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Operation description and physicochemical characteristics of influent, effluent and the tertiary treatment from a sewage treatment plant of the Eastern Region of Cyprus under warm climates

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ABSTRACT

Urban wastewater systems, having sewer system, wastewater treatment plant and receiving water as their main elements, can be found throughout the world. Many of them are operated with little or no control. Characterization of municipal wastewaters has been the subject, or the indispensable starting point, of many studies. This paper (as there are a few studies available in the literature) deals with the operation description and characterization of the phases of influent (municipal and mainly domestic liquid waste), the secondary treated sample (effluent) and the tertiary as well as the characterization of the sewage sludge from the sewage treatment plant (STP) of the Municipalities of Paralimni and Ayia Napa in the eastern of Cyprus. The area presented with a long period of warm and high temperature conditions (>27 °C, and during summer > 33°C). The BOD_5 and the COD presented to increase from year to year. The tertiary sample does not have any pathogens bacteria, while the COD and BOD_5 presented less than 75 and 5 ppm respectively and is suitable for agricultural purposes. The average monthly flow of Influent varies from 88,625 m^3 to 382,153 m^3. The sludge almost 4,200 *t*/*y* does not present with significant consecration of have metals. However, the sewage sludge contains high concentration of organics and phosphorus and with further treatment like composting may be used in agriculture purposes. From year to year the average treated $KgBOD_5$ per month is from 27,093 to 120,859 the average KWh per month from year to year is from 90,124 to 332,037 (total KWh/*y* 2.12–2.25 million), the total KWh/$KgBOD_5$ per month is from 1.97 to 3.13, while the total KWh/m^3 of waste ranges from 0.62 to 1.36. The efficiency of the STP is for BOD_5 98.5–100%, for SS is from 97.99–98.98%, the TN from 72.46–94.69%, the NH_4 99.98% and the TP from 15.17–99.12%. At the same time, the total chemical consumption chlorine, polymer, and lime were 641–2,675 kg/m, 1,064–4,586 kg/m and 20–5,400 kg/m respectively. Waste waters characterization is essential for the optimization of the operation of such systems as well as for the design of wastewater treatment systems in rural areas under warm climate conditions.

Keywords: Wastewater treatment plant; STP; Liquid and solid characteristics; Energy consumption; Chemicals consumption; Sludge

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1. Introduction

In the greater eastern area of Cyprus are the Municipalities of Paralimni and Ayia Napa. These municipalities with a stable population of almost 22,000 citizens (19,000 and 3,000 respectively) are the main economical lungs of the island due to the fact that in this area are the largest hotel resorts. During the winter the population is estimated at 22,000 citizens but from the beginning of April until October it is estimated at 75,000—with tourists per day. Cyprus, "The island of Venus" is the major Tourist destination in the eastern Mediterranean. With almost 2 million tourists per year who visit Cyprus, from all around the world, and especially the European Union, the two Municipalities have the ability to quest almost the 35–40% per year of the total tourists that visit the Island [1].

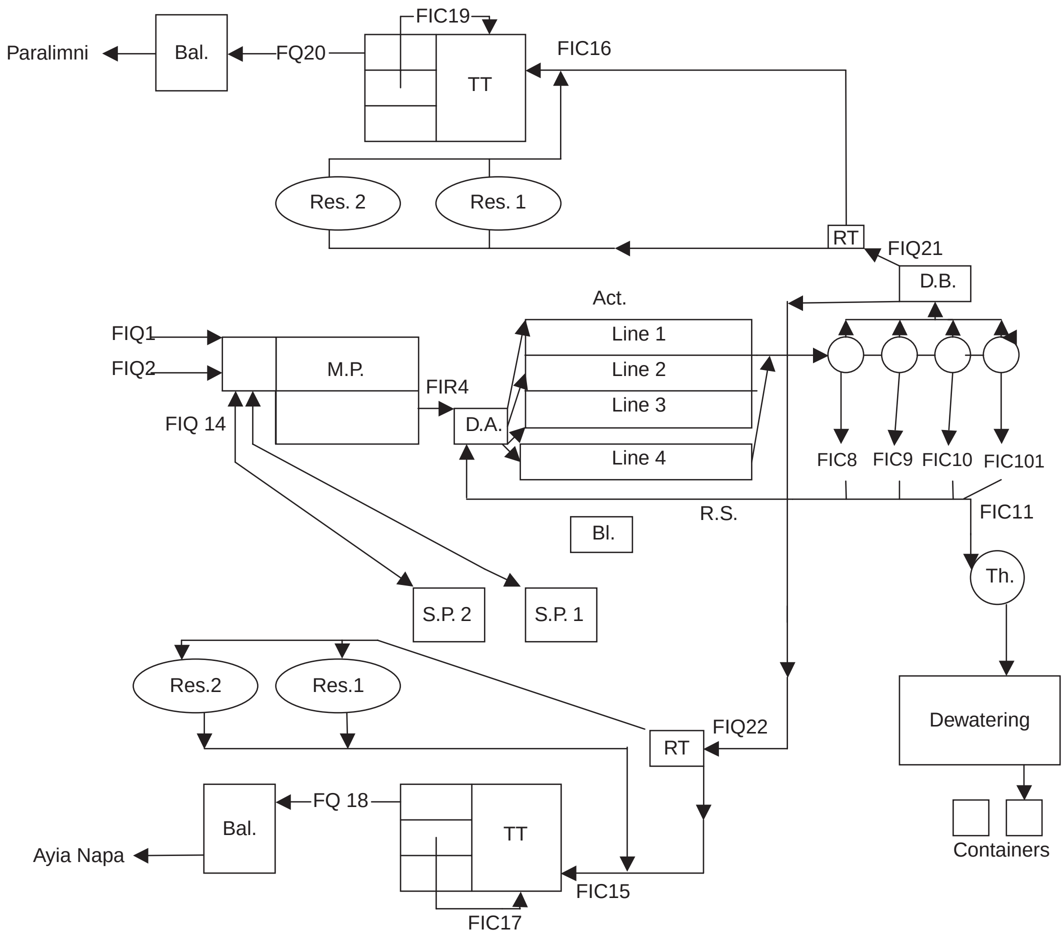
Wastewater treatment systems have been designed to minimize the environmental impacts of discharging untreated wastewater. Different options for wastewater treatment have different performance characteristics and also different direct impacts on the environment. Some systems have high energy usage, some use materials that have a high embodied energy (e.g. plastics) others occupy a lot of land [2]. The objective of sewage treatment is to produce a disposable effluent without causing harm or trouble to the communities and prevents pollution.

