TALLINN UNIVERSITY OF TECHNOLOGY

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MUNICIPAL WASTEWATER TREATMENT IN TURKEY AND ESTONIA

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Hereby I declare that this master thesis, my original investigation and achievement, submitted for the master degree at Tallinn University of Technology has not been submitted for any degree or examination.

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- Metcalf & Eddy. Wastewater Enginerring Treatment and resource Recovery
- Tallinna Vesi, Wastewater Treatment, 2013
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There are 18 Tables, 19 Figures and 32 Charts in this thesis.

Table of Contents

List of Abbreviations

WWTP- Wastewater Treatment Plant

WWT- Wastewater Treatment

BOD- Biological Oxygen Demand

COD- Chemical Oxygen Demand

TS- Total Solids

TSS- Total Suspended Solids

SS- Suspended Solids

EPA- Environmental Protection Agency

UNEP- United Nations Environment Programme

TDS- Total Dissolved Solids

DO- Dissolved Oxygen

TSI- Turkish Statistic Intuition

MEUP- Ministry of Environment and Urban Planning

SP- Stabilization Ports

BNR- Biological Nutrient Removal

EAAS- Extended Aeration Activated Sludge

WPCR- Water Pollution Control Regulation

UWTR- Urban Wastewater Treatment Regulations

BEWTP- Bursa Eastern Wastewater Treatment Plant

UWWTD- Urban Waste Water Treatment Directive

WFD- Water Framework Directive

RWB- Receiving Water Body

TV- Tallinn Vesi

HELSINKI HSY- Helsinki Region Environmental Services Authority

Abstract

This study researched wastewater treatment\plants in Turkey and Estonia including environmental laws\legislations and comparison of characteristics of municipal wastewater treatment\methods. The situation of Turkey and Estonia about water\wastewater were given as an initial knowledge in the beginning of the parts. The wastewater treatment methods and numbers were analysed by regions\cities in Turkey and Estonia. All related environmental legislations, laws and limit values regarding wastewater management were explained by the countries. Additionally, one specific municipal wastewater treatment plant was selected in both countries. Their characteristics, treatment methods, and conditions were analysed separately. In the last part of thesis, all mentioned fundamental methods\properties regarding wastewater treatment were compared between Turkey and Estonia. Additively, the most common problems\issues in wastewater treatment were researched and given some recommendations related to them. Untreated wastewater amount, lack of sewerage systems and, odour, occurring foam at municipal wastewater treatment plants were determined as the major problems in Turkey. In Estonia, having so many small-scale wastewater treatment plants that cannot comply the limit values, problem of nitrogen and phosphorus removal were determined as the key issues.

As a result, this study researched the general situation of municipal wastewater treatment in Turkey and Estonia. In addition, it clarified the basic difficulties in this subject and, gave recommendations for improving the wastewater treatment efficiency for both countries.

Keywords: Municipal wastewater treatment; Biological Treatment

1. Introduction

Wastewater treatment is one of the most significant problems in the world which affects human health and environment significantly. This thesis mainly analyses the situation of municipal wastewater treatment in Turkey and Estonia included the legislations and characteristic of wastewaters. The point of choosing this topic is these two countries are in different continents and accordingly considering that their methods, regulations and approaches regarding wastewater treatment are not similar. Thus, analysing their approaches and comparing their methods in wastewater treatment give important ideas and results.

Municipal wastewater treatment is quite large and complicated subject therefore, source of wastewater and its characteristic are explained in the beginning of the thesis in general terms. In the following chapter, characteristic of wastewater and the most common treatment methods (physical, chemical, biological) are defined and all unit processes are explained with related figures and tables. When explaining these main subjects regarding municipal wastewater treatment, mostly Metcalf & Eddy is used as a main source.

The situation of Turkey is defined regarding municipal wastewater treatment. Firstly, mentioned about water potential and usage of water by cities in Turkey. The major WWTP are analysed by regions and the applications that used in the treatment process are determined. According to the survey in 2014, very different methods are used in Turkey for municipal wastewater treatment. For instance, the municipalities mostly use extended aeration activated sludge process in Marmara region, but in Eastern Anatolia region, biological nutrient removal process is mostly used. The amount of generated wastewater and the discharge areas are also depending on the regions in Turkey. For example, ordinarily deep see discharges are used in Black Sea region but in Southern Anatolia, stream-rivers are used as a recipient for discharging the wastewater. All reasons of applying for these different methods in different areas are defined by graphics and some examples are given.

In the next chapter, similar subjects are analysed for Estonia. Water consumption and potential are explained by graphics and tables in the beginning of the chapter. Wastewater treatment methods are defined. Municipal and industrial wastewaters are treated in the same WWTP because the amount of industrial wastewater is low, and it doesn't affect the treatment efficiency. Basically, there are 59 agglomerations which are over 2,000 PE and only 22 of them have population more than 10.000 PE. The biggest WWTP in Estonia is Paljassaare which is in Tallinn City and it is responsible more than % 43 of total wastewater in Estonia.

Two special WWTPs are selected and their properties are researched to understand and compare the methods\differences between Turkey and Estonia. The characteristic of Bursa Eastern and Paljassaare WWTP are compared and their properties are explained by numbers, graphics, tables.

These two countries have different legislations are regulations regarding WWT. All related legislations are defined, and their aims and scopes are explained.

In Turkey, there are 3 main regulations about water and wastewater treatment. They are;

- Water Pollution Control Regulation
- Urban Wastewater Treatment Regulations
- Regulation on Control of Pollution Caused by Dangerous Substances in Water Bodies

In Estonia, there are 4 main regulations regarding wastewater treatment. These legislative acts are harmonized with European Council Directive 91/271/EEC concerning urban waste-water treatment. They are:

- Water Act
- Public Water Supply and Sewerage Act
- Government Regulation on Wastewater Treatment
- Environmental Charges Act

In Chapter 6, the characteristic of municipal wastewater treatment plants is compared between Turkey and Estonia. All related data are shown by graphics and tables to understand the differences. The main problems regarding WWT are determined in general and the solutions\ recommendations are given for each main problem. In the following stages, the most common problems are defined regarding WWT in Turkey and Estonia separately. To understand and determine the main problems at WWTP in Turkey, arranged a meeting with the experienced engineer of Bursa Eastern wastewater treatment plant and discussed regarding the most common problems and checked the reports of the plant. Unfortunately, there was no such a chance in Estonia and could not have a meeting with manager of Paljassaare WWTP.

Turkey's legislations are mostly based on European regulations and Estonia has exactly European regulations. There are some differences between limit values. Limit values for public sewerage system and the discharge standards to the receiving areas are compared according to regulations. It can be say that there are some big and slight differences between limit values in general terms. The differences about limit values are defined in the study and these differences are mostly depending on characteristic of wastewater, its treatment\generated methods and the situation\type of receiving areas.

In the end of the thesis, the most significant problems are determined regarding municipal wastewater treatment for both countries and recommendations are given for a solution of these problems.

2. Wastewater treatment

Wastewater is water used by human beings in domestic, industrial, agricultural sector. It contains components that make it unsuitable for usage without treatment. If the wastewater is untreated and it piles up in a septic, it means that the decomposition of organic substance will cause trouble conditions, including the production of some malodorous gases. In addition, the wastewater that is untreated or inadequate treated contain countless pathogenic microorganisms that can live in the human intestine. Besides, as we know wastewater comprises nutrients that can stimulate the accrual aquatic plants, and can contain toxic substances or compounds, which have potential of cancer or maybe it is mutagenic. For these reasons, wastewater must be treated correctly, it is necessary to protect the whole environment and human health. [8]

The development of wastewater treatment is mostly about human health and environmental issues, especially the size of the cities has been increased. Wastewater treatment methods were developed hereon to concern for human health and opposite conditions caused by the discharge of wastewater to the environment and receiving water body. Also since the cities are much bigger than in the past, wastewater treatment facilities and disposal need more land and area, principally by irrigation and intermittent filtration was not existing anymore (these methods were used in the 1900s). Thereby, the methods of wastewater treatment needed to be developed that could be used to speed up the powers of nature, under the inspected circumstances, in projected treatment plants that necessary less land. [8]

2.1 Source of wastewater

The primary constituents in wastewater, classified from domestic, municipal, and industrial sources. They are human faeces, water from the bath, household products, food waste and another kind of inorganic and organic materials. This all wide variety of constituents that may be found in wastewater, it is prevalent practice to characterize wastewater in term of its physical properties and its biological and chemicals constituents. [8] [13]

Sources of wastewater:

Domestic wastewater: it is the wastewater discharged from a commercial and residential area, public facilities and institutional. Domestic wastewater is also the same with sanitary wastewater.

Industrial wastewater: Wastewater is pertinent industrial wastes.

Infiltration/inflow: The water that enters the collection system through direct and indirect ways. Inflow is storm water, which enters the collection system from roof leaders, drain connections. Infiltration is the external water, which gets into to the collection system through cracks, breaks, and leaking,

Storm water: It is inflow caused by rainfall and snowmelt. [8]

2.1.1 Municipal wastewater

Municipal wastewater is mainly formed of water with a relatively tiny amount of suspended solids and dissolved organic\ inorganic solids.

Municipal wastewater also can contain harmful substances and heavy metals that could be toxic. Even if these kinds of toxic materials are not present in concentrations most likely to affect human health, they can be at phytotoxic levels, that would restrict their agricultural use. Bacteria, pathogenic viruses, protozoa, and helminths can be present in raw municipal wastewater and they can live long time in the environment. [14]

The sewer systems for municipal wastewater is mostly designed based on average daily per capita flow of 400 litres that includes normal infiltration, but the pipes must other kinds for peak flows and 1500 l\person. d is a good assumption for design. In Table 1, the average composition of sanitary wastewater is shown. [6]

Table 1. The approximate composition of average sanitary wastewater (mg/l) based on 400 l person. d [6]

Parameter	Raw	After Settling	Biologically treated
Total solids	800	680	530
Total volatile solids	440	340	220
Suspended solids	240	120	30
Volatile suspended solids	180	100	20
BOD	200	130	30
Inorganic nitrogen as N	22	22	24
Total nitrogen as N	35	30	26
Soluble phosphorus as P	4	4	4
Total phosphorus as P	7	6	5

2.1.2 Industrial wastewater

Industrial wastewater is wastewater from nondomestic sources in which industrial wastes predominate. [8]

Industries where are in municipal areas generally discharge the wastewater to the municipal sewer system after pre-treatment. Because some toxic compounds and constituents are very harmful to microorganisms in the wastewater. In this case, the municipality has the responsibility regarding final treatment of wastewater and disposal. The majority of industrial wastewater is quite proper for biological treatment after dilution part with domestic wastewater; however, a large amount of high-strength wastewater must be considered in sizing of municipal wastewater treatment. If perchance the cooling wastewater is uncontaminated, it can be directed to a storm water sewer. Pre-treatment of industrial wastewater must be considered for wastewater having forces or characteristics dramatically different from sanitary wastewater. Modern industrial treatment plant design necessitates discrimination of separate waste flows for pre-treatment, controlled mixing or divided disposal. Both uncontaminated cooling wastewater, which can be discharged to surface water bodies and harmful wastes, which cannot be sufficiently processed by the municipal wastewater treatment and must be processed or staved by the industry. Industrial plants have different operations may be necessary to equalize wastewaters in a basin for stabilization before the discharge to the sewer system. If the wastewater is unequalised and discharges to the system, it can affect the efficiency of biological treatment. For instance, metal industry wastewaters need pre-treatment for removal of toxic metal substances. Besides, if the municipal wastewater plants plan to reuse of wastewater, then discharge of industrial wastewater will be more significant and it must be under the control because of the considerable number of substances-ions in industrial wastewaters are relatively removed by conventional treatment and will be an important problem for water reuse. [6]

The composition of wastewater in industrial processes varies widely depending on the activity of the industry. In Table 2, the characteristics of some selected industrial wastewaters are listed, and it can be compared with sanitary wastewater in Table 1. It clearly seems that the BOD concentration of industrial wastewater is 5 to 20 times greater than domestic wastewater. [8] [6]

Table 2. Average characteristics of selected industrial wastewaters [6]

Industries	**Milk Processing**	**Meat Packing**	**Synthetic Textile**	**Chlorophenolic Manufacture**
BOD, mg/l	1,000	1,400	1,500	4,300
COD, mg/l	1,900	2.100	3.300	5.400
Total Solids, mg/l	1,600	3,300	8.000	53,000
Suspended Solids, mg/l	300	1,000	2,000	1,200
Nitrogen, mg N/l	50	150	30	0
Phosphorus, mg P/l	12	16	0	0
pH	7	7	5	7
Temperature, °C	29	28	-	17
Grease, mg/l	-	500	-	-
Chloride, mg/l	-	-	-	27,000
Phenols, mg/l	-	-	-	140

2.1.3 Infiltration/inflow/Storm water

It is the water, which enters the collection system through direct and indirect ways. Inflow is storm water entering collection system from roof leaders, drain connections, cellar and yard area drains, cooling water from air conditioners and other clean water discharges from industrial and commercial facilities. Infiltration water is the external water, which gets into to the collection system through cracks, breaks, and leaking. Storm water is runoff resulting from rainfall and snowmelt besides, anything the rain carries through it. [8] [6]

The amount of infiltration water entering a sewer system depends on pipe joints, condition of the pipe, groundwater levels, and permeability of the soil. Leaks into the new lines can be controlled by suitable design, choosing of the pipe and good control of construction. [8] [6]

2.1.4 Wastewater collection systems

Sewers systems are underground, waterproof pipes for transferring wastewaters by gravity flow from urban areas to treatment facilities. In 16th and 17th, the first drainage systems were constructed, to carry storm runoff from the built-up regions protecting them against flood and inundation. (Mark J. Hammer et al)

There are 3 types of collection system which are used for the removal of wastewater and storm water. They are sanitary wastewater collection systems, combined wastewater systems, and storm water collection systems. It is shown in Figure 1. [8]

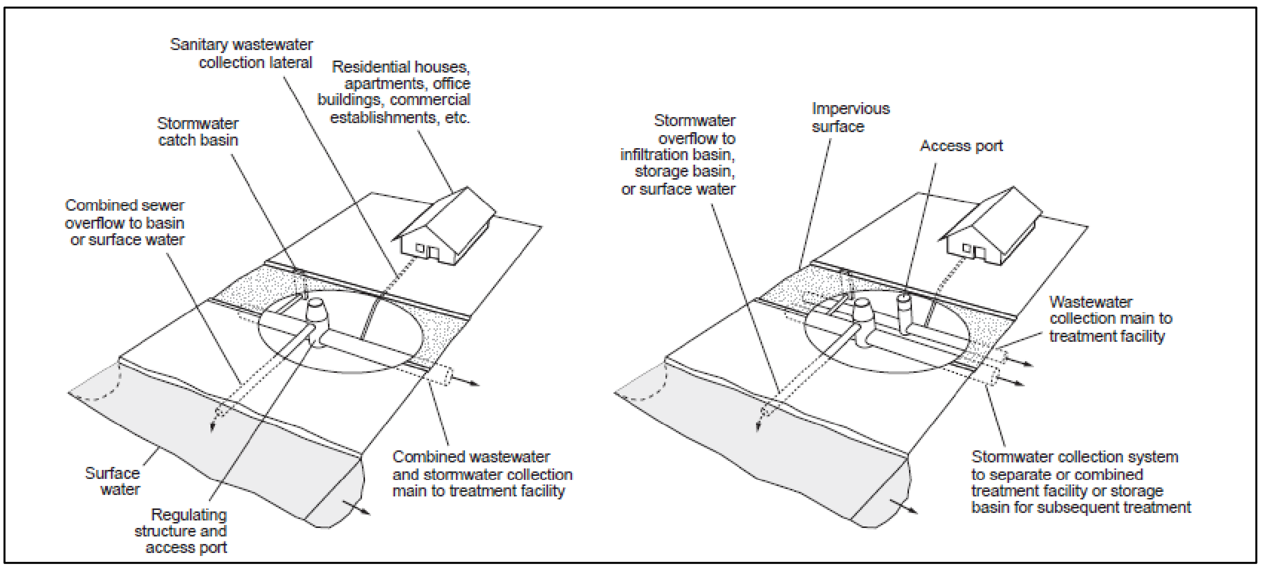


Figure 1. Schematic diagram of wastewater collection system infrastructure: (a) combined (wastewater and storm water) collection system and (b) separate wastewater and storm water collection systems. [8]

2.1.5 Sanitary wastewater collection system

Sanitary wastewater collection systems transport domestic and commercial wastewaters by gravity flow to wastewater treatment plants. Lateral sewers collect discharges from houses and carry them to another sewer, and no tributary sewage pipes. Submain pipes receive the wastewater from laterals and transmit it to larger common mains. The main sewer system can be called outfall or trunk sewage, it carries discharges from built-up areas to treatment facilities. At these treatment facilities, the wastewater is processed (treated) before being returned to the environment. [6] [13]

Design flows for sewage system are based on population numbers served, these amounts can be used per capita: nowadays it is 130-150 liters per capita per day.

2.1.6 Combined wastewater collection system

Many of the earliest sewer systems were combined collection sewers systems, designed to collect both sanitary wastewater and all storm water runoff in a single system. These combined sewer systems were designed to provide storm drainage from streets and roofs to prevent flooding in urban areas. Afterwards, pipes were added to transfer domestic wastewater away from houses and place of business. [27]

In addition to domestic and industrial wastewater, as mentioned before, other important different variables in calculation wastewater flow rates are the collaboration with infiltration/inflow and from storm water runoff and snowmelt, where combined wastewater collection systems are used, besides if there is extra filtration from collection system, it can affect the amount of wastewater. Identification of infiltration/inflow is shown in Figure 2. [8]

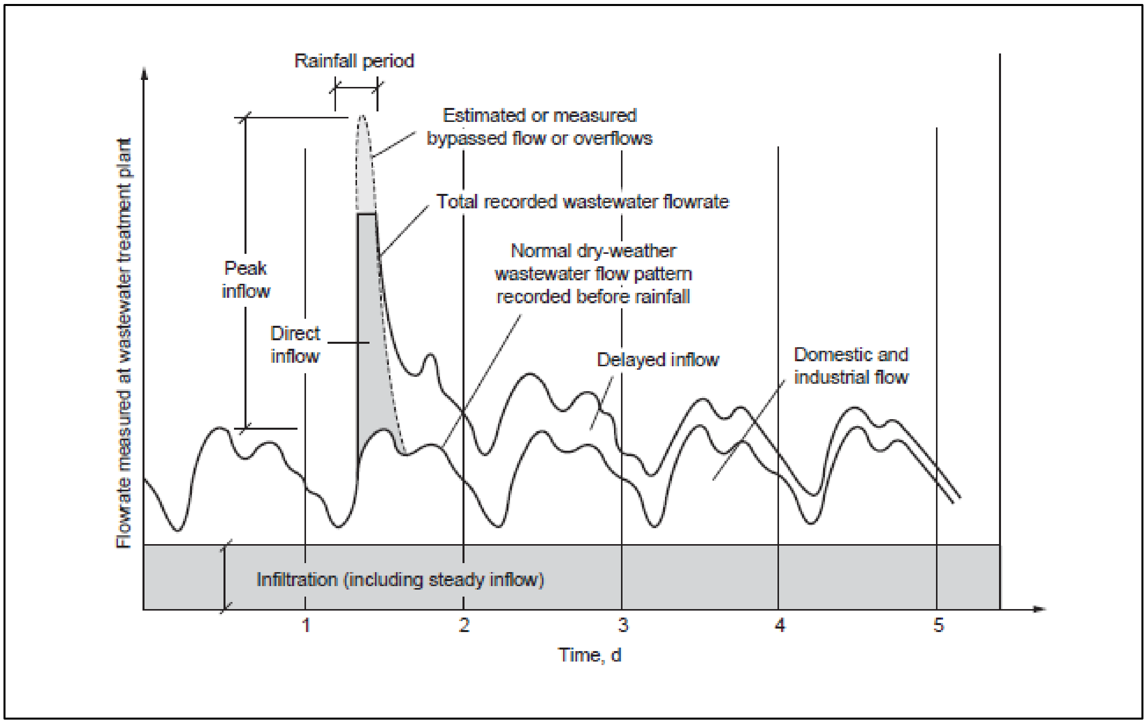


Figure 2. Graphic identification of infiltration/inflow. [8]

2.1.7 Storm water Collection system

Storm water flows over through the landscape's drainage system. The piped storm water collection system is a progress in the cities to make a success of odour and aesthetics of wastewater disposed of storm water. The covering of ditches for combined wastewater sewage was a midlevel part for using drainage sewage for combined wastewater and storm water. Piped sewage collection systems also allow more land for footway and road. Separate systems have an opportunity to return some storm water. [6] [27]

2.2 Characteristics of wastewater

2.2.1 The origin of wastewater

The quality and quantity of wastewater are specified by many elements/factors. Also, it is obvious that humans and industries do not produce the same amount of waste because the activities and their durations are very different in this case. The type and amount of waste produced in households are affected by the lifestyle of people, behaviour and other factors. For instance, American and European people produce different amount of wastes in their households. In residences, the waste mostly ends up as solids and liquid waste and, there are important opportunities for changing the quantity and composition of the two-waste stream generated, it is also the same for industries. [10]

2.2.2 Wastewater constituents

The primary constituents in wastewater, classified from domestic, municipal, and industrial sources, they are human faeces, water from the bath, household products, food waste and another kind of inorganic and organic materials. This all wide variety of constituents that may be found in wastewater, it is prevalent practice to characterize wastewater in term of its physical properties and its biological and chemicals constituents.
The constituents in wastewater can be divided into main categories according to Table 3.

Table 3. Constituents present in domestic wastewater [10]

Wastewater constituents	Examples	Effects
Microorganisms	Pathogenic bacteria, virus and worm eggs	Risk when bathing and eating shellfish
Biodegradable organic materials	Oxygen depletion in rivers, lakes, and fjords	Fish death, odors
Other organic materials	Detergents, pesticides, fat, oil and grease, colouring, solvents, phenols, cyanide	Toxic effect, aesthetic inconveniences, bioaccumulation in the food chain
Nutrients	Nitrogen, phosphorus, ammonium	Eutrophication, oxygen depletion, toxic effect
Metals	Hg, Pb, Cd, Cr, Cu, Ni	Toxic effect, bioaccumulation
Other inorganic materials	Acids, for example, hydrogen sulphide, bases	Corrosion, toxic effect
Thermal effects	Hot water	Changing living conditions for flora and fauna
Odour (and taste)	Hydrogen sulphide	Aesthetic inconveniences, toxic effect
Radioactivity		Toxic effect, accumulation

2.2.3 BOD and COD

Biochemical oxygen demand (BOD) is the most common to identify the strength of a municipal or organic industrial wastewater. This definition comprises the measurement of the dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter in the wastewater. In the aerobic oxidation of an organic substance in a sample of wastewater, the temperature is 20 °C ± 1 °C in an air incubator. A plastic cup is placed on the flared on the outlet of the BOD bottle throughout incubation process to decrease evaporation of the water seal. Measured wastewater, diluted with a prepared sample of water, is put in 300-ml BOD bottles. Seed microorganisms are procured the oxidize the organic waste if enough microorganisms are not already present in the sample of wastewater. [6]

General biological reaction: [6]

$$\text{Organic Matter} \xrightarrow[\text{(bacteria)}]{\text{(dissolved oxygen)}} CO_2 + \text{Bacterial Cells} \xrightarrow[\text{(protozoa)}]{\text{(dissolved oxygen)}} CO_2 + \text{Protozoa Cells}$$

Chemical oxygen demand (COD) is a measure of the capacity of water for consuming the oxygen throughout the decomposition of organic substance and the oxidation of inorganic chemicals such as nitrite and ammonia. Measuring of COD is in a widespread manner made on wastewater samples or natural waters, which are contaminated by domestic and industrial wastes. COD is measured as a standardized laboratory analysis in which a closed water sample is incubated with strong chemicals oxidant under some specific conditions such as temperature and period time. The most known in COD assay is potassium dichromate ($K_2Cr_2O_7$) and it is used for combination with boiling sulfuric acid (H_2SO_4). The reason is this chemical oxidant is not specific oxygen-consuming chemicals matters, which are organic or inorganic, these sources of oxygen demand are measured in a chemical oxygen demand assay.

Also, COD is related to biochemical oxygen demand, another standard test for assaying for oxygen demanding strength of wastewaters. But the BOD only measures the quantity oxygen consumed by microbial oxidation and mostly it is about waters rich in organic matter. It is the significant part that chemical oxygen demand and biochemical oxygen demand don’t necessarily measure the same kinds of consumption of oxygen. For instance, COD doesn't measure the oxygen-consuming potentially related to dissolved organic matters like acetate. However, it is known that acetate can be metabolized by microorganisms and it can be detected by BOD test. Contrary, the oxygen-consuming potential of cellulose is not measured during BOD test, but it can be measured during a COD test. [20]

2.2.4 Composition of sanitary wastewater

The common value of sanitary wastewater for 450 l/person\d includes commercial and domestic wastewaters besides, some infiltration. Characteristics of this wastewater prior to treatment, after settling, and following biological process shown in Table 1. Total solids (TS) is a measure of all suspended, colloidal, organic matter and dissolved in a water. BOD is a measuring of wastewater strength. Sedimentation of a typical municipal wastewater decreases BOD approximately 35 % and suspended solids 50%. Processing, including secondary biological treatment unit, decreases BOD and the suspended solids almost 85 %, volatile solids 50 %, total nitrogen is about 25 % and phosphorus 20 %. [6]

The excess of nutrients in the treated effluent indicates which sanitary wastewaters have phosphorus (P) and nitrogen (N) in a surplus of biological entails. As general, BOD/N/P weight ratio is 100/5/1 (100 mg/l BOD to 5 mg/l nitrogen to 1 mg/l phosphorus). For raw sanitary wastewater, the ratio is 100/17/3 and it turns to 100/23/5 after settling, and thus contains ample nitrogen and phosphorus for microbial growth. [6]

3. Municipal wastewater treatment methods

The components, which found in wastewater can be removed by physical, chemical and biological treatment methods. These methods mostly classified as physical, chemical and biological unit processes.

