Municipal wastewater treatment plants in Slovenia

DANIJELA DOBERSEK, DARKO GORICANEC, PETER TROP

Abstract**—**Wastewater treatment system in the European Union member states is unequally developed. Approximately 70% of the EU population is connected to the wastewater treatment plant. Slovenia is characterized by a high proportion of dispersed settlement, which occurs particularly in hilly and mountainous areas, which requires a specific approach in the design and construction of municipal wastewater treatment plants. The article presents the current status of treatment of municipal wastewater in the region, supported by the presentation of established legislation and implementing on-going programs.

Keywords**—** wastewater, wastewater treatment plants, current state analysis, legislation

I. Introduction

IN a balanced ecosystem self-purification of water is ensured, because of the development of urban settlements, agriculture and industry, this is no longer possible, therefore new solutions and introduction of processes for purification of generated waste water are needed. Protection of waters is one of our fundamental duties, for this reason we all have an obligation to take care of our water resources.

With increased growth of the population and industrial development the quantity of waste is increasing. The result is a rise in environmental awareness of people, who know that the improper management of waste can seriously jeopardize the future of life on earth.

Increasing rate of wastes production and its negative influence to environment, together with increasing awareness of its influence on society, accelerated the changes in the field of waste treatment. Changes include legislation, and development of new technological processes for use of wastes for energy production [1- 5].

Some decades ago very little attention was given to nature conservation; today the problem is faced at every turn. Nature conservation begins at the source of pollution, where wastewater is produced.

- At households, where it is possible to retain or otherwise eliminate many materials from wastewater.
- In the industry, where comprehensive prevention of pollution is necessary with regard to the technology.

D. Dobersek, D. Goricanec and P. Trop are with the Faculty of Chemistry and Chemical Engineering, University of Maribor, Smetanova ul. 17, 2000 Maribor, SLOVENIA (corresponding author to provide phone: 00386 2 220 77 61; e-mail: danijela.dobersek@uni-mb.si, darko.goricanec@uni-mb.si, peter.trop@uni-mb.si).

However some substances remain in wastewater and greatly upset the balance in ecosystem, therefore it is necessary to eliminate them with purification, which can be very problematic, especially if the substances are toxic, poorly degradable, or with synergistic effects. Wastewater treatment is performed using range of chemical, physical and biological processes, which often complement each other, depending on the type of waste water or the substances that must be removed [8].

Not long time ago substantially less sewage was produced and manly of organic origin, easily degradable by different natural microorganisms (bacteria, algae, etc.); the process of self-cleaning capacity of water took place.

Wastewater treatment is expected to avoid or minimize environmental degradation. Municipal wastewater contains range of wastewaters with approximately 99.9 % of water and 1% of solids. Typical large developed city produce daily from 380 to 450 litters of wastewater per person, including private residences, commercial establishments, small industry and handicrafts.

The beginnings of the construction of sewage treatment plants in major industrial centres in Slovenia date back to the years from 1970 to 1980. The expansion of the construction of sewage treatment plants was recorded until 1990.

In this area 233 municipal wastewater treatment plants, with a total capacity of 2.040.000 PU (population units), had been in operation until the end of 2008 [7].

II. Operation of Wastewater Treatment Plant

Every wastewater treatment plant, (Fig. 1) provides two final products purified water and waste, which is in solid and liquid phase. Highest level of waste and the most technologically complex problem is the produced biological sludge.

The primary objective of wastewater treatment plant is sufficient protection of groundwater and surface water, while ensuring safety and health of the employees and the environment. Generally operation of each wastewater treatment plant can be presented by four stages:

- mechanical,
- aerobic,
- anaerobic,
- treatment of the produced sludge.

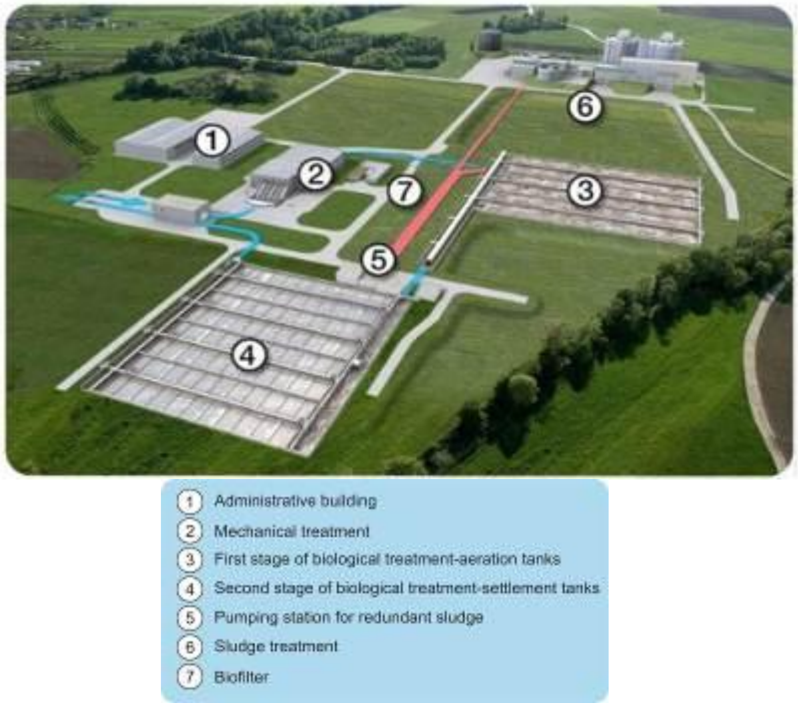


Fig. 1: Municipal wastewater treatment plant [8]

