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Review Article

Nitrification Processes in Tehran Wastewater Treatment Plant

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A wastewater treatment plant is designed to daily treat 450000 m^3 of wastewater collected from the city of Tehran. The wastewater treatment plant is located at the south of Shahr-Ray in southern Tehran with the area of 110 hectares. The treatment plant effluent will be transferred to Varamin agricultural lands to be used for the irrigation of crops. A conventional activated sludge for carbon removal and a high-rate trickling filter for nitrification of ammonia to nitrate are designed and constructed. The treatment plant consists of inlet pumping station, primary treatment, primary sedimentation tanks, selector and aeration tanks, trickling filter, and sludge treatment units. A mass balance analysis method which is a new approach for optimum design is used to achieve cost saving for the construction of south Tehran wastewater treatment plant. The comparison between combined system of activated sludge with trickling filter and an activated sludge alone shows that the combined system is 20% less costly and more efficient for the treatment of Tehran wastewater, the system has low volume demand, maximum biogas yeild, and low process control and is less variable to pH and chemical effects and highly energy-efficient.

1. Introduction

The city of Tehran is one of the fastest growing metropolitan cities in Iran. Due to various socioeconomic factors, the process of urbanization not only continues but also becomes faster with the passage of time. Such and similar reasons aggravate the stress on civic amenities like water supply, sanitation, dwelling, transport, and health care facilities. This results in the creation of slum dwellings without basic civic amenities.

For economic reasons it is extremely difficult to provide proper water supply and sewerage facilities for all the population. Even the most developed countries have not been able to achieve 100 percent results. Such facilities are not only costly in terms of capital outlay but also beyond the affordability of smaller communities in meeting operation and maintenance costs, but if no facility is provided, health hazards will overtake communities with various communicable diseases.

Tehran city is situated at the foothills of Alborz mountain in the north, surrounded by Damavand mountain in the north east, Karaj road in the south west, and Varamin road, Tehran refinery, and Saveh road in the south. The city is located between latitudes of 35°-32′ and 35°-50′ and longitudes of 51°-4′ and 51°-33′. The sewerage project area is of steep slope, 5%, in the north but relatively flat in the south 1.3%. The difference in ground elevations at northern and southern ends of project area is approximately 810 meters in a horizontal distance of over 29 km. Figure 1 shows the site plan of sewerage project area.

The total wastewater generated in all Tehran area will be distributed in Southern Treatment Plant and South-Western Treatment Plant in accordance with the respective capacities. Due to congested area requiring long lengths of sewers, steep slopes, large quantity of sewage requiring large size of sewer and obstructions such as other underground utility lines and metro crossing, the entire eastern trunk sewer and many lengths of other sewers are to be constructed as tunnels. This is planned to convey wastewater flows to the treatment plants along the shortest possible routes. The present population living in the project boundary is 9 million for the year 2003, and it is projected to grow to 11 million in the year 2016, for which that the project is planned.

The development of predators (e.g., worms, filter flies, etc.) has caused several problems in sustaining nitrification in trickling filter due to thin biofilms. Snails and filter flies

