Central America providing water for over one million people. The plant produces water from rivers with flow rate of 2,500 l/s utilizing two production lines. Different rivers are led to these production lines and treatments are different due to quality of the water. The plant is maintained very well and well-designed, no obstacles or things not belonging there on the way, so it was easy to wander around and observe unit processes.

5.2 Water treatment process

Process consists of mechanical, biological and chemical treatment, which is very common with surface water as source of raw water. The first stage of the treatment is removing bigger particles and apparent pollutants that can be seen or smelt allowing the treatment to be easier in later stages. Then aluminium sulphate is added to the water to precipitate solids and the water is led to three flocculation basins. After the flocculation comes three sedimentation basins and finally three laminated sedimentation basins (see Figure 3). Both production lines are connected after these unit processes and led to filters (see Figure 4). Different kinds of sand (see Figure 5) are used in the unit process, which contains of 16 basins. After a sand filtration the water is led to a disinfection and a final distribution basin, three pipes (450 mm, 600 mm and 900 mm diameter) distributes potable water to human consumption. Results (see Table 3) have been received by personal discussion with staff.

TABLE 3. Results of treatment process on 21.3.2023 at AyA Tres Ríos

PARAMETER	**BEFORE**	**AFTER**
DISCHARGE (l/s)	673 (only one line)	2339 (both lines)
TURBIDITY (NTU)	50	0,23
COLOUR	143	0
PH	7,8	6,94
RESIDUAL CHLORINE (mg/l)	-	0,98

FIGURE 3. Laminated sedimentation basin at Tres Ríos water treatment plant (Hoffrén 2023, CC BY-NC)

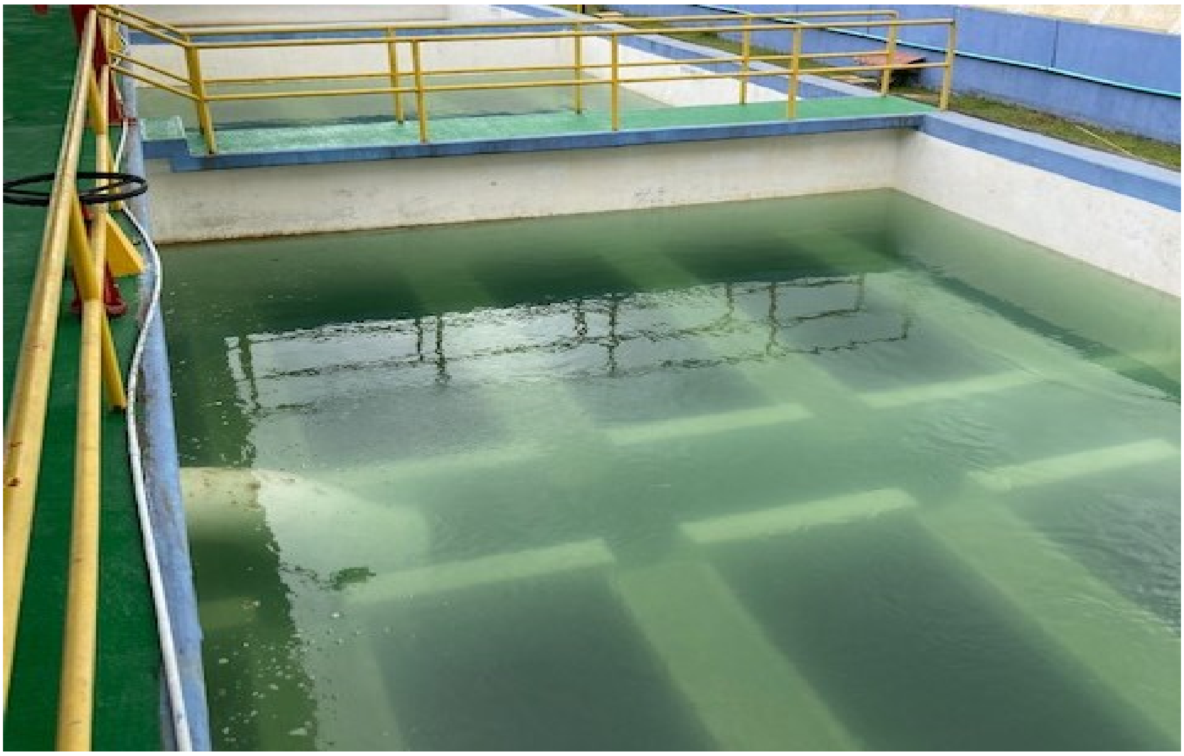

FIGURE 4. Sand filtration basin at AyA Tres Ríos water treatment plant (Hoffrén 2023, CC BY-NC)