Physical unit processes are the treatment methods in which the application of physical forces predominates. Since these methods are about directly from people's observations of the world, they were the first application regarding wastewater treatment. The physical unit process has basic unit process as screening, mixing, flocculation, sedimentation, flotation, filtration, and adsorption. For instance, adsorption process comprises removal of some specific matters from the wastewater over solid matters surfaces using the strengths of attraction between bodies.

Chemical unit processes are the treatment methods in which the removal of substances is consisted by the addition of chemicals or by other chemical reactions. Precipitation, gas transfer, adsorption, and disinfection are the most known processes used in wastewater treatment.

The biological unit process is the treatment methods in which the removal of substances is consisted by biological activates. The biological treatment process is used primarily for remove the colloidal or dissolved biodegradable organic compounds which found in wastewater. Fundamentally, these compounds are converted into gases that can go to the atmosphere and biological cell that can be removed by settling or another, separation process. Biological treatment processes are also used for removing the nitrogen (N) and phosphorus (P) from wastewater. [8]

The typical treatment process flow diagram is shown in Figure 3. The conventional secondary treatment process is used primarily for the removal of biological oxygen demand (BOD_{5}) and total suspended solids (TSS). The primary treatment part of the flow diagram is used for the removal of large, coarse solids by screening and these particles of adequate density to be removed by gravity settling. Biological treatment is used to remove BOD_5, and TSS for the control of microorganisms as mentioned before. Tertiary treatment typically comprises the filtration of settled secondary effluent for remove any kind of effluent suspended solids and thereby increase the disinfection process. [8]

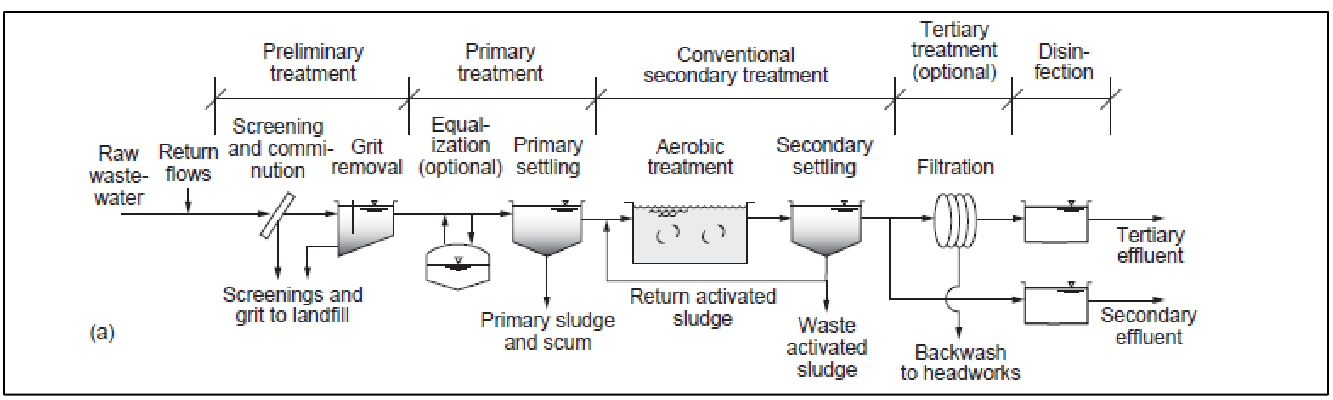


Figure 3. Typical flow diagrams for the treatment of wastewater and biosolids- conventional biological treatment [8]

3.1 Physical treatment

The physical unit processes most used in primary treatment of wastewater involve some or all these following (1) screening, (2) coarse solids reduction, (3) mixing and flocculation, (4) gravity separation, (5) grit removal, (6) primary sedimentation, (7) high-rate clarification, and (8) flotation. [8]

The first step in the treatment of municipal wastewater is known as primary treatment and coarse solids are removed from the wastewater in the physical unit process. In some of the wastewater treatment plants, primary and secondary parts can be united into one essential process.

In preliminary treatment, screens remove large floating stuff, like rags, cans, some plastic and metal bottles and sticks-bars that can clog pumps of the system, small pipes, and downriver processes. The screens are made with parallel iron bars or steel. [27]

3.1.1 Main stages of physical treatment

Screening, it is the first step of wastewater treatment plants. Screening is a tool and it has some spaces, it is usually uniform size, that is for to retaining the large solids which are in wastewater. The main goal of this screens is to remove coarse materials from the stream because these materials can be a problem the process equipment, can decrease the treatment yield and its stability.

Most used screens in wastewater treatment plants shown in Figure 4. In general, there are 2 types of screens, they are coarse and fine screens, can be used in preliminary wastewater treatment. Fine streams also can be used to remove the other organic solids from sludge flow to sludge processing. [8] [19]

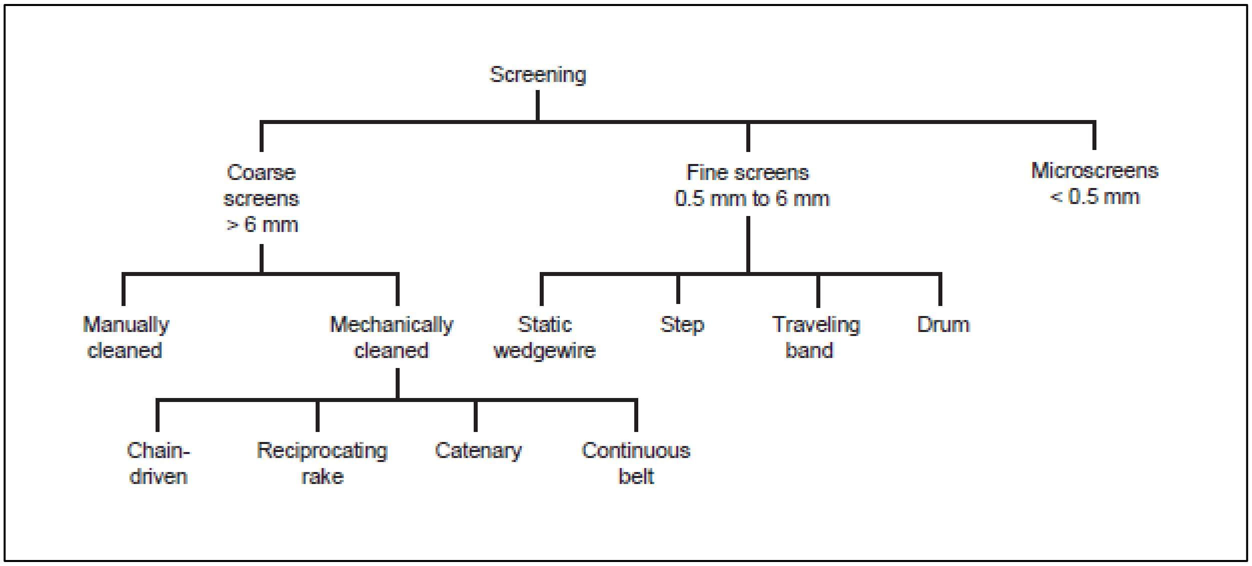


Figure 4. The general classification of the types of screens used in wastewater treatment. [8]

Coarse solids reduction, it is an alternative process to fine screen or coarse screen, macerators and comminutors could be used for stopping the coarse solids and it can shred or grind them in the screening process. These processes, macerators -comminutors – grinders, basically eliminate the whole messy and disposal from the wastewater. In addition, these processes have some advantageous about wastewater equipment, they protect the pumps against the clogging of the system. Especially they are more useful in the countries that have cold climate and problem with freezing. [8]

Mixing and flocculation, it is one of the most important processes in all wastewater treatment operations. Continues rapid mixing operation is for where one substance must be mixed with another one. Basic principles of this process are the blending of some chemicals such as alum or iron salts, the blending of miscible liquids and the supplement of some chemicals to sludge enhance their dewatering properties. The main goal of flocculation is making flocs from small particles and from chemically destabilized particles. Flocculation is a stage to make big particles from the destabilized particles that can be removed by settling or filtration systems. Flocculation basically follows rapid mixing where the chemicals are added to the basin to destabilize the particles. This process which is responsible for destabilization with added chemicals, calls coagulation. [8] [19]

Grit removal, it contains sand, cinders, gravel and other heavy particles, which can settle in the wastewater when the velocity of the flow rate is decreased. The main goals of the grit removal operation are to remove all grit along flow and to form a product in the end that is suitable for landfill. Grit removal system contains 3 stages, they are grit separation, grit washing, and grit dewatering. A complete grit removal system is shown in Figure 5. [6]

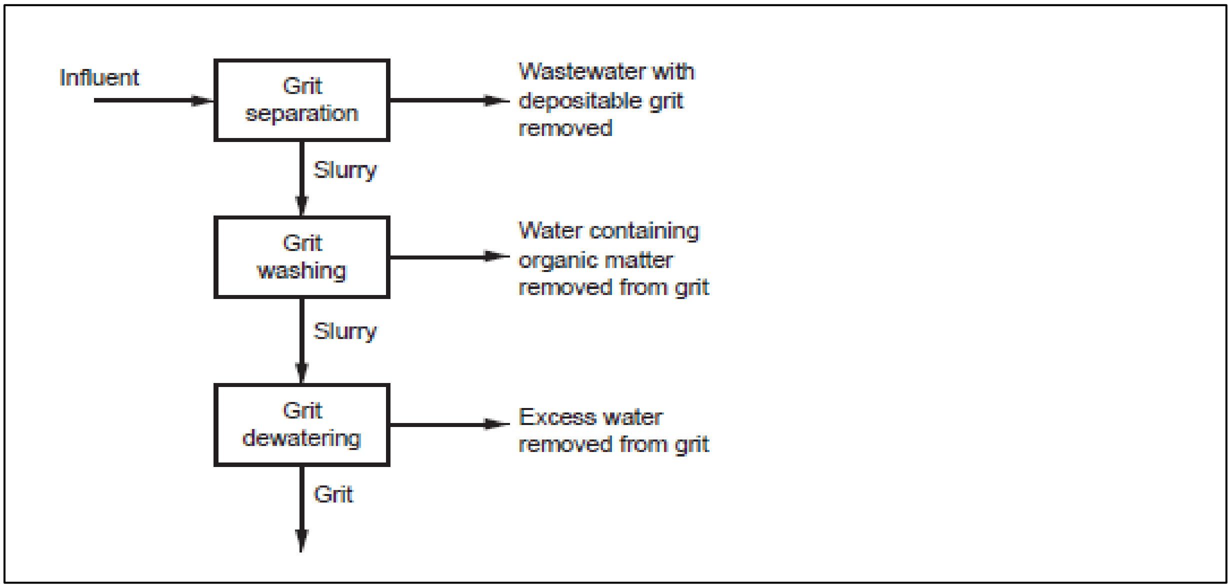


Figure 5. A complete grit removal system is shown in Figure 5 [8]

Primary sedimentation; the purpose of sedimentation is to remove the bioaccumulation settleable solids and floating substances which found in wastewater and it decreases the suspended solids (SS) amount. Primary sedimentation is the first step in wastewater treatment after removal of some coarse solids and grit. In proper designed and operated primary sedimentation tanks, it is acceptable that from 50 to 70 percent of suspended solids (SS) and from 25 to 50 of the biological oxygen demand (BOD) can be removed. [8] [19]

Mostly all wastewater treatment plants, which have primary sedimentation tanks, use mechanically cleaned primary sedimentation basins of standardized circular or rectangular types. The selection of these two different unit processes depends on some circumstances that can be about some specific rules and regulations also, the size of the installation, local conditions, and judgment of engineers. Figure 6 shows the types of sedimentation tanks [8]

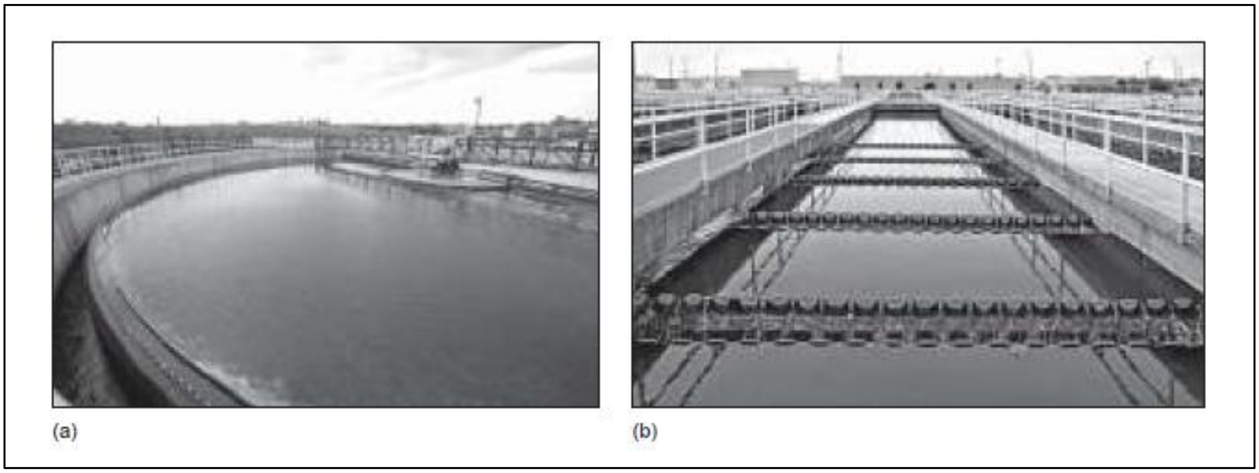


Figure 6. Typical sedimentation basins (a) circular with peripheral and (b) rectangular with inboard [8]

3.2 Chemical treatment

In chemical wastewater treatment, the chemicals are used in processes to speed up the disinfection. These processes, including the chemical reactions, are called chemical unit processes and they are used with physical and biological treatments to achieve required water quality standards. There are several significant chemical processes, including chemical coagulation, chemical oxidation, chemical precipitation, and advanced oxidation, ion exchange, and chemical neutralization and stabilization, which can be used for wastewater treatment. Applications of chemical unit processes are shown in Table 4. [8] [27]

There are some significant applications of the chemical unit process in chemical wastewater treatment, which are the removal of phosphorus, disinfection, coagulation of particle matter, pH control, neutralization, alkalinity supplementation and stability control and water stabilization. These applications are quite important in wastewater treatment but also these applications have connatural disadvantages regarding some chemicals that can be used in the processes (some substances are added to wastewater, to remove other matters in the wastewater). As an example, when some coagulants are added to wastewater to increase the efficiency of particle matter in sedimentation process, the total dissolved solids (TDS) amount will be increased [8] [19]

Table 4. Applications of chemical unit processes in wastewater treatment [8]

Process	Application
Advanced oxidation processes	Removal of refractory organic compounds
Chemical coagulation	The chemical destabilization of particles in wastewater to bring about their aggregation during prokinetic and orthokinetic flocculation.
Chemical disinfection	Disinfection with chlorine, chlorine compounds, bromine, and ozone Control of biofilm growth in sewers Control of odors
Chemical neutralization	Control of pH
Chemical oxidation	Removal of BOD, grease, etc Removal of ammonium Destruction of microorganisms Control of odors in sewers, pump stations, and treatment plants Removal of resistant organic compounds
Chemical precipitation	Enhanced removal of total suspended solids and BOD in primary sedimentation facilities (chemically enhanced primary treatment, CEPT). Removal of phosphorus Removal of ammonium Removal of heavy metals Physical-chemical treatment Corrosion control in sewers due to H_2S
Chemical scale control	Control of scaling due to calcium carbonate and related compounds
Chemical stabilization	Stabilization of treated effluents
Ion exchange	Removal of ammonium (NH_4), heavy metals, total dissolved solids

3.2.1 Physical-chemical treatment

In some regions, treating of industrial wastewater is difficult and physical-chemical treatment can be an alternative for wastewater treatment if there is no chance to treat the wastewater by biological treatment. This kind of treatment alternative is not the best choice because this treatment has some limited success regarding discharge requirements, cost of chemicals and the amount of sludge, which caused by chemicals and other operating processes. Also, the activated carbon columns can remove 50-60 % of BOD and the process doesn't reach the standards of secondary treatment. Because of these cases, physical-chemical treatment applications are not so popular for the treatment of municipal wastewater treatment. This process usually can be used for industrial wastewater because it is more efficient in this case. In Figure 7, there is a flow diagram of physical-chemical treatment for untreated wastewater.

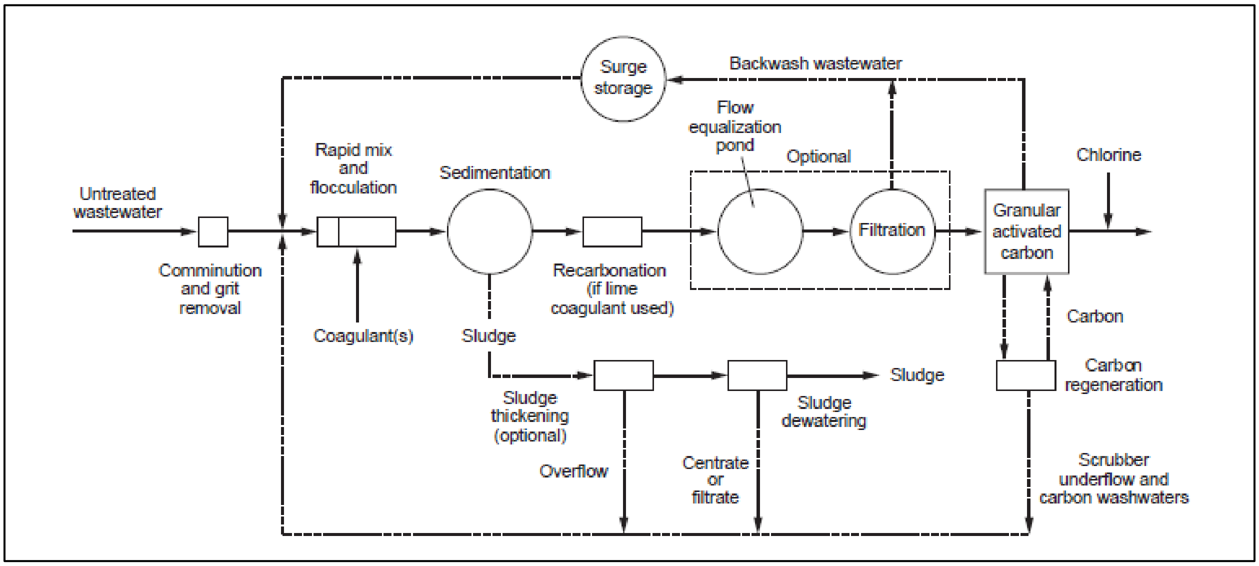


Figure 7. Typical flow diagram of an independent physical-chemical treatment plant. [8]

As shown in this figure, after first sedimentation and adjusting of pH by carbonation, the wastewater passes through the granular medium filter for removal all remnant floc and after that through carbon columns to remove dissolved organic compounds in the process. [8]

3.2.2 Chemical coagulation

Coagulation is the destabilization of colloidal particles. Coagulation and flocculation are used in wastewater and water treatment plants. In biological wastewater treatment processes, microorganisms are produced with natural flocculation and other matters that are suspended in wastewater, they can need some coagulating agents to help their flocculation. Also, coagulants can be added to the process for removal of nutrients. Physical-chemical wastewater treatment methods are based on coagulation and flocculation to remove suspended matter in the wastewater.

The power of the coagulating agent is based on it is charge and the size of synthetic polymers is also a significant factor. There is more than an order of magnitude enhance the efficiency of an ion like its charge enhances by one. [19]

The most well-known coagulants are iron salts, alum (aluminium sulphate). In Table 5, there is a list, which is related coagulation power of salts. The basic reaction of alum (aluminium sulphate) is: [19]

$Al_2(SO_4).\ 18H_2O + 6H_2O \longrightarrow 2Al(OH)_3\,(s) + 6H^+ + 3SO_4 + 18H_2O$

With an increase in H^+, pH is depressed and no more $Al(OH)_3$ is formed. If natural alkalinity is present, then

$HCO^-_3 + H^+ \Longleftrightarrow H_2CO_3 \Longleftrightarrow CO_2 + H_2O$

$Al_2(SO_4).\ 18H_2O + 3Ca\ (HCO_3)_2 \longrightarrow 2\ Al(OH)_3\,(S) + 3CaSO_4 + 6CO_2 + 18H_2O$

If natural alkalınıty is insufficient, then lime or caustıc soda can be added.

$Al_2(SO_4)_3\ .\ 18H_2O + 3Ca\ (HCO_3)_2 \longrightarrow 2\ Al(OH)_3 + 3CaSO_4\,(S) + 18H_2O$ [19]

Table 5. The most common coagulating agents [19]

Electrolyte	Positive colloids	Negative colloids
NaCl	1	1
Na_2SO_4	30	1
Na_3PO_4	1000	1
$BaCl_2$	1	30
$MgSO_4$	30	30
$AlCl_3$	1	1000
$Al_2(SO)_4{}^a$	30	> 1000
$FeCl_3$	1	1000
$Fe_2(SO_4)_3{}^a$	30	>1000

3.2.3 Estimation of Sludge Quantities from Chemical Precipitation

In chemical treatment, managing and disposal of the sludge that caused chemical sedimentation are one of the most important and difficult parts. Sludge is produced in big volume the chemical precipitation processes, usually 0.5 % of the volume of treated wastewater when lime is used in the process. Estimation of the mass and volume of sludge in untreated wastewater without and with the use of ferric chloride for the increased removal of TSS. Also, estimation of the amount of lime which is necessary for the determined ferric chloride dose. For instance, 60 %

of the total suspended solids can be removed in the primary settling chamber without the addition of coagulants, and that the addition of ferric chloride gets the result in an enhanced removal of total suspended solids to 85 %. [8]

Assume that the following data apply to this situation:

1. Wastewater flowrate, m^3/d	1,000
2. Wastewater total suspended solids, TSS, mg/L	220
3. Wastewater alkalinity as $CaCO_3$, mg/L	136
4. Ferric chloride ($FeCl_3$) added, kg/1000 m^3	40
5. Raw sludge properties	
Specific gravity	1.03
Moisture content, %	94

According to these amounts and properties of wastewater, sludge mass and volume without and with chemicals are shown in Table 6. [8]

Table 6. The sludge mass and volume produced without and with chemical precipitation. [8]

Treatment	Mass, kg\d	Volume, m^3 \d
Without chemical precipitation	132.0	2.13
With chemical precipitation	213.4	2.71

3.3 Biological treatment

Biological wastewater treatment is primary used treatment method for removing dissolved and colloidal substance in wastewater. Also, there are some suspended organic materials which will be metabolized and by means of the natural flocculation and settling properties of the biomass in biological treatment.