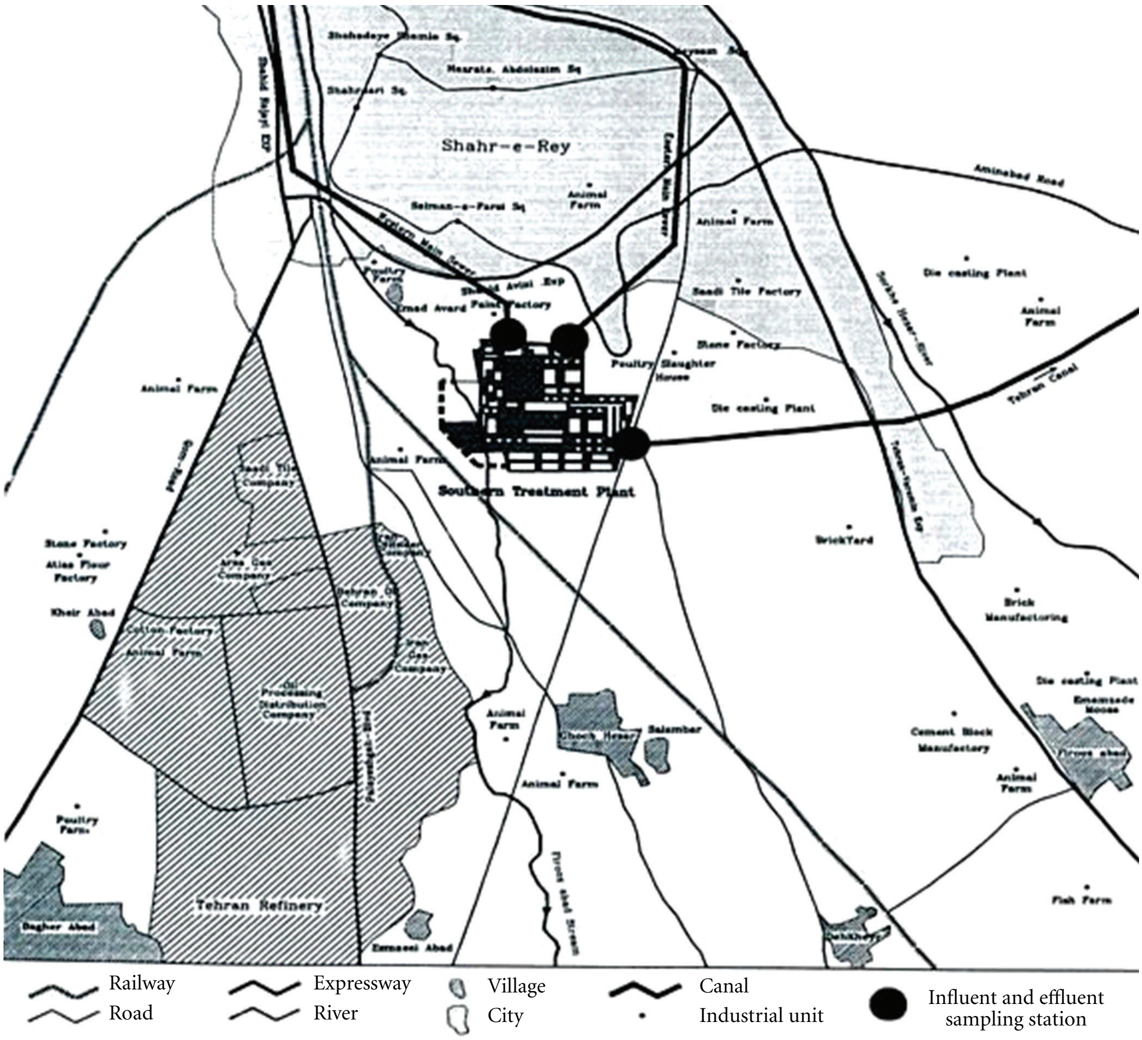

FIGURE 1: Site plan of Tehran sewerage project area.

were both observed during pilot plant testing in central valley, Utah (Parker et al. [2]). In that study, it was found that the observed nitrification rates were somewhat lower than predicted maximum zero-order rates, perhaps due to either prediction or competition with heterotrophy for oxygen.

In the design of south Tehran sewerage treatment plant, efforts have been made to design nitrifying trickling filter to the extent that oxygen transfer through the media becomes maximum, to control the formation of biofilm patchiness by complete carbon removal through aeration tank, to provide ammonia to even out diurnal ammonia loads by returning supernatant from sludge storage, and to control the levels of nuisance organisms by the following processes: (1) flooding and backwashing to control filter fly larval development, (2) temporary saline flooding to control worm development, and (3) using substances toxic to eukaryotic organisms to control biofilm predators and also to increase nitrification rates in the trickling filter.

The combination of conventional activated sludge and trickling filter will be operated for the treatment of south Tehran wastewater treatment plan. This has been experimented in full scale as presented by Christensen [1].

The objective of the paper is the study of sewage treatment for a wide range of ambient temperatures in order to produce effluents of adequate quality to meet the Department of Environment (DOE) standards.

1.1. Previous Works. Achieving cost savings with nitrifying trickling filter is dependent upon the ability to obtain high nitrification rates, and minimizing the size of the required process units; therefore, the unique characteristics of trickling filters that distinguish this from other processes must be recognized and accounted for in design. For recognizing these processes, the activity of the nitrifying biofilm can be maximized and controlled. The following techniques have been applied for optimizing biofilm development and thereby maximizing nitrification rates in nitrifying trickling filters:

(1) maximization of oxygen transfer through media selection and the prevention of stagnation through positive ventilation (Parker et al. [2]),

(2) the use of two-stage instead of single-stage operation to avoid biofilm patchiness in the lower part of the nitrifying trickling filter where ammonia levels are low (Boller and Gujer [3], Andersson et al. [4]),

(3) maximization of wetting and minimization of dry spot development within the media (Boller and Gujer [3], Parker et al. [5]),

(4) storage and control of ammonia-laden supernatant returns from solids processing operations to even out diurnal ammonia loads (Parker et al. [2]), and Balmer et al. [6] have shown that high rate tertiary nitrification could be achieved in cross-flow media trickling filters.

On-site pilot plant experiments were carried out with results indicating that nitrification rates of 1.0–1.5 g $N/m^2 \cdot d$ could be achieved in a 7.2 m high-rate trickling filter with a 230 m^2/m^3 cross- flow media (Mattson and Rane [7]).

