International Symposium on Water Management and Hydraulic Engineering

Ohrid/Macedonia, 1-5 September 2009

Paper: **A11**

Wastewater and Landfill Leachate Treatment Plant for the Municipality of Centar Župa

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Abstract. Wastewater from the settlements in the municipality of Centar Župa are discharged into the nearby recipients without any treatment. However, the very low discharge of the rivers, particularly during the summer months results in water quality degradation. For the particular case of the settlements in the municipality of Centar Župa it is necessary to highlight that the location is close to the Debar Lake. As a multipurpose reservoir, beside for energy production, Debar Lake is also used for recreation of the inhabitants of Debar and nearby villages. So, the need for wastewater treatment plant construction is obvious. Also, leachate from the nearby solid waste landfill Centar Župa is planned to be transported and treated together with the wastewater from the settlements. The paper presents the results of the analyses of the wastewater quantities and constituents from the Centar Župa municipality and leachate quantities and leachate composition, mass loading from the wastewater and also from the leachate. Total wastewater quantities and total wastewater flow pollutant concentrations have been calculated. Results of the calculations of the wastewater treatment structures are presented in the paper.

Keywords: Wastewater, landfill, leachate, treatment plants

1 Introduction

Wastewater from the settlements in the municipality of Centar Župa are discharged into the nearby recipients without any treatment. However, the very low discharge of the rivers (particularly during the summer months) results in water quality degradation. For the particular case of the WWTP in Centar Župa it is necessary to highlight that the location is close to the Debar Lake. As a multipurpose reservoir, Debar Lake is also used for recreation of the inhabitants of Debar and nearby villages. So, the need for wastewater treatment plant construction is obvious.

1.1 Site Selection

Wastewaters from the villages: Centar Župa, Bajramovci, Žitinani, Mal Papradnik i Crno Boci is planned to be treated in the Wastewater treatment plant in Centar Župa. Main collectors from Centar Župa and Žitinani are already constructed and gravitate towards location that is planned for construction of the WWTP (labeled as location No. 1 – Fig. 1). Major part of the wastewaters from the other settlements (Mal Papradnik, Bajramovci, Crno Boci) can not reach the WWTP location No. 1 by gravity. Significant part of wastewaters should be pumped in order to be transported to the WWTP location No. 1 and treated.

Location No 1 for WWTP Centar Župa has been selected in previousy performed anlyses. The location is situated about 400 m below the village of Centar Župa in the vicinity of the river Žitinska Reka. The site elevation is 699 -702 m a.s.l. The topographical conditions of the selected site are not favorable for sitting all the necessary structures of the WWTP for treating leachate and wastewaters, mainly due to the great slope of the terrain on the both sides of the river. Also, for sitting of the WWTP structures it is necessary river training works of Žitinska Reka to be performed. A great part of the wastewaters from the villages situated below the location No. 1 (Fig. 1) should be transported to the WWTP by pumping.

The designers recommend further analysis of alternative location (labeled as location No. 2) as possible location of WWTP for the next design phase.

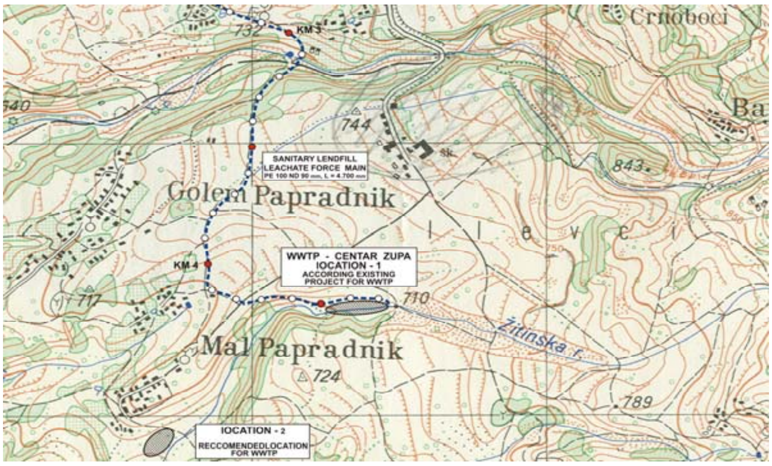

Fig. 1. Review map of possible location for WWTP "Centar Župa"

The recommended location No. 2 is situated below the village of Mal Papradnik at 670 m above sea level. Compared to the location No. 1, alternative location No. 2 (Fig. 1) has the following advantages:

- favorable topographical conditions for sitting all the necessary structures of the WWTP, and
- major part of the wastewaters can be transported to the location of the WWTP by gravity (no need of pumping).