Process of purification in MWTP (municipal wastewater treatment plant) is schematically presented on Fig.2.

The first stage of purification of raw waste water is rough cleaning with rakes, sieves and sand catchers. Raw wastewater usually contains branches, rocks and other solids. These objects can cause damage to pumps, reduce the flow of wastewater or completely clog the pipes, which in turn leads to reduced efficiency of wastewater treatment plant, Fig. 3.

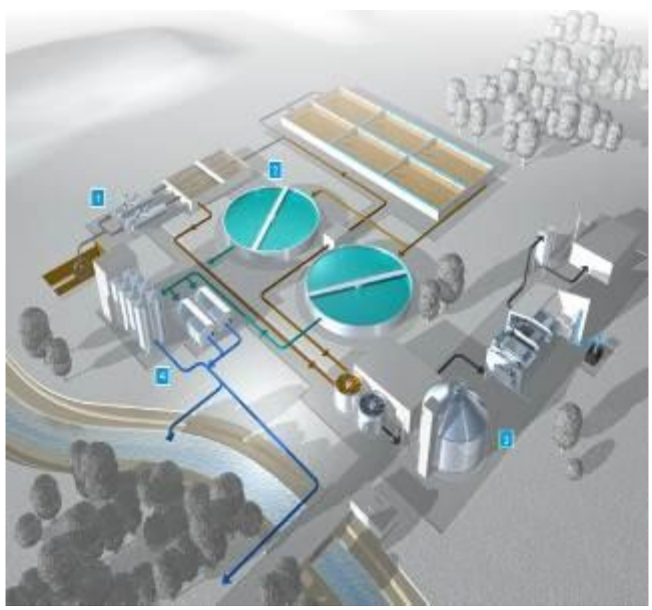


Fig. 2: Schematic presentation of water purification in MWTP
(1-Mechanical preliminary treatment, 2 – Sedimentation, 3 - Sludge treatment, 4 - Microscreening, filtration) [9]

Next stage is primary treatment for elimination of materials by means of sedimentation and flotation in basins where flow velocity of water is reduced.

Processes for biological purification (secondary treatment) are used first of all for elimination of dissolved and suspended organic substances, which cannot be eliminated by economically viable chemical or physical processes. Therefore dissolved and suspended substances are transformed in sediments by means of microorganisms.

Wastewater from primary settlement tank usually flows in vent basin where oxygenation takes place by means of compressed air through membrane blowers.

In the next basin active sludge is subsiding, which is recycled into the aeration basin, redundant sludge is recycled into the primary basin, Fig. 4. Purified water flows through the overflow into the second stage of treatment in the next aeration basin and then into the environment

Active sludge is recycled into the aeration basin. At the starting point in the primary settlement tank primary and redundant sludge (from secondary settlement tank) is collecting in conical deepening, from where it is pumped into the thickening tanks and further to sludge dehydration. From here on sludge is often discharged to landfill. Further tertiary treatment is increasingly used, where the sludge is processed in the anaerobic digester for production of biogas, Fig. 5.

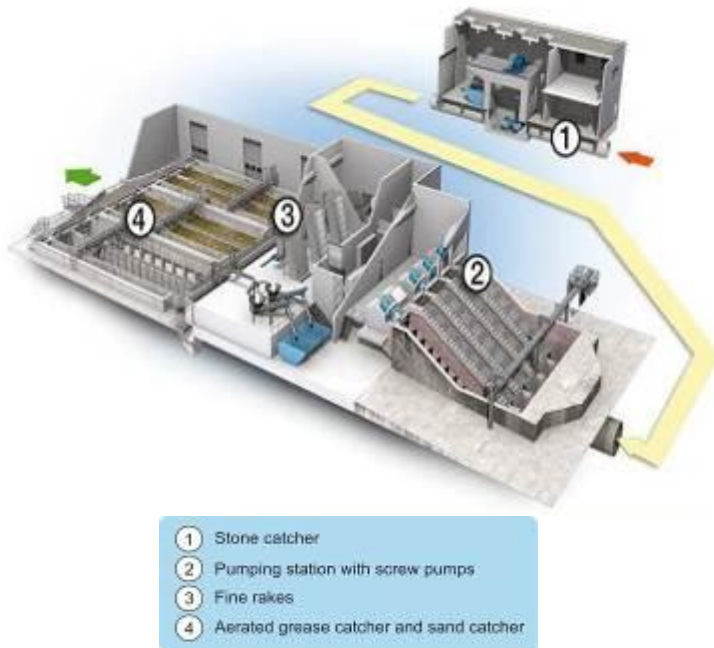


Fig. 3: Process of mechanical treatment [8]