1.1. STP Process Description (Fig. 1)

Because the treated effluent will be used for irrigation the treatments shall consist of primary pre-treatment, secondary and tertiary stages and disinfection. The disinfected tertiary effluent will be led into the daily balancing reservoir and the surplus secondary treated effluent stored without disinfections into the separate storage reservoirs of each municipality, volumes 200,000 m^3 (Paralimni) and 150,000 m^3 (Ayia Napa). The tertiary stage and chlorination occur after the reservoirs before discharging the water to irrigation. The treatment plant also receives septage sludge. For emergency situations there will be two spill ponds, total volume 50,000 m^3, in connection with the mechanical pre-treatment stage. The wastewater from Paralimni and Ayia Napa pumped in a separate force mains to the treatment plant, while each influent is measured. The proposed wastewater treatment process consists of pre-treatment for wastewater and septage, secondary-biological treatment based on activated sludge method (extended aeration) and a tertiary treatment stage after reservoirs. Finally, the water will be disinfected and conveyed in the tourist areas for irrigation use. The secondary treated water stored in reservoirs to be used for irrigation while surplus water, which cannot be stored, will be led to forest areas for irrigation. During low flows and at the beginning of the operation of the treatment plant (coverage of sewers connected into the system <50%) two or three of the four lines of the aeration stage shall be closed down. Also, the secondary clarifiers and the tertiary units shall be operated to 50 or 75% capacity during low flow.

The influence enters the plant via screening. There is one mechanically operated coarse screen and two parallel lines for mechanically operated fine screens. Hand raked screen also is located in the bypass channel. Normally, influent flows to the mechanical screens, each of which can be bypassed to the hand raked screen. Timers and level sensors control the operation. Also, the water level difference on the channel starts the function of the cleaning system. Screenings are removed from the screens to a screening compactors system directly. Screenings are then conveyed to a transportable bin for disposal by landfill. The wastewater then flows gravitationally into two aerated grit removal basins. Pre-aeration also reduces odor emissions. Air is supplied to the bottom of the basin and the airflow remains constant. Sand–water mixture flows into a tank and is conveyed into the screenings bin. Overflow from the sand tank is led back to sand removal basins. Influent flows to the distribution basin A and mixed with the returned sludge while lime is possible added to the influent at this point. Then the mixture liquid flows into four parallel aeration. The aeration process is extended. Oxidation of ammonia to nitrate takes place during aeration. Nitrification consumes alkalinity from the water; consequently pH must be adjusted by added lime. Aeration takes places with submerged aerators (air-diffusers). When bottom aeration is applied, air is fed from blowers. Concentration of oxygen is kept at the required level by controlling with valves the airflow entering the process. The flow of air from blowers is controlled automatically by oxygen meters which are applied in activation lines. Air pressure in the main pipes from the blowers is kept constant (Fig. 1).

Mixed liquor flows by gravitation from aeration into four parallel secondary clarifiers. Clarified effluent by gravity flows to tertiary units of the process. There are two tertiary units one for each municipality. Most of the sludge sediment on the bottom of clarifiers return by pumping to the distribution basin A. Excess sludge produced in the biological process is pumped to the aerated buffer tank and from there by pumping sludge flows to the dewatering unit (two mechanical thickeners and two centrifuges). Secondary treated effluent in distribution basin B shared between the two tertiary units according to the influent flow proportion. Tertiary stage is separated for Paralimni and Ayia Napa. It comprises chemical coagulation and up/down flow sand filtration. When chemical precipitation is included coagulant



FIQ1 = Influent from Paralimni
FIQ2 = Influent from Ayia Napa
FIQ3 = Septage transported
FIR4 = Influent to activation (Wastewater for treated)
FIQ14 = Influent from Spill pond
D.A. = Distribution point A (mixture of influent and returned sludge)
S.P. = Spill pond (for emergence situation)
M.P. = Mechanical pretreatment (course screen, fine screens, grid chamber)
Act. = Activation lines (anoxic, anaerobic and oxic zones in each activation line)
Bl. = Blower room
FIC8 to FIC101 = Returned sludge flow meter
FIC11 = Excess sludge flow meter
D.B. = Distribution point B (secondary treated water share to Paralimni tertiary or Ayia Napa tertiary)
FIQ21 = Secondary effluent to Paralimni
FIQ22 = Secondary effluent to Ayia Napa
R.T. = regulating tank (distributed the effluent to tertiary or reservoirs)

Res. = reservoirs (2 for Paralimni 100000m^3/each and 2 for Ayia Napa 75000m^3/each)
T.T. = Tertiary treatment

Paralimni
FIC16 = Effluent to tertiary
FQ 20 = Treated water to Paralimni for irrigation
FIC19 = Backwash water for cleaning the filters
Bal. = daily balancing tank (6000m^3)

Ayia Napa
FIC15 = Effluent to tertiary
FQ 18 = Treated water to Ayia Napa for irrigation
FIC17 = Backwash water for cleaning the filters
Bal. = daily balancing tank (5000m^3)

Dewatering = dewatering unit (2 mechanical thickeners and 2 centrifuges)
Th. = Sludge to aerated Thickener
Containers = Skips of dry sludge (for transportation)

Fig. 1. Flow diagram of Paralimni and Ayia NAPA wastewater treatment plant.

is mixed in wastewater in rapid mix chamber. Wastewater then flows into flocculation basins where it is stirred with slow speed stirrers to allow coagulation and forming of flocs. Coagulant aid is added with demand. Chemical flocs and residual solids (organic and solids) are removed in flotation sand filtration stage.

The secondary treated effluent from the biological stage flows to sand filters for removal of residual solids. The tertiary treated water after chlorination flows by gravity into a daily balancing basin. Filter beds are washed with filtered effluent and pressurized air. Backwash water flows into a dirty water basin and recycled to mechanical pre-treatment unit. Filtered effluent flows to disinfections with chorine. Chlorination takes place with gaseous chlorine. Chlorine dosing is flow controlled. Occasionally sand filters are washed with chlorinated water pumped from this basin. From chlorinated water basins water flows by gravity to daily balancing tank. Treated effluent will be used for irrigation. The spill pond will be equipped with diffuser aerators and propeller mixers. From the pond wastewater is pumped to the process (to screening). Flow diagram of Paralimni and Ayia NAPA wastewater treatment plant is shown in Fig. 1 while Fig. 2 presents the location of the STP.