According to the available data, there is a necessity of additional construction of around 800 m length wastewater collector from Centar Župa and Žitinani.

1.2 Wastewater Constituents

Typical data on the total quantities of wastewater discharged per capita per day (dry weight basis) from individual residences are: BOD_5 = 60 (g/capita/day), COD = 120 (g/capita/day), N = 11 (g/capita/day), P= 1.8 (g/capita/day)
Wastewater flow pollutant concentrations are the following: $C_{BOD_5} = 300 \quad g/m^3$, $C_{COD} = 600 \quad g/m^3$, $C_{TKN} = 55 \quad g/m^3$, and $C_P = 9 \quad g/m^3$

1.3 Effluent Quality

The WWTP effluent quality is suppose to meet EU Directive (91/271/EEC) standards and existing national legislation -Water Law (Off. Gazette of RM, No. 4/98). According to the standards the effluent should fulfill the standards of $BOD \leq 25 \ (mgO_2/L)$ and $TSS \leq 35 \ (mg\, SS/L)$. For the particular case of the WWTP in Centar Župa which is close to the Debar Lake, a lake with high water quality, the biological treatment is designed for BOD removal and nitrification.

2 Wastewater Quantities and Constituents from Communal Wastewater and Leachate from Sanitary Landfill

Wastewater treatment plant in Centar Župa is planned to treat wastewaters from the villages: Žitinani, Centar Župa, Bajramovci, Crno Boci and Paparadnik. The number of population growth until 2030 are 3000 equivalent peoples.

Wastewater flow rates can vary depending on the quantity and quality of the water supply; rate structure; and economic, social, and other characteristics of the community. For the Centar Župa region, the wastewater norm per capita per day is assumed on 200 l/capita/day.

Design Flow rates. The development and forecasting of flow rates is necessary in order to determine the design capacity as well as the hydraulic requirements of the waste treatment plant. Flow rates are predicted for the time horizon 2030 as end of the planned period (2030).
The flow rate from various case and components are present in Table 1. In Table 2 are presented the constituent of mass loading for various cases of BOD_5, COD, TKN and P, while in Table 3 are presented the constituent concentration for various case. In the previous three table are present flow rate, mass loading and constituents concentration

for communal wastewater, leachate from sanitary landfill and together dilute water from communal wastewater and leachate, also in Table 3 are presented BOD5/COD ratio.

Table 1. Flow rate for various case

	Q_{aver}	dry flow $Q_{max/d}$	wet flow $Q_{max/d}$	Q_{min}
	(m^3/d)	*(m^3/h)*	*(m^3/h)*	*(m^3/h)*
Community	600	33,33	66,67	16,25
Leachate	25	1,05	3,6	0
Together	625	34,38	70,27	16,25

Table 2. Constituent of mass loading for various case

	BOD_5	COD	TKN	P
	(kg/d)	*(kg/d)*	*(kg/d)*	*(kg/d)*
Community	180	360	33	5,4
Leachate	25	125	5	0,625
Together	205	485	38	6,025

Table 3. Constituent concentration for various case

	C_{BOD5}	C_{COD}	C_{TKN}	C_P	BOD/COD
	(mg/L)	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(%)*
	Average flow				
Community	300	600	55,0	9,00	0,50
Leachate	1000	5000	200,0	25,00	0,20
Together	328	726	60,8	9,64	0,45
	Maximum dry weather flow				
Community	225	450	41,3	6,75	0,50
Leachate	1000	5000	200,0	25,00	0,20
Together	249	587	46,1	7,31	0,42
	Maximum wet weather flow				
Community	113	225	20,6	3,38	0,50
Leachate	1000	5000	200,0	25,00	0,20
Together	126	298	23,8	3,70	0,42

Source: McBean Edward, Rovers F.A., Farquhar G.J., 1995, Solid Waste Landfill Engineering and Design, Prentice Hall

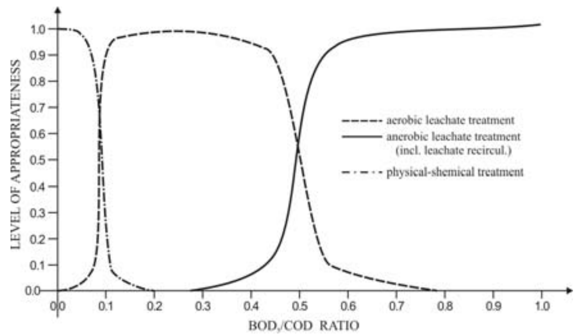

Fig. 2. Proposed appropriateness levels for biological and physical-chemical leachate treatment

As BOD_5:COD ratio for leachate water is in the range of 0.2, until BOD_5:COD ratio communal wastewater and dilute water from communal wastewater and leachate is about 0.42 to 0.5. According to the previous values and the graph from Fig. 2 (McBean *et al.*), aerobic biological treatment is appropriate.