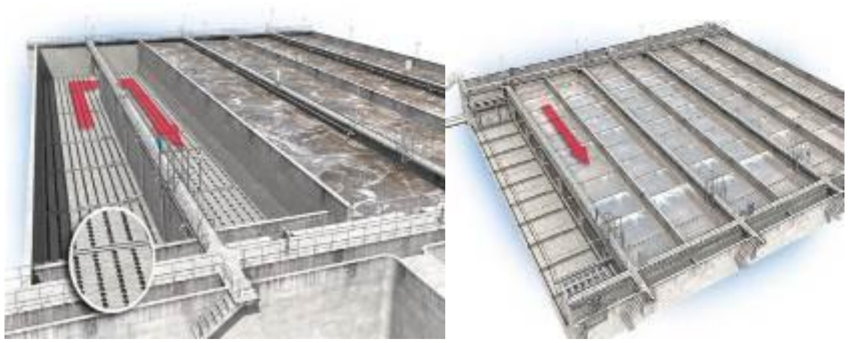


Fig 4: Aerobic process of biological wastewater treatment [8]

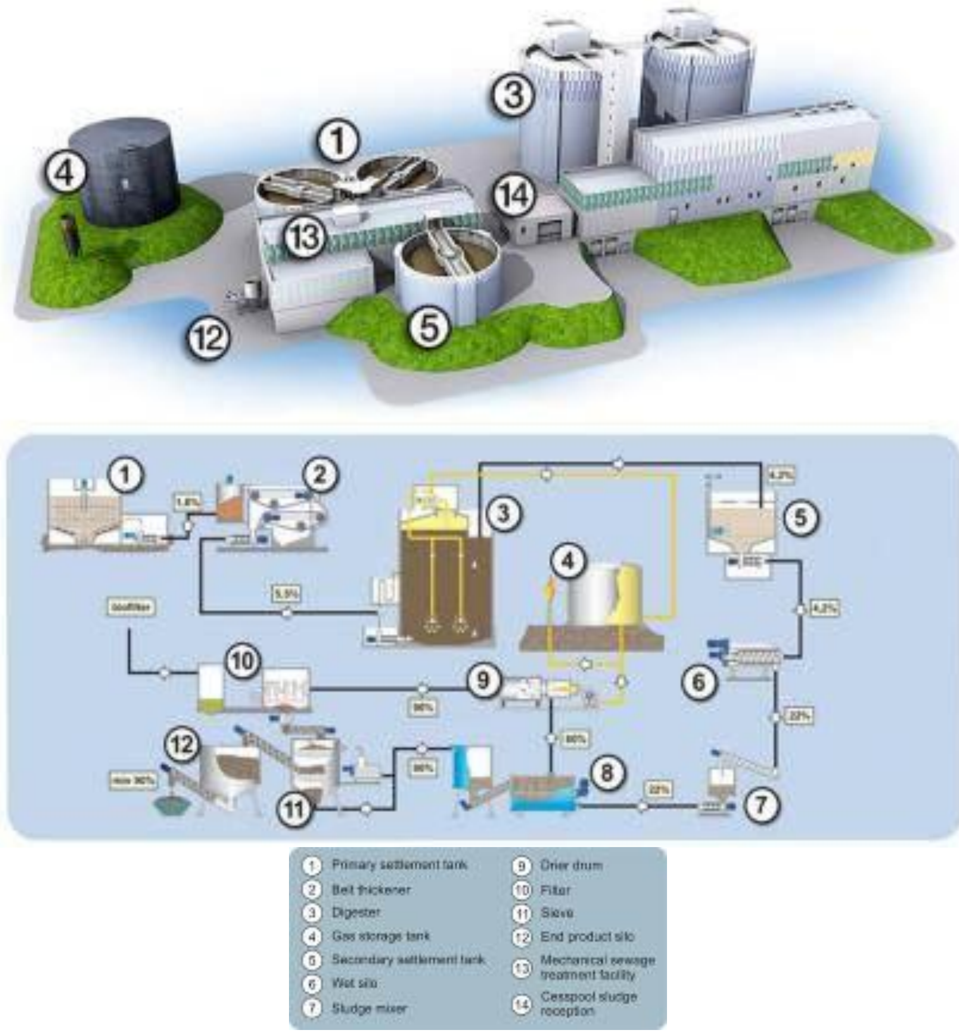


Fig 5: Anaerobic process biological treatment of wastewater [8]

Sewage sludge produced in biological wastewater treatment presents the largest proportion of waste from MWTP. Sludge for treatment process has a high proportion of water and organic matter. The objective of sludge treatment is reduction of the water content and controlled decomposition of sludge. The final product of sludge treatment is stabilized biodegradable waste, which is easily stored and transported and suitable for material and energy utilization, because of its properties and quantity.