Tehran southern wastewater treatment plant is located at the south of Shahr-Ray, and it is out of the development limit of Tehran city in the next 25 years, and an area of 110 hectares is owned by the client. Four modules of the plant are proposed to be constructed in the current phase having capacity of 1.3 cubic meters per second, each which will serve a population of 2.1 million in this phase. The plant is to be extended up to 8 modules. The coverage area for sewer systems and southern treatment plant is approximately 32000 hectares. Later on another plant called south western treatment plant will be constructed that will cover about 40000 hectares.

The treatment plant effluent will be transferred to Varamin agricultural lands by preconstructed Tehran Varamin canal in capacity of 8 cubic meters per second to be used for the irrigation of agricultural farm lands.

The selected biological wastewater treatment plant is based on the so-called combined conventional activated sludge and trickling filter having the following components as shown in Figure 2: inlet screw pumps, mechanical screens, grit and grease removal, primary clarifier, aeration tank, secondary clarifier, return sludge line, trickling filter, primary sludge thickener, sludge digesters, sludge storage tank, and mechanical dewatering.

The Iranian environmental protection agency will establish and implement formal programs for the monitoring of discharges to the environment from the wastewater treatment plant and wastewater produced from the industry, surface water quality, and soil quality in the Varamin plane. It will develop a system of controls on discharges into Firouzabad and Sorkhe-Hessar canals.

The overall objective of this study was to select a combination of treatment processes that optimize the cost of South Tehran wastewater treatment plant under construction, and also, to improve public health, reduce surface and ground water pollution, and daily provide 450000 m^3 of treated wastewater for irrigation of about 15000 hectares of the Varamin agricultural lands.

Table 1: Design hydraulic loads and pollution loads WWTP.

Parameter	Unit	Value
Pollution load		
Service population	PE	
BOD_5	Kg/d	2,100,000
COD	Kg/d	126,000
NH_3/NH_4-N	Kg/d	240,000
NO_3-N	Kg/d	18,000
Total N	Kg/d	1,200
Total P	Kg/d	24,000
TSS	Kg/d	5,100
TDS	Mg/L	147,000
Nematode eggs*	Pcs/L	680
Design wastewater temperatures		<50
T_{min}	°C	
T_{max}	°C	12
		25

*as monthly average.

Table 2: Required effluent quality.

Parameter	Unit	Value	Analyses' frequency
BOD_5	mg/L	25	Daily
TSS	mg/L	25	Daily
Total N	mg/L	30	Daily
Faecal coliforms	MPN/100 mL	<400	Daily
Nematode eggs	pcs/L	<1	Twice a week

2. Basis of Design

The raw wastewater collected in the catchments area is transported to the south Tehran wastewater treatment plant (STWWTP) within two main gravity sewer systems namely western main trunk and eastern main trunk.

The two wastewater streams are combined down-flow of separate flow measurements and treated together by mechanical and biological treatment steps supplemented with sludge treatment units.

The STWWTP will be built on a dedicated area, measuring approximately 110 hectares in total.

The proposed STWWTP for the first stage is 450000 m^3/d and total nitrogen TKN < 30 mg/L.

The basis for the design or the influent data is given in Table 1; also the effluent requirements are given in Table 2.

2.1. Wastewater Treatment Units. The Tehran sewerage project—southern wastewater treatment plant—consists of the following units:

Inlet Pumping Station and Inlet Structures.

(i) Inlet pumping station western main trunk,

(ii) inlet structure eastern main trunk,

(iii) overflow western trunk located within an independent structure upstream of the pumping station,

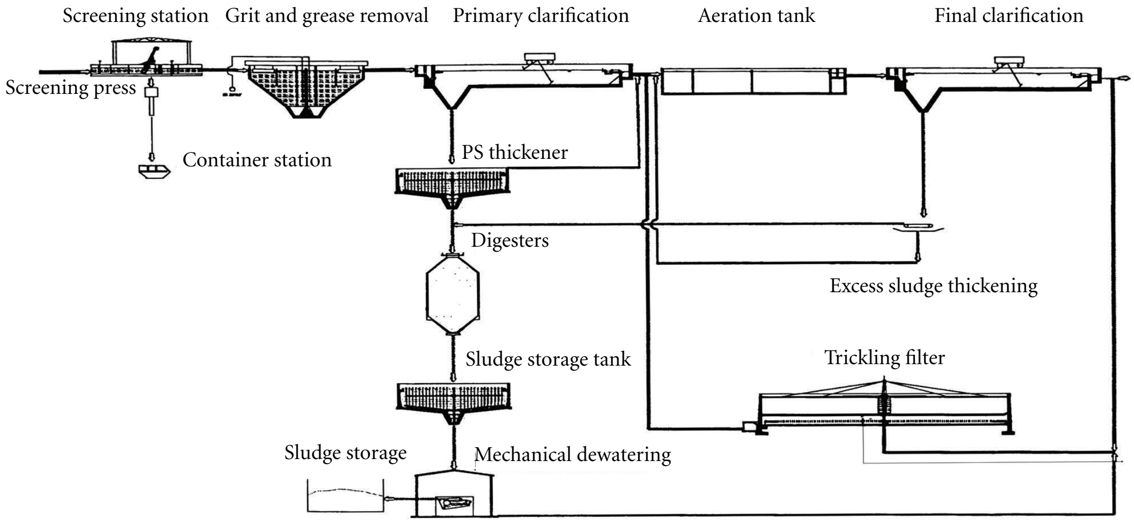

Figure 2: Flow diagram of WWTP.