FIGURE 5. Different kind of sands used in sand filter at AyA Tres Ríos water treatment plant (Hoffrén 2023, CC BY-NC)

5.3 ASADA Santa Elena

Santa Elena is located in province of Puntarenas very close to tourist attraction of Monteverde. This ASADA has 10 employees, 1,800 connections for potable water and provides to more or less 6,300 people and 200,000 tourists a year. The production is 125 l/s and the highest peak is on a dry season due to the amount of tourists in the area. The Raw water source is a groundwater aquifer, which does not need much treatment. Only a disinfection by sodium chloride is currently being used. Chemical is pumped to a tank of 400 m^3 with an automatic system during day time (see Figure 6).

There is no wastewater treatment plant in Santa Elena or a sewerage system currently but design and development work is under way. Septic tank system handles 98 % of the wastewater for now. Employees of ASADA have visited several treatment plants to help designing their own. Current plan is building the sewerage system, have a pretreatment and Upflow Anaerobic Sludge Blanket (UASB) reactor and a byproduct management. Ideas as a secondary treatment are either Artificial Subsurface-flow Wetland, Trickle Filter or Activated Sludge.

FIGURE 6. Disinfection pumping system at ASADA Santa Elena (Hoffrén 2023, CC BY-NC)

5.4 ASADA La Angelina

This ASADA is very small and located in province of Cartago with only 279 connections to potable water. Some of these connections are industrial areas so consumption will be higher than domestical. Groundwater is a source of water in La Angelina and it only has disinfection treatment. Combined water analysis from tanks 1-4 for physical-chemical and microbiological results (see Table 4) have been received by paper from staff.

TABLE 4. Combined analysis results in La Angelina

PARAMETER	**RESULT**
COLOUR (U-pt-Co)	< 5
SMELL	Acceptable

TEMPERATURE (°C)	17,8
TURBIDITY (NTU)	0,14
PH	6,14
CONDUCTIVITY (µS/cm)	210
FREE RESIDUAL CHLORINE (mg/l)	0,64
COLIFORM BACTERIA (CFU/100 ml)	Not detectable
E. COLI (CFU/100 ml)	Not detectable

6 VISITED WASTEWATER TREATMENT PLANTS

6.1 AyA Los Tajos

Wastewater treatment plant AyA Los Tajos is the biggest in Costa Rica located in province of Heredia. It is very near of intersection between provinces of Alajuela, Heredia and San José. The plant treats 2.8 m^3/s of wastewater mainly from a metropolitan area, including approximately one million people. Aim is to have 65 % of the wastewaters from households in few years covering up to 1.7 million people. General view of the wastewater treatment plant can be seen in Figure 7.

FIGURE 7. General view of wastewater treatment plant AyA Los Tajos (Hoffrén 2023, CC BY-NC)

6.2 Wastewater treatment process

Treatment plant has a biological-chemical process starting with a preliminary sedimentation basin and mechanical screening (see Figure 9) that captures bigger materials and things not belonging to a treatment following up with an aeration (see Figure 8) and sedimentation basins. After these unit processes comes a filtration of fibres and the process byproduct sludge is digested in two 7,000 m^3 digestors and produced to a biogas. The wastewater continues to a chemical treatment reducing smells and finally to a receiving body of water river Torres. Efficiency of the process can be seen in Table 5.