After sedimentation and mechanical compaction sludge is transported to anaerobic digester, for biodegradation of organic matter under anaerobic mesophilic conditions. The sludge is then mechanically dehydrated and dried in the dryer drum to a dry matter content of 90 % or more in the final product. Final product of sludge treatment is usually dried, free-flowing and sanitized waste in the form of pellets with a diameter of 2 - 4 mm. Its final treatment can be composting or it can be used as complementary combustion fuel in industry.

The product of anaerobic fermentation is biogas which contains mainly methane and carbon dioxide and small amounts of hydrogen sulphide and moisture and can be used as burning fuel.

III. Formation and Chemical Composition of Sewage Sludge

The sludge is processed by biological, physico-chemical and thermal processes. The process is clearly represented at the Fig. 6.

The amount of “fresh” sludge depends on the way of processing, and on characteristics of waste water. Average annual production of sludge is from 20 to 45 kg of dry material per person.

Primary sludge is generated from hard materials, stored in unprocessed waste water. Secondary sludge contains biomass produced in the biological cleaning of waste water.

Important processes of sludge treatment are:

- Tidy
- Removal of disruptive material
- Disinfection
- Removal of water with mechanical processes

- Drying with water evaporation
- Increment with thermal oxidation of organic species

The quality of waste sludge is usually determined by pathogen organisms, and by concentration of hard metals. The concentration depends on activities of industrial and communal contaminants connected to the sewer system.

The chemical composition of primary and secondary sludge from biological sewage treatment is represented at the table 1.

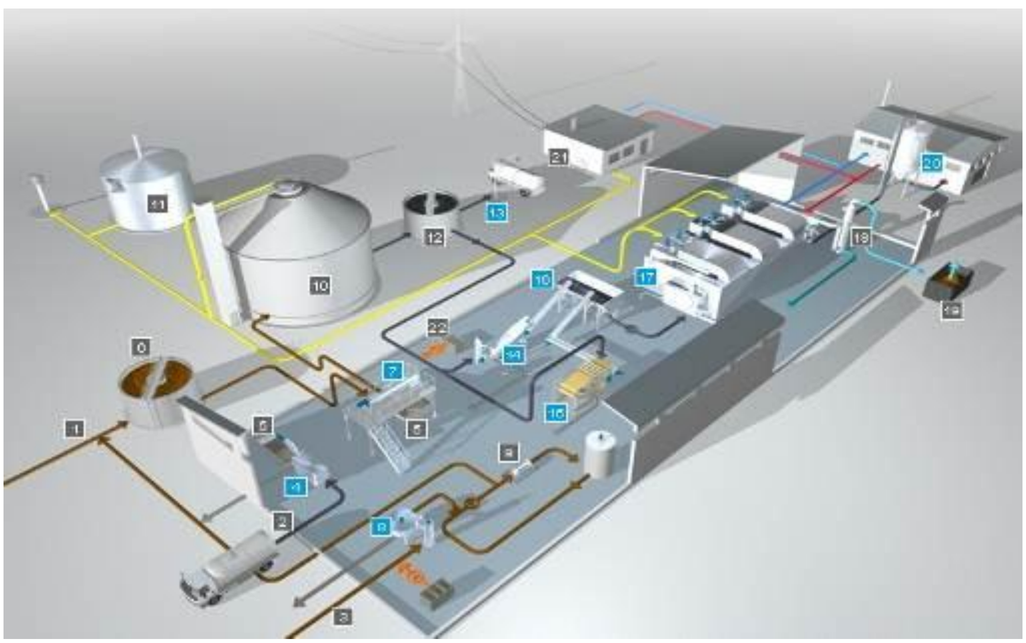
Concentration of hard metals (arsine, cadmium, copper, cobalt) changes due to the contribution of industry and economy to the sewage, and regarding to the effectiveness of the sludge processing unit.

Waste water from industry contains different composition of dissolved and suspended materials. On the other hand communal waste water differs only in concentration of pollutants.

In the modern communities approximately 400 L of waste water is produced per person. The ware contains less than 0.1% of suspended materials, from 100 to 350 mg/L of suspended materials and from 110 to 400 mg/L BPK_5.