(iv) overflow eastern main trunk,

(v) flow meter eastern main trunk,

(vi) flow meter western main trunk.

Primary Treatment.

(i) Coarse screening,

(ii) fine screening,

(iii) aerated grit and grease chamber,

(iv) primary sedimentation,

(v) overflow channel.

Biological Treatment.

(i) Selector,

(ii) aeration tank,

(iii) final clarifier,

(iv) overflow channel,

(v) chlorination,

(vi) trickling filter for nitrification of sludge liquor and internal recirculation.

Sludge Treatment.

(i) Static prethickening,

(ii) mechanical thickening,

(iii) anaerobic digestion,

(iv) sludge dewatering,

(v) sludge storage.

Biogas Treatment and Utilization.

(i) Gravel filter,

(ii) gas storage,

(iii) gas flare,

(iv) desulphurization plant,

(v) cogeneration plant.

3. Mass Balance Analysis for Optimum Design

3.1. Primary Sedimentation Tanks. The primary sedimentation tanks (PSTs) are designed on the basis of maximum average flow. This approach is justified by the fact that short time fluctuations cause only little variations of pollutant removal efficiency in the PST. Besides, the sludge age (cell residence time) in the downstream-activated sludge system depends on the average pollutant load. For the Tehran Southern WWTP, the PSTs are designed for an average hydraulic retention time (HRT) of 1 hour. Although the flow variations are not relevant to the stipulated design removal efficiency of the PST, it should be noted that during maximum flow the HRT decreases to 40 min, whereas during minimum flow (night time) the HRT will increase to more than 1.5 hours.

The suspended solid removal efficiencies of PST as compared to the design efficiency on the German design guideline ATV A 131 (2000) are considered to be as given in Table 3.

With the above-interpolated removal rates, the mass balance for the primary sedimentation tank is calculated as "Mass Balance primary clarifiers."

The stipulated removal rates of suspended solids are well below the maximum removal efficiencies that could be achieved with an HRT greater than 1.5 hours, but the lower HRT of only 1 hour is well considered in the design. The comparison with operational data of the main wastewater treatment plant of Vienna shows that the design

Table 3: The suspended solid removal efficiencies of PST.

Parameter	HRT in the PSTs During dry weather flow		
	0.5–1.0 hr	1.5–2.0 hr	1.0 hr
BOD_5 removal	25%	33.33%	27.09%
COD removal	25%	33.33%	27.09%
TSS removal	50%	64.29%	53.58%
TKN removal	9.09%	9.09%	9.09%
TP removal	11.11%	11.11%	11.11%

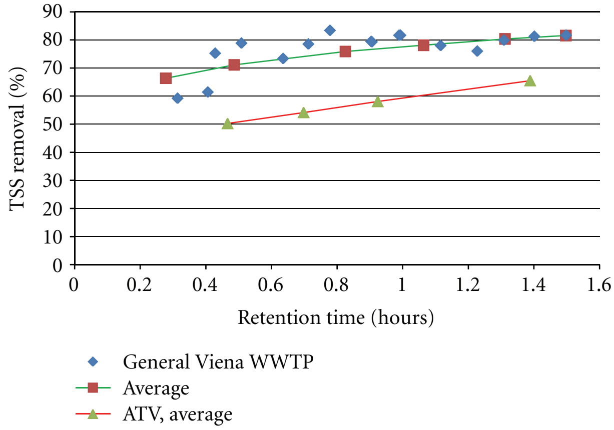

Figure 3: TSS removal rate versus retention time.

removal rates taken from ATVA 131 obviously are on the very safe side in Vienna, and removal rates for total suspended solids of more than 70% are observed as can be seen in Figure 3. In this figure the PST of Tehran WWTP for 1.0 hour retention shows about 53% removal efficiency. However, since low removal rates are also considered for design calculations and the mass balance for the higher design wastewater temperature is (25°C), therefore, the calculated oxygen demand in the aeration tanks is on the very safe side. The mass balance shows that the actual COD and BOD removal efficiency can be expected to be higher, and the load for the down-flow activated sludge system will be lower; on the other hand, more COD removal with the primary sludge will result in increased biogas production. Furthermore, it should be noted that a large PST and an average retention time of more than 1.0 hour would have negative effect on the sludge setting rate in the down-flow activated sludge system. Therefore, 1.0 hour HRT during average flow is the optimum approach for the Tehran wastewater treatment plant.