FIGURE 8. Aeration unit process in AyA Los Tajos (Hoffrén 2023, CC BY-NC)

TABLE 5. Wastewater treatment plant Los Tajos efficiency in 2021 (Laboratorio Nacional de Aguas)

PARAMETER	INFLUENT	EFFLUENT	REDUCTION %
FLOW RATE (l/s)	575,8	575,8	-
TEMPERATURE (°C)	23,2	22,9	-
BOD (mg/l)	165,0	85,0	48,5
COD (mg/l)	435,0	184,8	57,5
TSS (mg/l)	201,0	67,3	66,5
E. COLI	-	$7{,}9 \times 10^6$	-
COLIFORM BACTERIA	-	13×10^6	-

FIGURE 9. Mechanical screens at AyA Los Tajos (Hoffrén 2023, CC BY-NC)

6.3 Rabsa Puntarenas

Rabsa is a waste management company operating with different municipalities in Costa Rica. Landfill site is located in province of Puntarenas, canton of Miramar. The site has a huge area of final disposal, which leads to a high volume of seepage water that needs to be treated. A treatment process for the seepage water is complicated because of quality of the water changes a lot.

Process begins with a mechanical screening and a sand filtration, following with a nanofiltration and an inverted osmosis. Then a preliminary sedimentation, a biological treatment (see Figure 10) and a sedimentation with added flocculant and finally filters. The water will be treated again if certain physical-chemical values are not achieved. Effluent parameters can be seen in Table 6.

FIGURE 10. Biological treatment basin at Rabsa Puntarenas (Hoffrén 2023, CC BY-NC)

TABLE 6. Parameters for treated seepage water on 23.2.2023

PARAMETER	RESULT OF EFFLUENT
FLOW RATE (m^3/d)	75,9
PH	7,5
TEMPERATURE (°C)	30
BOD (mg/l)	146
COD (mg/l)	995
TSS (mg/l)	49

6.4 Instituto Tecnológico de Costa Rica

Instituto Tecnológico de Costa Rica, known as TEC, is a university in province of Cartago, canton of Cartago. They have a treatment for domestic wastewater, which is utilized in degree of Environmental Engineering. Process includes only a biological treatment (see Figure 11) with three basins. First one is an anaerobic, second and third facultative, which means the basin’s bottom is anaerobic, top aerobic and middle something between. TEC is considering adding other methods to improve efficiency of the process. Results of the efficiency can be seen in Table 7.

FIGURE 11. Biological treatment's first basin at TEC (Hoffrén 2023, CC BY-NC)

TABLE 7. Results after treatment process

PARAMETER	**RESULT (REDUCTION %)**	**MAXIMUM ADMISSIBLE VALUE**
FLOW RATE (m^3/d)	51,6	-
TEMPERATURE (°C)	24,7	15 to 40
PH	8,42	5 to 9
BOD (mg/l)	104	50
COD (mg/l)	206 (60,8)	150
TSS (mg/l)	91	50
TOTAL NITROGEN (mg/l)	15,5 (78,5)	50

6.5 Fumigadora Alto

Field of this company is producing fertilizers from wastewater of septic tanks. Treatment plant is located in province of San José, canton of San Isidro de El General. It is a family business and has been founded in 1982, only company in Costa Rica having a license on this kind of operation. The company also manufactures septic tanks and sewerage systems.

Treatment has two different lines that separates in middle of the process. Two mechanical screens receives wastewater brought by trucks where one line leads the wastewater to a biological treatment (see Figure 12) consisting of five 1.97 meters deep facultative basins. Retention time in this phase is 15 days. The first line has five 0.7 meters deep filtering basins where the wastewater dries for further processing. Retention time is 30 days. The second line has a sedimentation (see Figure 13) and an oxidation basin where the wastewater goes to drying field for further processing. After these treatments the wastewater is led to a bio garden and finally to a river. Manager of Fumigadora Alto claims the treatment follows guidelines of Costa Rican government's regulation 33601.

FIGURE 12. Biological treatment basins at Fumigadora Alto (Hoffrén 2023, CC BY-NC)