Septic sludge is the waste from septic tanks that are cleaned out periodically to prevent septic disposal beds from clogging. Septic tank wastes are transported to settling lagoons; the solids from these lagoons are removed as the lagoons reach capacity [3]. The wastewater treatment plant includes facilities for receiving and treating septage transported to the plant in vehicles. Septage is taken after appropriate pre-treatment to the wastewater process. Septage from tanks is emptied through pipes into a basin with a sand trap preventing grit entering the equalization basin. The equalization basin is equipped with re-circulating pumps and aeration to minimized odors. The storage volume of the basin meets the demand for one day. Septage arrives to the plant during daytime and shall be pumped into the wastewater process as side flow whenever there is treatment capacity available. Industrial septage sludge is not transferred to the wastewater treatment plant. Septages are usually presented with COD from 5,300–7,200 ppm, BOD_5 varies from 2,500–3,500 ppm and the pH varies from 6.4–7.1.

1.2. Sludge handling

Sludge is separated from wastewater in secondary clarifiers. Secondary sludge (excess sludge from biological process) is pumped from the bottom of the secondary clarifiers into aired buffer tank and from there by pumping flows to the dewatering unit (two mechanical thickeners and two centrifuges). Pumping is controlled with timers and level sensors. The thickeners are equipped with torque measurement. Thickened sludge is pumped with two pumps to centrifuges to be dewatered. Polymer is dosed during the dewatering process. Each of the two sludge lines controls a respective polymer pumps. Preparation and dosing of polymer solution takes place automatically. Dewatered sludge falls from the centrifuges on a conveyor screw at the end of each equipment. Dewatered sludge is stabilized with lime (CaO). Lime is dosed from lime silo with dry feeder. Mixing of sludge and lime occurs in a conveyor screw. Stabilized sludge is transferred by means of a belt conveyor to the transported to the landfill site.

Sewage sludge, also referred as biosolids, is a byproduct of sewage treatment processes [4]. The sludge is classified as difficult solid waste that requires special treatment before the disposal because of the noxious properties. The sludge contains salts, organic pollutants and mainly heavy metals. Knowledge of heavy metal content and its form distribution in the sludge are the most important factors in selecting the disposal alternatives, [5–11].

1.3. Sewage amount

There is no major water consuming industry in the project area, and according to the available development plants the situation will remain the same in the future. In the nearby area there are mainly tourist activities like Hotels, restaurants, bars, pubs, night clubs, and water parks. A total of 115 hotels and apartments in the Municipality of Paralimni and 185 hotels and apartments in the Municipality of Ayia Napa, are presented, almost 6,000 houses, one water park (100,000 m^2 approximately), eight petrol stations and 12 cars cleaning services, approximately 15 machinist's craftsmanship, small industries like bakeries, confectioneries, car wash, food suppliers, supermarkets, schools, six clinical laboratories, two private clinics and one public hospital, football fields and athletic activities, two chicken farms (approximately 30,000 chicken/y), two big laundries, one concrete plant and some small industrial activities which don't produce liquid waste consist the main activities of the area [1].

The water consumption arising from small-scale industries is included in per capital/per bed consumption figures with the daily visitors in the tourist area. Intrusion of storm water/groundwater into the sewer system is omitted as the sewers will be installed above the ground water table and the possible storm water leakage would occur during the low tourist season when water consumption is low. Total population served is 120,000 including residents, tourist and labor force in tourism. The number of tourist beds used as the dimensioning basis is 44,000 in Paralimni and 36,000 in

Fig. 2. Location of STP.

Ayia Napa [1]. The estimated total wastewater flow is 28,000 m^3 d^{-1} about, during the peak season and about 18,000 m^3 d^{-1} during the low season. The average flow (yearly average) is estimated to be about 20,000 m^3 d^{-1}.

This paper described one of the few studies available in the literature, the phases of the STP and chemical characterization of influent, effluent, and the tertiary treatment as well as, the energy consumption, the chemical consumption, the sludge characteristics, of the wastewater treatment plant from the Municipality of Paralimni and Ayia Napa in Cyprus. The plant is working under warm climates conditions.

2. Materials and methods

The unit figures of influent characteristics (including wastewater load flow values) used in calculating guaranteed performance must be valid over the average of the following minimum and maximum flows and loads (Tables).

The sample from influent is collected electronically by using an automatic collector, which has the ability to collect a homogenized sample of a total volume of 3 l in a total time of 24 h. The other sample (1 l d^{-1}) from the effluent and the tertiary are collected manually before the analyzing. Also, the sludge is collected manually before the analyzing.

The liquid samples daily are analyzed for the last years in the following parameters: pH, electronic conductivity (EC), temperature (T), suspended solids (SS), BOD_5, COD, total phosphorus (TP), alkalinity, total nitrogen (TN), NO_3, NO_2, total coliform, faecal coliform, NH_4, fats and oils, total Cl_2, fat and oils (FOG), mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), settled sludge volume, sludge volume index (SVI), volatile suspended solid (VSS). All the parameters are determined according to Standards Methods [12,13]. The sampling point was the influent (I), effluent (E), tertiary of Paralimni (TPA), and tertiary of Ayia Napa (TAN). Several times per year sludge is analyzed for total phosphorus (TP), organic matter (OM), ash, total organic carbon (TOC) content, total kjeldahl nitrogen (TKN), ammonia content, VSS, moisture, pH. Several times per year (every 3 months) sludge, I, E, TP and TAN were analyzed for heavy metals such as Cd, Cu, Cr, Ni, Pb, Zn, Mn, Co, Hg, As, Fe, Na, K, Ca, Mg, CN, B according to several methods describe elsewhere, [11,12–16]. Statistical analysis (Standard Deviation) was performed using Microsoft Excel 2003 (Microsoft Corp).