3 Technological Scheme of the Wastewater Treatment Plant

The technological scheme of the wastewater treatment plant for combined treatment of domestic wastewaters from the settlements and leachate from the solid waste landfill is made according to the consulted literature for such treatment, expert knowledge, local conditions and under the expert consultancy provided by the donor. The main aim of the technological scheme is to enable treatment of leachate in combination with domestic sewage at the wastewater treatment plant in Centar Župa using more simple treatment techniques in the terms of operation and maintenance.

The technological scheme of the wastewater treatment plant for the wastewaters from the settlements and the leachate from the landfill is consisted of separate processes and facilities. The treatment system include: fine screening, grit chamber, imhoff tank, trickling filter, secondary clarifier, disinfection with contact chamber, and drying beds (Fig. 3).

Also other operations and facilities like: pump stations, flow meter chamber, distributor chamber, pipe network for treated water, recirculation, primary and secondary sludge are included in the WWTP.

3.1 Leachate Tank

Leachate aeration tank (No. 3 in Fig. 3) is designed for two days accumulation of the leachate from the municipal solid waste landfill in Centar Župa. Leachate is aerated in the leachate tank and then discharged before the fine screens. Leachate is transported from the municipal solid waste landfill in Centar Župa toward WWTP by pressurized pipe. The pipe diameter is designed to be OD 90 mm and the length is around 4700 m.

3.2 Fine Screening

Fine screens (No. 5 in Fig. 3) are designed to hold floating materials, because these floating materials might interfere the following treatment operations. The screened material, is discharged and sacked in a suitable container and than transported into the municipal solid waste landfill Centar Župa.

Fine screen type FC Screw filter is recommend. The screw filter is suitable for many applications, in particular for the micro-screening. The type FC consists of one multifunction screw and a semi-cylindrical filtering screen, which is, in its turn, formed by longitudinal wedge wire bars. The screw is controlled by a sturdy gear motor ensuring the filtering screen cleaning, the lifting, compacting and sacking of the screened material.

The screened material, before being discharged and sacked in a suitable container, is submitted to compaction and de-watering involving an about 50% decrease in weight. The screw filter is able to totally eliminate the suspended solids having diameter bigger than the size of the filtering gap, and considerably cut down the polluting load.

3.3 Grit Chamber

Grit Chamber (No. 6 in Fig. 3) is designed for separation of solid inorganic particles, mainly for sand removal. The type of the recommended grit chamber is Vortex-type grit chamber. Wastewater enters and exits tangentially. The rotating turbine maintains constant flow velocity, and its adjustable pitch blades promote separation of organics from the grit. The action of the propeller produces a toroidal flow path for grit particles. The grit settles by gravity into the hopper in one revolution of the basin's contents. Solids are removed from the hopper by a airlift pump.

The sand is pumped towards sand compartment (No. 7), and than transported into the municipal solid waste landfill Centar Župa.

3.4 Primary Sedimentation Tank

Primary sedimentation – Imhoff tank (No. 9 in Fig. 3) is a primary sedimentation process which performs two functions, the removal of settleable solids and the anaerobic digestion of those solids. The Imhoff tank consists of a two-story tank in which sedimentation occurs in the upper compartment and the settled solids are deposited in the lower compartment. Solids pass through a horizontal slot at the bottom of sloping sides of the sedimentation tanks to the unheated lower compartment for digestion.

The Imhoff tank has no mechanical parts and is relatively easy and economical to operate. It provides sedimentation and sludge digestion in one unit and should produce a satisfactory primary effluent with a suspended solids removal of 40% to 60% and a BOD reduction of 15% to 35%. The two-story design requires a deep overall tank. The Imhoff tanks is best suited to small municipalities and large institutions where the tributary population is 5,000 or less.

Also sludge from secondary clarifier (No. 19 in Fig. 4) enters into Imhoff tank. Stabilized sludge is pumped from the Imhoff tank towards drying beds (No. 20). The aim of the drying beds is to dewater the sludge. The drained water from the drying beds is returned into the treatment process (No. 21) at the pump station (10).