It is very important to notice that for activated sludge system the critical parameter is the F/M ratio. All other important design figures, such as sludge age and oxygen demand, are calculated according to ATV A131 design for mules using the selected F/M ratio.

In the present study and design a F/M ratio of 0.3 kg BOD_5/kg MLSS,d is required to achieve complete purification which correlates with a maximum BOD_5 effluent concentration of 15 to 20 mg/e. It is of significance that the calculated design values are valid for a wastewater temperature as low as 10°C, which typically is the design temperature for cold regions. For Tehran southern WWTP, a BOD_5 effluent concentration of 25 mg/e is required and guaranteed. To achieve that concentration, an F/M ratio of 0.39 kg BOD_5/kg MLVSS, d is calculated for 12°C, which is the critical temperature. With an F/M ratio of 0.39, the calculation of the sludge age results is 2.41 days. Suspended solids of more than 70% are observed as can be seen in Figure 3. In this figure, the PST of Tehran WWTP for 1.0 hour retention shows about 55% removal efficiency. However, since low removal rate is also considered for design calculations and the mass balance for the higher design wastewater is temperature (25°C) therefore, the calculated oxygen demand in the aeration tanks is on the very safeside. The mass balance shows that the actual COD and BOD removal efficiency can be expected to be higher and the load for the down flow activated sludge system will be lower. On the other hard more COD removal with the primary sludge will result in increased biogas production. Furthermore, it should be noted that a large PST and an average retention time of more than 1 hour would have negative effect on the sludge setting rate in the down flow activated sludge system. Therefore 1 hour HRT during average flow is the optimum approach foe the Tehran waste water treatment plant.

3.2. Aeration Tanks and Selector. Aeration tanks are employed for carbon removal (C_{BOD}) using activated sludge process. Four aeration tanks consisting of a selector cascade are designed as plug flow reactors of rectangular shape. Wastewater flow and return sludge flow will be mixed in the selector cascade, pass through the tank as activated sludge, and finally leave the tank via a fixed outlet weir crest from where it is transferred to the final sedimentation tanks. The aeration tanks represent the reactors in which the biological treatment of wastewater takes place by adopting the medium loaded, the so-called conventional activated sludge process. The main target in the system chosen is mainly degradation of organic carbon or carbonaceous BOD. A further main target is the complete denitrification of nitrate which is produced in the trickling filters and transferred in to aeration tanks by a recirculation flow. Also, some nitrification will take place due to continuous flush out of nitrifying biomass from the trickling filters, which then accumulates in the activated sludge and will cause some nitrification in the aerated zones of the aeration tanks.

The sludge age is controlled by the MLVSS concentration within the tanks which is varied depending on wastewater temperature and by excess sludge withdrawal, respectively. The required denitrification will mainly be achieved in the anoxic selector cascade and by simultaneous denitrification in anoxic zones of the aerated part of tank and within the sludge flocks.

During periods with low wastewater temperature, the predenitrification and simultaneous denitrification will provide a nitrate free effluent. During periods with high wastewater temperature, some nitrate might remain in the effluent, which does not affect the effluent quality as long as severe denitrification in the final sedimentation tanks is prevented.

A selector is employed to prevent and to control filamentous bacterial growth. Generally, selectors can be operated as aerated-anoxic, aerobic, or in an alternating environment as also reported by Metcalf and Eddy [8]. Air or mechanical mixers can be used for sufficient mixing within the selector compartment.

In this case the selector will mainly provide anoxic conditions due to the inlet of nitrate from trickling filter effluent. Further, it should be pointed out that the plug flow design already provides on its own favorable conditions for floc forming microorganisms.

The proposed 3 chambers aeration tank with tuned selector design further improves the process. Since the South Tehran WWTP the selector followed by diffused air plug flow reactor, therefore, only one selector chamber is proposed.

The parameters of Table 3 for the design of activated sludge aeration tank are used. Then the mass balance for the aeration tank is calculated upon "Mass Balance Aeration Tank Activated Sludge System."

It is very important to notice that for activated sludge system the critical parameter is the F/M ratio. All the important design figures, such as sludge age and oxygen demand are calculated according to ATV A131 design formulas using the selected F/M ratio.

In the present study and design, with an F/M ratio of 0.3 kg BOD_5/kg MLVSS,d is required to achieve complete purification which correlates with a maximum BOD_5 effluent concentration of 15 to 20 mg/L.

It is of significance that these design values are valid for a wastewater temperature as low as 10°C, which typically is the design temperature for cold regions. For Tehran Southern WWTP, a BOD_5 effluent concentration of 25 mg/L is required and guaranteed.

To achieve that concentration, an F/M ratio of 0.39 kg BOD_5/kg MLVSS,d is calculated for 12°C, which is the critical temperature. With an F/M ratio of 0.39, the calculation of the sludge age results in 2.41 days.