The biological process is a natural process. It depends on the role of microorganisms and organic matter in wastewater naturally are decayed in the biological process. If there are high organic loads in wastewater, it will affect the biocenosis of receiving water body and it can cause other needless effects. [8] [19]

3.3.1. Microorganisms in biological wastewater treatment

In biological treatment, microorganisms in wastewater are used to oxidize the dissolved and particulate carbonaceous organic matter into simple end products and additional biomass. In this following equation shows oxidation of organic matter. [8] [19]

$v1$ (organic material) + $v2O_2$ + $v3\ NH_3$ + $v4PO_4^{3-}$ $\xrightarrow{\text{microorganisms}}$ v5 (new cells) + $v6\ CO2$ + v $7H_2O$ [8]

As shown in this equation, O_2 (oxygen), NH_3 (ammonia) and PO_4^{3-} (phosphate) is used in this process to decay the organic matters in the presence of oxygen and the nutrients. The 'new cells' is used to represent the biomass which is produced because of oxidation of the organic matter. These microorganisms are also for removing the nitrogen and phosphorus in the wastewater. For this process, there must be some specific bacteria which they can oxidize ammonia to nitrite and nitrate, it is nitrification, while other specific bacteria are diminishing the oxidized nitrogen to gaseous nitrogen. [8] [19]

3.3.2. Methods of biological treatment

In wastewater treatment, the biological process can be divided 2 main categories which are suspended growth and attached growth (biofilm) processes. Most important and commonly used processes are shown in the following Figures. [13]

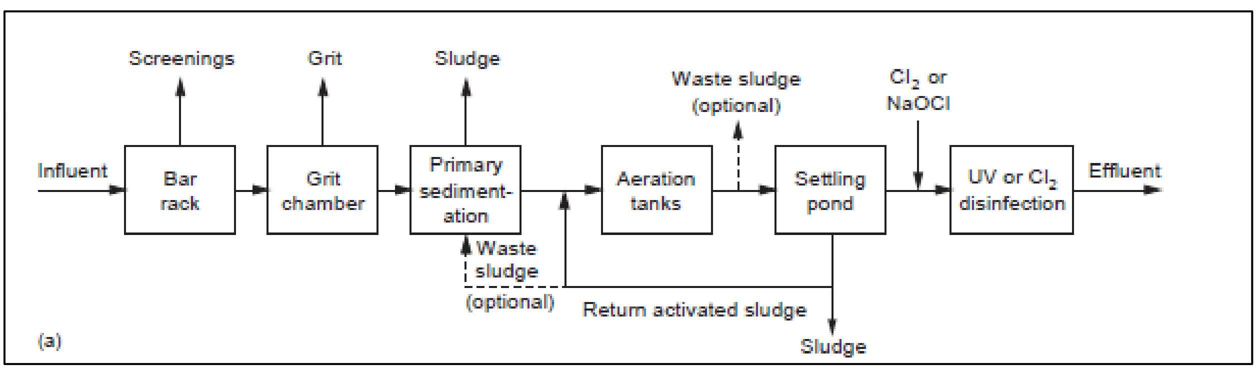


Figure 8. Activated sludge process. [8]

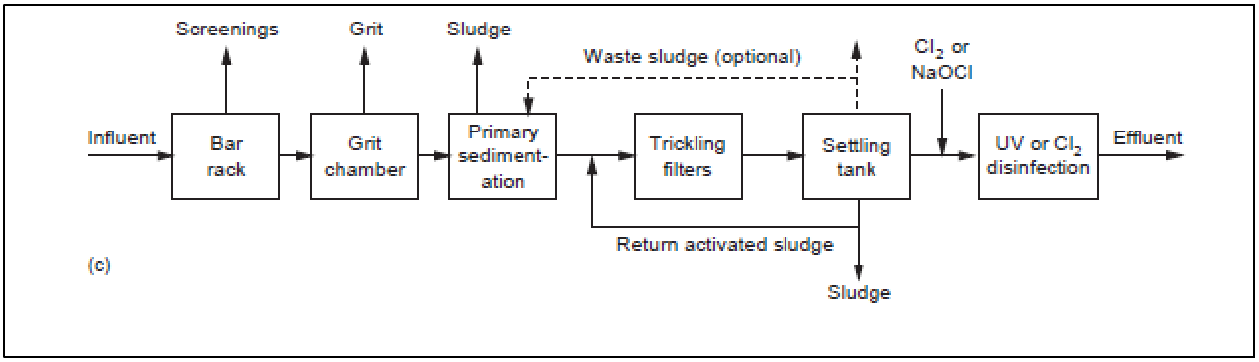


Figure 9. Aerated lagoons. [8]

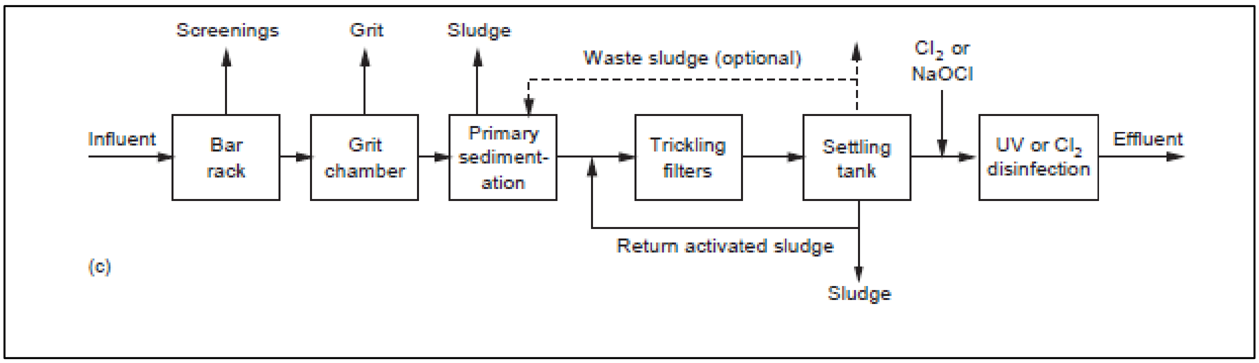


Figure 10. Trickling filters. [8]

3.3.3. Suspended growth process

There are the microorganisms that are responsible for the treatment of the wastewater by proper methods in the suspended growth process. These processes are used for municipal and industrial wastewater treatment. It is based on biodegrading of organic matters, which can be operated with DO (dissolved oxygen) in an aerobic process or with nitrate\nitrate usage in anoxic process, however there are some applications for suspended growth anaerobic process (no oxygen), like industrial wastewater and some organic sludge that have high organic concentration. The most common suspended growth process used in municipal wastewater treatment is activated sludge process and it is shown in Figure 11. [8] [19] [27]

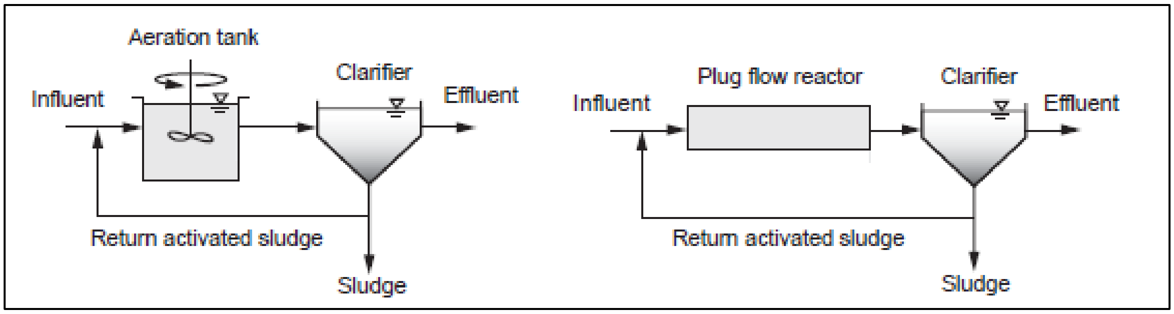


Figure 11. activated and plug-flow activated sludge process. [8]

3.3.4. Attached growth process

There are variations of microorganisms responsible for the conversion of the nutrients and organic substances are attached to an ineffective packing matter in the attached growth process. In this process, organic matter and nutrients can be removed from the wastewater flowing past the process, and this process also known as a biofilm. There are different packing materials used in the attached growth process, they are rock, gravel, sand, redwood, and a wide range of plastic and, also other synthetic materials can be used in this process. This process can be managed as anaerobic or aerobic processes.

The most common aerobic attached growth process used is the trickling filter and rock was used the most well-known material as the packing material for this application. Trickling filter application is shown in Figure 12. [8] [27]

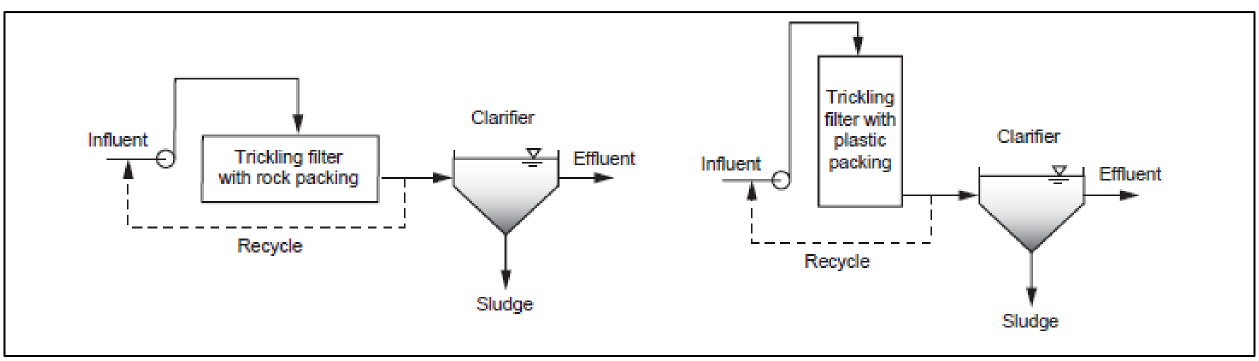


Figure 12. Trickling filter with rock packing and with plastic packing. [8]

3.3.5 Treatment of sludge

Screenings, grit, scum, sludge, biosolids and the constituents removed and produced in wastewater treatment plants. Sludge is a consequence of wastewater treatment and they are mostly shaped like liquid or semisolid liquid that can basically contain 0,25-12 % solids as weight, it depends on the processes used in the wastewater treatment. The amount and nature of sludge are about the characterization of the raw wastewater and process used. In primary settling, the process produces an anaerobic sludge of raw organic matters and they are being actively decomposed by bacteria. Secondary biological sludges thicken and dewater easily because they have fibrous and coarse nature.

In wastewater treatment plant, the sources of sludge vary based on the type of treatment plant and its methods. The major sources of sludge and the types generated are shown in Table 7.

Table 7. Sources of sludge from conventional wastewater treatment plants [8]

Unit operation	Types of sludge	Remarks
Preparation	Grit and scum	In some plants, scum removal facilities are not provided in pre-aeration tanks. If the pre-aerationtanks are not preceded by grit removal facilities, grit deposition may occur in pre-aeration tanks.
Primary sedimentation	Primary and scum	Quantities of sludge and scum depend upon the nature of the collection system and whether industrial wastes are discharged to the system.
Biological treatment	Secondary and scum	Suspended solids are produced by the biological conversion of BOD. Some form of thickening may be required to concentrate the waste sludge stream from biological treatment.

Treating and reusing of the sludge which is from wastewater treatment plant in the best way, it is significant to understand the properties and characteristics of the sludge that will be operated. These characteristics are related to the source of the sludge and type of process.

Activated sludge is usually kind of brown colour but if the sludge seems like black, it means the sludge can be in a septic condition. Besides, trickling filter sludge is brownish, and it digests easily. [8] [27]

3.3.6 Sludge processing and flow diagrams

Basically, the most well-known and common used process flow diagram for sludge handling involves biological treatment. The basic flow diagrams involving biological processing are shown in Figure 13. Thickeners can be used related to the source of sludge and the type of stabilization of it, dewatering the sludge, and disposition of the sludge. Then biological digestion, any methods can be used to dewater the sludge: the options depends on the economic situation, requirements, and some local conditions. [8] [27]

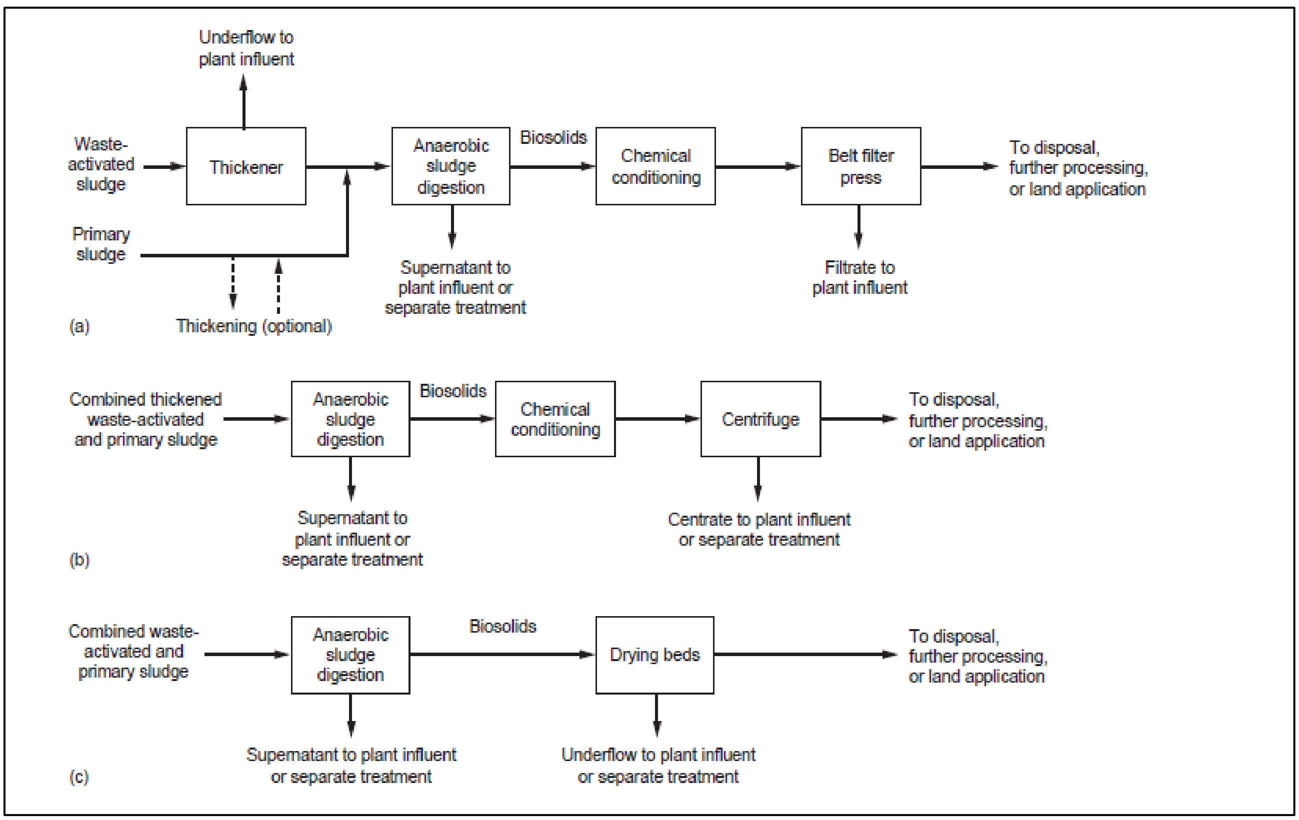


Figure 13. Typical sludge treatment flow diagrams with biological digestion and three different sludge dewatering processes: (a) belt filter press, (b) centrifuge, (c) drying bed. [8]

4.Municipal wastewater treatment in Turkey

Turkey is a country in a point where the 3 continents (Asia, Africa, and Europe) of the world are closest to each other and where Asia and Europe meet and lies like a natural bridge between Asia and Europe. Turkey is a democratic, secular, unitary, parliamentary republic with a diverse cultural heritage, Turkey is bordered by eight countries: Bulgaria and Greece in the northwest; Georgia in the northeast; Armenia, the Azerbaijan, and Iran in the east; there are Syria and Iraq on the south side. Turkey is encircled by seas on the three sides: there is the Aegean Sea in the west, the Black Sea in the north, and there is the Mediterranean Sea in the south.

The capital city of Turkey is Ankara and the largest city is Istanbul. Turkey has divided 81 provinces for administrative goals and the provinces are divided the districts which are 923 in total. Turkey has also divided 7 regions and 21 sub regions for some geographic and other purposes. The population of Turkey is 79,814,871 people currently.

4.1 Water use and sources in Turkey

The average precipitation was 643 mm, available water potential was 112 billion m^3 and the used water amount was 44 billion m^3 in 2013.

In 2013, approximately 32 billion m^3 water used for agricultural activates. According to the research, this amount will be between 50 m^3 -112 m^3 in 2023.

According to the results of Municipal Water Statistics Survey 2014, which was applied to all municipalities, 1 394 municipalities out of 1 396 were served by water supply network. 5.2 billion m^3 of water was abstracted from water sources by municipalities to water supply network. Out of this amount, 36% was abstracted from dams, 27.2% from wells, 18.8% from springs, 12.5% from rivers and 5.5% from lakes/artificial lakes and sea. [24]

The average amount of water abstracted by municipalities to water supply network was calculated as 203 liters per capita per day. In case of three largest cities, amount of abstracted water per capita per day was 181 liters for İstanbul, 211 liters for Ankara, and 180 liters for İzmir. [24]

4.2 Municipal wastewater treatment and plants

According to statistical studies, there are 234 major municipal wastewater treatment plants in Turkey and most of them located in Marmara region, it covers 29 %of them. Based on regions;

There are 67 plants and the amount of wastewater is 3,397,237 m^3\d in Marmara region,

In Black Sea region, 32 plants, and 394,611 m^3\d,

In Aegean region, 45 plants, and 1,192,301 m^3\d,

In Mediterranean region, 40 plants, and 1,024,487 m^3\d,

In Central Anatolia region, 31 plants 1,439,462 m^3\d,

In Southeast Anatolia region, 12 plants, and 401,491 m^3\d,

And in Eastern Anatolia region, 7 plants and 231,300 m^3\d,

The water consumption per person per day was 203 liters in 2014 in Turkey. According to Turkish Statistical Institution in 2014, 12,330,000 m^3 wastewater occurs in a day and the amount of wastewater which treated in the wastewater treatment plants is 8,080,59 m^3/d. It shows that only 66 % of this water can be treated in wastewater treatment plants. When these amounts and numbers consider, Marmara region has the biggest amount of wastewater. Chart 1 shows the treated wastewater amount based on regions. [9]

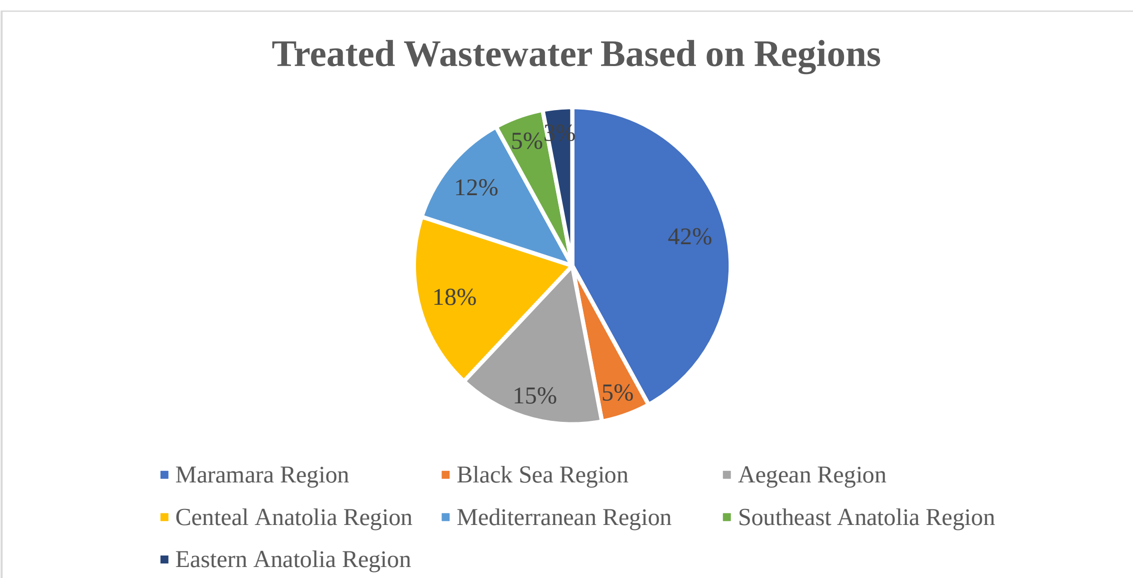


Chart 1. Treated wastewater amount based on regions. [9]

The wastewater treatment implementations in the regions can be classified into three categories, which are biological treatment, deep see discharge system and pretreatment- physical treatment processes. The most common biological treatment processes are Activated sludge method, Extended aeration activated sludge process, Bardenpho Process, Sequencing batch reactor, A2/O Process, trickling filter process and Rotating Biological Contactor. In deep see discharge systems, one or several these processes can be applied which are screening, preliminary settling, grit chamber. In physical treatment plants, one or several these processes can be applied which are screening, preliminary settling, grit chamber and then the treated wastewater directly discharge to receiving bodies. In Chart 2, the distribution of these treatment methods is shown based on the regions. [9]

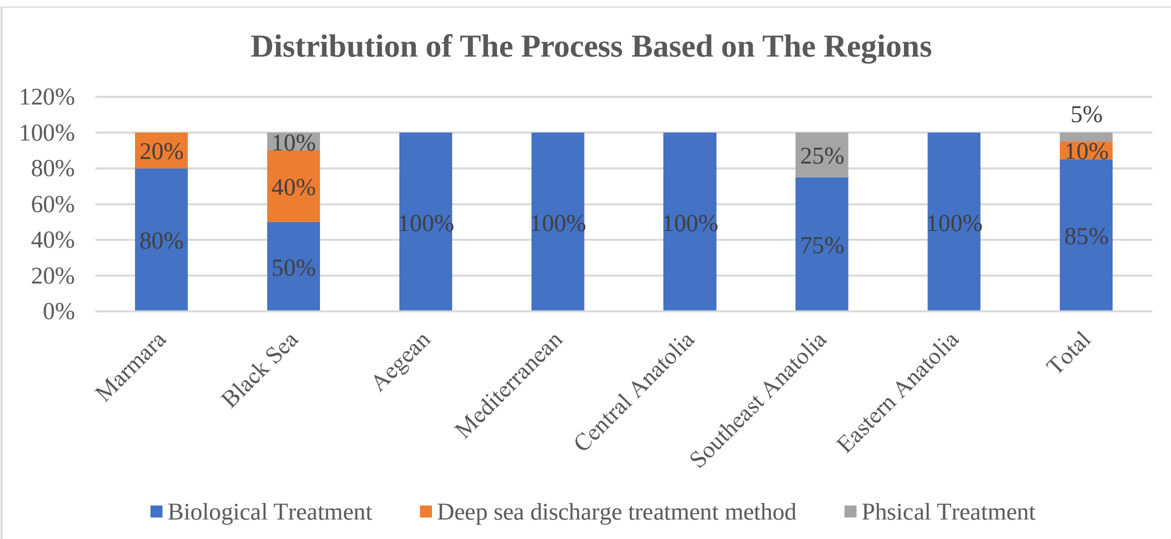


Chart 2. The processes based on the regions In Turkey [9]

As it is seen in the Chart 2, there are only biological treatment and no deep-sea discharge treatment method in Mediterranean and Aegean regions because these regions are touristic places in Turkey and discharging the wastewater without great treatment is forbidden. There is only biological treatment in Central Anatolia and Eastern Anatolia regions. In the Black Sea and Southeast regions, some of the plants discharge their wastewater after pre-treatment and/or preliminary settling.

In Turkey, there are two types of municipal wastewater treatment plants. One of them is the urban wastewater treatment plants that receive the industrial wastewater that is not fully treated and from leakages. Another one is the domestic wastewater treatment plants receiving the wastewater only from houses and hotels and other residences. Accordingly, there are 66 urban wastewater treatment plants and 168 domestic wastewater treatment plants out of 234. The resources show that most of the urban wastewater treatment plants are in Marmara Region, it is 22 of them. It is illustrated in Chart 3. [9]

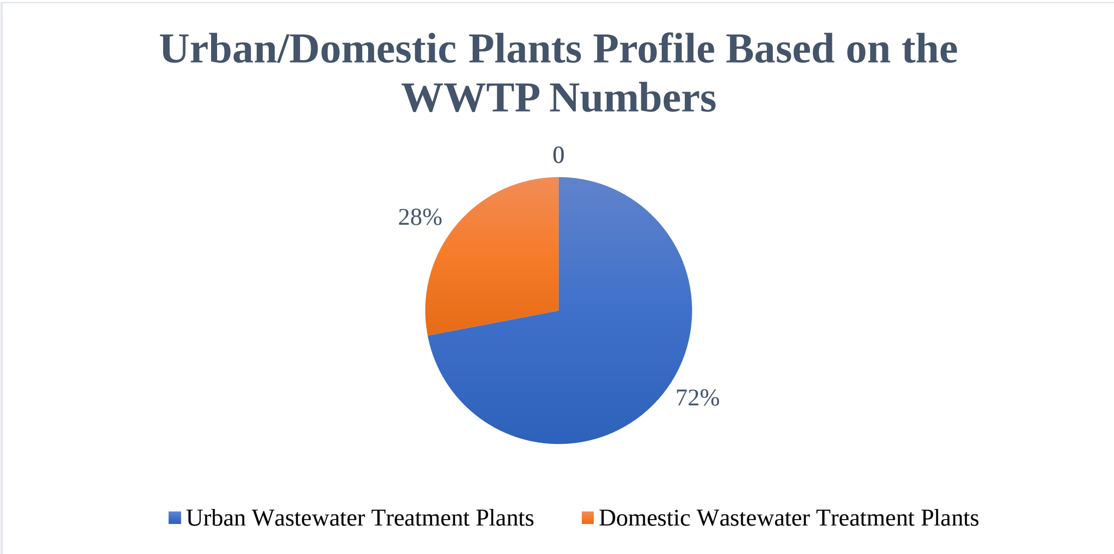


Chart 3. Percentage of Urban and Domestic WWTP in Turkey [9]

According to Turkish statistical institute, the quantity of treated wastewater from Urban and Domestic plants are almost the same in Turkey. In Chart 4, treated wastewater amounts in Urban and Domestic plants are illustrated based on the regions of Turkey.