3. Results and discussions

In the past, domestic wastewater treatment was basically confined to organic carbon removal. In recent years, increasing pollution in the receiving waters and more stringent effluent limitations for discharges to sensitive zones have been the driving force in developing and implementing new treatment techniques to control, in addition to carbon, other significant parameters such as nitrogen, phosphorus, and priority pollutants. This new approach for wastewater management has greatly affected the concept of wastewater characterization [17]. Estimation of wastewater flow and influent concentrations in small localities is still commonly based on bibliographic data, this criterion producing important fails in system design and adequacy to the socio-economical situation of these localities. The consequence is that absence of maintenance is very common in small wastewater treatment plants. To avoid this problem, regional government and other administrations are nowadays interested in the study and detailed characterization of wastewater previously to plant design in small localities [18].

Sewage treatment, or domestic wastewater treatment, is the process of removing contaminants from wastewater and household sewage, both runoff (effluents) and domestic. It includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants. Its objective is to produce a waste stream (or treated effluent) and a solid waste or sludge suitable for discharge or reuse back into the environment. Residences, institutions, and commercial and industrial establishments create sewage. Raw influent (sewage) includes household waste liquid from toilets, baths, showers, kitchens, sinks, and so forth that is disposed of via sewers.

3.1. Characterization of municipal wastewaters

Characterization of municipal wastewaters has been the subject, or the indispensable starting point, of many studies. Fig. 3, present the characteristics of the influent from 2002–2009. It is obvious that the yearly average temperature is more than 26 °C while at the same time in other European Countries is less than 20 °C [19,20,21]. COD and BOD_5 are increasing from year to year. From 2005 until today BOD_5 is greater than 315 ppm while the COD is greater than 630 ppm for the same period. pH remain stable and is from 7.40–7.55 every year. EC remain in high level and is more than 2 ms cm^{-1}. High concentrations of EC for long period may create corrosion to the STP. Corrosion can result in damage to underwater metal surfaces and equipment damage. Corrosive conditions can be eliminated or controlled by the adjustment of the pH, total alkalinity and calcium hardness. The reason for the high concentration of EC is due to the quality of the waters in the Greater Area of the two Municipalities. Total phosphorus increasing from year to year as more manor houses and activities are getting through the STP. From 2003 until the end of 2008 the total phosphorus

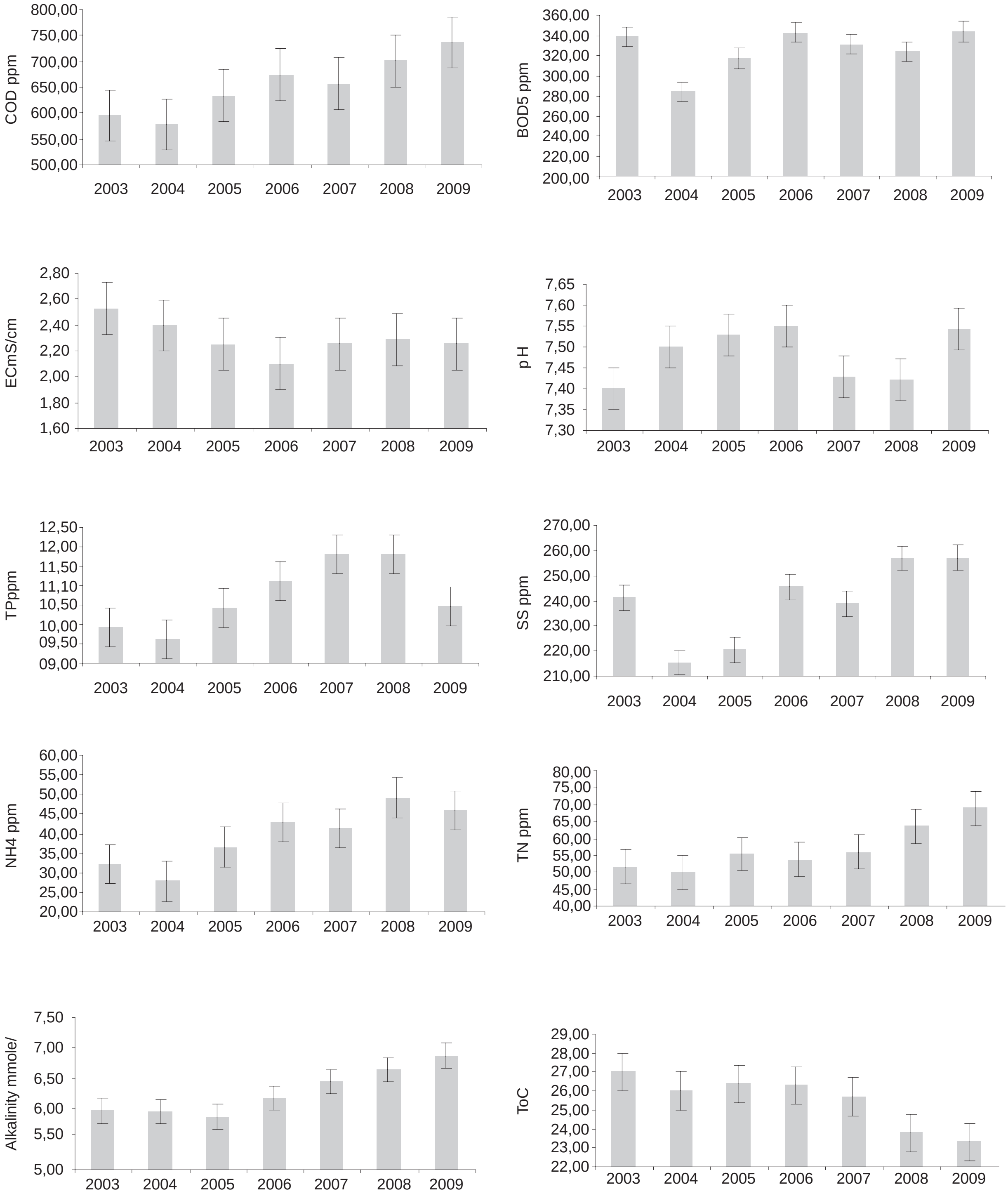


Fig. 3. Influent characteristics (COD, BOD_5, EC, pH, TP SS, NH_4, TN, Alkalinity, T) from 2002–2009.

has increased up to 22.78% which indicated that the main load of the treated wastes were municipal. Also, total Nitrogen is increasing yearly and from 2004 it was increased up to 36.9% until the end of 2008. NH_4 was increased by 76.33% from 2004 until the end of 2008.