The final sedimentation tank design an executed according to design guidelines of the German association for water quality control (ATV). The mass balance for the final sedimentation tank (without consideration of the return sludge) is calculated upon "Mass Balance-Final Sedimentation Tank."

3.3. Trickling Filter. In order to achieve partial nitrification trickling filters are employed, which provide the following main advantages compared to other systems:

(i) less energy consumption,

(ii) simple operation,

(iii) low maintenance.

Trickling filters are employed for nitrification of ammonia contained in the highly concentrated filtrate from sludge dewatering. Additionally, apart of the effluent of the activated sludge stage is recirculated via the trickling filters for nitrification. Due to subsequent denitrification of the produced nitrate in the activated sludge stage the effluent requirement of N total = 30 mg/L will be achieved.

Beside the transfer of ammonia to the trickling filters, the recirculation of final clarifier effluent also serves for dilution of the sludge dewatering filtrate in order to provide sufficient alkalinity in the trickling filters.

Due to this process adaptation the BOD_5 load and the suspended solids (SSs) load to the trickling filters will be very low. Due to the low BOD_5 and SS load it is evident that the main target of this treatment step is oxidation of ammonia only. Some degradation of organic pollutants can be seen as side effect, and it should be stressed that with the low organic load figures, TF clogging is definitely prevented.

The biologically active biomass will adhere to the filter material and will create a biological lawn mainly consisting of nitrifying bacteria (*nitrosomonas* and *nitrobacter*), which will accomplish the oxidation of ammonia to nitrite and further to nitrate. Oxygen is supplied by natural draught through the bed. For air ventilation, sufficient openings will be foreseen at the base of the structure.

After passing the filter material, the nitrified water is collected and transferred to the inlet of the aeration tank by gravity. The recycle of the trickling filter effluent to the activated sludge stage contributes to an overall low energy demand of the biological treatment stage. The normal flow (filtrates from sludge dewatering and recirculation flow from final clarifiers) will provide sufficient flushing of the filter material. An internal recirculation for increasing the flushing effect during normal operation is not required.

In order to optimize the performance and for predator control, it will be possible to automatically run periodic flushing cycles. During those flushing mode operations, the distributor arms will be stopped and automatically moved stepwise in order to increase hydraulic flushing forces for a limited flushing time.

The mass balance for the trickling filter is calculated upon "Mass Balance-Trickling Filter."

The following steps show the trickling filter design:

(1) The oxygen demand for nitrification in the trickling filter ($\mathrm{Ovd_{Nit}}, T_f$) is based on the minimum nitrification capacity within the trickling filter if

$$\begin{aligned} \mathrm{NH_4 - N_{nit,Tf,min}} &= 5347\,\mathrm{kg\,N/d} \\ \mathrm{Ovd}_{\mathrm{Nit},T_f} &= \mathrm{NH_4 - N_{nit,Tf,min}} \times (4.57 - y_A) \\ &= 5347 \times (4.57 - 0.24) = 23153\,\mathrm{kg\,O_2/d}, \end{aligned} \tag{1}$$

where y_A is the autotrophic yield

$$\left[g_{\mathrm{COD}}, \frac{X_A}{g_{\mathrm{NH_{4-N}}}} \right] = 1.42\,\mathrm{kg\,COD/kg\,ODS}. \tag{2}$$

(2) The oxygen demand uptake for nitrification is related to the total minimum autotrophic biomass (M_{X_A,T_f}) via

$$\begin{aligned} M_{X_A,T_f}(12^\circ\mathrm{C}) &= \mathrm{Ovd_{Nit,Tf}} \times \frac{y_A}{M_A(12^\circ\mathrm{C}) \times (4.57 - y_A)} \\ &= 23153 \times \frac{0.24}{0.47 \times 1.1^{T-15} \times (4.57 - 0.24)} \\ &= 3634\,\mathrm{kg_{CSB,X_A}}, \end{aligned} \tag{3}$$

where $M_A(12°C)$ is autotrophic net growth rate including decay at $12°C = 0.47 \times 1.1^{T-15}$ $(/d)$.

The total minimum autotrophic biomass in the trickling filter as dry substance is:

$$\frac{3634}{1.42}\ \mathrm{kg_{CSB}/kg_{DS}} = 2559\ \mathrm{kg_{DS}}. \quad (4)$$

(3) Alternatively, the change of autotrophic biomass ($dM_{X_A/T_f}/dt$) in the trickling filter can be expressed by the following equation with D_X the sludge washout rate:

$$\frac{dM_{X_A,T_f}}{dt} = \mathrm{NH_4} - \mathrm{N}_{\mathrm{Nit},T_f} \times y_A - (b_A + D_X) \times M_{X_A,T_f}. \quad (5)$$