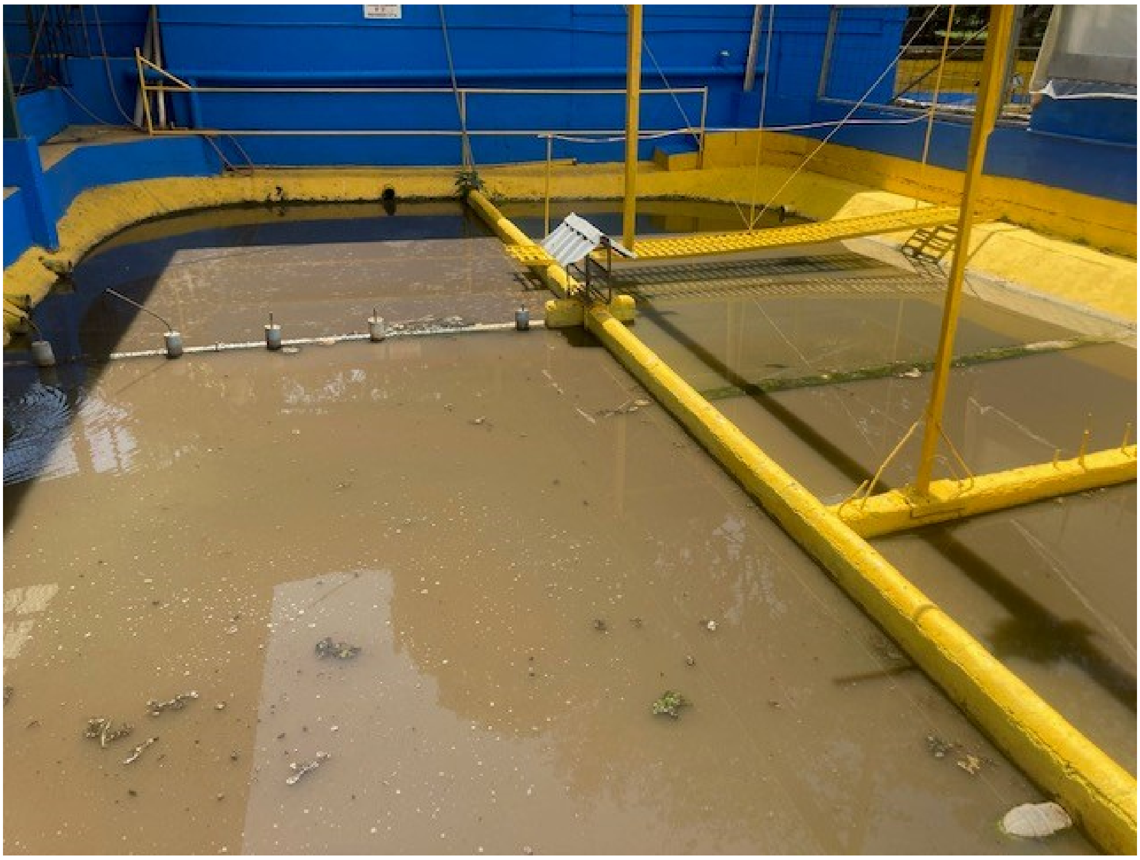

FIGURE 13. Sedimentation basin at Fumigadora Alto (Hoffrén 2023, CC BY-NC)

6.6 Tenería Pirro

Field of this company is producing different kind of leathers. The company is located in province of Alajuela, canton of Sarchí. Quality of wastewater changes every day due to unhairing and tanning processes and creates a challenge to treatment process. The company had clearly own areas for each process and it was easy to observe and detect them.

First, wastewater is led to a mechanical screening where bigger pieces of leather and grease are removed up to 10 mm diameter. Then the wastewater from unhairing process goes to a chemical oxidation of sulfide, transforming it to sulfur and removing it. Next the wastewater goes to a primary treatment consisting of homogenization, preliminary sedimentation and chemical treatment where adding coagulant makes some particles flocculate and therefore easy to remove. After the primary treatment comes a secondary treatment, a biological treatment with an aeration and an activated sludge process (see Figure 14). Then a denitrification basin before leading effluent to a river. Next to the biological treatment is a sludge maturation basin that receives the sludge from the primary treatment. Efficiency of the process can be seen in Table 8.

FIGURE 14. Tenería Pirro's biological treatment process (Hoffrén 2023, CC BY-NC)

TABLE 8. Efficiency of Tenería Pirro's treatment process

	BOD (mg/l)	**COD (mg/l)**	**TSS (mg/l)**	**PH**	**°C**	**m^3/d**
1ST	26334	43869	5332	11,2	-	-
2ND	33	82	11	8,2	24	119,6
%	99,87	99,81	99,79	-	-	-

7 TARGETS FOR DEVELOPMENT

7.1 Potable water development ideas

Generally, matters related to potable water are on a very good basis in Costa Rica as tap water is drinkable all over the country. Considering some development ideas on water supply, line pressures are quite low compared to Finland. For instance, the tap water's flow rate is low and have to wait for a longer period of time to fill up a glass, a drinks container or a pot. Also, many places did not have a temperature regulator with the tap water.