Orhon presents in his research several characteristics from other STPs in Istanbul [17]. The consecration of COD from a domestic wastewater in Kadikoy ranges from 220–775 ppm, BOD_5 is from 150–410 ppm, pH is 7.2, TKN from 22–73 ppm, NH_3–N from 25–39, TP from

1.5–5 ppm, SS from 140–930 ppm. The results carried out from the Baltalimam STP is for COD 265–645 ppm, BOD_5 range from 73–200 ppm, pH is 7.2, TKN from 23.9–57 ppm, NH_3–N from 10–26.3, TP from 5–8.63 ppm, SS from 85–318 ppm. Gašpariková et al., (2004) mention that influent characteristics of the domestic wastewater from Devínska Nová Ves (≈ 40,000 PE) in Slovak Rebuplic was for COD at 410 ppm (140–915), for BOD_5 was 202 ppm (54–420), SS was 226 ppm (30–760), NH_4 was 44.2 (20.8–48.6) and the pH was 7.7 (7.2–8.05). COD varied from 172 mg l^{-1} at the "Nazafgarh", to 672 mg l^{-1} at the "Delhi Gate", BOD_5 from 120 mg l^{-1} at "Nazafgarh" to 350 mg l^{-1} at "Delhi Gate" and turbidity from 50 NTU at "Coronation Pillar" to 521 NTU at "Vasant Kunj" from several STPs in India according to [22]. According to Tchobanoglous domestic wastewater contains approximately 0.2–0.6 g l^{-1} organic matter by weight, which is contributed by human, kitchen, and cleaning wastes [23]. The organic matter is mostly composed of proteins and carbohydrates and smaller amounts of lipids, but also includes two classes of contaminants; anthropogenic organic chemicals and microbial pathogens. Proteins and urea contribute over 97% of the 20–70 mg l^{-1} of N typically found in wastewater [23]. Tchobanoglous mention that the COD varies from 200–1,000 ppm for domestic wastewater [23]. The pH of domestic wastewater typically falls between 6.5 and 8.0 [23,24] while the alkalinity is higher than that of the original water supply by 100 to 200 mg l^{-1} (expressed as $CaCO_3$, [23]).

3.2. Chemical consumption of the STP

The chemical consumption of the STP is presented in Table 2. It is obvious that during the low tourist season in the area (November–March) the consumption of the chemicals, the consumption of electricity in KWh per month, the Flow rate (m^3), the sludge production (Table 3, Fig. 4 and Fig. 5) are too low. February and December usually are the months with the minimum consumption every year while the months with the maximum demand in chemicals and electrical consumption are June, July and August where there is a pick in the tourist activities (foreign and locals) in the area. Observing the results that the three last August's presented (2007–2009) it is obvious that the total flow range from 369,599 m^3 to 382,153 m^3. During August Cypriot are make their holidays in Paralimni (with Protaras and Fig-Tree location) and Ayia Napa are the most famous and popular places in the island. During August the KWh/KgBOD_5 range from 2.06 to 2.84 presenting an increase of 37.86% from 2007 to 2009. At the same time the demand in KWh m^{-3} of Flow is 0.62–0.89 and the production of sludge is up to 800 m^3.

Modern day wastewater treatment plants must use a variety of physical, chemical and biological processes to meet effluent treatment guidelines. During the course of treatment these plants consume a variety of different chemicals. In some treatment plants an alkali is used to provide the alkalinity required to maintain effective biological activity and for pH control. Alkalinity can be defined as the ability of a water to neutralize acid or to absorb hydrogen ions. It is the sum of all acid neutralizing bases in the water. In municipal and industrial wastewater there are many factors, which contribute alkalinity. Factors which contribute to alkalinity include the type of dissolved inorganic and organic compounds present in the water, the amount of suspended organic matter in the water, whether the water is strongly or weakly buffered, the presence or absence of free hydroxyl alkalinity, the amount of bicarbonate in the water, the bicarbonate to dissolved CO_2 ratio and is indirectly correlated to the amount of dissolved solids in the water. The alkalinity, which is presented in Fig. 3 for 2005, is continually increasing. The bacteria and other biological entities, which play an active role in wastewater treatment, are most effective at a neutral to slightly alkaline pH of 7 to 8. In order to maintain these optimal pH conditions for biological activity there must be sufficient alkalinity present in the wastewater to neutralize acids generated by the active biomass during waste treatment. This ability to maintain the proper pH in the wastewater as it undergoes treatment is the reason why alkalinity is so important to the wastewater industry [25,26].

3.3. STP efficiency

The STP presented with a great efficiency (Table 4), which is up to 99.35% for the BOD_5, 98.58% for the SS, 86.56–92.29% for the N, 99.99% for the NH_4, and 45.12–90.60% for the P. Also, Table 4 presents the removal efficiencies (%) of different STPs in India [22] and it can be seen that the percentage removal of BOD_5 varies from 70.61–99.43 % while the TKN varies from 21.08–94.58%.

Usually the efficiency on anaerobic wastewater treatment plant confirm with the reduction of COD. Settled sewage with initial COD 135–218 ppm (conditions: T = 5–20 °C and with hydraulic retention time (HRT) from 1–10 h) the efficiency of the anaerobic expanded bed reactor range from 35–77% [20,27]. The anaerobic sequencing batch reactor has efficiency on COD removal from 62–95% for a non-fat dairy milk as substrate and with initial COD 600 ppm (conditions: T = 5–20 °C and HRT = 6–24 h) according to some researchers [20,28]. Settled sewage as substrate with initial COD up to 186 ppm in 20 °C and HRT from 1–5 h has 70–80% reduction in anaerobic attached-film expanded bed [20,29]. Kobayashi mention that the efficiency of the anaerobic filter for the treatment of settled sewage with initial COD 288 ppm is 73% (T = 7.5–18 °C, HRT = 24 h) [30]. Up flow anaerobic sludge