Table 1: Average composition of waste sludge [9]

Parameter	Value
pH	7,70
Dry materials	30,50%
Organic N_2	14,18 g/kg dry materials
Total N_2	25,19 g/kg dry materials
Ca	70,98 g/kg dry materials
K	2,63 g/kg dry materials
Mg	9,17 g/kg dry materials
P	31,00 g/kg dry materials
As	6,05 mg/kg dry materials
Pb	53,82 mg/kg dry materials
Cd	1,19 mg/kg dry materials
Cr	43,40 mg/kg dry materials
Co	6,53 mg/kg dry materials
Cu	197,10 mg/kg dry materials
Mn	220,86 mg/kg dry materials
Mo	3,90 mg/kg dry materials
Ni	27,69 mg/kg dry materials
Hg	1,00 mg/kg dry materials
Zn	809,52 mg/kg dry materials



1 primary sludge
2 septic sludge
3 secondary sludge
4 septage receiving
5 screenings
6 pre-thickener
7 sludge screening
8 sludge thickening
9 sludge desintegration / homogenisation
10 anaerobic digester
11 gas holder
12 post-thickener
13 HUBER Sludge Gallow
14 sludge dewatering
15 sludge dewatering
16 Tank
17 middle temperature sludge drying
18 Quenscher
19 Biofilter
20 - thermal sludge utilisation
21 power/heat cogen.
22 polymere station

Fig. 6: Schematic representation of sludge processing [10]

IV. Legislation in the field of wastewater treatment

Water Framework Directive [11], the directive on urban waste water treatment [12] and the Environmental Protection Act [13], the umbrella regulations governing laws related to the fundamental principles of environmental protection measures, environmental monitoring and information, economic and financial tools, utilities and other environmental protection-related issues.

From the Environmental Protection Act arising numerous implementing regulations governing the discharge of wastewater. The law governing the protection of the environment against pressures as a prerequisite for sustainable development and within this framework lays down the principles of environmental protection measures related to environmental protection, environmental monitoring and environmental information, economic and financial instruments of environmental protection, public services and other related environmental protection issues.

In what way waste water will be purified depends on surface waters, groundwater, lakes, seas, in summary from the source in which it flows. To ensure the best possible quality of waste water and to avoid the bad state of watercourses and pollution there are legal requirements and criteria that must be considered in the treatment of wastewater.

Scope of municipal wastewater in Slovenia is largely determined by the following rules:

- Water Act [14] regulates the management of sea, inland waters, groundwater, water bodies and coastal land. The Act claims are made for the granting of water rights, water permit, described process of obtaining the water consent and the process of obtaining a concession for utilization of water for irrigation of agricultural land.
- Decree on the emission of substances and heat in the discharge of wastewater into waters and public sewage system [15], determines limit values of efficiency of water purification specific measures related to the design and operation.
- Decree on the emission of substances in waste water discharged from urban waste water treatment plants [16] and Decree on the discharge and purification treatment of urban wastewater and meteoric water [17]; both regulations presents nominal rules, which govern the discharge of wastewater into the aquatic environment. Provide overall limits of emissions of heat and matter in the water.
- Decree amending the Decree on the emission of substances and heat in the discharge of waste waters from urban treatment plants [18],
- Rules on initial measurements and operational monitoring of waste water and on conditions for their implementation [19], is the landmark legislation, which determines sets of parameters, which are the subject of initial measurements and operational monitoring of waste water, measurement methodology and format for reporting information to the Environmental Agency.
- Operational programme for the discharge and treatment of urban waste water 2005 – 2017 [7] is Implementation Act, which determines settlement areas, for which is obligatory to ensure discharge of waste water into public sewers and adequate wastewater treatment plants in the prescribed time frame.

Under current legislation, 31.12.2015 or 31.12.2017 is the deadline for the sanitation of cesspools. All treatment plants must be designed in accordance with EN 12566 [19] and have the CE mark.

Discharge of waste water into public sewers must be provided no later than:

- 31. December 2010 agglomerations with a load equal to or greater than 100.000 PE,
- 31. December 2015 agglomerations with a load equal to or greater than 2.000 PE and less than 15.000 PE.
- 31. December 2017 agglomerations with a load between 50 and 2.000 PE, with density between 10 PE/ha and 20 PE/ha.

Implementation of the above-mentioned legislation is confirmed by Fig.7, which shows growth in investments for discharging and treatment of municipal wastewater in the period from 2000 to 2009.

Table 2 contains the permissible limits for certain contaminants in the purified waste water, according to the capacity of individual treatment plants.

Table 2: Limit values of substances in purified water [20]

Parameter	Unit	Capacity of MWTP in PE		
		2.000 – 10.000	10.000 – 100.000	≥ 100.000
Insoluble solid	mg/l	60	35	35
KPK	mg/l	125	110	100
BPK_5	mg/l	25	20	20
Total nitrogen		15	15	10
Total phosphorus	mg/l	2	2	1
Effect of treatment of total nitrogen	%	70	70	80
Effect of treatment of total phosphorus	%	80	80	80