Considering physical-chemical parameters, chlorine levels were quite elevated even close or above alert value (see Table 1). ASADA La Angelina's free residual chlorine (see Table 4) was measured as 0.64 mg/l and alert value has been delineated as 0.3 mg/l. In addition, maximum permissible value is 1.0 mg/l and AyA Tres Ríos measured their free residual chlorine as 0.98 mg/l (see Table 3). This causes smell and taste of chlorine in the tap water. Noticing pH-levels being quite low (see Table 4) is a risk for pipelines because of corrosion that low pH-level causes. Also, decreasing lifetime of the pipes and could dissolve metals in them such as iron.

Climate change is a relevant matter in Costa Rica as droughts increase and form a serious threat to sufficient volume of raw water resources. This creates a lot of problems to industry, agriculture and human welfare. Possible new technologies to treat water could expand the raw water resources as more polluted water could be purified.

Raw sewage contaminates natural waters and abates state of water systems. This is a concrete problem in Costa Rica where households lead the raw sewage to a close by river or other receiving body of water. Actions from authorities to control this kind of practices or residents taking responsibility are in need. Not only endangering the state of waters, smell problems are already occurring and a potential risk to the raw water resources exists.

7.2 Wastewater development ideas

Wastewater management and treatment has more development potential than potable water in Costa Rica. Starting from system created, septic tanks will work if all the wastewater is collected and treated properly. There is an uncertainty about where and how the treatment is done with the septic tanks. Building a sewerage system nationwide could be a next step in the wastewater management as the wastewaters would flow directly to the treatment plant. This could also solve a problem with households that lead the wastewaters directly to a river, even it is illegal, having negative influence on condition of the river.

There are high values in many places considering physical-chemical parameters for wastewater effluent (see Table 6), and reduction percentages (see Table 5) are not quite high. Enhancing different unit processes in a treatment plant to reduce more biological and chemical oxygen demand as well as total suspended solids would have a positive impact on a receiving body of water. In addition, an idea about individual environmental permit for operations related to wastewater management restricting more the effluent. Different operations and plants have different quality of the wastewater, which could be controlled better with the environmental permit.

Microbiological analysis from wastewater indicates high concentration of Escherichia coli and coliform bacteria (see Table 5). Reducing bacteria from a receiving body of water is very important as it could lead to water epidemic in public beaches for example. Assuming that there is no treatment for microplastics or residues of medical products, it could be one addition to a development plan of wastewater treatment.

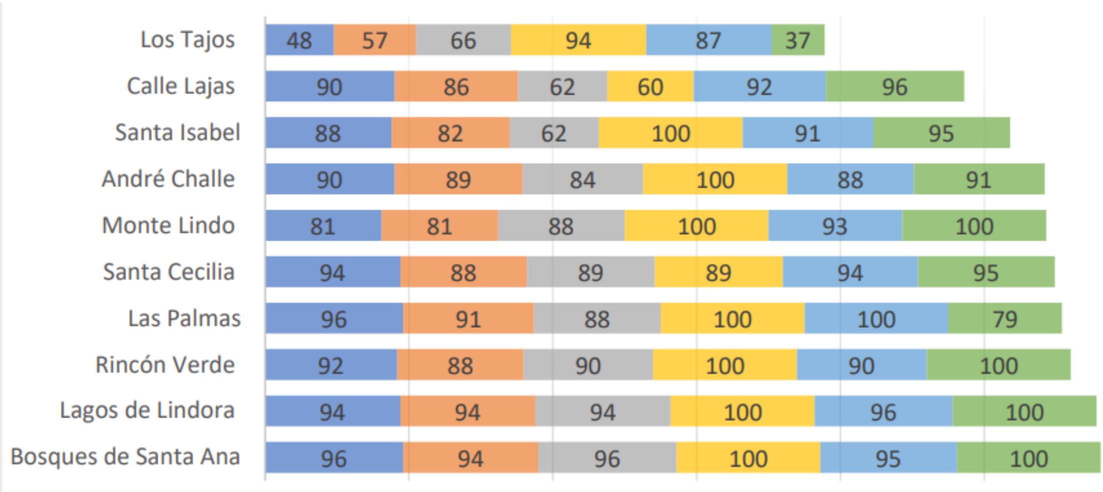

FIGURE 15. Clip from LNA's presentation of reduction percentages on different wastewater treatment plants in Costa Rica (Campos Gamboa 2023)