3.5 Trickling Filters

Trickling filters (TFs) (No. 11 in Fig. 3) are used to remove organic matter from wastewater. The TF is an aerobic treatment system that utilizes microorganisms attached to a medium to remove organic matter from wastewater. These systems are known as attached-growth processes.

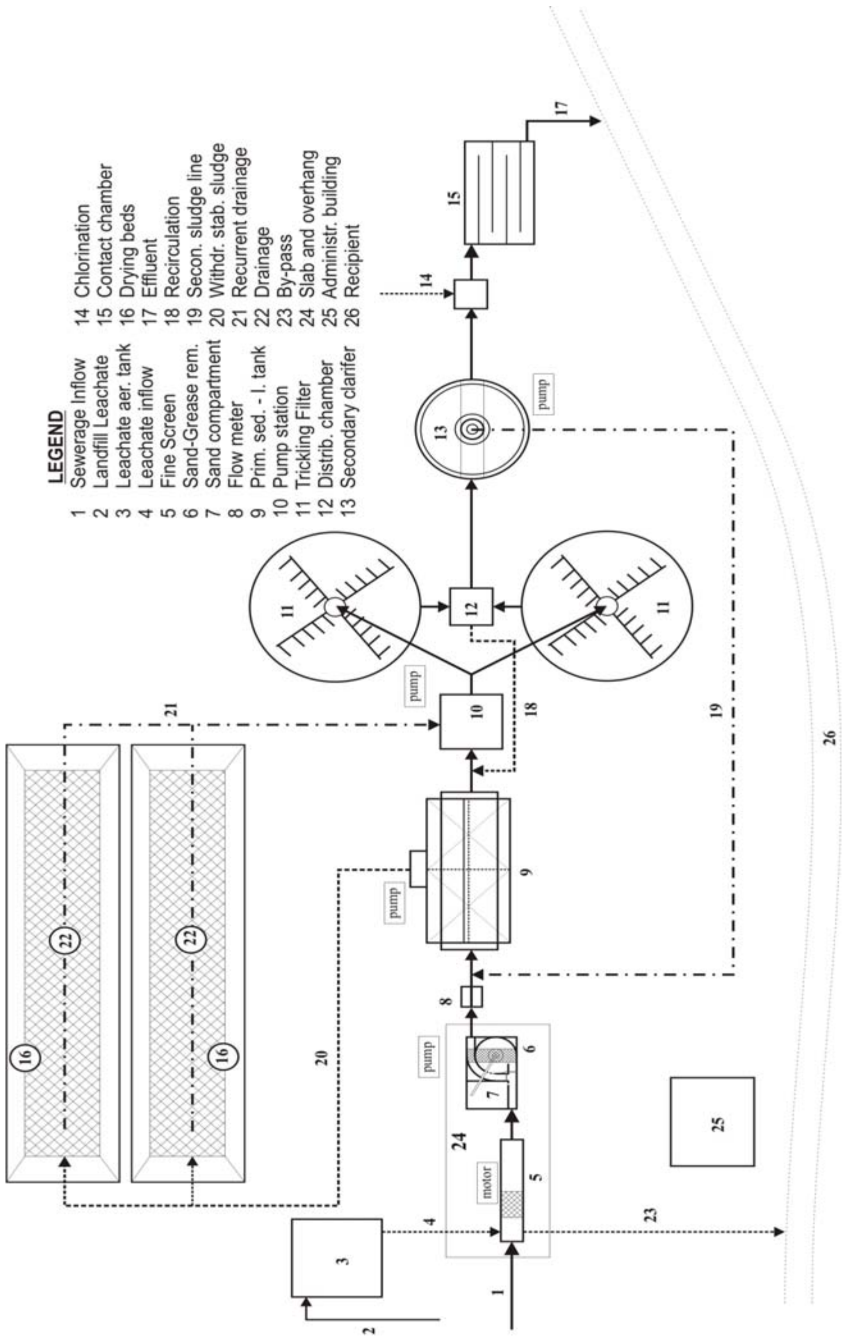

Fig. 3. Schematic flow diagram of WWTP Centar Župa

TFs enable organic material in the wastewater to be absorbed by a population of microorganisms (aerobic, anaerobic, and facultative bacteria; fungi; algae; and protozoa) attached to the medium as a biological film or slime layer (approximately 0.1 to 0.2 mm thick). As the wastewater flows over the medium, microorganisms already in the water gradually attach themselves to the rock, slag, or plastic surface and form a film. The organic material is then degraded by the aerobic microorganisms in the outer part of the slime layer. As the layer thickens through microbial growth, oxygen cannot penetrate the medium face, and anaerobic organisms develop. As the biological film continues to grow, the microorganisms near the surface lose their ability to cling to the medium, and a portion of the slime layer falls off the filter. This process is known as sloughing. The sloughed solids are picked up by the under drain system and transported to a clarifier for removal from the wastewater.