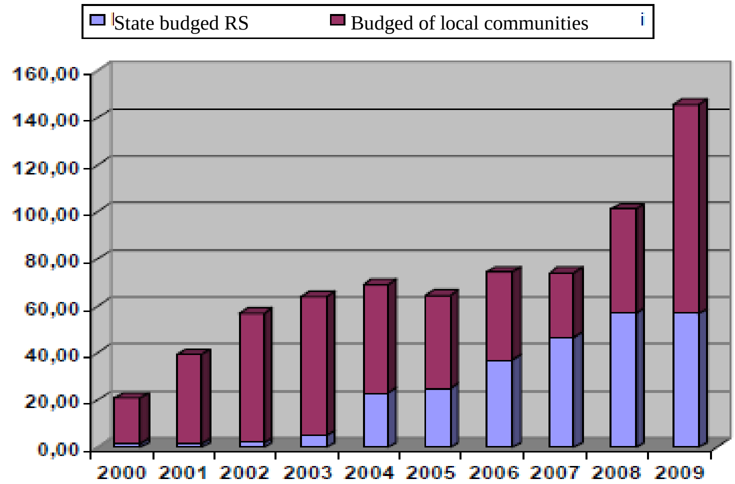


Fig. 7: Investments for discharging and treatment of municipal wastewater in the period from 2000 to 2009 in millions EUR [7].

V. Wastewater Treatment Plants in Slovenia

Each wastewater treatment plant provides two final products, purified water and waste in the form of solid and liquid phases.

Slovenia with a population of around 2 million people is characterized by a high proportion of dispersed settlement, which occurs particularly in hilly and mountainous areas, about half the population lives in towns with fewer than 2,000 inhabitants.

Typical rural areas account for 30.5% of the entire territory of our country and comprise 38.5% of the total population. In these areas the problem is the waste water treatment, because it is virtually impossible to combine wastewater from individual units and transport it into the municipal wastewater treatment plant [21].

According to the principle of operation, for medium and larger capacities, processes of aerobic and anaerobic degradation are manly used in Slovenia. On the relief map of Slovenia, Fig. 9, the locations of municipal or common water treatment plants are marked, arranged according to size. Fig. 8 presents the total size of treatment plants by year

Figures 10 and 11 present the quantities of treated wastewater by level of cleaning and years. Decree on the emission of substances in the discharge of waste waters from urban wastewater treatment, plants, states, that in primary stage of purification settleable substances are removed and BPK5 is reduced by 20 % and the total amount of suspended solids by 50 %.

Secondary stage of purification is aerobic and anaerobic wastewater treatment, resulting in a biologically treated water effluent and sludge, which still contains pollutants such as nitrogen and phosphorus.

In tertiary stage eutrophication (excessive overgrowth of the watercourses) is prevented, which means that which means that nutrients (nitrogen, phosphorus) from the effluent treatment plant are removed.

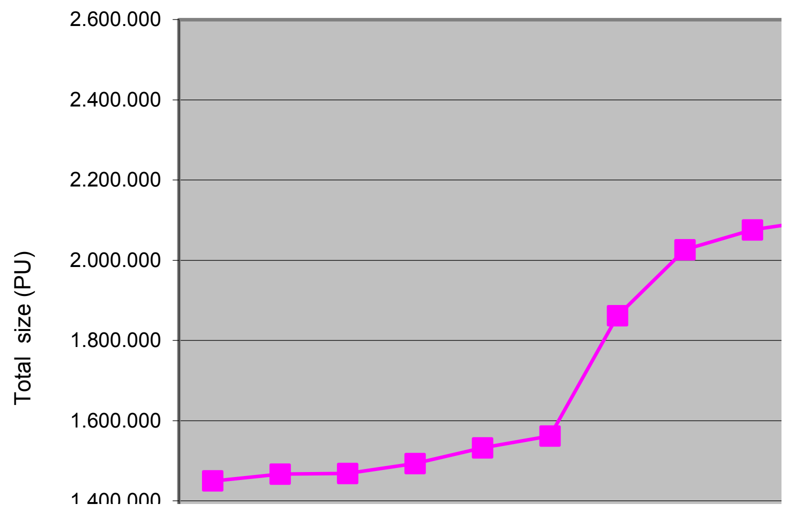


Fig. 8: The total size of treatment plants by year [22]