Reduction percentages (see Figure 15) on annual average for different wastewater treatment plants in Costa Rica on 2021 indicates BOD with blue color, COD with orange, TSS with grey, settleable solids with yellow, greases and oils with sky blue and methylene blue active substances with green. Los Tajos has smaller reductions because of a renovation and some unit processes were not in use. BOD and COD reductions are generally good but there is clearly room for improvement, which could result in an international cooperation.

8 SUMMARY AND CONCLUSIONS

Different plants were visited and many processes observed along the way. Even though a plan was to visit as many water treatment plants as possible, also some other companies related to a natural resources management were visited to understand bigger picture. Goal of this thesis was achieved as total amount of eight treatment plants were visited and their operations mapped out. Three of these plants were potable water treatment plants and five were wastewater treatment plants, of which only two were not industrial. Discussions with personnel clarified that the processes were understood well and gave important data about physical-chemical and microbiological analyses. These results, as well as what was seen and observed, background targets of development.

Results indicate that there are some issues, especially in the wastewater treatment, in need of development such as enhancing unit processes to reduce effluent's effect to nature. Some of the treatment processes did not achieve maximum limits for the effluent, which demands an alteration and adjustment of the processes. In addition, nowhere near all households have access to a sewerage system even inside a metropolitan area, which is increasing due to a development plan of AyA.

Water supply generally is very similar to Finland and quality of water is good and tap water drinkable. Costa Rican potable water treatment plants that utilizes an aquifer or a groundwater as a source do not need much of treatment but naturally the plants utilizing a surface water have to treat it more heavily and carefully.

Gathering general information and laboratory analyses was done successfully and mostly without delays or other problems. Even though Costa Rica has totally different culture and native language is Spanish, eager to learn and understand differences and a new language helped a lot during time of research. If there were any problems the most common reason was related to the language but with an optimistic and open mindset everything worked out. A high recommendation is to learn the native language as it helps very much with conversations, but it is not a mandatory.

There is definitely potential for a cooperation with companies and organizations interested in working with Costa Rican wastewater and potable water treatment plants. Finnish water technology and expertise would be beneficial to these plants, but also give new challenges for Finnish companies and organizations. Mostly work would be with natural waters or wastewater management but potable water in some zones of the country could need new purification technologies as it is crucial natural resource.

REFERENCES

Arroyo Fernandez, Magdalena 2022. Nomination for spring 2023. Email message 14.11.2022. Recipient: Lauri Hoffrén.

Britschgi, Ritva, Rintala, Jari & Puharinen, Suvi-Tuuli 2018. Pohjavesialueet – opas määrittämiseen, luokitukseen ja suojelusuunnitelman laadintaan. Helsinki: Ministry of the Environment. https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161164/OH_3_2018_Pohjavesialueet_opas_nettiin.pdf. Accessed 10.5.2023.

Campos Gamboa, Andrea 2023. Water laboratory information. Email message 30.3.2023. Recipient: Lauri Hoffrén.

Centers for Disease Control and Prevention 2022. https://www.cdc.gov/healthywater/drinking/public/water_treatment.html. Accessed 19.4.2023.

Center for Sustainable Systems, University of Michigan 2021. https://css.umich.edu/us-wastewater-treatment-factsheet. Accessed 13.5.2023.

Costa Rican Government Regulation for Drinking Water Quality 38924-S. http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?param1=NRTC&nValor1=1&nValor2=80047&nValor3=123709&strTipM=TC. Accessed 8.2.2023.

Costa Rican Government Regulation for Wastewater Discharge and Reuse 33601. http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?param1=NRTC&nValor1=1&nValor2=59524&nValor3=83250&strTipM=TC. Accessed 14.2.2023.

Costa Rican Ministry of Environment, Energy and Telecommunications 2008. National Plan for Integrated Water Resources Management. Internet publication. Updated October 2008. https://da.go.cr/wp-content/uploads/2018/05/Plan_Nacional_Gestion_Integrada_Recursos_Hidrico.pdf. Accessed 11.5.2023.