Design criteria. A TF consists of permeable medium made of a bed of rock, slag, or plastic over which wastewater is distributed to trickle through. Rock or slag beds can be up to 60 m in diameter and 0.9-2.5 m deep with rock size varying from 2.5-10.2 cm. Most rock media provide approximately 150–40 m^2/m^3 of surface area and less than 40 percent void space.

The design of a TF system for wastewater also includes a distribution system. Rotary hydraulic distribution is usually standard for this process. Recently some distributors have been equipped with motorized units to control their speed. Distributors can be set up to be mechanically driven at all times or during stalled conditions.

In addition, a TF has an under drain system that collects the filtrate and solids, and also serves as a source of air for the microorganisms on the filter. The treated wastewater and solids are piped to a settling tank where the solids are separated. Usually, part of the liquid from the settling chamber is re-circulated to improve wetting and flushing of the filter medium, optimizing the process and increasing the removal rate.

Typical application, process loadings criteria, and effluent quality are summarized in Table 4.

Table 4. Loading based on packing surface area

Application	Loading		Effluent quality	
	unit	range	unit	range
BOD removal	kgBOD/m^3 d	0.3-1.0	BOD, mg/L TSS, mg/L	15-30 15-30
Combined BOD removal and nitrification	kgBOD/ m^3 d	0.1-0.3	BOD, mg/L	< 10
	gTKN/ m^2 d[(a)]	0.2-1.0	NH4-N, mg/L	< 3

Intermediate trickling filter with rock size (30 to 50 mm) packing with specific surface area (80 to 100) m^2/m^3, and filter depth 2.5 m is recommended.

Design for BOD removal and Nitrification. The volume of rock packing required for 70 % TKN removal in trickling filter with depth of 2.5 m for the given wastewater characteristic is determined.

The specific area of rock packing material is assumed on 90 m^2/m^3. Hydraulic application rate and mass loading are presented in Table 5.

Table 5. Hydraulic application rate and mass loading

Wastewater characteristics		
parametar	unit	value
Flow	m^3/d	925
BOD_5	g/m^3	161
TKN	g/m^3	41.45
TSS	g/m^3	70

Determine the specific TKN removal rate:

$$R_n = 0.82 \cdot \left(\frac{BOD}{TKN}\right)^{-0.44} = 0.82 \cdot \left(\frac{161}{41.45}\right)^{-0.44} = 0.82 \cdot (3.884)^{-0.44} = 0.45 \quad (1)$$

Determine the TKN removal in dry weather:

$$Q_{\max/d} = Q_{av/d} \cdot k_{\max} + 25 = 600 * 1.33 + 25 = 825 \quad (m^3/d) \quad (2)$$

$$TKN \text{ remov} = 0.70 \cdot 41.45 \cdot 825 = 23937.375 (gTKN/d) \quad (3)$$

Determine the required surface area (m^2) of packing:

$$A_S = \frac{23957}{R_n} = \frac{23937.375}{0.45} = 53194.17 \quad (4)$$

Determine the volume (m^3) of packing material:

$$Vol = \frac{53194.17 \text{ m}^2}{90 \text{ m}^2/m_3} = 591 \quad (5)$$

Determine the horizontal surface (m^2) of trickling filter:

$$A = \frac{volume}{depth} = \frac{591}{2.5} = 236.40 \quad (6)$$

- Hydraulic loading in dry weather:

$$q = \frac{Q}{A} = \frac{825}{236.40} = 3.49 \quad (m^3/m^2 d) \quad (7)$$

or (0.040 *L/m2 s*)

- Hydraulic loading in wet weather:

$$q = \frac{Q}{A} = \frac{1625}{236.40} = 6.87 \quad (m^3/m^2 d) \quad (8)$$

or (0.0796 *L/m2 s*)

- Diameter of Trickling filter:

$$D = \sqrt{\frac{4 \cdot A}{2 \cdot 3.14}} = \sqrt{\frac{4 \cdot 236.4}{2 \cdot 3.14}} = 12.27 \qquad (9)$$