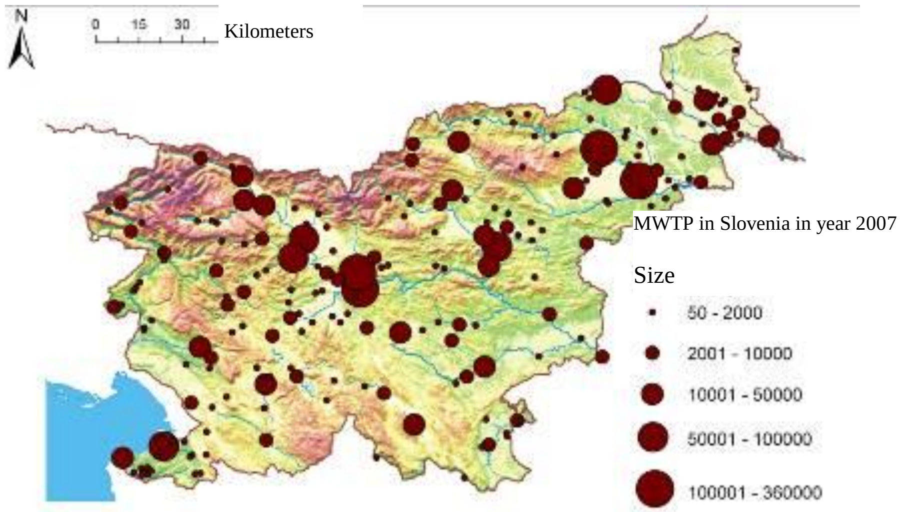
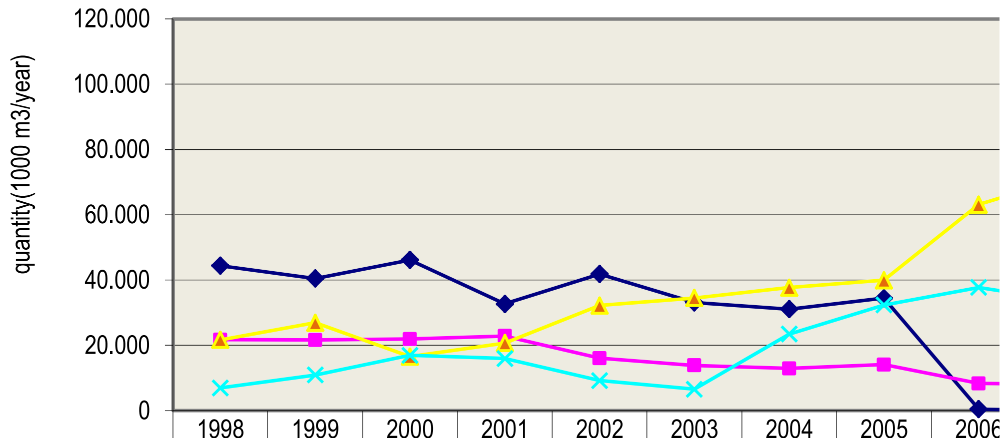
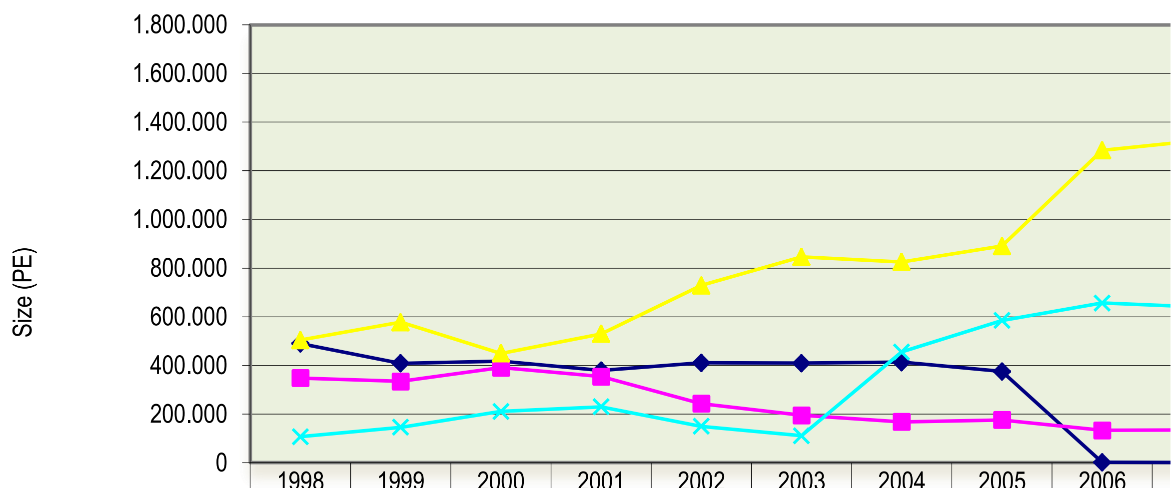


Fig 9: Locations and sizes of treatment plants [22]



	1998	1999	2000	2001	2002	2003	2004	2005	2006
Mechanical	44402	40507	46141	32683	41866	33126	31077	34450	437
Primary	21749	21639	21936	22876	16038	13855	12919	14086	8342

Fig. 10: The quantities of treated wastewater by level of cleaning vs. years [22]



	1998	1999	2000	2001	2002	2003	2004	2005	2006
Mechanical	490150	408855	417500	379055	410900	409550	412850	375000	1500

Fig. 11: Total capacity of MWTPS by stages vs. years [22]

VI. Conclusion

Composition of urban waste water and sludge volume depends on the lifestyle in a particular environment (water use, watering gardens, smaller industrial installations, etc...).