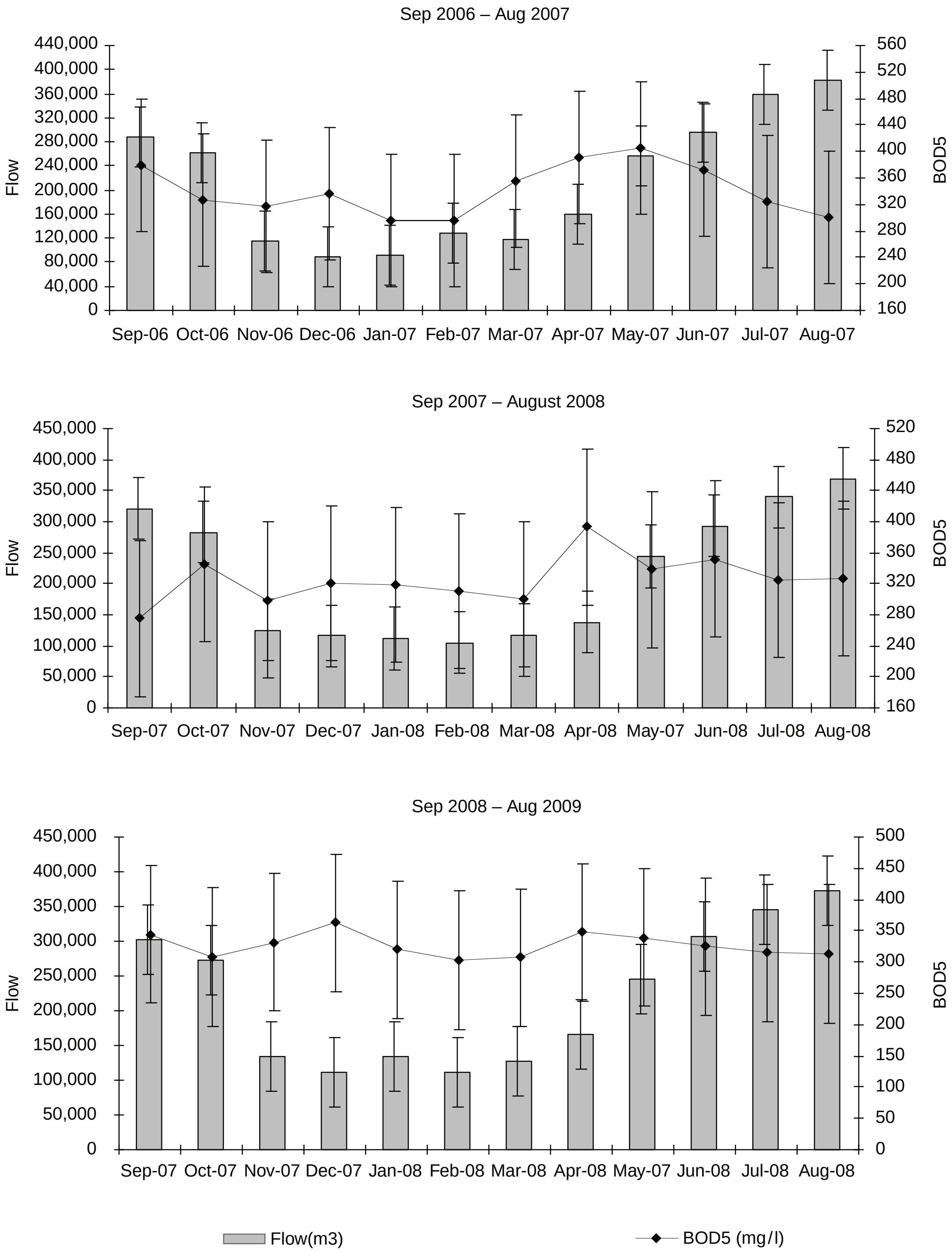


Fig. 4. BOD_5 variation in relation with the monthly flow rate from 2006–2009.