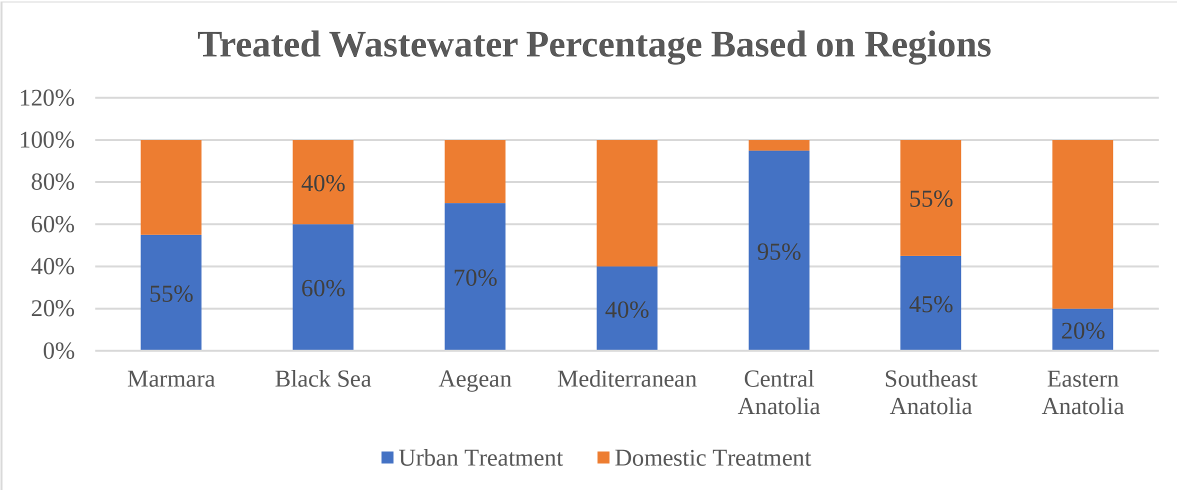


Chart 4. Treated wastewater amounts in regions [9]

As it is mentioned before, there are 234 municipal wastewater treatment plants in Turkey and 201 of them is biological wastewater treatment plant and 33 of the rest is non-biological wastewater treatment plants. Chart 5 shows the percentage and numbers of the processes which used in wastewater treatment in Turkey. [9]

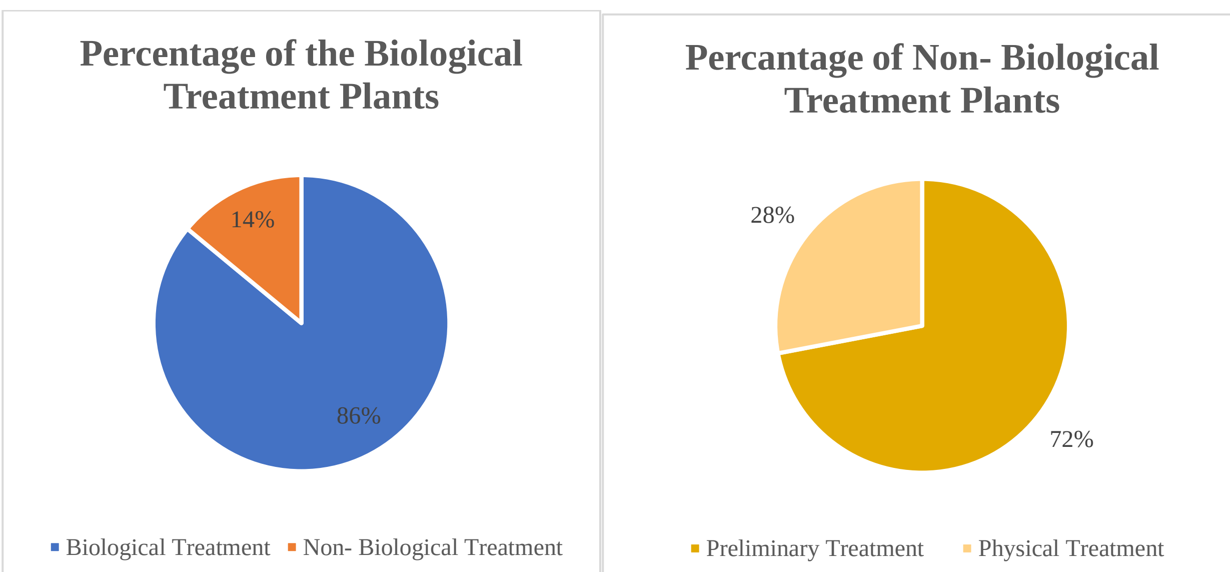


Chart 5. The percentage of processes which used in WWTP in Turkey. [9]

Also, Chart 6 shows which biological processes are used in wastewater treatment and gives their percentage based on the number of wastewater treatment plants in Turkey. According to researchers, Extended Aeration Activated Sludge Process are the most preferred methods of biological wastewater treatment. However, Biological Nutrient Removal and Activated Sludge Processes are mostly used methods, if the flow rate is quite high in a region. [9]

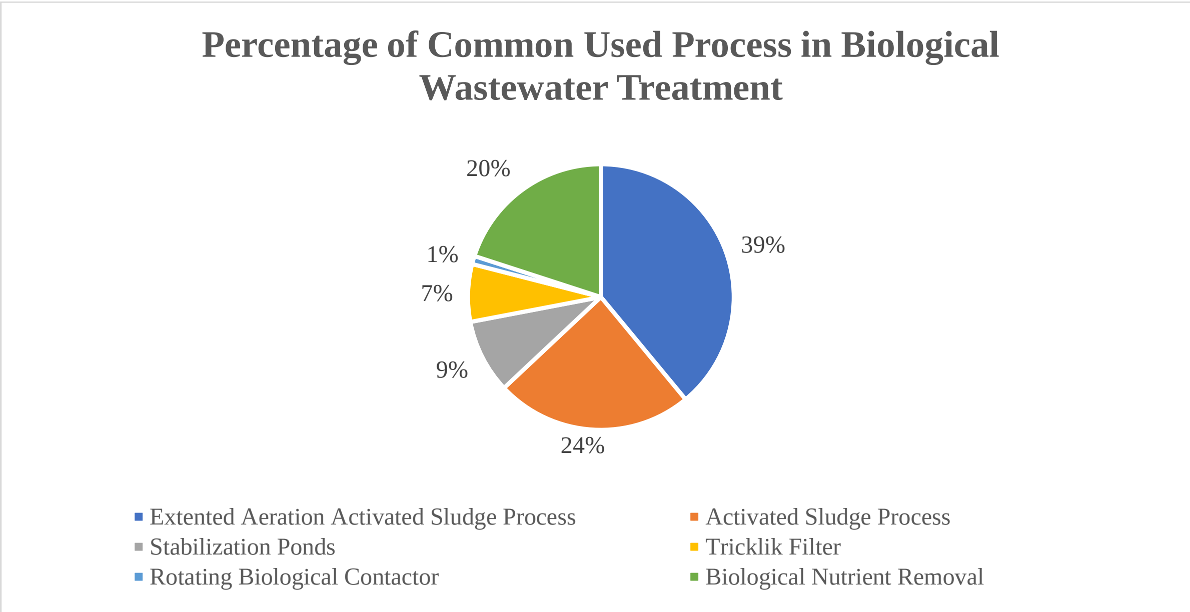


Chart 6. Percentage of the common used process in biological treatment**.** [9]

In each region, different methods are used in Turkey. Chart 7 shows which processes are popular in the regions. In Southeast Anatolia, mostly BNR and SP (Stabilization Ports) are used and in Marmara Region usually extended aeration activated sludge process, activated sludge and BNR processes are preferred. In Black Sea Region, the same processes are used with Marmara Region. In Central Anatolia, additively SP process is used. In Eagan Region and Mediterranean Regions, extended aeration activated sludge process (EAASP), activated sludge and BNR processes are mostly used and in Eastern Anatolia Region, SP process is also used. [9]

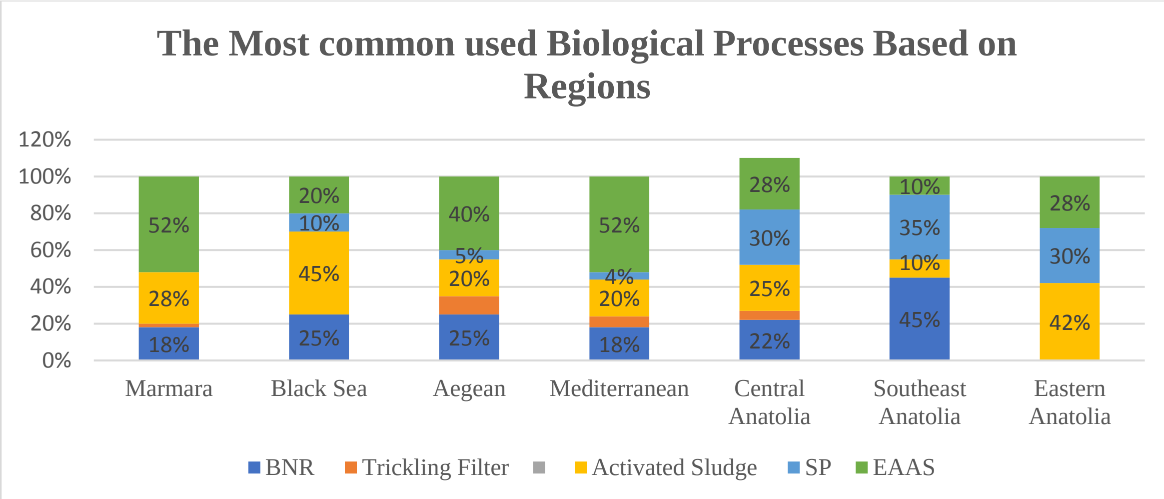


Chart 7. The Most common used Biological Processes Based on Regions. [9]

In Chart 8, it is shown that preliminary settling is applied in 81 of 234 municipal wastewater treatment plants. Preliminary settling is usually used in the treatment plants which are applied the biological treatment and in trickling filter processes, preliminary settling is applied as a system requirement. 70 % of activated sludge process have preliminary settling and other processes such as BNR, SP (Stabilization Ports), extended aeration activated sludge process, physical and preliminary treatment systems have preliminary settling at a rate of %50. [9]

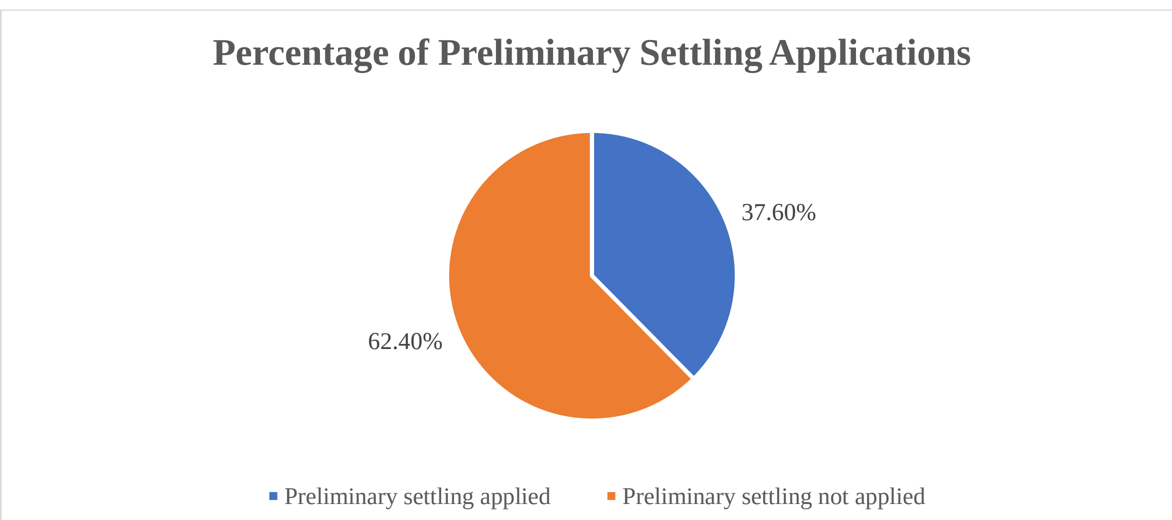


Chart 8. Percentage of preliminary settling applications. [9]

According to researches, almost 55 % of the wastewater plants discharge their treated wastewater to receiving bodies such as rivers, lakes, streams. However, the wastewater plants which are in coastal regions, they discharge their wastewaters to the sea via deep-sea discharge systems. In this case, it can be said that the amount of discharged wastewater to the sea and lakes-rivers are almost the same. In Chart 9, discharged wastewater quantities to receiving bodies are illustrated based on regions in Turkey. [9]

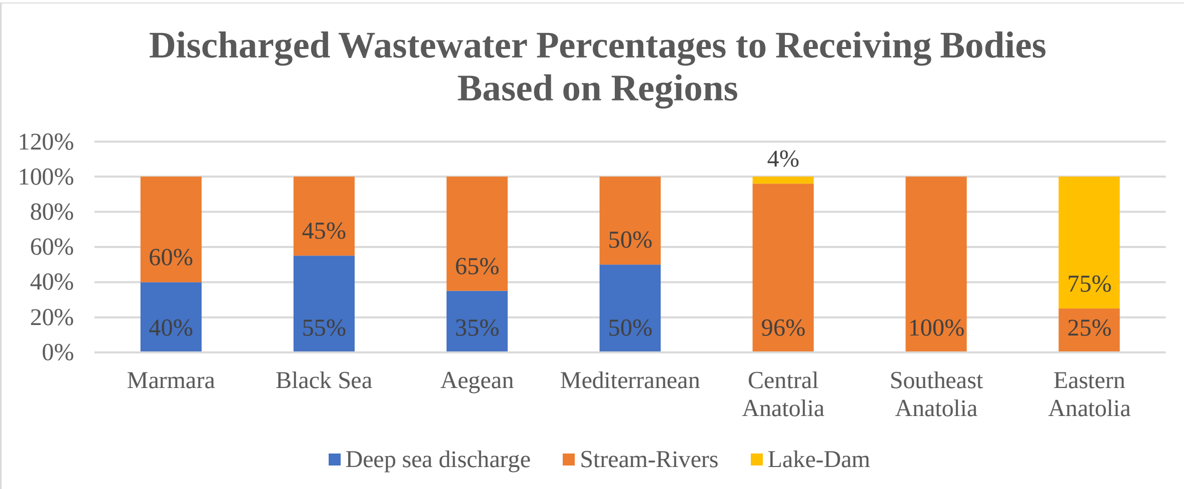


Chart 9. Discharged wastewater quantities to receiving bodies. [9]

4.3 Legislations and regulations regarding wastewater in Turkey

Basically, there are 9 regulations regarding water – wastewater treatment in Turkey. Three of them are directly about wastewater - water quality and rest of them are indirect. The most important regulations are following:

- Water Pollution Control Regulation
- Urban Wastewater Treatment Regulations
- Regulation on Control of Pollution Caused by Dangerous Substances in Water Bodies

4.3.1 Water pollution control regulation

The objective of this regulation is the protection of groundwater/surface water potential and prevention of water pollution with sustainable development goals. This regulation covers the quality classification of water bodies, usage purpose of water, the prohibitions and plans for protection of water quality, discharging of wastewater principles, rudiments of wastewater infrastructure facilities and the monitoring and measurements studies for prevention of water pollution. [16]

This regulation also contains some principles about protection of water. They are listed below:

- For prevention of water pollution, all types of pollutant sources should have a permit document.
- The quantity of domestic wastewater must be same with the water amount that reaches to a residence.
- Reducing the wastewater amount and its pollution concentration.
- Selection of proper and economical treatment methods for wastewater treatment.
- Providing common wastewater treatment plants for the residential areas that have similar characteristic wastewater.

Some of the basic principles to be applied for discharging wastewater into sewage systems are;

- In places where there is sewerage system, it is a right and obligation to connect all types of wastewater to the sewerage network in principle.
- Sewerage systems can’t be destroyed, and their intended use can’t be changed.
- To determine the amount of wastewater, those who supply water outside the drinking water network, they must certify the amount of water and report it to the management of infrastructure facilities and, it must be connected to the sewage system for the cost.

And if industrial wastewater to be sent to sewage system directly, it needs some requirements according to the regulation: [16]

- It must not damage the structure and operation of the sewerage system.
- It must not create health hazards for employees and surrounding communities.

- It must not affect the operation and efficiency of the wastewater treatment plant.
- It must not contain the substances that are toxic for biological treatment.

Water Pollution Control Regulation set up standards regarding wastewater discharge to the receiving water bodies and sewerage systems. In Table 8, limit values of wastewater discharges to the sewerage system are shown. [16]

Table 8. Wastewater limit values applicable to discharge of wastewater into a sewerage system [16]

Parameter	The wastewater limits for sewerage system	The wastewater limits if the sewerage systems end up with deep sea discharge
Temperature (˚C)	40	40
pH	6.5-10	6-10
Suspended Solids (mg/l)	500	350
Oil and Grease (mg/I)	250	50
Tar and oil based oils(mg/I)	50	10
(COD) (mg/l)	4,000	600
(BOD) (mg/l)	-	400
Sulfate ($SO_4^{=}$) (mg/l)	1,700	1,700
Total sulfur (S) (mg/l)	2	2
Phenol (mg/l)	20	10
Chlorine as Free (mg/l)	5	5
Total Nitrogen (N) (mg/l)	*	10
Total Phosphorus (P) (mg/l)	*	
Arsenic (As) (mg/l)	3	10
Total Cyanide (CN) (mg/l)	10	10
Total Lead (Pb) (mg/l)	3	3
Total Cadmium (Cd) (mg/l)	2	2
Total Chromium (Cr) (mg/l)	5	5
Total mercury (Hg) (mg/l)	0.2	0.2
Total copper (Cu) (mg/L)	2	2
Total nickel (Ni) (mg / l)	5	5
Total zinc (Zn) (mg / l)	10	10
Total tin (Sn) (mg / l)	5	5
Total silver (Ag) (mg / l)	5	5
Chloride (mg / l)	10,000	-
MBAS (mg / l)	Forbidden	Forbidden

Table 9 shows the discharge standards to the receiving areas for the pollution load with more than 6,000 kg\day as BOD and the population is more than 100,000 people.

Table 9. The discharge standards to the receiving areas. [16]

Parameter	Composite sample 24 hours \ Pop.>100,000 PE
BOD (mg/l)	40
COD (mg/l)	80
Suspended Solids (mg/l)	40
pH	6-9
Total Nitrogen (mg/l)	15
Total Phosphorus (mg/l)	2

4.3.2 Urban wastewater treatment regulation

The legislative act regulates collection, treatment, and discharge of urban wastewater besides, protection of the environment against the adverse effects of the wastewaters coming from specific industrial facilities.

The scope of this regulation is collection, treatment, discharge, monitoring, reporting, and supervision of the urban and some specific industrial wastewater. [28]

Principles for the implementation of this Regulation:

- In case the current treatment rate is insufficient, to prevent the environment from being adversely affected, the second treatment step of this urban treatment is necessary according to the instructions of this regulation.
- In less sensitive water areas, it is essential to use of primary treatment methods and in sensitive water areas, the advanced treatment methods must be preferred.
- The connection of industrial wastewater to the sewerage system and the acceptance of the wastewater discharge to the receiving body are subject to permission.
- It is forbidden to discharge any kind of solid waste, treatment sludge, and septic tank sludge into receiving water environments.
- Monitoring of treatment plants, wastewater and receiving environment is necessary for the protection of the environment.

- It is essential to publish the information of wastewater and treatment sludge disposal. [28]

4.3.3 Regulation on control of pollution in water bodies caused by dangerous substances

Purpose of this Regulation is prevention, and gradual reduction of pollution caused by dangerous substances in and around water.

This regulation covers identification of dangerous substances causing pollution, the forming of pollution reduction program, prevention and monitoring of pollution, inventory of hazardous materials discharged into the water and determination of discharge standards and quality criteria in surface waters, in estuary waters, in regional waters.

The industries that have dangerous substances, they need to have ‘Environmental Permission’ from Environment and Urban Ministry to discharge their wastewater to the receiving bodies. If an industry has this permission, they can discharge their wastewater to the receiving bodies, but they must notify all information to online Ministry system such as parameters, flow etc. Thus, the Ministry can monitor all discharges from the industries.

4.4 Bursa Eastern wastewater treatment plant

Bursa Eastern wastewater treatment plant was constructed in between 2003-2006 and it is in Osmangazi county in Bursa. The aim of this plant is treating the wastewater coming from the eastern side of Bursa.

The capacity of this plant is 240,000 m^3/day. The system is operated by 5-stage Bardenpho process. This process contains carbon removal as well as nitrogen and phosphorus treatment. Under favor of this system, the plant can reach the European effluent water quality standards. Removal of nitrogen from the system is carried out in aeration pools and phosphorus is removed with excess sludge by taking anaerobic/aerobic conditioning and taking into bacteria (sludge). In Table 10, the unit processes of the plant are shown. [11]

Table 10. The main unit processes and their design criteria. [11]

Unit process	Volume
Selector Tank (2-chamber tank)	4,408 m^3
Anaerobic Reactor (2 parallel lines)	33,940 m^3
Anoxic Reactor 1	72,123 m^3
Aerobic Reactors 1	144,247 m^3
Anoxic Reactor 2	52,650 m^3
Aerobic Reactors 2	19,473 m^3
Total Process Tank Volume	326,841 m^3
Sedimentation Tanks (12 Tanks)	71,100 m^3

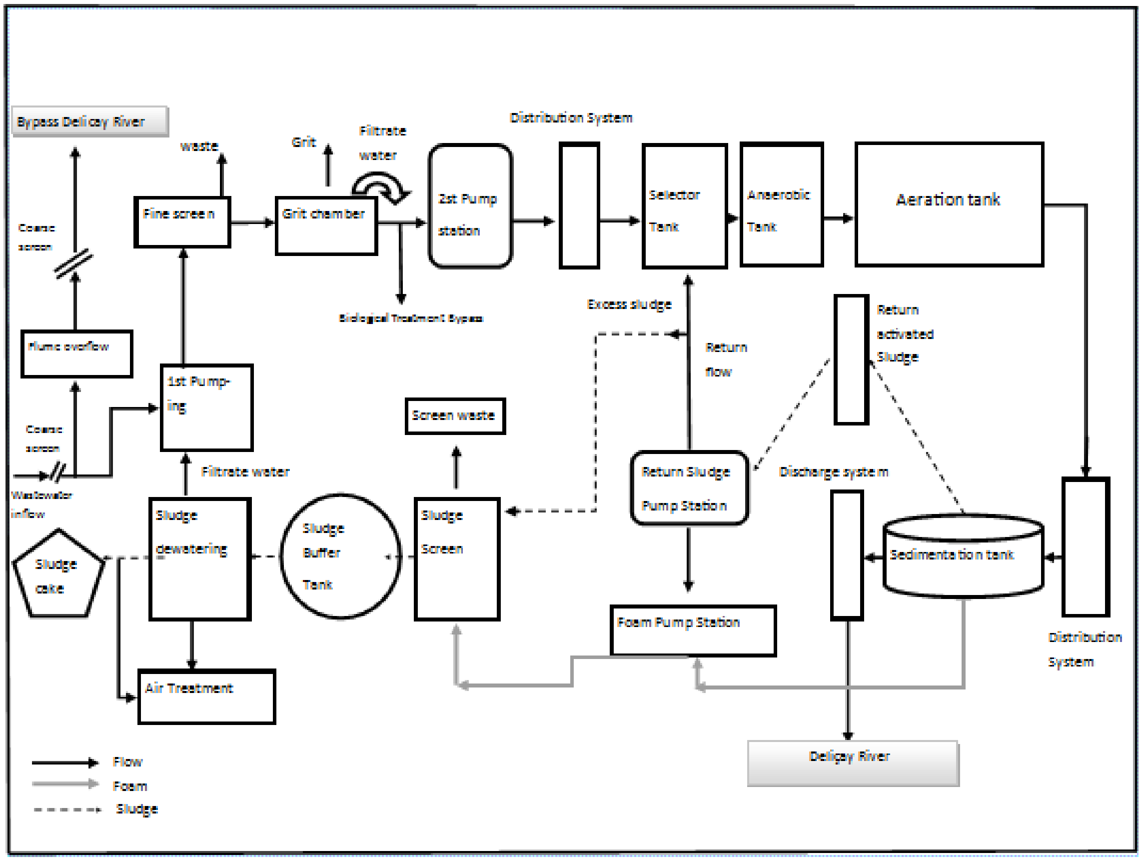
The wastewater arrives at the plant by 2 sewer pipes that have 2,000 mm diameter each. In Table 11, the all unit process of this wastewater treatment plant and their numbers are shown.

Table 11. The all unit process and numbers. [11]

Process	Numbers
Flume overflow	1 unit
Coarse Screen	8 units
1st Stage Pumping station	4 units
Mechanical Fine Screens	4 units
Grit Chamber	3 units
Selector	1 unit 2 pieces
Anaerobic tanks	4 units 2 lines
Anoxic and Aerobic tanks	12 units on 3 lines
Sedimentation tanks	12 units
Return Activated Sludge pumping station	2 units
Excess Sludge Pumping Station	1 unit
Foam Pumping Station	3 units
Sludge Screen	1 unit
Sludge Buffer Tank	3 units
Sludge dewatering	1 unit
Sludge Lime Stabilization	1 unit
Service Water / Fire Pump Station	1 unit
Overflow Pumping Station	1 unit

4.4.1 Flow diagram of the treatment plant

Bursa Eastern wastewater treatment plant was constructed in between 2003-2006. The main processes are Primary Treatment, Biological Treatment (Bardenpho), Sludge Treatment. The entire process is shown in Figure 14.