Environmental Protection Act 527/2014. https://www.finlex.fi/fi/laki/alkup/2014/20140527#Pidm45053757387440. Accessed 18.4.2023.

Finnish Environment Institute 2022. Pohjavesien tila on Suomessa yleisesti hyvä. Internet publication. Updated 2.5.2022. https://www.ymparisto.fi/fi/ympariston-tila/vesi/pohjavesien-tila. Accessed 11.5.2023.

Finnish Government Decree on Domestic Wastewaters 888/2006. https://www.finlex.fi/fi/laki/alkup/2006/20060888?search%5Btype%5D=pika&search%5Bpika%5D=888%2F2006#Pidm45053757006240. Accessed 19.4.2023.

Finnish Government Decree on Quality and Control of Domestic Water and the Risk Management of Water Installations in Buildings 1352/2015. https://www.finlex.fi/fi/laki/ajantasa/2015/20151352#a3.1.2023-2. Accessed 25.1.2023.

Finnish Institute for Health and Welfare 2023. Talousvesi. Internet publication. Updated 17.3.2023. https://thl.fi/fi/web/ymparistoterveys/vesi/talousvesi. Accessed 2.4.2023.

Finnish Water Utilities Association s.a. Ammattiasiaa talousvedestä. Internet publication. https://www.vvy.fi/vesihuolto/ammattiasiaa-talousvedesta/. Accessed 11.5.2023.

Finnish Water Utilities Association s.a. Jätevesistä eksperteille. Internet publication. https://www.vvy.fi/vesihuolto/jatevesista-eksperteille/#osio-1-1511881740-8473-1. Accessed 4.4.2023.

Kuopion Vesi s.a. Jätevedenpuhdistus. Internet Publication. https://www.kuopionvesi.fi/tietoa-vedesta/jatevedenpuhdistus/. Accessed 6.4.2022.

Laitinen, Jyrki, Juntunen, Janne, Kotamäki, Niina, Laukka, Vuokko, Siimes, Katri, Loikari, Arto, Dubovik, Maria, Rinta-Hiiro, Ville, Wendling, Laura, Miettinen, Ilkka T. & Meriläinen, Päivi 2022. Yhdyskuntajätevesien satunnaispäästöjen merkitys ja vaikutukset vastaanottavissa vesistöissä. Helsinki: Finnish Government. https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/163912/VNTEAS_2022_22.pdf?sequence=1&isAllowed=y. Accessed 18.4.2023.

Laitinen, Jyrki, Nieminen, Jenni, Saarinen, Risto & Toivikko, Saijariina 2014. Paras käyttökelpoinen tekniikka (BAT) – Yhdyskuntien jätevedenpuhdistamot. Helsinki: Ministry of the Environment. https://helda.helsinki.fi/bitstream/handle/10138/43199/SY_3_2014.pdf?sequence=1&isAllowed=y. Accessed 6.4.2023.

Pelto-Huikko, Aino & Vieno, Niina 2009. Vesikoulu. PDF file. Published 13.11.2009. https://www.vesikoulu.fi/assets/docs/vesikoulu_tietopaketti_juomavedesta.pdf. Accessed 3.4.2023.

The Water and Sanitation Observatory for Latin America and the Caribbean s.a. https://www.olasdata.org/en/costa-rica/. Accessed 24.1.2023.

United States Environmental Protection Agency 2022. Types of Septic systems. Internet publication. Updated 23.8.2022. https://www.epa.gov/septic/types-septic-systems#septictank. Accessed 25.4.2023.

Vesi.fi s.a. Raakavesi. Internet publication. https://www.vesi.fi/sanasto/raakavesi/. Accessed 10.5.2023.

Water Services Act 119/2001. https://finlex.fi/fi/laki/ajantasa/2001/20010119?search%5Btype%5D=pika&search%5Bpika%5D=vesihuoltolaki#L3. Accessed 18.4.2023.