(4) During normal steady-state operation, the change of autotrophic biomass is zero. Consequently the washout rate D_X can be calculated as follows:

$$\begin{aligned} D_X &= \frac{\mathrm{NH_4} - \mathrm{N}_{\mathrm{Nit},T_f} \times y_A}{M_{X_A,T_f}} - b_A \\ &= \frac{5347 \times 0.24}{3634} - 0.068 \\ &= 0.285/d. \end{aligned} \quad (6)$$

b_A is autotrophic decay rate at

$$12°\mathrm{C} = 0.15\mathrm{e}^{(-0.098/20-5)}. \quad (7)$$

(5) Subsequently, the nitrification population in the excess sludge ES_{X_A,T_f} can be calculated as:

$$\begin{aligned} &\mathrm{ES}_{X_A,T_f} = M_{X_A,T_f} \times D_X = 3634 \times 0.285 = 1034\ \mathrm{kg/d}, \\ &\text{as} \\ &DS = \frac{1034}{1.42}\ \mathrm{kg_{CSB}/kg_{DS}} = 729\ \mathrm{kg_{DS}}. \end{aligned} \quad (8)$$

(6) Considering the sludge age in the aeration tank the nitrification population MLVSS_{X_A,T_f} in the aeration tank can be calculated as

$$\begin{aligned} \mathrm{MLVSS}_{X_A,A_t(12°C)} &= \mathrm{ES}_{X_A,T_f(12°C)} \times T_{\mathrm{TS}} \\ &= 1034 \times 2.41 = 2488\ \mathrm{kg/d}, \\ \text{as} \\ DS &= \frac{2488}{1.42}\ \mathrm{kg_{CSB}/kg_{DS}} = 1752\ \mathrm{kg_{DS}}. \end{aligned} \quad (9)$$

T_{TS} is the total sludge age in the aeration tank at relevant temperature in day.

(7) The maximum nitrification capacity of this nitrifying population is

$$\begin{aligned} &\mathrm{NH_4} - N_{\mathrm{NiT},T_f,\max} \\ &\quad = \mathrm{MLVSS}_{X_A,A_t(12°C)}/y_A \times M_A \times 1.1^{(t-15)} \times T_{\mathrm{TS},A} \\ &\quad = 2488/0.24 \times 0.47 \times 1.1^{(12-15)} \times 2746\ \mathrm{kg}\ N/\mathrm{d} \\ &\quad = 1.80/2.41. \end{aligned} \quad (10)$$

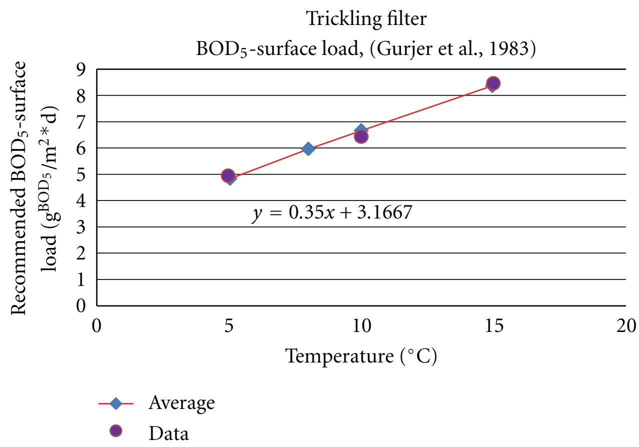

Figure 4: $\mathrm{BOD_5}$ surface load of trickling filter as a function of temperature [9].

(8) The design of the volume of Trickling filter V_{T_f} is based on a calculation of the volume required for $\mathrm{BOD_5}$ removal ($V_{T_f,\mathrm{BOD_5}}$) and the volume required for nitrification $V_{T_f,\mathrm{NiT}}$; therefore, the total volume of trickling filter is

$$V_{T_f} = V_{T_f,\mathrm{BOD_5}} + V_{T_f,\mathrm{NiT}}. \quad (11)$$

Figure 4 shows the $\mathrm{BOD_5}$ surface load of trickling filter as a function of temperature.

Required volume for $\mathrm{BOD_5}$ removal calculation is as follows:

$$\begin{aligned} &\mathrm{BOD_5}\ \text{load to}\ T_f, \quad \mathrm{BOD}_{5-L_{T_f}} = 5470\ \mathrm{kg/d}, \\ &\text{Degradable}\ \mathrm{BOD_5} - \text{fraction} = 65\%. \end{aligned} \quad (12)$$

There is good agreement between Tehran rNit, design, and Kempten at temperature about 18°C

$$V_{T_f,\mathrm{BOD,Exp.}} = [2000 \times 0.4 \times 0.65] \times \frac{1000}{(7.4 \times 130)} = 751\ \mathrm{m^3}. \quad (13)$$

Design safety is represented as follows:

$$V_{T_f,\mathrm{BOD_5,Safety}} = 3696 - 751 = 2945\ \mathrm{m^3}. \quad (14)$$

Required volume expected is calculated as follows:

$$\mathrm{BOD_5} - L_{T_f,\mathrm{Deg.}} = 5470 \times 0.65 = 3555\ \mathrm{kg/d}. \quad (15)$$