Bypass Delicay River
waste
Grit
Filtrate water
Distribution System
Coarse screen
Fine screen
Grit chamber
2st Pump station
Selector Tank
Anaerobic Tank
Aeration tank
Biological Treatment Bypass
Excess sludge
Return activated Sludge
Flume overflow
Return flow
1st Pumping
Screen waste
Coarse screen
Filtrate water
Return Sludge Pump Station
Discharge system
Wastewater inflow
Sludge dewatering
Sludge Buffer Tank
Sludge Screen
Sludge cake
Sedimentation tank
Foam Pump Station
Distribution System
Air Treatment
Delicay River
Flow
Foam
Sludge

Figure 14. Flow diagram of eastern wastewater treatment plant**.** [11]

4.4.2 Wastewater characteristics of Eastern wastewater treatment plant

In 2016, Eastern wastewater treatment plant received 107 million m^3 wastewater in total. 83.533.786 m^3 of this total amount was treated by biological process and 24,214.,262 m^3 wastewater treated in primary treatment due to the overflow (precipitation) and power cut in the facility. According to the amount of wastewater in 2016, the average daily quantity was 299,300 m^3. During 2016, the number of rainy days was 97 and in the overflow days, the flow sometimes was increased to 710,000 m^3\d. The daily energy consumption was 92,849 kWh / day and the yearly energy consumption was 33,345,605 kWh/year. [11]

The wastewater input and output values are shown in Chart 10 and 11. According to Chart 10 values, pollution rates are 79.3 %for BOD, 97.5 % for COD, 105.09 % for suspended solids, 80.6 % for total nitrogen and 70.6 %for phosphorus. [11]

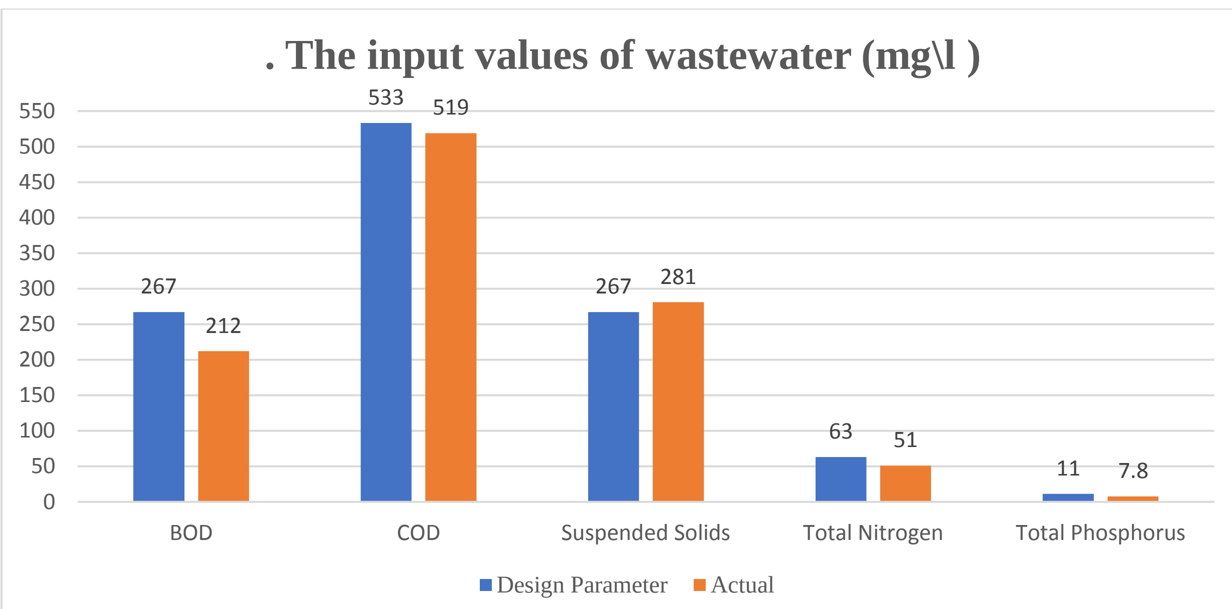


Chart 10. The input values of wastewater. [11]

When Chart 11 values are analyzed, can be seen, that COD treatment efficiency is almost 94 %, BOD is 97%, Nitrogen is 90 % and phosphorus is 84 %. COD, BOD, and Suspended solids concentrations are less than the limit values as it is shown in the Chart 11.

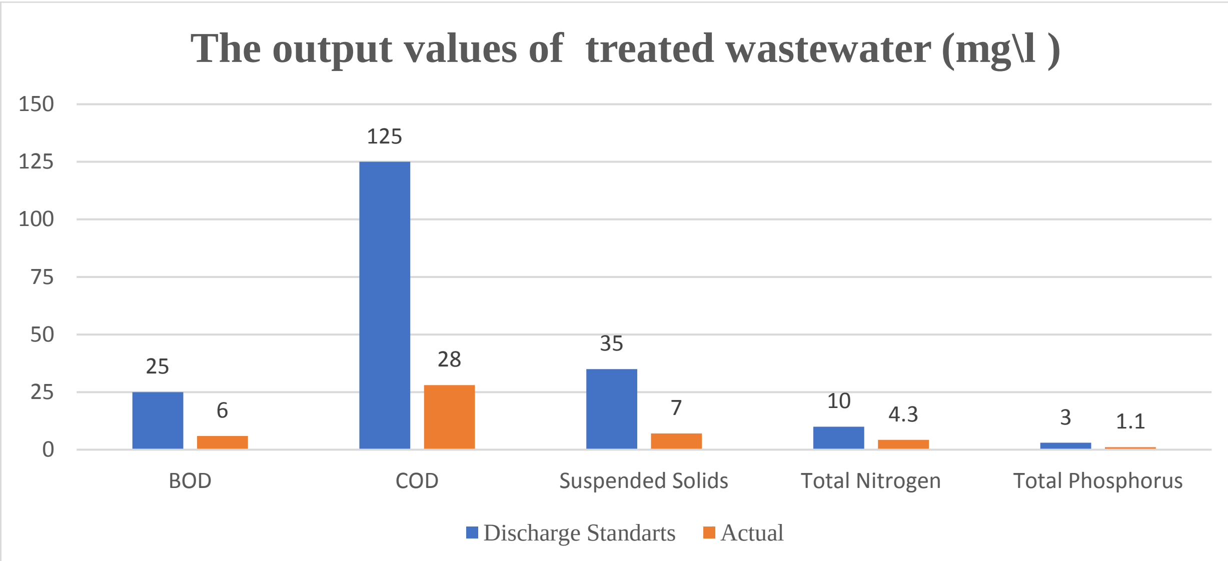


Chart 11. The output values of treated wastewater. [11]

The amount of flow by years is shown in Chart 12 for Eastern wastewater treatment plant. The flow in 2016 was more than 240,000 m^3\d. It means the flow was higher than the capacity of the plant, and the numbers of rainy days in 2016 were 100 days. [11]

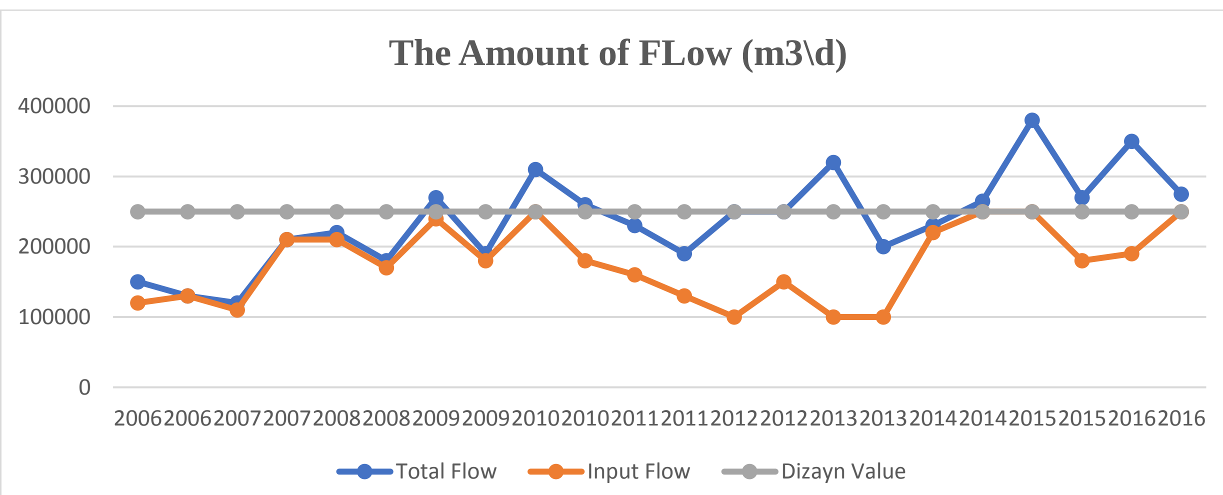


Chart 12. The amount of flow by years. [11]

In 2016, 197 tons solid waste and 290 tons sand removed by the screening process. In sludge dewatering unit, 2,760,420 m^3 sludge processed and stabilized with 5.694 tons lime. The sludge is removed as sludge cake from the plant and they are removed in lagoons. The sludge in lagoons is sent incineration process and the ash is sent to tile factory and used for producing tile. Used lime is illustrated in Chart 13 and consumption of Polyelectrolyte are shown in Chart 14 for 2016 by months. [11]

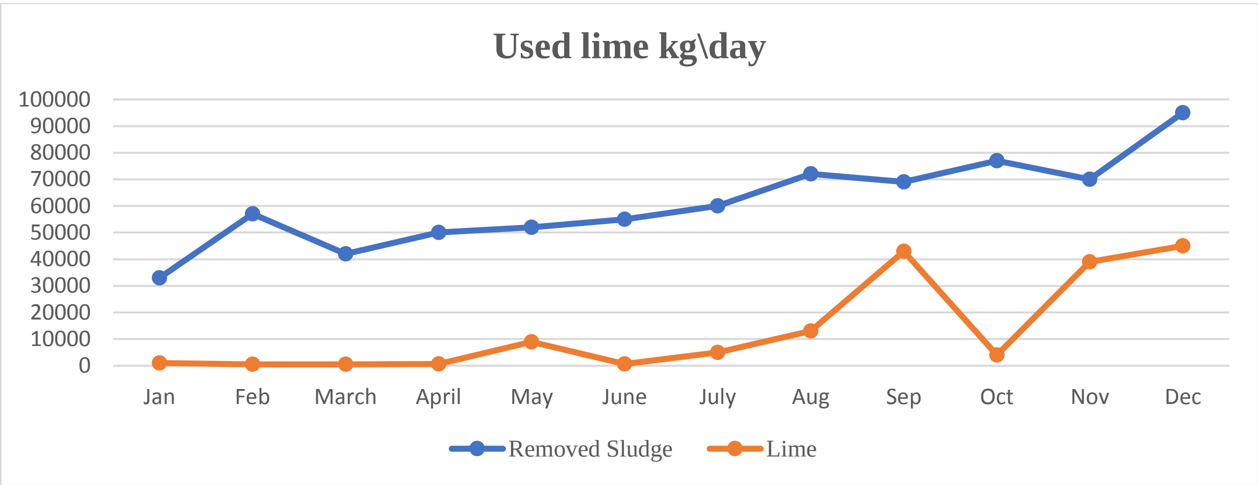


Chart 13. Used lime by months by months in 2016 [11]

and consumption of Polyelectrolyte is shown in Chart 14 for 2016 by months.

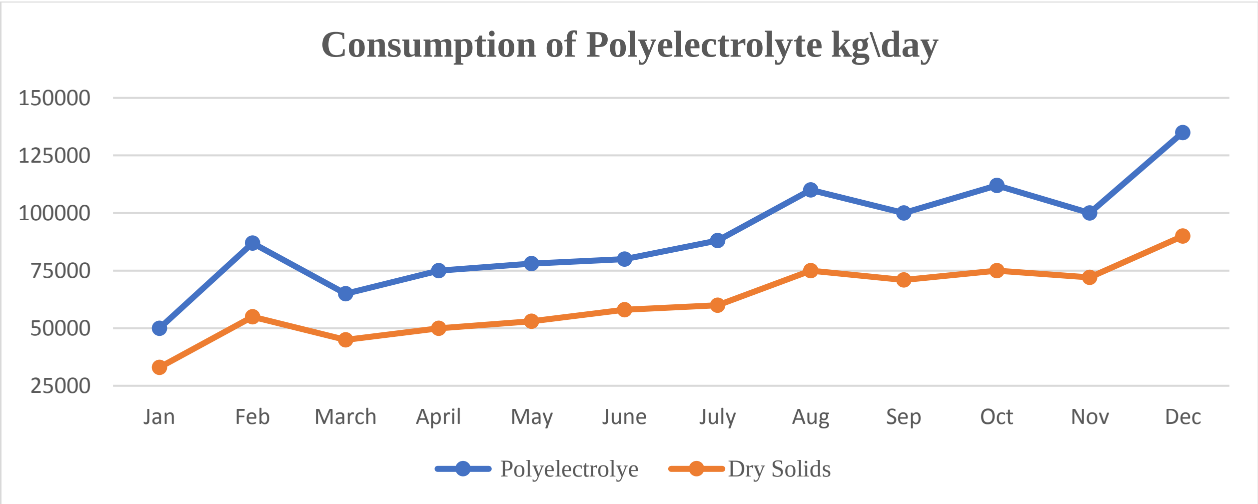


Chart 14. Consumption of Polyelectrolyte by months in 2016. [12]

In 2016, the average energy consumption was 100,000 kW\h monthly in the Eastern wastewater treatment plant and the average electricity consumption per unit produced at the wastewater was 0.57 kWh\m^3. [12]

5. Municipal wastewater treatment in Estonia

Estonia is mainly a lowland country bordered by the Baltic Sea, Latvia, and Russia. It has numerous lakes and forests and many rivers. Estonia is a democratic parliamentary republic country and it is divided into fifteen different counties. Tallinn is the capital and largest city of Estonia. Tartu and Narva are the other large cities. Its population is approximately 1.3 million, it is one of the least-populous member states of the European Union.

5.1 Water use and sources in Estonia

Estonia is a country which is very well supplied with water and have a wealth of lakes, rivers, springs, and mires. On the other hand, there are some regions where have scarcity about water. This amount of water is available for agriculture, industry and human consumption but it should be taken into consideration, water is limited in the hydrosphere and only some part of it is proper for use. The average precipitation is between 550 and 800 mm in a year in Estonia, total evaporation is almost twice as much. The renewable water sources in surface water depend on the precipitation quantity and it is different from the years; the average annual amount is about 12 km^3. Groundwater constitutes the second part of the renewable water resource in Estonia. The confirmed groundwater resource is about 0.18 km^3 per year (about 500,000 m^3 per day). In general, Estonian urban communities use groundwater. Surface water is usually used in Tallinn, Narva and by some industrial areas for water supply (in Sillamäe, Kohtla-Järve, and Kunda). [4]

Water abstraction stably decreased in Estonia. It was 450 million m^3 in the 1990s and it is below 100 million m^3 per year nowadays. These kinds of changes were caused by the economy and using water more sustainable. Water price is affected by water consumption also. The quantity of groundwater abstracted during the decade is between 45 and 50 million m^3 per year and the quantity of surface water is between 50 and 57 million m^3 per year. (Chart 15) [5]

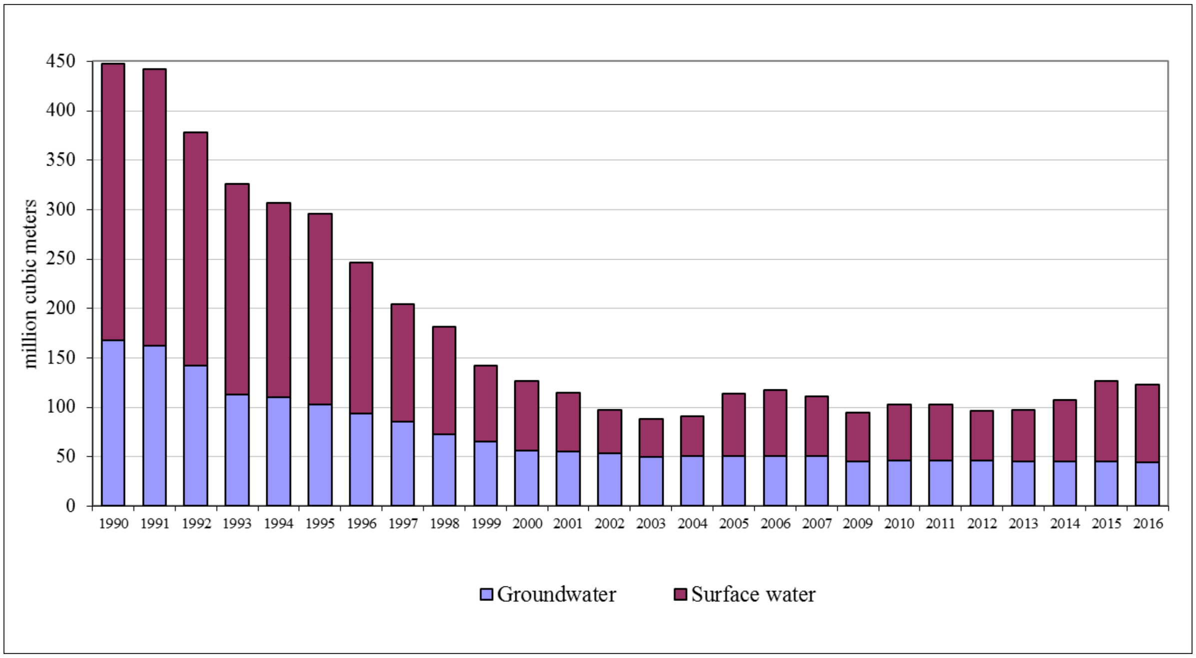


Chart 15. Water abstraction (excluding mining and cooling water) [5]

Tallinn as one of the largest user of water abstracted nearly 21.5 million m^3 of surface water from Lake Ülemiste in 2011; the amount of groundwater abstracted in Tallinn remained below 2.5 million m^3. Narva used 6.46 million m^3 of surface water and 6.5 million m^3 of groundwater in 2011. Chart 16 shows surface water abstraction for Tallinn and Narva in 2002–2011. [4]

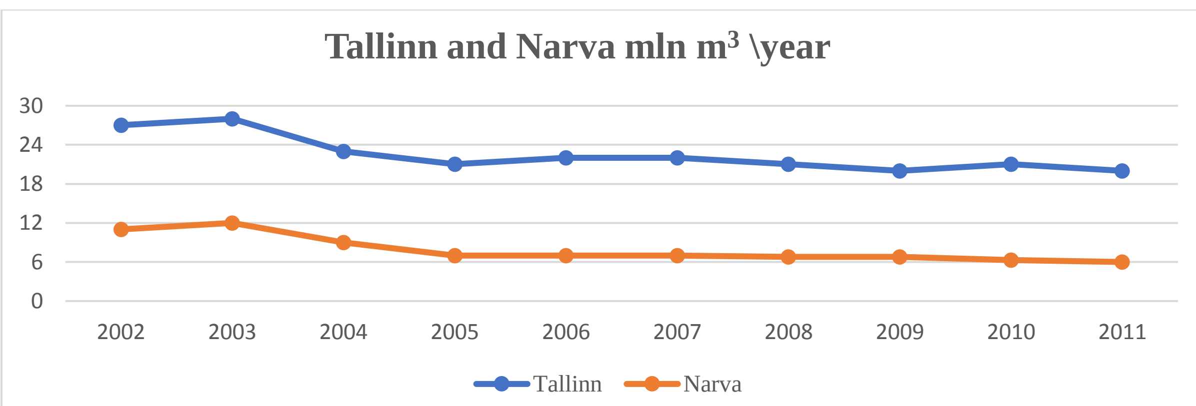


Chart 16. Surface water abstraction for Tallinn and Narva. [4]

The water consumption has decreased for industrial purposes by almost five times compared with the 1990s, the reasons are the implementation of new, sustainable technologies and the reuse of water. The water consumption has decreased by 7.5 times by agriculture, the main reason is the decrease in agricultural production. The consumption of water by residences has decreased least. According to the data, it can be said that the quantity of water used for human consumption has stayed almost in the same level of 50 million m^3 per year. (Chart 17) [4]

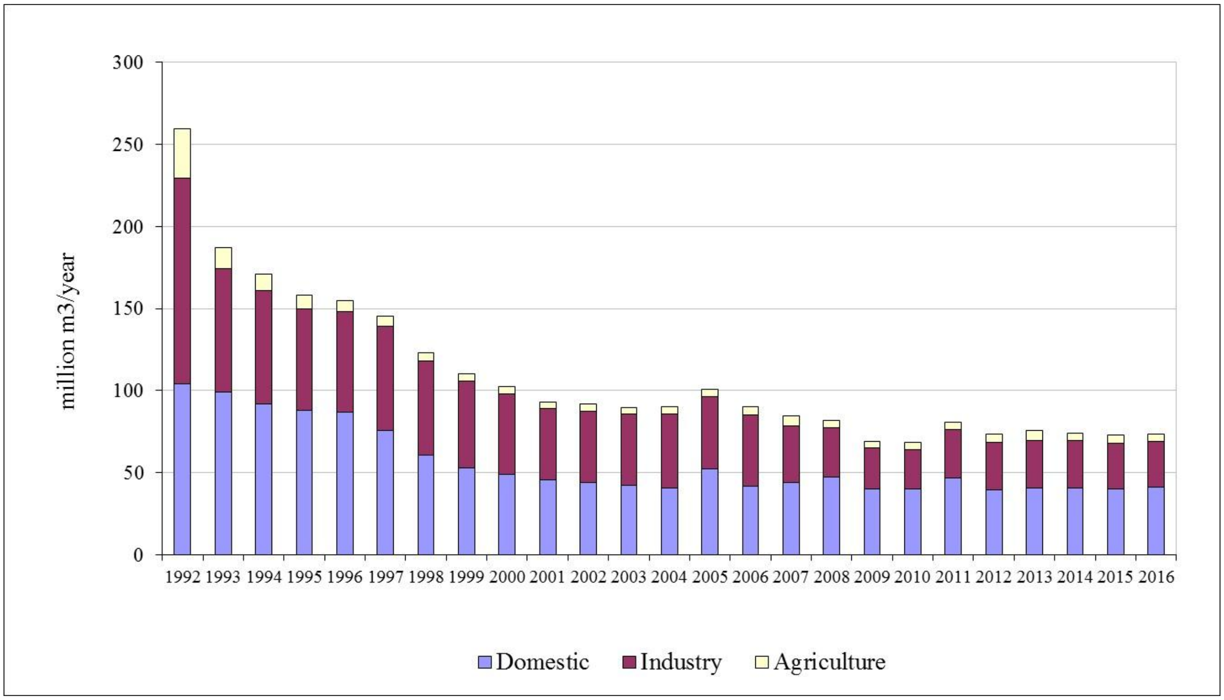


Chart 17. Use of water in agriculture, manufacturing and for human consumption. [5]

The use of water was 69 m^3 per capita in 1992, it was 33 m^3 in 2007 and 26 m^3 in 2011. In 1992, an average of 188 liters of water per person a day was used for human consumption, while the respective figure was 83 liters in 2007 and 70 liters in 2011 in Estonia. Today average water use is approximately 95 liters per capita per day. Figure 15 illustrates water use for human consumption and the price of water. [30]

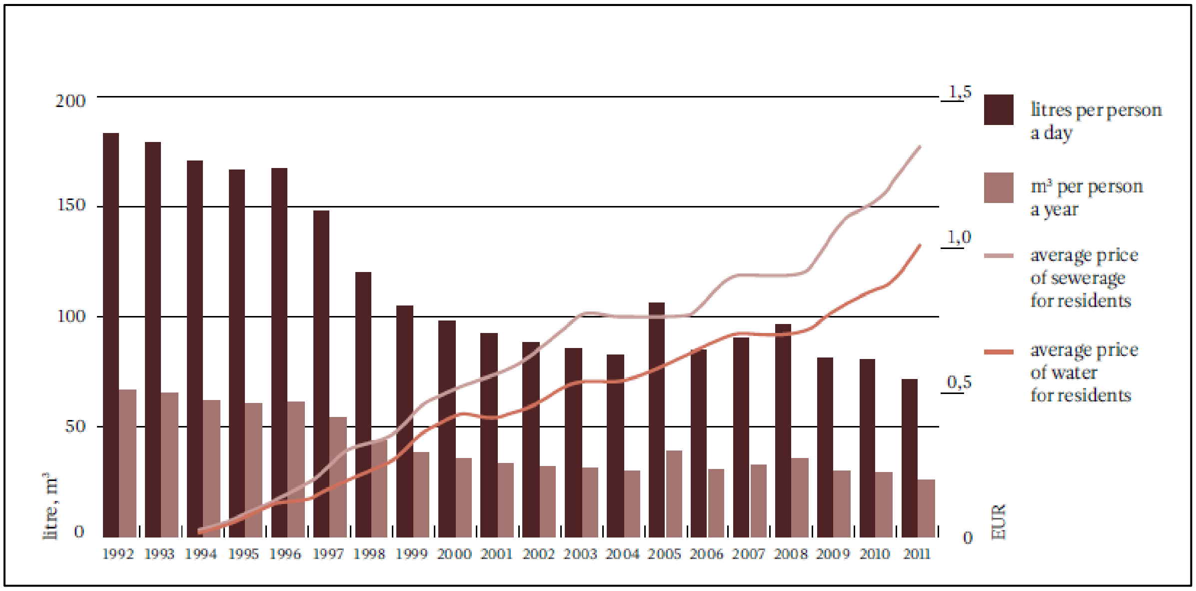


Figure 15. Water use for human consumption and the price of water. [4]

Chart 18 illustrates the distribution of water consumption in 2011 in Estonia. About 95% of water forms cooling water which used by Balti Elektrijaam and Eesti Elektrijaam power plants. The 5% water which is left, they used for human consumption and by the industrial, energy and agricultural as well as for irrigation. Almost half of this amount is used for human consumption. The situation in 2016 is almost the same as in 2011.