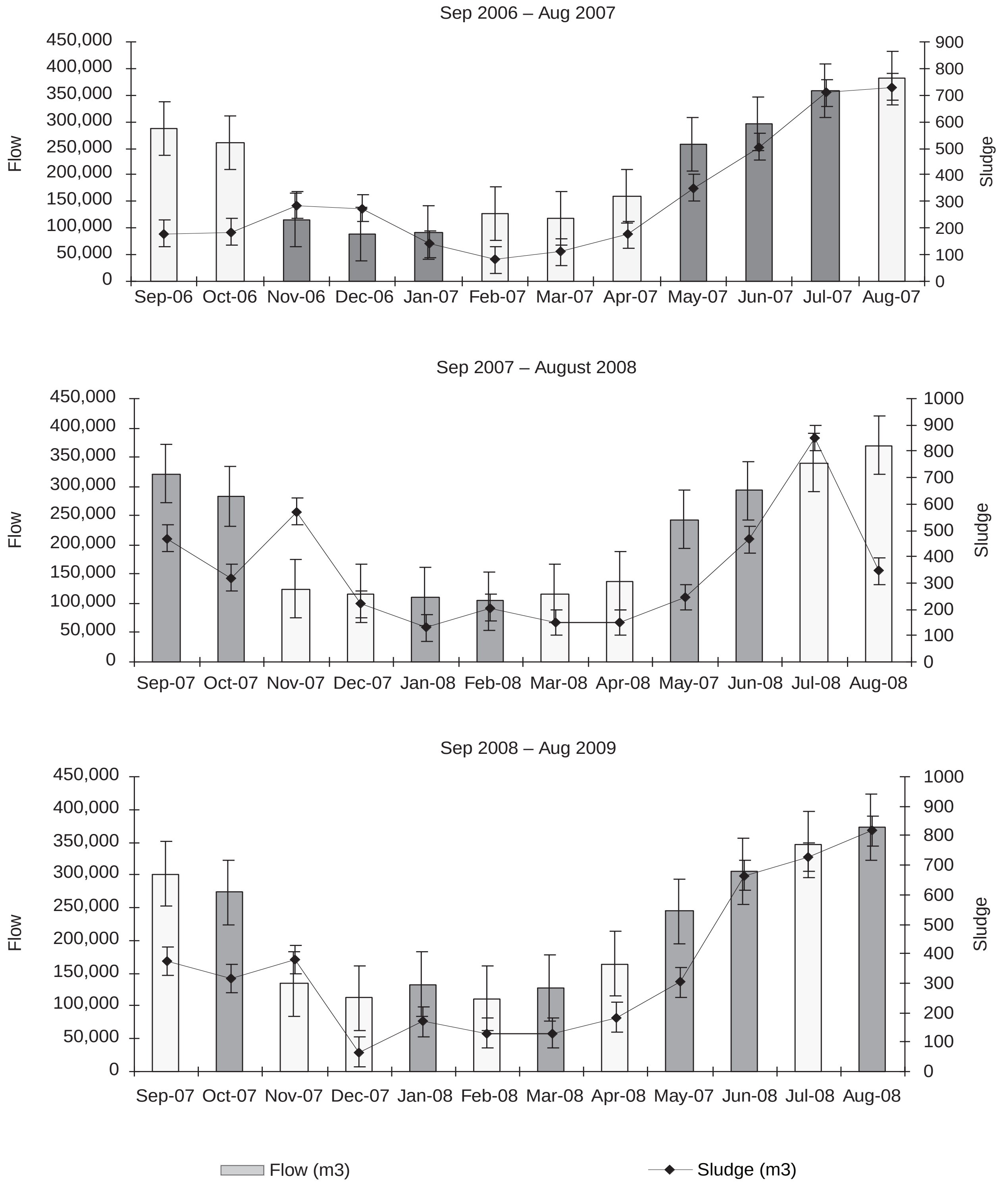


Fig. 5. Sludge production in relation with the monthly flow rate from 2006–2009.

bed efficiency on COD removal for raw sewage varies from 65 to 89 % with initial value on COD from 322–948 ppm (T = 7.5–18 °C, HRT = 8–24 h) [20]. Finally, the efficiency of the expanded granular sludge bed on settled sewage with initial COD up to 391 ppm on 13–19 °C with HRT to be from 1–3.5 h is up to 16–34% [20,31].

3.4. Sludge amount and characteristics

Sludge's resulting from wastewater treatment constitutes a valuable source of essential nutrients for agricultural cultivation [32]. In addition, organic matter from sludge improves some physical and chemical properties of soil, leading to better plant growth. Along with this, sludge application to soils is considered a useful method for their final disposition [32,33]. However, sludge's may contain high amounts of potentially toxic trace elements which may exceed soil natural concentration by two or more order of magnitude [32,34,35].

VSS is at 72 %, SVI varies from 104.23 to 131.06, the MLVSS from 3.65 to 3.92 mg l^{-1} and the MLSS range from 432.11 to 476.11 g l^{-1} (Table 5). A minimum of 14 d was required for optimum MLSS and MLVSS reductions. The longer the retention time, the higher the reductions achieved. For domestic sludge's, a high reduction in settled sludge volume was observed between days 14 and 21. Therefore, the best retention time appears to be about 17 d, just after the improvement in settle ability; at this time the filterability was still reasonable. The SVI may be monitored each day, and the supernatant removed as soon as the sludge settle ability reaches optimum. However, the retention time should not be longer than 21 d because of the risk of foam production and the decrease in filterability [36].

Comparing the results with other studies of Zorpas [14,37] and the directive 86/278/EC [38] the concentrations of the examined metals in sludge (Table 6) are to low due to the fact that the STP does not receive (Table 7) any heavy wastes and the examined metals are in the limits of the specific directive for the safe discharge of the sludge.

The domestic wastewater from the Beer Sheva, Israel, presents the following concentration of the examined metals; 224.2 μg l^{-1} of Zn, 2 μg l^{-1} of Cd, 53 μg l^{-1} of Pb and 34.3 μg l^{-1} of Cu [39]. Primary-treated wastewater produced by the two plants was in Alexandria, Egypt (Egypt has two primary treatment plants, the eastern and the western wastewater treatment plants—EWTP and WWTP—that receive mixed domestic–industrial influents) presented the following characteristics: BOD_5, COD, TSS, TDS, FOG, Zn, and Cu recorded averages of 155, 380, 184, 1,250, 22, 0.1779 and 0.0577 mg l^{-1}, respectively, in the primary-treated wastewater of the EWTP. Significantly higher levels for almost all the tested parameters were detected in the WWTP effluent especially organic content, solids and oil and grease where 280, 519, 435, 1,609, 32 mg l^{-1} were recorded as average levels for BOD_5, COD, TSS, TDS and FOG, respectively. This is mainly attributed to the fact that WWTP serves wider sectors of Alexandria and overloaded with much more quantities of industrial effluents from Alexandria West where more than 80% of industrial activities centralized. However, Zn recorded much lower average in the WWTP effluent (0.0564 mg l^{-1}) compared to that of the EWTP (0.1779 mg l^{-1}) while no significant differences were recorded in the Cu levels among the two plants (0.0528 and 0.0577 mg l^{-1} in the WWTP and EWTP effluents) [40].

Psittalias' waste water treatment plant (municipal and industrial waste) which is the biggest in the greater area of Athens (Greece) the heavy metals concentration on sludge is (in mg g^{-1} dry bases): 0.002 for Cd, 0.563 for Co, 0.552 for Cr, 0.258 for Cu, 5.089 for Fe, 0.150 for Mn, 0.041 for Ni, 0.326 for Pb, 1.739 for Zn [11,15]. Zorpas mention that the concentration of metals in mg g^{-1} dry base from Komotinis STP (North Greece, mainly municipal waste) was 0.044 for Cr, 0.040 for Cu, 7.760 for Fe, 0.218 for Mn, 0.750 for Mg, 0.864 for Zn, 0.050 for Ni, 0.139 for Pb, 14.50 for Ca, 2.36 for K, 1.16 for Na [41]. Also, the same researcher mentions that the metal concentration in mg g^{-1} dry base in sewage sludge from the Metamorphosis STP in Athens (Greece mainly municipal waste) is 0.210 for Cr, 0.282 for Cu, 11.048 for Fe, 0.141 for Ni, 0.275 for Pb and 1.193 for Zn [41]. Savvides mentions that the sewage sludge from the STP of Limasol (Cyprus, treat only municipal waste) in mg g^{-1} dry samples was 0.090 for Cr, 0.060 for Cu, 5.56 for Fe, 1.760 for Ni, 0.050 for Pb, 0.40 for Zn [42]. Carmen presents the following concentration from sewage sludge from Spain STP, in mg kg^{-1} dry mater: K is at 1,527.0, Fe at 13.67, Cd at 0.030, Cr at 0.10, Cu at 7.62, Mn at 6.54, Ni at 1.26, Pb at 0.50 and Zn at 26.64 [43]. Samples of sewage sludge were taken from Beixiaohe Waste Water Treatment Plant, located at Haidian District of Beijing City, where activated sludge process is used to treat sewage. The raw sludge is characterized by metal contents of 154; 1,280; 88.0; 61.4; 15.6; 469 mg kg^{-1} (dry matter) respectively for Cu, Zn, Pb, Ni, Cd and Cr according to [9]. Land application of sewage sludge (biosolids) has been a worldwide agricultural practice for many years [3]. Land application of sewage sludge has been extensively used as an effective dispersive method throughout Canada, the United States and Europe for more than 40 years. Many studies have demonstrated the positive effect of land application of sewage sludge or sludge compost on corn and forage yields and soils [11,44–48]. It effectively disposes of a 'waste' product while recycling valuable nutrients into the soil–plant ecosystem; however, too often, the dispersal has created environmental problems that force government agencies to restrict the amount and type of sewage sludge which can be land applied.