Wastewater treatment system in the European Union member states is unequally developed. Approximately 70% of the EU population is connected to the wastewater treatment plant. This proportion is highest in the Netherlands, where 99 % of the population is connected to the waste water treatment plant. In Spain, Germany, Italy and Austria the share is 90%. The lowest proportion is in Malta, where only 13 % of the population is connected to the waste water treatment plant. According to data from 2010, this share amounts to 54% in Slovenia, which means that we are among the countries where the share of population connected to wastewater treatment plants is small and nearly half the population in Slovenia is still using cesspools [22].

In Europe, the average water consumption is 200 l/(PU day), the amount of pollution is 60 g BPK5/(PU day), while producing 45 g/(PU day) primary sludge and 35 g/(PU day) secondary sludge. Therefore in conventional biological waste water treatment plant, with active sludge, 80 g/(PU day) of sludge is produced.

In recent years, the processes of secondary or tertiary treatment cleans more and more waste water, while the primary treatment processes only are on the fall. The amount of wastewater that was treated with secondary treatment processes, has since 2003 increased by 244%, from 36 million m3 (in 2003) to 88 million m3 (in 2010). In 2003 the extent of tertiary process of waste water treatment was negligible, by the year 2010 the amount of tertiary treated waste water increased to 39 % or 57 million m3 [22].

Operational program for collection and treatment of urban waste water, among other things set the following key objectives:

I. Build wastewater treatment plants with a capacity equal to or exceeding 2,000 PU by 2015, which will provide:

- secondary treatment,
- tertiary treatment on the regions sensitive to eutrophication.
- tertiary treatment for the regions with a load of 10.000 PU or more
- additional microbiological treatment in sensitive areas of bathing water,
- additional microbiological treatment of indirect discharges to groundwater in the area of karst and fractured aquifers,
- tertiary treatment, if the effluent is discharged to the liquid surface water.

II. Build small wastewater treatment plants with a purification capacity equal to or greater than 50 PU and less than 2,000, which will provide:

- secondary treatment with microbiological purification during the bathing season in the region of bathing waters, no later than 31.12.2015
- secondary treatment in regions with a density greater than 20PU/ha no later than 31.12.2017.

References

[1] Dobersek D., Goricanec D., Krope J. Economic analysis of energy savings by using rotary heat regenerator in ventilating systems. IASME Trans., vol. 2, iss. 9, 2005, pp. 1640-1647.

[2] Krope J., Dobersek D., Goricanec D. Economic evaluation of possible use of heat of flue gases in a heating plant. WSEAS trans. heat mass transf., vol. 1, iss. 1, 2006, pp. 75-80.

[3] Zlak J., Agrez M., Dobersek D., Goricanec D., Krope J, Rentability of rotary heat regenerator use in ventilating systems, Strojarstvo, vol. 52, no. 6, 2010, pp. 665-671.

[4] E. Berglez-Matavž, J. Krope, D. Goricanec, Techno-economic comparison of the efficiency of various energy source heating systems. WSEAS transactions on power systems, 2007, vol. 2, iss. 1, pp. 13-20.

[5] M. Umberger, T. Krope,J. Krope , Enegy economy and the protection of environment with building-in insulated windows. WSEAS transactions on heat and mass transfer, vol. 1, no. 1, str. 32-38 (2006).

[6] Crepinšek-Lipus L., Dobersek D., Influence of magnetic field on the aragonite precipitation. Chem. eng. sci., Apr. 2007, vol. 62, iss. 7, pp. 2089-2095.

[7] http://www.arhiv.mop.gov.si/fileadmin/mop.gov.si/pageuploads/zakonodaja/okolje/varstvo_okolja/operativni_programi/operativni_program_komunalne_vode.pdf

[8] http://jh-lj.si/vo-ka/predstavitev/centralna-cistilna-naprava-lj/mehansko-ciscenje

[9] http://www.huber.de/solutions/sewage-treatment-plants/systems-concept-for-centralized-wastewater-treatment.html

[10] http://biteks.si/clanki/1000.

[11] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000

[12] Directive 91/271/EEC concerning urban waste water treatment of 21 May 1991

[13] Environment Protection Act (ZVO-1) Ur.l. RS, št. 41/2004

[14] Water Act (ZV-1), Ur.l. RS, št. 67/2002

[15] Decree on the emission of substances and heat in the discharge of wastewater into waters and public sewage system Ur.l. RS, št. 47/2005

[16] Decree on the emission of substances in waste water discharged from urban waste water treatment plants Ur.l. RS, št. 35/1996

[17] Decree on the discharge and purification treatment of urban wastewater and meteoric water Ur.l. RS, št. 88/2011

[18] Decree amending the Decree on the emission of substances in the discharge of waste waters from small urban waste water treatment plants, Ur.l. 30 / 2010

[19] Rules on initial measurements and operational monitoring of waste water and on conditions for their implementation, Ur. L. RS, št. 54/11.

[20] European Standard EN 12566-3 - Small wastewater treatment systems for up to 50 PE

[21] http://www.uradni-list.si/files/RS_-2007-045-02451-OB~P002-0000.PDF

[22] http://www.arso.gov.si/