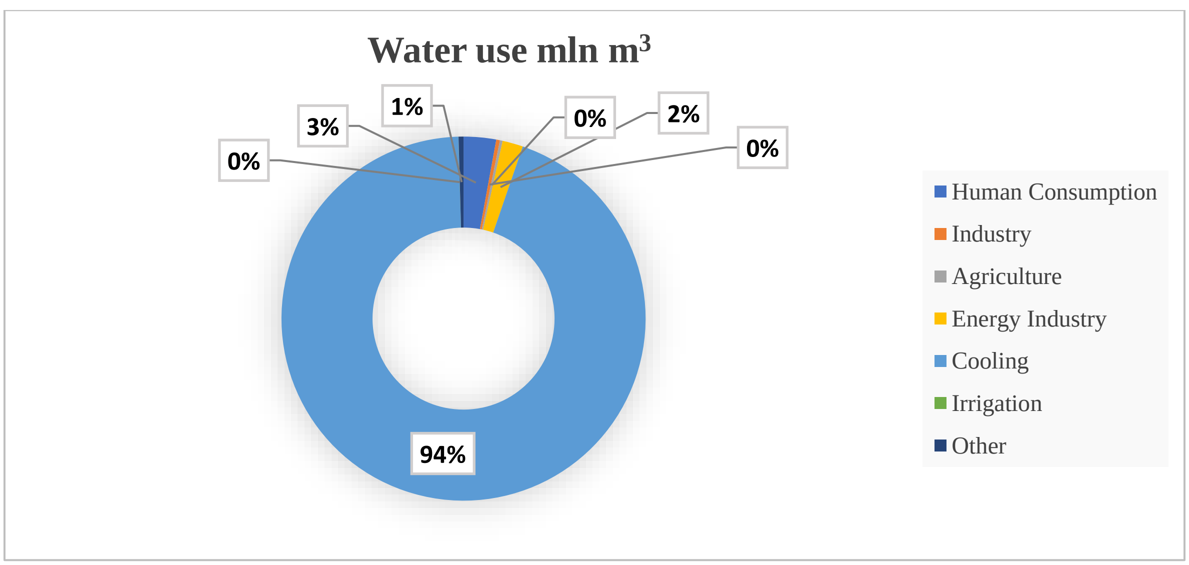


Chart 18. Water use in Estonia in 2011, mln m^3. [4]

5.2 Municipal wastewater treatment and plants

In 2011, approximately 117 million m^3 of wastewater was generated in Estonia. %81 of this amount of wastewater (or 95.1 million m^3) came from agglomerations over 2,000 PE. Tallinn city generated % 43 of it, Tartu city %7 and Kohtla-Järve %6. [4]

In 2014, the amount of water to be treated coming from agglomerations of more than 2,000PE forms 78% of the total wastewater to be treated in Estonia (excl. mine and cooling water). In 2014, 0.1 million m^3 of wastewater was treated biologically which is known secondary treatment. 80 million m^3 of wastewater was treated with the combined biological-chemical method that is known tertiary treatment of which 54% or 57.0 million m^3 was treated at the Tallinn wastewater treatment plant. [5]

In 2008, wastewater amount was bigger than the past years because, in that year, new sewerage systems connected to Tallinn network and the autumn was rainier. According to the statistics, the wastewater amount increased by %3 after 2008 and the main reasons were precipitation and the economic depression. [4]

Wastewater is treated at the place where it is generated in Estonia. Domestic and industrial wastewaters are processing in biological or biochemical treatment, which has phosphorus removal and\or nitrogen removal. Figure 16 shows the treatment of wastewater in 1992-2016 in Estonia.

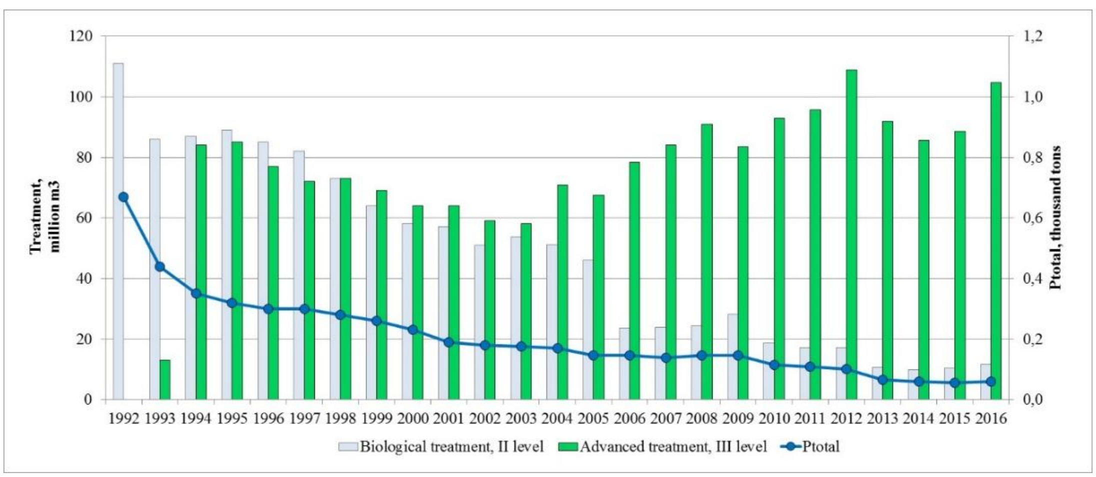


Figure 16. Treatment of wastewater in Estonia by years. (mln m^3) [4]

By the year 2013, nearly 84% of domestic and industrial wastewater undergoes tertiary treatment. About 2% of wastewater was treated mechanically in 2011. It is illustrated in Figure 17.

New agglomerations were designated in Estonia. There are 664 municipal WWTPs, form which 59 are with pollution load over 2,000 PE. These 59 agglomerations, that are over 2,000 PE, 37 of them have population between 2,000 and 10,000 PE and 22 of them have population over 10,000 PE: Tallinn, Kohtla-Järve, Tartu, Pärnu, Narva, Rakvere, Kehra, Põlva, Kuressaare, Viljandi, Ahtme, Valga, Sillamäe, Võru, Põltsamaa, Haapsalu, Paide, Rapla, Haljala, Jõhvi, Järva-Jaani, and Keila. In 2011, there were 680 WWTP under 2,000pe in Estonia. [4]

By the year 2013, new sewerage systems were built, and the available ones reconstructed in Pärnu, Keila, Narva, Otepää, Paide, and Põltsamaa. Also, Räpina, Kehra, Järva-Jaani, Kose, Türi, and Võru had new WWTPs. In Haljala and Tõrva, the construction of WWTPs were built.

Wastewater treatment facilities have been renovated in Kohtla-Järve, Kuressaare, Vändra, Elva, Otepää, Kadrina, Tamsalu, Põlva, and Aruküla; those in Tapa and Rakvere were under development in 2013. [4]

Figure 18 shows treatment of wastewater in 2011 in agglomerations of more than 2,000 PE and the colorful signs illustrate the level of treatments as primary, secondary and tertiary treatment.

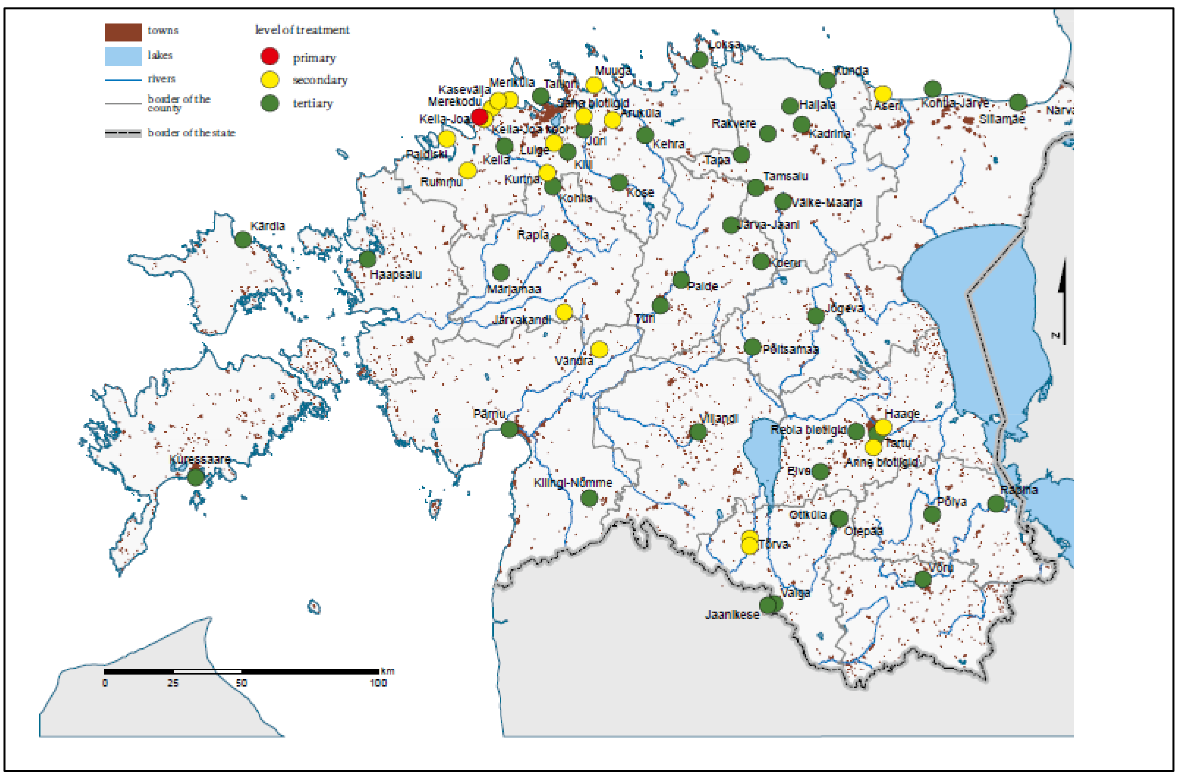


Figure 18. Treatment of wastewater in 2011 in Estonia. [4]

In 2014, 20 thousand tons of dry sludge was dredged. 1.7 thousand tons of sludge was disposed on grounds in the plants. The rest of the sludge, 18.3 thousand tons was reused in agriculture, landscaping or recultivation. [5]

During 1960s–1980s, the major problem was the low water quality about Estonian water bodies, but currently, the inferior quality of water affects the aquatic biota only in some rivers. Mostly, the wastewater (about 60%) in Estonia is discharged into the coastal sea, as the majority of the population and industries are concentrated in seaside towns. Almost all the rest of wastewater is discharged into rivers and lakes in Estonia. [4]

5.3 Legislations and regulations regarding wastewater in Estonia

There are 5 main regulations regarding water – wastewater treatment in Estonia. They are;

- Urban Waste Water Treatment Directive 91/271/EEC – Estonian legislative acts are harmonized with the directive
- Governmental Regulation nr 99 on wastewater treatment
- Public Water Supply and Sewerage Act
- Water Act
- Environmental Charges Act

5.3.1 Urban Waste Water Treatment Directive 91/271/EEC

The Urban Waste Water Treatment Directive (UWWTD) is very significant part of EU water policy and forms a minimum background for the program of measures and river basin management plans for the implementation of the Water Framework Directive (2000/60/EC, also WFD). Important is the protection of lakes, rivers and coastal area waters against eutrophication and pollution as required by the Water Framework Directive that can be accomplished by effective collection and treatment of urban wastewater as laid down in the UWWTD. This directive is not only about collection and treatment of urban wastewater, over and above this imposes different reporting imperativeness. [28]

The fundamental elements for the implementation of the UWWTD are;

- The designation of receiving areas

➢ The delineation of the agglomeration

The agglomeration size and the sensitivity of receiving area, that can have discharges from wastewater define the treatment level needs for the wastewater treatment plants serving the agglomeration.

The first step for the implementation of the directive is the identification of the type (coastal, estuary, freshwater) and sensitivity of the receiving water body.

The second step for the implementation of the UWWTD contains the delineation of the agglomeration, resulting in the size (generated load) of the agglomeration. According to the size classes described in the UWWTD diverse types of wastewater treatment are required. Being founded on the first and the second step of implementation of Urban Waste Water Treatment Directive the requirements for wastewater collection and treatment standards in the UWWTP(s) serving the agglomeration are described. [28]

The third step for implementation of the Directive is compliance of aggregated information at MS level (sewage sludge).

Principal pathway of urban wastewater as foreseen by UWWTD;

Agglomeration ⇒ Collecting System ⇒ UWWTP ⇒ Discharge Point ⇒ Receiving area/RWB

Table 12 shows the requirements for discharges from urban wastewater treatment plants based on UWWTD.

Table 12. The requirements for discharges from urban waste water treatment. [28]

Parameter	Concentration Pop> 100,000 PE
BOD (mg\l)	15
COD(mg\l)	125
Total Suspended Solids (mg\l)	15
Total Nitrogen (mg\l)	10
Total Phosphorus (mg\l)	0.5

Table 13 shows the limit values of wastewater pollution indicators lead to public sewerage in Estonia.

A water undertaking is required to receive waste water from a customer whose concentrations of waste do not exceed the limit values given in column 2 in Table 12 for which the water leaving the Paljassaare Wastewater Treatment Plant complies with the requirements established by the Water Act and wastewater managed by the public sewerage system does not harm the operation of the public sewerage system and does not cause disturbance in the treatment process. When exceeding the limit values for pollution parameters given in column 2 in Table 12, this is a source of danger to the public sewer system [25]

The limits are given in column 1 guarantee that the water leaving the Paljassaare WWTP complies with the requirements established by the Water Act and that wastewater managed by the public sewerage system does not harm the operation of the public sewerage system and does not cause additional expenses in the wastewater treatment process. The limit value is the norm for calculating excessive pollution charges for wastewater exceeding the concentration of a waste water or a hazardous substance. [25]

Table 13. Limit values of wastewater pollution indicators lead to public sewerage. [25]

Pollutant Indicator	**Sign**	**Unit Of Measurement**	**Limit Value**	**Limit Value**
A	**B**	**C**	**1**	**2**
Minimal Content Of Hydrogen Ions In Wastewater	pHmin	pH-unit	6.5	5.0
Maximal Content Of Hydrogen Ions In Wastewater	pHmax	pH-unit	8.5	11.5
Content Of Suspended Solids		mg/l	500	2,000
Biochemical Oxygen Demand	BHT7	mg/l	375	1,500
Chemical Oxygen Demand	KHT	mg/l	750	2,500
Content Of Polar Hydrocarbon		mg/l	50	300
Content Of Oil Products		mg/l	5.5	22
Total Nitrogen Content		mg/l	125	225
Content Of Monobasic Phenols		mg/l	2.9	11.6
Content Of Surfactants		mg/l	44	176
Total Phosphorus Content		mg/l	15	28.5
Mercury Content	Hg	mg/l	0.05	0.2
Silver Content	Ag	mg/l	0.2	0.8
Cadmium Content	Cd	mg/l	0.2	0.8
Total Chromium Content	Cr	mg/l	0.5	2.0
Content Of Chromium Compounds	Cr(VI)	mg/l	0.1	0.5

Copper Content	Cu	mg/l	2.0	8
Lead Content	Pb	mg/l	0.5	2
Nickel Content	Ni	mg/l	1.0	4
Zinc Content	Zn	mg/l	2.0	8
Tin Content	Sn	mg/l	0.5	2
Cyanide Content		mg/l	0.2	0.8
Arsenic Content	As	mg/l	0.2	0.8

5.3.2 Governmental Regulation nr.99 on wastewater treatment

Regulation on the wastewater treatment and requirements of waste- and storm water discharges into receiving water, waste- and storm water pollutants thresholds and compliance verification measures (regulation nr.99) adopted by the Government in Estonia. Regulation introduces the requirements for wastewater treatment, waste- and storm water discharges as well thresholds and verification of compliance with the requirements.

Table 14. Wastewater limit values in Estonia (Regulation nr.99)

Parameter	Agglomeration pollution load									
	< 300 PE		300–1999 PE		2000–9999 PE		10 000–99 999 PE		100 000 PE and >	
	LV, mg/l	R, %	LV, mg/l	R, %	LV, mg/l	R, %	LV, mg/l	R, %	LV, mg/l	R, %
BOD_7	40	is not adapted	25	80	15	80	15	80	15	80
COD	150	is not adapted	125	75	125	75	125	75	125	75
TP	is not adapted	is not adapted	2	70	1	80	0,5	90	0,5	90
TN	is not adapted	is not adapted	60	30	45	30	15	80	10	80
SS	35	70	35	70	25	80	15	90	15	90

5.3.3 Public Water Supply and Sewerage Act

The first Public Water Supply and Sewerage Act was adopted in 1999 in European Union. This Act regulates the organization of water supply management, treatment of wastewater and collection, rainwater, drainage water and another kind of wastewater by way of the public water supply and sewerage system. It is regarding necessities of the country, local governments, water users and it also regulates the price of water services.

Water Supply and Sewerage Act was adopted in 2010 as a new law amendment, it is aimed at better regulation of water supply and management, and regular control of water service price and protection of water users in the event of privatization of the municipal water companies.

Water users are protected from arbitrariness from the water companies by new revision. This revision also helped to water companies about providing fair and transparent prices for water services. [15]

5.3.4 Water Act

The legislation of Water Act was adopted in 1994. Water protection measures were based on HELCOM recommendations. Limit values of discharges into the water and soil are regulated.

The main purpose of the Water Act is to guarantee transboundary water bodies and the purity of midland groundwater sources, and the balance of ecology in water bodies. The Water Act regulates the usage and protection of water sources, relations between water users and landowners and the use of public water bodies and water bodies specified for public use. [29]

5.3.5 Environmental Charges Act

This environmental charge act ensures the grounds for specifying the natural resource charges, the ratio of the pollution charge, the methods for calculation and payment, and the grounds and specific goals for having state budget revenue gained from environmental use.

Purpose of imposing environmental charges and general principles;

- The main purpose of imposing environmental charges is to reduce the damage regarding the use of natural resources, emissions of pollutants into the environment and waste disposal.
- The state budget is used for the purposes of the protect the state of the environment, restoration of natural resources and find the means for environmental damages.
- The revenue from the use of renewable natural resources (fishery resources, forest stand, and game) is used for the restocking and protection of such resources.
- ‘The proceeds of environmental charges are divided, to the rating provided by the Act, between state budget and the budgets of the local authorities of the location of the environmental use’. [3] (§4**)**

5.4 Tallinn Paljassaare wastewater treatment plant

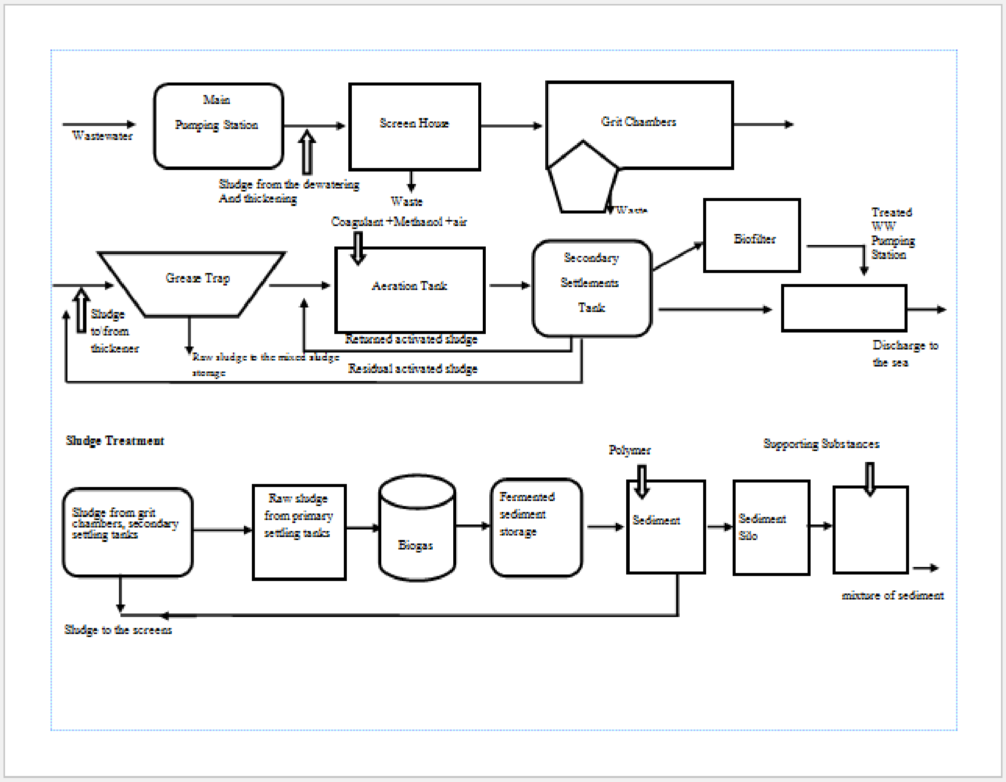
Paljassaare wastewater treatment plant started operating in 1980 and its treatment processes have been extended modernized and made more environmentally-friendly year over year. Chemical precipitation was implemented in 1983 and the biological treatment process was completed in 1991. In 2011, AS Tallinna Vesi launched the construction of an additional treatment stage at Paljassaare– the biofilter. Treated effluent discharged into the Baltic Sea. Tallinn sewerage system has 21 separate system that contains only wastewater and 7 combined system that contains wastewater and storm water by the year 2014. Comparatively, the combined system covers almost 35 % of the area of Tallinn. The combined sewerage system is in the older regions of Tallinn basically, City Centre and Northern Tallinn. The public sewerage system comprises 1104 km of wastewater networks and 478 km of storm water networks in 2016. [23]

In Tallinn, all generated wastewater is treated. 99.8 % of the population of Tallinn use the public (municipal) sewage system. 0.2 %of them can't use municipal sewerage system They are compelled to collect wastewater in septic tanks from which it is transported to the sewerage system. This amount was approximately 105,000 m^3. The treated wastewater is directed to Tallinn Bay which is 2.8 km away from the coast and a depth of 26 meters. Tallinn also receives and treats the wastewater from other regions that are close to Tallinn and they represent 4 %of the total amount of wastewater.

Paljassaare wastewater treatment plant has 12 main processes:

Wastewater collection, mechanical treatment, sludge removing from the process, addition of coagulants for the chemical treatment of the phosphorus, biological treatment, Biofilter, the activated sludge's settling, treated waste water's pumping into the sea, sludge's pumping to the sludge treatment plant, sludge's digesting, created biogas during the treatment processes is using for the technological processes and heating, dry sludge's mixing with supporting substances and out coming sludge's using in cultivation. [23]

5.4.1 Flow diagram of Paljassaare wastewater treatment plant



Main
Pumping Station
Wastewater
Screen House
Grit Chambers
Sludge from the dewatering
And thickening
Waste
Waste
Coagulant +Methanol +air
Grease Trap
Aeration Tank
Secondary
Settlements
Tank
Biofilter
Treated
WW
Pumping
Station
Sludge
to/from
thickener
Raw sludge to the mixed sludge storage
Returned activated sludge
Residual activated sludge
Discharge to
the sea
Sludge Treatment
Polymer
Supporting Substances
Sludge from grit chambers, secondary settling tanks
Raw sludge
from primary
settling tanks
Biogas
Fermented
sediment
storage
Sediment
Sediment
Silo
mixture of sediment
Sludge to the screens

Figure 19. Flow diagram of Paljassaare WWTP. [4]

Paljassaare wastewater treatment plant started operating in 1980 and its treatment processes have been extended modernized and made more environmentally-friendly year over year. The main processes are Primary Treatment, Chemical Treatment, Biological Treatment, Sludge Treatment. The main processes are shown in Figure 19.