3.5. Characteristics of the tertiary

The characteristics of the tertiary of Paralimni and Ayia Napa are presented in Table 8. Both tertiary present COD < 75 ppm, BOD_5 < 5, pH at 7, SS < 5 ppm, NO_3 up to 30 ppm while the TP and TN are less than 5 ppm. According to Cyprus Legislation 111/2004 the tertiary is suitable for agricultural purposed [49]. Total Coliform and Faecal Coliform were in limited concentrations. Especially, during summer, the high temperature, which is present in the area, sustains the presence of the microorganism. FOG in TPA and TAN is almost 50% less from the initial concentration which is 75.9 ± 35.7 ppm for the period 09/06–08/07, 86.6 ± 33.2 ppm for the period 09/07–08/08 and 96.8 ± 49.2 ppm for the period 09/08–08/09. FOG is usually high during March, April, October and November every year, due to the fact that in the first two months and in the last two, all the tourist activities are plan to open and closed and they clean their spaces, so they left at the wastewater fats and oil. El-Bestawy mention that the annual 2007 averages of Total Coliform and Faecal Coliform in the EWTP (Alexandria, Egypt) effluent recorded 46×10^7 and 42×10^7 cell per 100 ml, respectively, in the influent reduced to 26×10^7 and 24×10^7 due to the preliminary and primary treatment [40]. At the same time the annual 2007 averages of Total Coliform and Faecal Coliform (supplied by the monitoring and data record unit, central lab of the drainage company) recorded 33×10^{10} and 30×10^{10} cell per 100 ml, respectively, in the influent of the WWTP which were reduced to 24×10^8 and 24×10^8 due to the preliminary and primary treatment [40].

4. Discussion

Urban wastewater systems, having sewer system, wastewater treatment plant and receiving water as their main elements, can be found throughout the world. Many of them are operated with little or no control. Characterization of municipal wastewaters has been the subject, or the indispensable starting point, of many studies. The present paper (as there is a very limited work on the subject) deals with the characterization of the influent (municipal liquid waste), the secondary treated sample and the tertiary as well as the characterization of the sewage sludge from the Sewage Treatment Plant of the Municipality of Paralimni–Ayia Napa in the eastern of Cyprus.

The STP presented with a great efficiency, which is up to 99.35% for the BOD_5, 98.58% for the SS, 86.56–92.29% for the N, 99.99% for the NH_4, 45.12–90.60% for the P. From the above results, it is clear that STPs exhibit different physical, chemical and microbiological efficiencies depending upon characteristics of influent sewage, percentage of capacity utilization etc. Therefore, there is a need to define one common parameter, which could determine the overall efficiency of plant in terms of physical, biochemical and microbiological removal efficiencies. The parameter will also help in making decision for efficient reuse of effluent.

Land filling is the main disposal route for sewage sludge at present in Cyprus. On the other hand, land filling generates potential environmental hazards, including the production of odor and methane gas, as well as contamination of groundwater by leachate. Comparing the results with other studies of Zorpas [14,37] and the directive 86/278/EC [38] the concentrations of the examined metals in sludge (Table 6) are to low due to the fact that the STP does not receive (Table 7) any heavy wastes and the examine metals are in the limits of the specific directive for the safe discharge of the sludge.

The tertiary sample does not have any pathogens microorganism, while the COD and BOD_5 presented less than 70 and 5 ppm respectively and is suitable for agricultural purposed. The average monthly flow for Influent varies from 88,625 m^3 to 382,153 m^3. The sludge almost 4,200 $t\ y^{-1}$ does not present with significant consecration of heavy metals. However, the sewage sludge contains high concentration of organics and phosphorus and with further treatment like composting may be able to be applied in agriculture. From year to year the average treated $KgBOD_5$ per month is from 27,093–20,859, the average KWh per month from year to year is from 90,124–332,037 (total KWh y^{-1} 2.12–2.25 million), the total KWh/$KgBOD_5$ per month is from 1.97 to 3.13, while the total KWh m^{-3} of waste range from 0.62 to 1.36. The efficiency of the STP is for BOD_5 98.5–100%, for SS is from 97.99–98.98%, the TN from 72.46–94.69%, the NH_4 99.98% and the TP from 15.17–99.12%. At the same time the total chemical consumption chlorine, polymer, and lime were 641–2,675 kg m^{-1}, 1.064–4,586 kg m^{-1} and 20–5,400 kg m^{-1} respectively.

5. Conclusions

Wastewater from two municipalities in the eastern region of Cyprus were described, surveyed, and characterized during the last seven years as there is a few studies available in the literature. Urban wastewater systems, having sewer system, wastewater treatment plant and receiving water as their main elements, can be found throughout the world. Many of them are operated with little or no control. Characterization of municipal wastewaters has been the subject, or the indispensable starting point, of many studies. Waste waters characterization is essential for the optimization of the operation of such systems as well as for the design of wastewater treatment systems in rural areas under warm or not, climate conditions.

Estimation of wastewater flow and influent concentrations in small localities is still commonly based on bibliographic data, this criterion producing important fails in system design and adequacy to the socio economical situation of these localities. The consequence is that absence of maintenance is very common in small wastewater treatment plants. To avoid this problem, regional government and other administrations are nowadays interested in the study and detailed characterization of wastewater previously to plant design in small localities.

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