APPENDIX 1. QUALITY DEMANDS AND RECOMMENDATIONS FOR DOMESTIC WATER

Taulukko 1. Mikrobiologiset laatuvaatimukset

Muuttuja	Enimmäisarvo	Yksikkö
Escherichia coli	0	pmy/100 ml
Enterokokit	0	pmy/100 ml

Taulukko 2. Kemialliset laatuvaatimukset

Muuttuja	Enimmäisarvo	Yksikkö	Huomautus
Akryyliamidi	0,10	µg/l	(1)
Antimoni	5,0	µg/l	
Arseeni	10	µg/l	
Bentseeni	1,0	µg/l	
Bentso(a)pyreeni	0,010	µg/l	
Boori	1,0	mg/l	
Bromaatti	10	µg/l	(2)
1,2-dikloorietaani	3,0	µg/l	
Elohopea	1,0	µg/l	
Epikloorihydriini	0,10	µg/l	(1)
Fluoridi	1,5	mg/l	
Kadmium	5,0	µg/l	
Kloorifenolit yhteensä	10	µg/l	(3)
Kromi	50	µg/l	
Kupari	2,0	mg/l	(4)
Lyijy	10	µg/l	(4)
Nikkeli	20	µg/l	(4)
Nitraatti (NO_3^-)	50	mg/l	(5)
Nitriitti (NO_2^-)	0,50	mg/l	(5)
Polysykliset aromaattiset hiilivedyt yhteensä	0,10	µg/l	(6)
Seleeni	10	µg/l	
Syanidit	50	µg/l	
Tetrakloorieteeni ja trikloorieteeni yhteensä	10	µg/l	
Torjunta-aineet	0,10	µg/l	(7 ja 8)
Torjunta-aineet yhteensä	0,50	µg/l	(7)
Trihalometaanit yhteensä	100	µg/l	(2 ja 9)
Uraani	30	µg/l	
Vinyylikloridi	0,50	µg/l	(1)

Taulukko 4. Laatusuosuositukset (tavoitetasot)

Muuttuja	Enimmäisarvo	Yksikkö	Huomautus
Koliformiset bakteerit	0	pmy/100 ml	
Clostridium perfringens (mukaan lukien itiöt)	0	pmy/100 ml	(1)
pH	6,5–9,5		(2)
Orgaanisen hiilen kokonaismäärä (TOC)	- ei epätavallisia muutoksia		(3)
Pesäkkeiden lukumäärä (22°C)	- ei epätavallisia muutoksia		
Haju ja maku	- ei epätavallisia muutoksiaja käyttäjien hyväksyttävissä		
Sameus	- ei epätavallisia muutoksia ja käyttäjien hyväksyttävissä		(4)
Väri	- ei epätavallisia muutoksia ja käyttäjien hyväksyttävissä		
Laatusuositukset (suurin hyväksyttävissä oleva pitoisuus)			
Alumiini	200	µg/l	
Ammonium (NH_4^+)	0,50	mg/l	
Hapettuvuus (COD_{Mn}-O_2)	5,0	mg/l	(5)
Kloridi	250	mg/l	(2 ja 6)
Mangaani	50	µg/l	
Natrium	200	mg/l	
Rauta	200	µg/l	
Radon	300	Bq/l	(7 ja 8)
Sulfaatti	250	mg/l	(2 ja 9)
Sähkönjohtavuus	2 500	µS/cm	(2)

APPENDIX 2. VISITED COMPANIES AND PLANTS

PLACE OF VISIT/COMPANY	DATE AND LOCATION
QUEBRADA LOS NEGRITOS	6.3.2023 San José
FUNDECOR	9.3.2023 San José
RABSA CENTRAL OFFICE	10.3.2023 Alajuela
AYA LOS TAJOS	14.3.2023 Heredia
AYA TRES RÍOS	21.3.2023 Cartago
LABORATORIO NACIONAL DE AGUAS	21.3.2023 Cartago
RABSA LANDFILL SITE	23.3.2023 Puntarenas
RESERVA BOSQUE NUBOSO SANTA ELENA	27.3.2023 Monteverde
ASADA SANTA ELENA	29.3.2023 Monteverde
COOPE TARRAZU	12.4.2023 Tarrazu
OBSERVATORIO DE AGUA Y SANEAMIENTO	13.4.2023 San Marcos
INSTITUTO TECNOLÓGICO DE COSTA RICA	17.4.2023 Cartago
FUMIGADORA ALTO	20.4.2023 San Isidro de El General
TERNERÍA PIRRO	24.4.2023 Sarchí
ASADA LA ANGELINA	25.4.2023 Cartago