5.4.2 Wastewater characteristics of Paljassaare wastewater treatment plant

The capacity of Paljassaare wastewater treatment plant is 120,000 m^3/day and the plant treats on average over 100,000 m^3 of wastewater per day. Slightly over 50 million m^3 of wastewater was treated at Paljassaare wastewater treatment plant in 2016. In Table 15, treated wastewater amount is shown by years. [23]

Table 15. Treated wastewater amount (million m^3) [23]

Year	**2012**	**2013**	**2014**	**2015**	**2016**
Amount	56.98	45.02	42.99	45.07	50.22

The legal acts determine the requirements of the quality of water, which is discharged to the sea. The concentration of the pollutants in the raw wastewater and discharged water are monitored to achieve the standards and the essential quality of effluent. The important pollution parameters are the following BOD, COD, SS, N, P and oil products. Amount of pollutants coming to the wastewater treatment plant and discharged into the sea in 2012-2016 are shown in the following charts. (Charts 19-20-21)

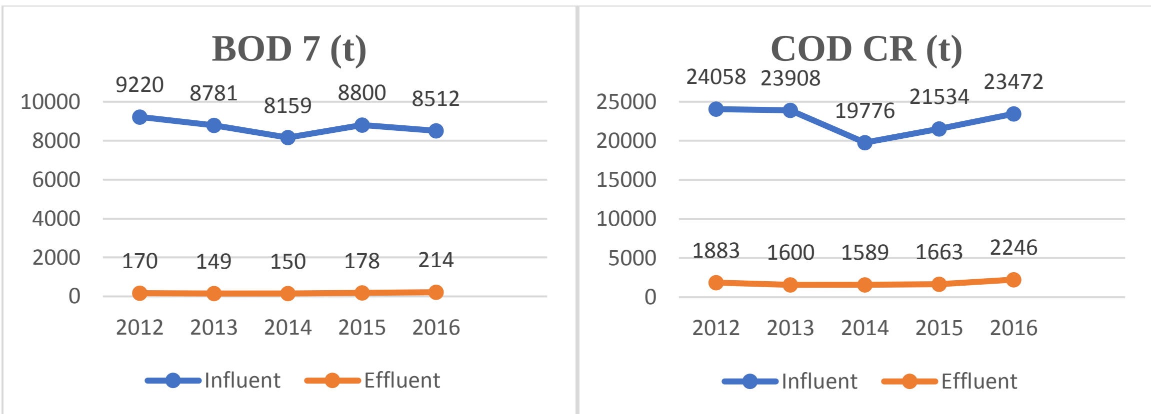


Chart 19. Influent and effluent amount of BOD and COD. [23]

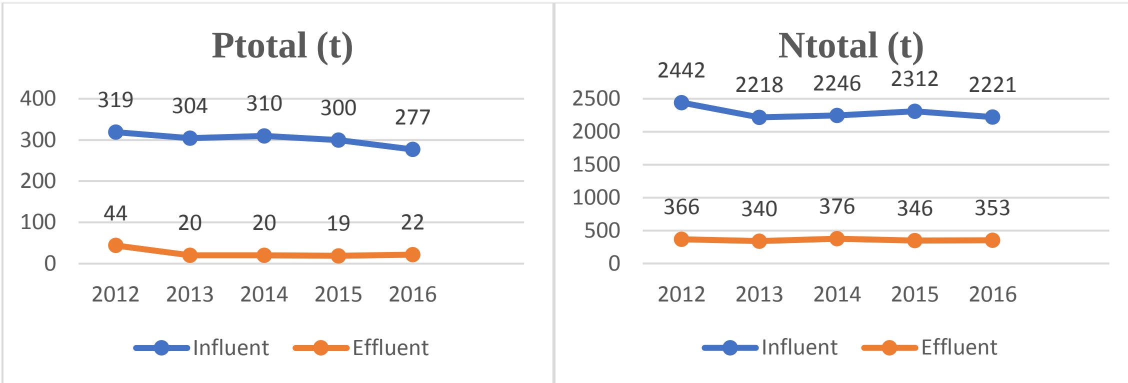


Chart 20. Influent and effluent amount of P and N total. [23]

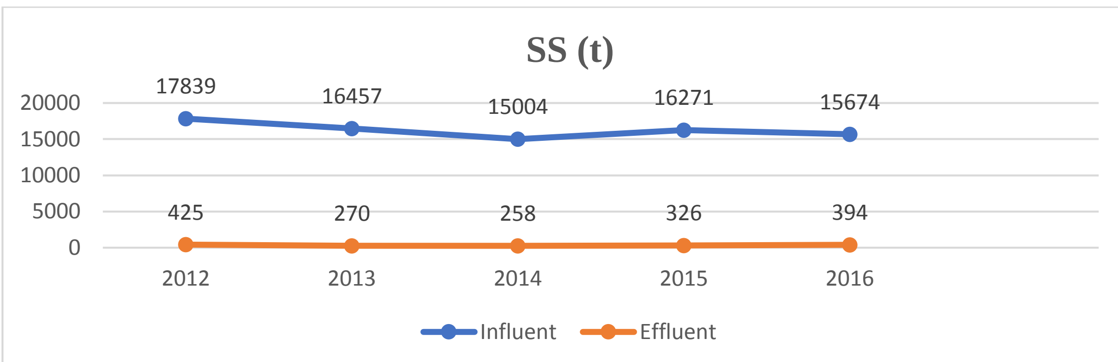
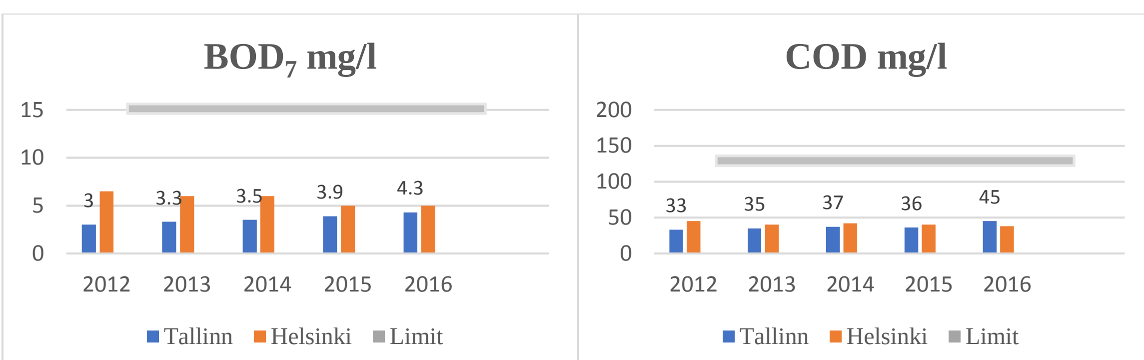


Chart 21. Influent and effluent amount of SS. [23]

Average treated effluent concentration in 2012-2016 are shown in the following charts, they are compared to regulatory maximum limit and results of Helsinki Region Environmental Services Authority (Helsinki HSY) mg/l. (Chart 22)



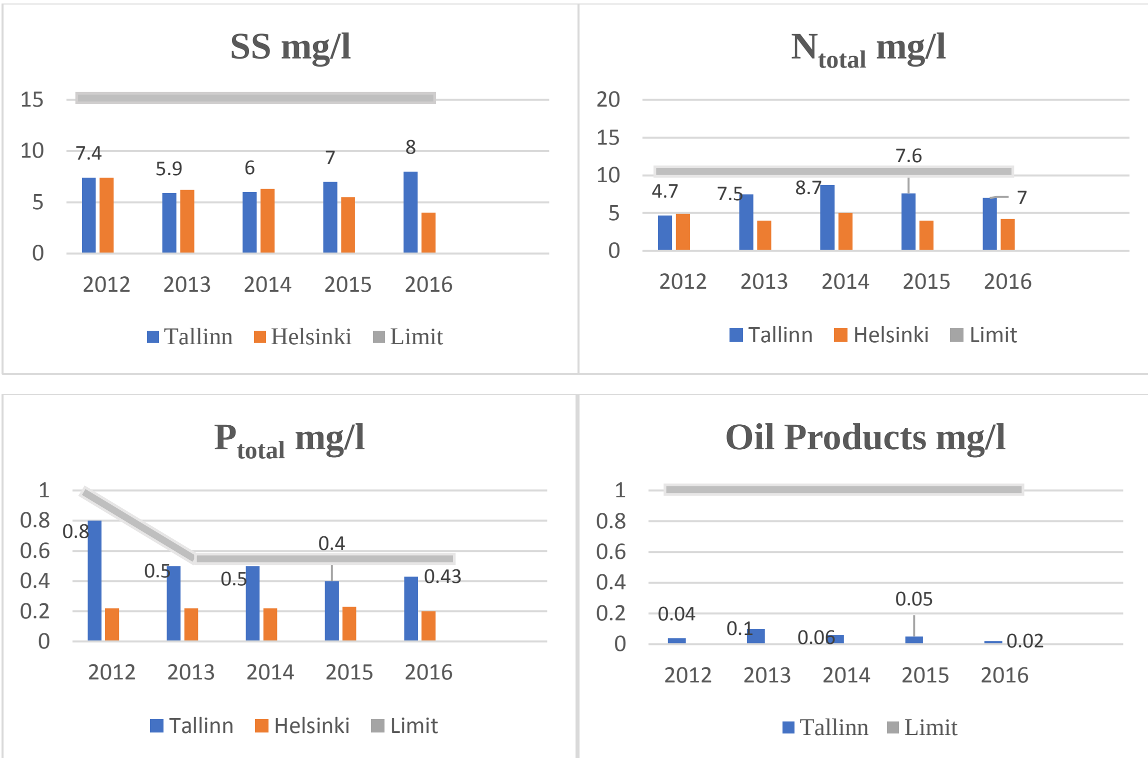


Chart 22. Average pollution concentration by years. [23]

All parameters of the effluent, which are discharged from Paljassaare WWTP were compatible with the limit values in 2016 but the cumulative treatment efficiency was lower than in 2015. If the main reasons are considered for this, snowmelting and high amount precipitation can be shown also, the temperature of incoming wastewater decreased by ca 2 ^{0}C per day. Especially, during the season a quick decreasing in temperature significantly affected the activated sludge process and wastewater treatment efficiency thereby, the annual average performance is affected. [23]

In Chart 23, wastewater treatment plant's treatment efficiency is shown by years. They are compared to regulatory minimum requirements and results of Helsinki Region Environmental Services Authority. As they are illustrated below BOD_7 efficiency was 97 %, COD_{Cr} was 89 %, N_{Total} was 83 % and P_{Total} efficiency was 92 % in 2016.

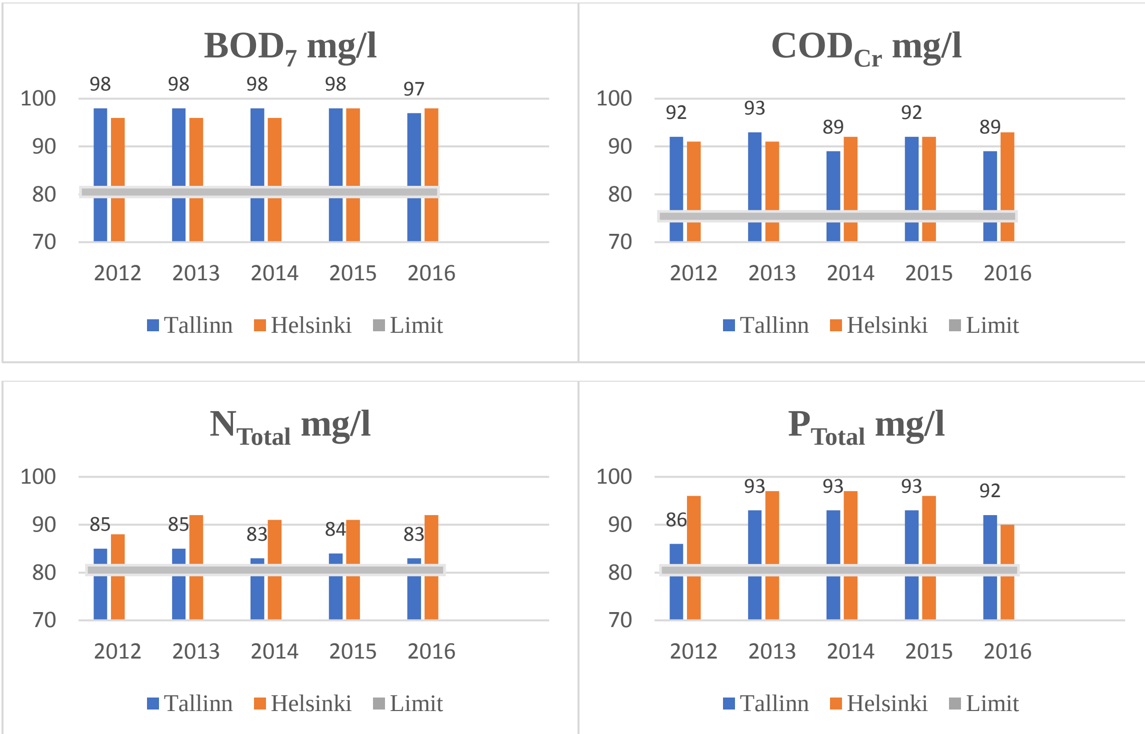


Chart 23. Wastewater treatment plant's treatment efficiency by years. [23]

In 2016, emergency outlets were opened 8 times in the wastewater treatment plant for a brief time during heavy rain showers, to prevent from any major damages. Approximately, 122 m^3 wastewater diluted by storm water (dilution was 25%) was discharged to the sea. (Chart 24) [23]

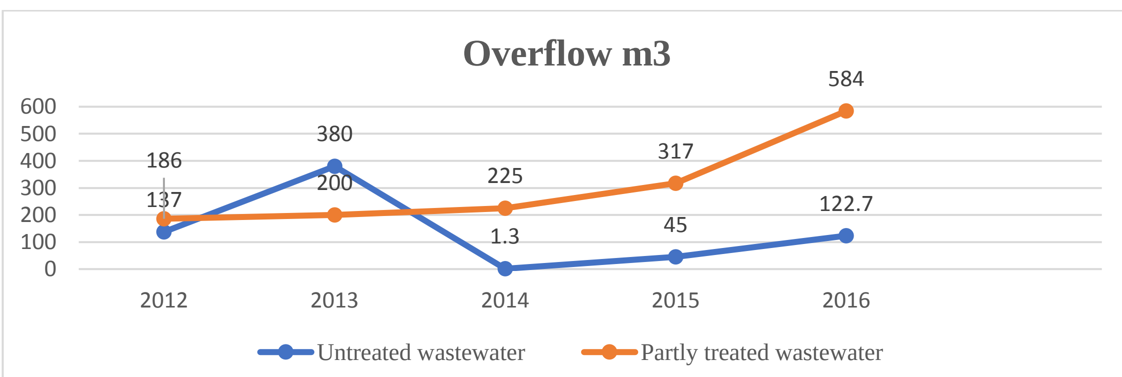


Chart 24. Wastewater treatment plant overflow by years. [23]

In 2016, use of chemicals was relatively smaller than in 2015. After improving the coagulant dosing plant promoted to the savings of coagulant and methanol. Coagulant dosing process moved to the end of the biological treatment unit provided very good conditions for activated sludge process, biological removal of nutrients, and the desired effluent quality was achieved with the smaller amount of chemicals. The quantity of chemicals that are used in the wastewater treatment process is depending on the pollution levels of incoming wastewater. Use of chemicals by years are illustrated below.

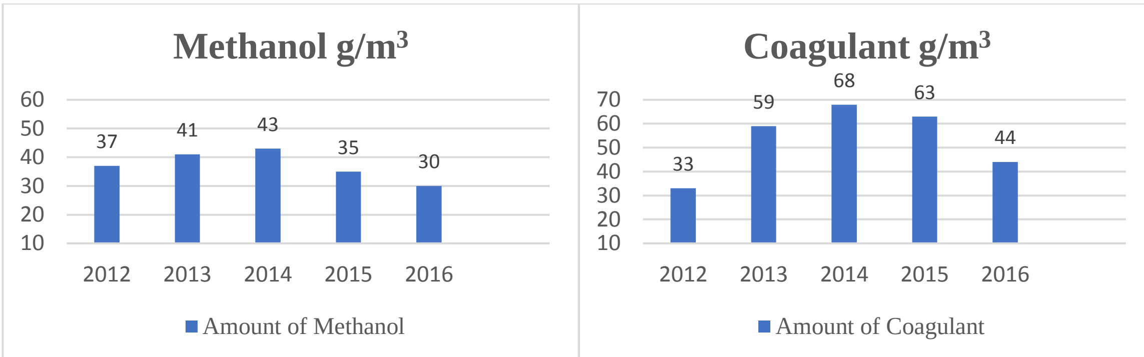


Chart 25. Use of chemicals by years. [23]

The usage of a polymer is about the quantity of dry solids and sludge to be treated. The sludge amount conducted to dewatering was lower in 2016 than in 2015, but its content of dry matter was lower, and less polymer was used.

The amount of wastewater sludge was 31,741 ton in 2016 and it is proper to reuse. The planned volume of sludge in stock on the composting field was 32074 tons. Approximately, 39,000 tons of soil were given to people for greenery free of charge. (Chart 26) [23]

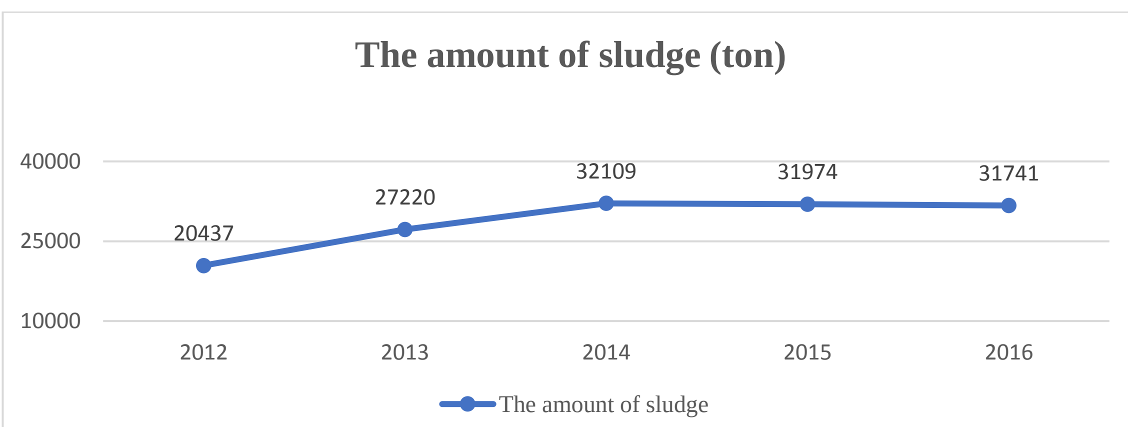


Chart 26. The amount of wastewater sludge by years. [23]

In wastewater treatment, energy consumption is quite high, and it depends on the season because of the weather conditions also, pumps and production of air in biological treatment are the main processes electricity used. Chart 27 shows electricity consumption per unit produced at the wastewater treatment plant in 2012-2016, kWh/m^3. [23]

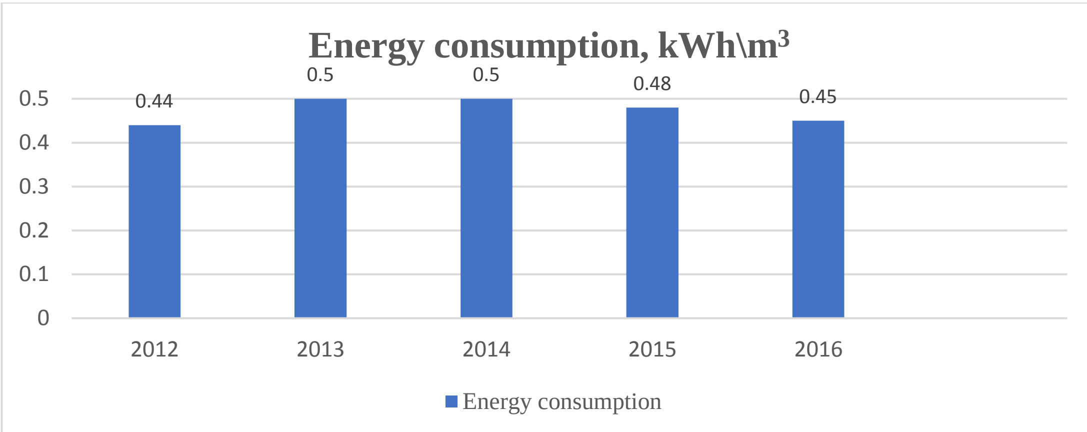


Chart 27. Electricity consumption per unit produced at the WWTP by years.

6. The comparison of municipal wastewater treatment in Turkey and Estonia

Turkey is a country between Asia and Europe. The population of Turkey is 79,814,871 people. Istanbul is the largest city and its population is 14.8 million people, the other largest cities are Ankara, Izmir and Bursa.

Estonia is mainly a lowland country where is bordered by the Baltic Sea, Latvia, and Russia. Its population is 1.3 million. Tallinn is the largest city of Estonia and its population is 426,000 people, the other largest cities are Tartu and Narva.

Due to country size and population, the water statistics are quite different between Turkey and Estonia.

The average precipitation was 643 mm, available water potential was 112 billion m^3 and the used water amount was 44 billion m^3 in 2013 in Turkey. The average precipitation is between 550 and 800 mm in a year in Estonia. Water abstraction is almost 100 million m^3 per year nowadays.

The quantity of groundwater abstracted during the decade is between 45 and 50 million m^3 per year and the quantity of surface water is between 50 and 57 million m^3 per year in Estonia, but these amounts are quite big in Turkey;

Water abstraction for surface water in a year is 112 billion m^3. (1)

Water abstraction for groundwater in a year is 14 billion m^3. (1)

As it is seen in Chart 28, surface water abstraction is 8 times more than groundwater abstraction in Turkey. The percentage of water abstraction is almost the same in Estonia.

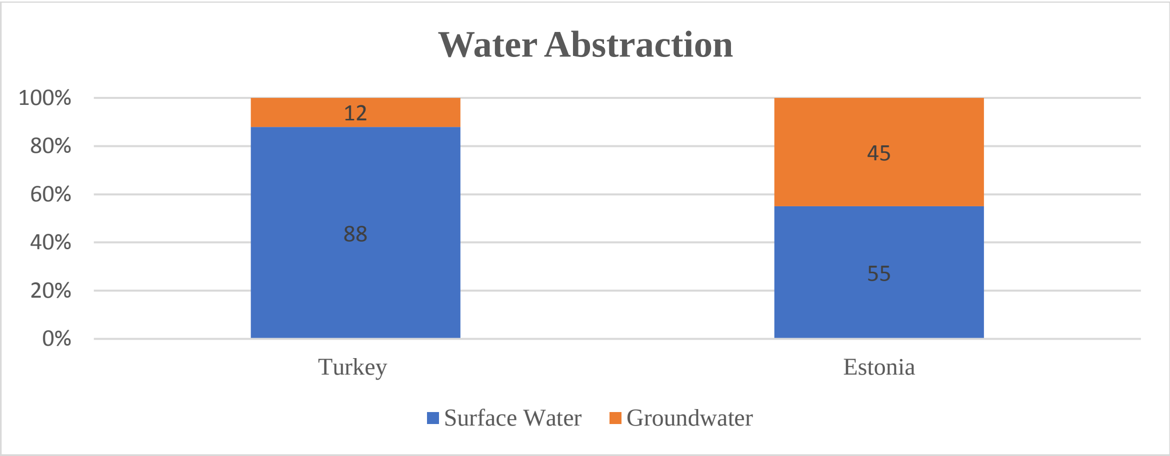


Chart 28. The percentages of water abstraction in Turkey and Estonia. (Content 4-5)

The average water consumption was 217 litres per capita per day in 2010 in Turkey. In 2014, this amount decreased to 203 litres. When the biggest cities are considered, water consumption statistics are different. For instance, in 2014;

In Istanbul, water consumption was 181 litres per capita day.

In Ankara, it was 211 litres.

In Izmir, it was 180 litres per capita per day.

The average water consumption per capita per day was 128 litres in 2010 in Estonia (Tallinn). In 2014, this amount decreased to 122.8 litres. In 2016 it was approximately 95 litres.

The numbers show that the average water consumption is different between both countries. Cultural differences, life style and climate can be considered as main reasons.

6.1 Comparison of wastewater treatment

Due to the size of the population, the numbers of wastewater plants are quite different in Turkey and Estonia. (Chart 29)

In Turkey, there are 234 major municipal wastewater treatment plants and most of them located in Marmara region, it covers almost 29 % of them. According to Turkish Statistical Institution in 2012, 12,330,000 m^3 wastewater occurs in a day. The amount of wastewater treated in the wastewater treatment plants is 8,080,59 m^3/d. It shows that only 66 %of this water can be treated in wastewater treatment plants in Turkey.

New agglomerations were designated in Estonia in 2008. In Estonia there is 664 municipal WWTPs. As mentioned in previous chapters, there are 59 agglomerations that are over 2,000 PE. 37 of these plants have population between 2,000 and 10,000 PE and 22 of them have population over 10,000 PE. In 2011, approximately 117 million m^3 of wastewater was generated in Estonia, it means approximately 320,000 m^3 in a day. 81 % of this amount of wastewater (or 95.1 million m^3) came from agglomerations over 2,000 PE. Tallinn city generated 43 % of it, Tartu city 7 % and Kohtla-Järve 6 %. (Chart 29)

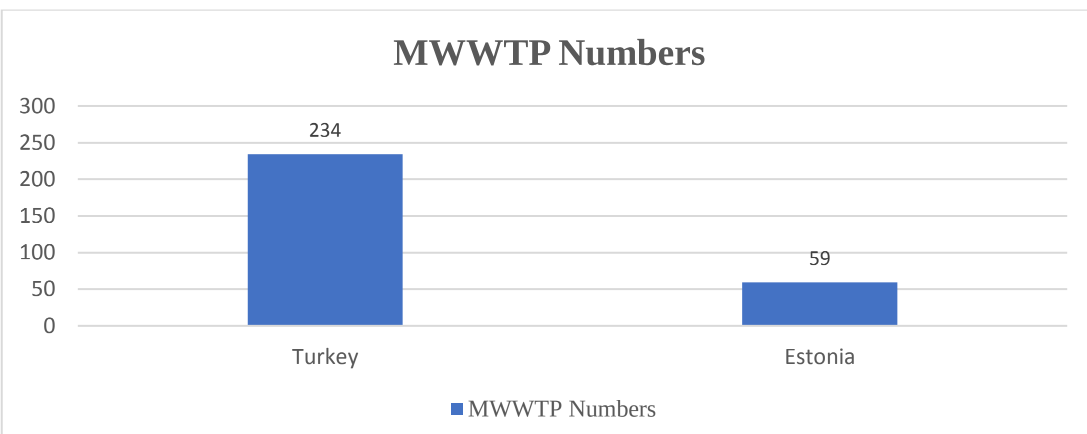


Chart 29. The comparison of major MWWTP numbers. (Content 4-5)

In Turkey, there are two types of municipal wastewater treatment plants. One of them is the urban wastewater treatment plants which receive the industrial wastewater that is not fully treated and from leakages. Another one is the domestic wastewater treatment plants that receive the wastewater only from houses and hotels and other residences. Accordingly, there are 66 urban wastewater treatment plants and 168 domestic wastewater treatment plants out of 234. According to Turkish statistical institute, the quantity of treated wastewater in Urban and Domestic wastewater treatment plants are almost the same in Turkey. 86 % of these wastewater treatment plants have biological treatment and 14 % of them are processed by Non-Biological treatment. Non-Biological treatment contains preliminary treatment (28 %) and physical treatment (72 %).

In Estonia, Domestic and industrial wastewater are treated in biological or biochemical treatment (Tertiary Treatment) with the removal of nitrogen and/or phosphorus. In 2013, nearly 84% of domestic and industrial wastewater undergoes tertiary treatment. About 2% of waste water was treated only mechanically.