Two trickling filters with diameter each D = 12.5 (m) are accepted.
To meet the minimum hydraulic application rate of 0.5 (L/m^{2}s) recirculation will be required.
Determine the BOD loading based on volume and surface area:

- Loading based on volume:

$$BOD\,load = \frac{0.7 \cdot 205\ kgBOD/d}{\frac{12.5^2 \cdot 3.14}{4} \cdot 2\ m^3} = \frac{0.7 \cdot 205\ kgBOD/d}{613.28\ m^3} 0.23\ \ (kgBOD/m^3 d) \qquad (10)$$

- Loading based on area:

$$BOD\,load = (0.23\ \ kgBOD/m^3 d)\left[1/90\ \ m^2/m^3\right] \cdot (10^3\ \ g/kg) = 2.55\ \ (gBOD/m^2 d) \qquad (11)$$

Determine the volumetric oxidation rate (VOR):

- VOR in dry weather

$$VOR = \frac{\left[S_o + 4.6 \cdot (NO_x)\right] \cdot Q}{V \cdot (10^3\ \ g/kg)} = \frac{\left[161 + 4.6 \cdot (0.8 \cdot 41.45)\right] \cdot 825}{613 \cdot 1000} = 0.42\ \ (kg/m^3 d) \qquad (12)$$

- VOR in wet weather

$$VOR = \frac{\left[S_o + 4.6 \cdot (NO_x)\right] \cdot Q}{V \cdot (10^3\ \ g/kg)} = \frac{\left[161 + 4.6 \cdot (0.8 \cdot 41.45)\right] \cdot 1625}{613 \cdot 1000} = 0.83\ \ (kg/m^3 d) \qquad (13)$$

The computed value for BOD loading, based on the packing material surface area, is within the range reported by Parker and Richards (1986). The computed value for VOR in wet weather is in range from 0.75 – 1.0 (Daigger, 1994), but in dry weather is little lower.
According to the previous calculations, and also taking into consideration both BOD removal and Nitrification, two intermediate trickling filters with diameter D=12.5 m with height of filter media 2.5, and recirculation R=1 are accepted.

3.6 Secondary Clarifier

Secondary clarifier (No. 13 in Fig. 3) which receive the biologically treated flow undergo zone or compression settling. Sludge from the bottom of the sludge compartment is re-circulated (No. 18) before Imhoff tank. The constitutive part of the secondary clarifier is denitrification compartment. Denitrification process enables oxidation of nitrates in gas nitrogen.

3.7 Disinfection

Chlorination (No. 14 in Fig. 3) is the most widely used method of disinfection and is accomplished with gaseous chlorine. For small treatment plants, liquefied chlorine gas is delivered in pressurized containers usually about 45 kg cylinders.

The design of any attendant chlorination facility at a wastewater plant must provide automatically controlled forced venting of chlorinator and chlorine tank storage rooms, and a chlorine contact chamber (No. 15) with a detention period of not less than 20 min following chlorine injection.

3.8 Dewatering

Dewatering of the sludge is on drying beds (No. 16 in Fig. 3). Drying beds are flat areas separated by banks or concrete partition, where stabilized sludge from Imhoff tank is deposited. The bottom of drying beds will be covered with geomembrane (synthetic foundation protective layer). Drainage layer will be set on the bottom of the drying beds. A drainage pipe (No. 22) for drained water collection and transportation will be set.

Drained water from the drying beds is recirculated into the treatment process (No. 21). Dewatered sludge is transported and disposed of into the municipal solid waste landfill in Centar Župa.

3.9 Other structures

Wastewater treatment plant is designed with all surrounding facilities for small WWTP such as: administration building with laboratory (approximate area of 50 m^2). Considering topographical and hydrological conditions of the terrain at the WWTP site it is necessary river training works of Žitinska Reka to be performed. In addition, corrections of the alignment of the access road and construction of internal road are necessary.

4 Conclusions

As a result of the performed analyses of the complex treatment plant for waste water and leachate, the following conclusions can be made:

- There are high oscillations of the leachate quantity and quality during time. Leachate contains many constituents and its quality is multidimensional. Due to that, when designing leachate treatment plant, special attention should be paid on the leachate design parameters in terms on its quantity and quality.
- Selection of the technological scheme of the wastewater treatment plant for combined treatment of domestic wastewaters and leachate from the solid waste landfill should be made very carefully, taking into consideration the latest scientific achievements, expert knowledge, local conditions and the necessity for operation and maintenance.

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