Required volume is shown as follows:

$$V_{T_f,\mathrm{BOD_5}} = 3555 \times \frac{1000}{(7.4 \times 130)} = 3696\ \mathrm{m^3}. \quad (16)$$

(9) The required volume for nitrification rate calculation is as follows:

$$\mathrm{NH_4} - \mathrm{N} - \text{Load to}\ T_f : \mathrm{NH_4} - \mathrm{N} - L_{T_f} = 8125\ \mathrm{kg/d}. \quad (17)$$

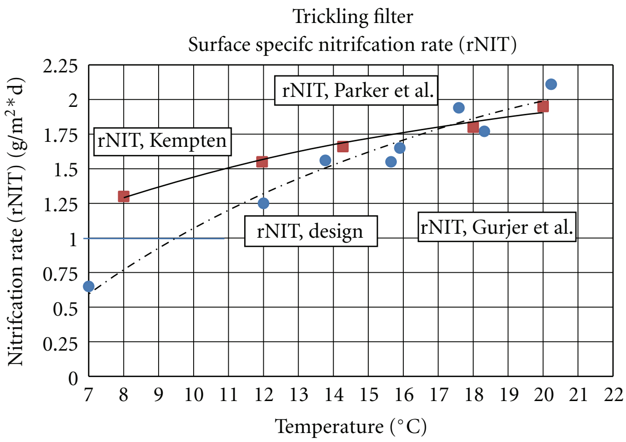

Figure 5: The surface-specific nitrification rate for trickling filter as a function of temperature.

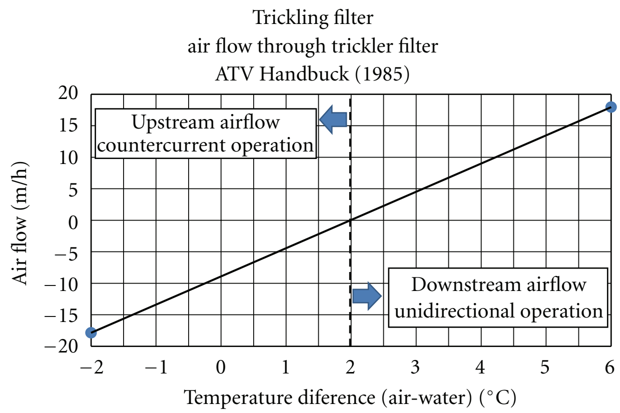

Figure 6: Air flow through trickling filter when the ambient air temperature is equal to wastewater temperature passing the filter media [11].

Assumed nitrification performance is 80%:

$$NH_4 - N - L_{T_f} - \text{Nit} = 8125 \times 0.8 = 6500\,\text{kg/d}. \quad (18)$$

Required volume is shown as

$$V_{T_f,NH_4N,\text{Design}} = 6500 \times \frac{1000}{(1.25 \times 130)} = 40000\,\text{m}^3. \quad (19)$$

Figure 5 shows the surface-specific nitrification rate for trickling filter as a function of temperature. The curve shows the design for Tehran WWTP (rNit, design) as compared to Kempten and other researchers [10].

The benefits and limitation of the influence of hydraulic surface loading of the trickling filter are as follows: The benefits are:

increased rinsing effect causing biofilm renewal,

specific frequently higher constant between wastewater and biofilm due to specific higher wetted surface,

faster renewal of wastewater/biofilm surface being in boundary.

Limitation of population of higher organisms due to washout will happen.

Thinner biofilm, less accumulation of water in biofilm compared to bypassing water flow, and the limitation is the free fall of water drops off the filling material and the air flow through trickling filter or the ventilation problem which occurs when the ambient air temperature is equal to wastewater temperature passing the filter media as shown in Figure 6.

4. Summary and Conclusion

A combination of activated sludge and trickling filter system with the optimum required cell residence time is applied to daily treat 450000 $m^3$of Tehran wastewater collected from municipal and industrial sewer facilities. Presentation of an optimum sewerage plant design certainly is in need of proper estimation of all affecting parameters of an operating mechanism during the life of a system. In this paper the best choice of each affecting parameter within the defined operating range is obtained in a rationalized and justified manner and upon providing adequate margin, and safety factor is presented.

A comparison between combined system of activated sludge and trickling filter and a conventional activated sludge alone is presented.

The comparison between the two systems shows that in a combined system the organic carbon is completely removed by the aeration tank, and nitrification is performed in trickling filter for nitrogen removal, but in conventional activated sludge system, carbon as well as nitrogen removal are completed in aeration tank alone. Therefore, the cost of construction, equipment, maintenance, and operation of the wastewater treatment plant is about 20% less and so called combined system is economically more suitable.The study of the south Tehran wastewater treatment plant has led to the design of treatment plant which is a 65-million dollars project under construction.

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