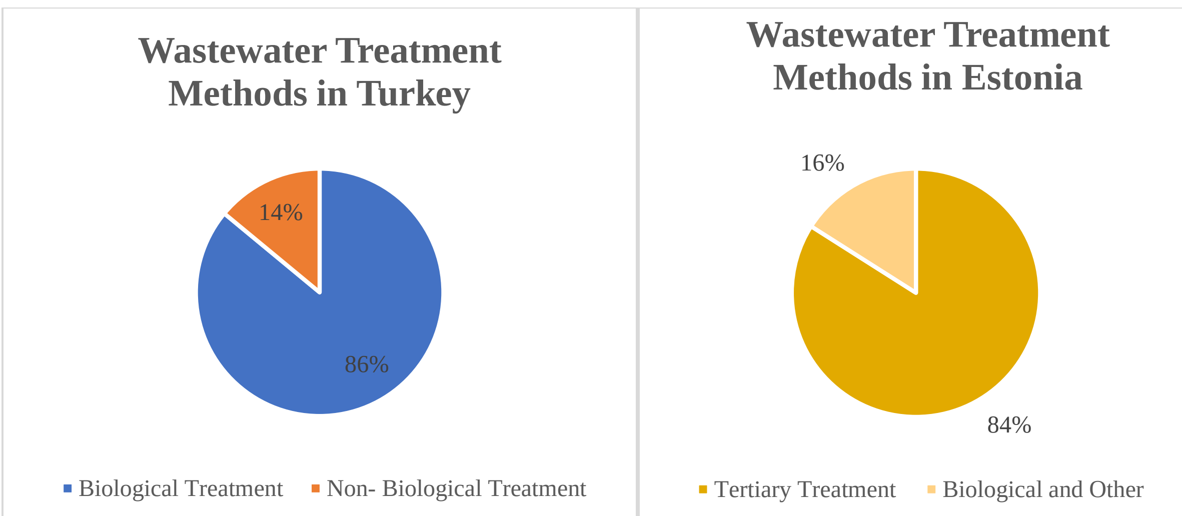


Chart 30. Wastewater Treatment Methods by countries. (Content 4-5)

In Turkey, almost 55 % of the wastewater plants discharge their treated wastewater to receiving bodies such as rivers, lakes, streams. However, the wastewater plants, which are in coastal regions, discharge their wastewaters to the sea via deep-sea discharge systems. In this case, it can be considered that the amount of discharged wastewater to the sea and lakes-rivers are almost the same.

Mostly, the wastewater (about 60 %) in Estonia is discharged into the coastal sea, most of the population and industries are concentrated in seaside towns. Almost all the rest of wastewater is discharged into rivers and lakes in Estonia.

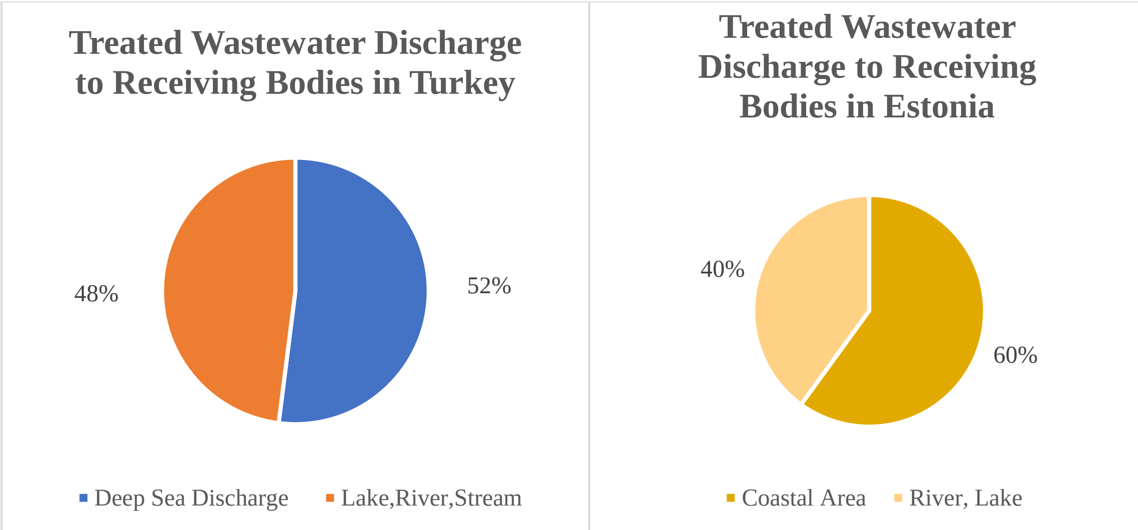


Chart 31. Treated Wastewater Discharge to Receiving Bodies by countries. (Content 4-5)

6.2 Comparison of legislations and limit values between Turkey and Estonia

In Turkey, there are 3 main regulations about water and wastewater treatment. They are;

- Water Pollution Control Regulation
- Urban Wastewater Treatment Regulations
- Regulation on Control of Pollution Caused by Dangerous Substances in Water Bodies

Water Pollution and Control Regulation is the most important one and it contains all limit values for sewerage system and receiving bodies.

In Estonia, there are 5 main regulations regarding water – wastewater treatment in Estonia. They are;

- Urban Waste Water Treatment Directive 91/271/EEC
- Governmental Regulation on wastewater treatment
- Public Water Supply and Sewerage Act
- Water Act
- Environmental Charges Act

Urban Waste Water Treatment Directive 91/271/EEC transposed to Estonian legislation and Public Water Supply and Sewerage Act, as well Governmental Regulation on wastewater treatment are the most important regulations and they contain the limit values for sewerage system and receiving bodies.

Basically, the aim of all these regulations is the protection of groundwater/surface water potential and prevention of water pollution with sustainable development goals. These regulations cover the quality classification of water bodies, usage purpose of water, the prohibitions and plans for protection of water quality, discharging of wastewater principles, rudiments of wastewater infrastructure facilities and the monitoring and measurements studies for prevention of water pollution.

6.2.1 The limit values

The discharge standards to the receiving areas are different between Turkey and Estonia. Basic parameters are shown in Chart 32. COD limit is 120 mg\l in some areas in Turkey.

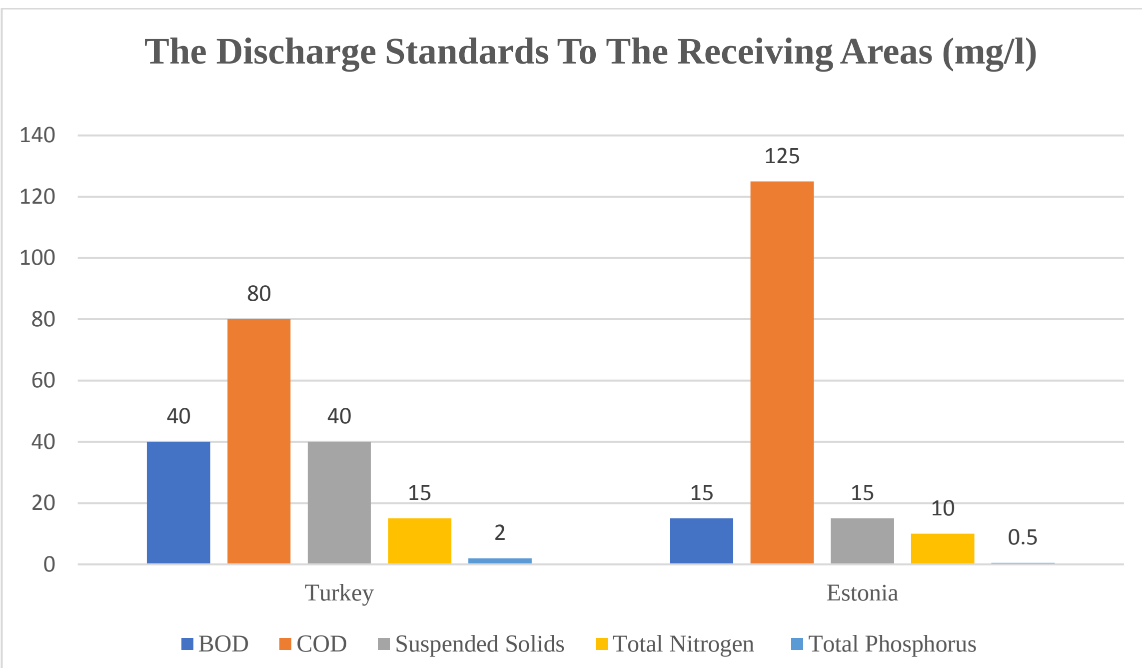


Chart 32. The discharge standards to the receiving areas in Turkey and Estonia. (Content 4-5)

6.2.2 Limit values of wastewater pollution indicators lead to public sewerage

There are differences in limit values for public sewerage system between Turkey and Estonia. The most important parameters are compared in Table 16.

Table 16. Limit values for public sewerage system in Turkey and Estonia (Content 4-5)

Pollutant indicator	Unit of measurement	Turkey	Estonia
pH	-	6.5-10	6.5-8.5
Suspended Solids	mg/l	350	500
Chemical Oxygen Demand	mg/l	600	750
Biochemical Oxygen Demand	mg/l	400	375
Mercury content (Hg)	mg/l	0.2	0.05
Cadmium content (Cd)	mg/l	2	0.2
Total chromium content (Cr)	mg/l	5	0.5
Lead content (Pb)	mg/l	3	0.5
Cyanide content (CN)	mg/l	10	0.2
Copper content (Cu)	mg/l	2	2

As it is seen in the table, there are some big differences between some parameters. For instance, Cyanide and Cadmium values are quite different between Turkey and Estonia. However, Copper and BOD limit values are almost the same. The differences are depending on characteristic of wastewater, its treatment\generated methods and the situation of receiving areas.

6.3 Comparison of Bursa Eastern and Paljassaare wastewater treatment plants.

Bursa Eastern wastewater treatment plant was constructed in between 2003-2006 and it is in Osmangazi county in Bursa. The capacity of this plant is 240,000 m^3/day and the system is operated by 5-stage Bardenpho process.

In 2016, Eastern wastewater treatment plant received 107,748,048 m^3 wastewater in total. 83,533,786 m^3 of this total amount was treated by biological process and 24,214,262 m^3 wastewater treated in primary treatment due to the overflow (precipitation) and power cut in the facility. The wastewater arrives at the plant by 2 sewer pipes that have 2,000 mm diameter each.

Paljassaare wastewater treatment plant started operating in 1980 and its treatment processes have been extended modernized and made more environmentally-friendly year over year. Chemical precipitation was implemented in 1983 and the biological treatment process was completed in 1991.

The capacity of Paljassaare wastewater treatment plant is 120,000 m^3/day and the plant treats on average over 100,000 m^3 of wastewater per day. Slightly over 50 million m^3 of wastewater was treated at Paljassaare wastewater treatment plant in 2016.

In Table 15, The characteristic of Bursa Eastern and Paljassaare wastewater treatment plants are compared.

Table 17. Comparison of the characteristic of the plants. (Content 4-5)

Paramaters	**Bursa Eastern**	**Paljassaare**
Method	Biological Treatment-Bardenpho process	Chemical-Biological Treatment
Capacity	240,000 m^3/day	120,000 m^3/day
Total treatment amount m^3/day	299,300 m^3	100,000 m^3
Total treatment amount m^3/year (2016)	107,748,048 m^3	50,000,000 m^3
Energy Consumption (2016)	0.57 kWh\m^3	0.45 kWh\m^3
Sludge Amount (2016)	83,500 Kg	31,741 Kg

The treatment efficiency of these wastewater treatment plants is shown in the below table by 2016. For two plants, the efficiency of the parameters is quite high.

Table 18. Wastewater treatment efficiency by 2016. (Content 4-5)

Paramaters	**Bursa Eastern**	**Paljassaare**
BOD	97	97
COD	94	89
Nitrogen	90	83
Phosphorus	84	92

6.4 Main problems and recommendations for municipal wastewater treatment

There are some main problems in municipal wastewater treatment. Cleaning of the coarse screening is one of the most critical issues. All plastics, wood, paper and other big solid materials must be removed by screening. Otherwise, they will be harmful for the entire process. For instance, they can clog the pumps, pipes etc. Thus, the efficiency of treatment will be affected. Regular control of the screening process is the key of the solution.

Grit camber is important process and they should be checked regularly and must be clean. The processes that have manual grit chamber unit, must be cleaned after strong precipitations. If the processes have mechanical grit chamber, they should be working at regular intervals such as scraping, and the removing capacity of the grit chamber must not be exceeded. Otherwise, the performance of the process would be affected.

Activated sludge process is a process of wastewater treatment for domestic and industrial wastewater. It is the most important process of the biological treatment. Obtaining excellent quality treated wastewater is related with this process. There are significant conditions to get expected outflow from the process.

- There must be enough microorganism in the activated sludge process.
- In aeration tank, there must be proper environment for growing of microorganisms.
- Activated sludge should be removed from the system immediately

If one of these conditions is not appropriate in the activated sludge process, the treatment efficiency would be low. [11]

6.4.1 The most common problems and their solutions in municipal wastewater treatment in Turkey

- **Excess occurrence of foam in activated sludge process.**

  The reason: Adding too much washing agents to the wastewater.

  The solution: The amount of washing agents must be reduced, the amount of air that adding to the tank should be reduced, adding defoamer to the wastewater.
- **Not collapsing of sludge and remaining on the water.**

  The reason: There is no enough oxygen in the aeration tank and having too much organic matters.

  The Solution: Providing more oxygen for aeration tank and organic load must be reduced. Nitrogen and phosphorus can be added to tanks thus, growing of filamentous organism will be stop.
- **Odor in the wastewater plants**

  The reason: It is one of the most important problem in sewerage systems and wastewater treatment plants. The sources of this odor problem can be organic and inorganic. The anaerobic digestion of the organic matters that contain nitrogen and Sulphur, can be caused the formation of the compounds which cause the odor in wastewater treatment.

The solution: Aeration and using ozone are the most common ways to solve odor problem in Turkey.

- **Decrease of biomass**

  The reason: There can be some toxic compounds in wastewater and they cause decreasing of biomass. If Ph<5 or >10, it will affect the biomass also.

  The solution: The sources of toxic compounds should be determined, and they must be inhibited. For Ph, neutralization tank can be provided thus, the Ph of the system can be fixed (between 6-8.5) during the day.

- **Decrease of treatment efficiency**

  The reason: If the temperature is less than 13 ^{0}C, it will affect the biological activity and biological removal.

  If there are unexpected changes in influent, pH or organic load, it can affect the efficiency of the treatment.

  The solution: pH should be fixed as much as possible during the day. Unexpected organic loads and influent must be prevented.

- **Solid accumulation**

  The reason: if the solid wastes like grit cannot be removed from the system properly, suspended solids are accumulated in the reactor and it would affect the interaction of biomass and wastewater. This situation causes the odor and the decrease the efficiency of the treatment.

  The solution: The best solution is emptying the reactor and determine the type and amount of the accumulation.

- **Hardened sludge problem**

  The reason: If the sludge contains too much grit, inorganic sludge and, compressible or heavy material, hardened sludge problem can be occurred.

  The solution: If there is no grit chamber in the process, it should be added. Backflush is need in the pipes. The pumps must be checked whether they are clogged or not. The pipes must be cleaned by pressure water at regular intervals. [7]

In 2014, 4.3 billion m^3 wastewater produced and 3.5 billion m^3 of this amount treated and discharged to the receiving areas. [24]

Recommendation: It means only 81% of wastewater treated at WWTPs. This percentage is lower in 2017, but Turkey must treat the wastewater as much as possible. Untreated wastewater is discharged to the receiving areas and this can be disaster for environment. Especially, industrial wastewater should be discharged to the receiving areas without proper treatment. There are villages that they don't have WWTP in Turkey. The related municipalities should provide investment for construction of proper plants for these villages.

Sewerage system was served almost %90 of population in 2014. [24]

Recommendation: This percentage must be higher. Otherwise, untreated wastewater will be discharged to the land (currently 0.2 %) randomly and this situation can create very bad consequences for environment.

6.4.2 The most common problems and their solutions in municipal wastewater treatment in Estonia

One of the main problems was small WWTPs (pollution load less than 2,000 PE) in Estonia. Since there were no national limit values for these WWTPs by 2013 and this case caused some socio-economic problems in the past. From June 2013, there is new governmental regulation on wastewater treatment adopted where limit values also for small WWTPs were set up and this regulation solved one of the main problems in Estonia. [2]

In Estonia, WWTPs with pollution load less than 2,000PE. don't have chemical and biological phosphorus removal process. Almost 50 % of these small WWTPs cannot reach the basic requirements. This percentage is different for the WWTPs with the pollution load more than 2000P. in Estonia, it was more than 70 % in 2011. Nowadays this percentage is quite high.

Recommendations are;

- Even these small WWTPs can have small accident and this kind of accidents can be caused a big disaster for environment. The great wastewater treatment is very significant case. Human errors can destroy the ecosystem and water bodies.
- Improving these WWTPs are so important and necessary. It is obvious that the improvement costs are lower than environmental costs.

- The small size plants are similar with bigger plants related to technology, development and management solutions.
- Training the new and simple technologies on these WWTPs are more feasible. There are a lot of alternatives and innovations. Monitoring and management are easier for these plants
- Some small wastewater treatment plants that are close to each other can be combined like the project example of the Meriküla, Keila-Joa and Türisalo wastewater treatment plants. The purpose of the project was to construct a single wastewater treatment plant that would treat the wastewater of both allocations. The first aim of the project for renovation of water and wastewater treatment in Türisalu and Keila-Joa was currently ongoing and it includes the connection of two wastewater systems to ensure that only one plant would be constructed.

Nitrogen removal is another challenge in wastewater treatment in Estonia. Especially, at Paljassaare WWTP in Tallinn by 2011(before biofilter process). The melting of snow in the spring period and the rainfall during the summer saw the flows into the Paljassaare wastewater treatment plant increase to nearly half a billion liters in each day, but the generally during dry summer time in Estonia resulted in the total nitrogen concentration in the wastewater entering the treatment plant being quite high. Although, the treatment plant could outperform about the percentage of removal of nitrogen, the final effluent discharged into the sea exceeded 10mg/l. All other parameters did not exceed the standards. In 2011, AS Tallinna Vesi launched the construction of an additional treatment stage at Paljassaare– the biofilter. [22]

Recommendation: Nitrogen is one of the reasons for sea pollution because it causes eutrophication. This case was also a big problem in Tallinn before Biofilter Process. Nowadays nitrogen removal is not a significant problem for Tallinn. If Paljassaare WWTP has this problem in the future, it must have some developments regarding nitrogen removal process. Nitrogen amount must be reduced before discharge to the sea. For instance, the plant can have A2\O process (Anaerobic-Aerobic-Oxic), if the biofolter would not be enough in the future. It should be established before biological treatment thus; nitrogen and phosphorus removal would be more efficiency.

In 2013, the amount of untreated wastewater discharged to the sea was 379,674 m^3 and partly discharged wastewater discharged to the sea was 200,117 m^3. In 2016, these amounts are reduced to 122,7 m^3 and 584 m^3. It is a proof that there was a considerable progress regarding increasing treated wastewater amount between 2013 and 2016 in Estonia. Nowadays these numbers are quite low but still it is a problem for environment. Untreated and partly treated wastewater amount must be lower as much as possible. [21] [23]

7. Conclusion

The aim of this study was analyzing of municipal wastewater treatment\plants in Turkey and Estonia including legislations and comparison of characteristics of Municipal Wastewater Treatment. Especially, these two countries were selected for this study because it had considered that there were remarkable differences between Turkey and Estonia such as regional, cultural, technological, water potential etc.

This study shows that there are quite notable differences regarding municipal wastewater treatment in Turkey and Estonia. These differences are mostly about applied wastewater treatment methods, limit values, discharge points. Also, the most common problems regarding wastewater treatment are different for both countries due to implementations and treatment methods. But the general problems were quite similar in both countries. In Turkey, mostly biological treatment is applied for treatment of municipal wastewater. However, the biological treatment methods are various by regions. This is a proof that the municipalities treat wastewater according to its characteristic and the prevenient discharge points. This study defined that one of the biggest problems regarding WWT in Turkey is untreated wastewater amount. The percentage was 34 in 2012 and 19 in 2014. It is conceivable that this percentage is lower in 2017 but it is still very critical problem for Turkey. Untreated wastewater is harmful for human life and environment. Turkey must expedite the construction of new WWTP and improving the exist ones. There are so many small villages (around 34.000) and some of them have no WWTP yet or their processes are not suitable for a proper treatment. In Estonia, Paljassaare WWTP treats 43 % of total wastewater amount in Estonia and it has Chemical-Biological treatment. It needs chemical treatment for municipal WWT on the contrary in Turkey because there are no separated chemical treatment plants in Estonia. Turkey has industrial areas and they have their own chemical WWTP. Estonia treats most of the wastewater (the untreated wastewater was only 122.7 m^3 in 2016) and almost all villages have their own WWTP. However, the main problem in Estonia, small WWTPs (less than

2,000 PE) do not comply with the limit values. In addition, some of WWTP don’t have nitrogen\phosphorus and grit removal process. Estonia has a chance to combine the wastewater treatment plans like the project in Meriküla, Keila-Joa and Türisalo wastewater treatment plants. This is very difficult implementation for Turkey because of long distances and mountains between small villages.

Another significant problem in Turkey is the lack of sewerage system withe same reason which is existence of so many small villages. Some of them are in out of town and serving them is difficult for responsible municipalities. Almost 10 % of population had no sewerage system in 2014. They collect the wastewater to the cesspits, but this is not a safe idea for environment. This percentage is lower in 2017, however, there are still so many villages, which cannot treat their wastewaters properly and discharge them to the sewerage system. The solution of this issue, should be providing new sewerage systems and end them up with WWTP. Municipalities need to reach all villages by sewerage system. In Estonia, there is no such a problem. The sewerage network is quite enough, and large majority of towns and villages have sewerage systems.

The main problems at WWTP in Turkey, the first thing is odor problem. There are a lot of WWTPs, which are close the residential areas and it affects the quality of life in that region. Turkish municipalities should invest more money for these kind of odor problems such as having more aeration tanks and using ozone at WWTP. Excess occurrence of foam in activated sludge process is also very common and important problem at WWTP in Turkey. Adding more defoamer to the wastewater can be a solution of this problem. Also, reducing of using washing agents can help for occurring of foam. In Estonia, the main problem is nutrients, especially phosphorus removal in small WWTPs. The limit for bigger WWTPs is 0,5-1,0 mg P/l and for small ones 2 mg P/l to discharge to the receiving areas. Especially, small-scale WWTPs (less than 2,000PE) exceed this limit because they don’t have proper process to remove nutrients.

As a result, this study researched the general situation, conditions and characteristics of MWWT in Turkey and Estonia. Additionally, it clarified the basic and major difficulties in MWWT and, gave recommendations for improving the wastewater treatment efficiency for both countries.

8. Summary

Summary in English

The aim of this thesis is analysing of municipal wastewater treatment\plants in Turkey and Estonia including environmental laws\legislations and comparison of characteristics of municipal wastewater treatment\methods. All necessary fundamental information regarding municipal wastewater treatment was given as an introduction. The situation of Turkey and Estonia about water\wastewater were given as an initial knowledge in the beginning of the parts. Then, the wastewater treatment methods and numbers were analysed by regions\cities in Turkey and Estonia. All related environmental legislations, laws and limit values regarding wastewater management were explained by the countries. Additionally, one specific municipal wastewater treatment plant was selected in both countries. (Bursa Eastern and Tallinn Paljassaare plants). Their characteristics, treatment methods, and conditions were analysed separately. In the last part of thesis, all mentioned fundamental methods\properties regarding wastewater treatment were compared between Turkey and Estonia. Additively, the most common problems\issues in wastewater treatment were researched and given some recommendations related to them. Untreated wastewater amount, lack of sewerage systems and, odour, occurring foam at municipal wastewater treatment plants were determined as the major problems in Turkey. In Estonia, having so many small-scale wastewater treatment plants that cannot comply the limit values, problem of nitrogen and phosphorus removal were determined as the key issues.

As a result, this study researched the general situation of municipal wastewater treatment in Turkey and Estonia. In addition, it clarified the basic difficulties in this subject and, gave recommendations for improving the wastewater treatment efficiency for both countries.

Summary in Estonian

Käesolev uurimistöö vaatleb reovee käitlemist reoveepuhastusjaamade näitel Türgis ja Eestis, sealhulgas keskkonnaalast seadusandlust, ja võrdleb reoveepuhastuse näitajaid ning meetodeid. Sissejuhatuses on esitatud vajalik taustinformatsioon seoses reoveekäitlusega. Ülevaate alguses on

kirjeldatud olukorda Türgi ja Eesti ühisveevärgi-/reoveekäitluses. Seejärel analüüsiti reoveepuhastus meetodeid ja -näitajaid Türgi regioonides/linnades ja Eestis. Selgitatud on reoveekäitlusega seotud keskkonna alast seadusandlust, seaduseid ja piirväärtusi Türgis ja Eestis. Mõlemas riigis valiti välja üks reoveepuhastusjaam – vastavalt Ida-Bursa ja Tallinna Paljassaare reoveepuhastusjaam. Neis analüüsiti eraldi iseloomulikke näitajaid, käitlusmeetodeid ja -tingimusi. Uurimistöö lõpus võrreldi kõiki eelnimetatud põhimeetodeid ja – omadusi seoses reoveekäitlusega Türgis ja Eestis. Samuti vaadeldi reoveekäitluses üldiselt esinevaid probleeme ning anti võimalikke soovitusi nendega tegelemiseks. Peamisteks probleemideks Türgis leiti olevat käitlemata reovee hulk, kanalisatsioonisüsteemide puudumine, lõhna ja vahu esinemine reoveepuhastusjaamades. Eestis on palju väiksemaid reoveepuhastusjaamu, kus ületatakse piirväärtusi, peamiselt liigse lämmastiku ja fosfori eemaldamise osas. Tulemusena on antud ülevaade üldisest olukorrast reoveepuhastuses Türgis ja Eestis. Lisaks on täpsustatud peamised raskused ning antud võimalikke soovitusi parandamaks reovee käitlemise efektiivsemaks muutmist mõlemas riigis.

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