Asian Journal of Water, Environment and Pollution, Vol. 5, No. 3, pp. 35-47.

Performance Evaluation of the Wastewater Treatment Plant of Sfax City (Tunisia): Influence of Intrinsic and Extrinsic Factors

Chafai Azri*, Habib Abida and Khaled Medhioub[1]

Faculté des Sciences de Sfax (FSS), Département des Sciences de la Terre, BP 802, 3018 Sfax (Tunisie)
[1]Institut Préparatoire aux Etudes d'Ingénieurs Sfax (IPEIS), BP 805, 3018 Sfax (Tunisie)
✉ chafai_azri@yahoo.fr

Received June 7, 2006; revised and accepted November 15, 2007

Abstract: This study detailed the effect of simultaneous multiple intrinsic and extrinsic factors on the characteristics of an aerated lagoon, located in a semi-arid Mediterranean region (Sfax city, Tunisia). The plant performance was evaluated through descriptive and statistical analysis of quantity and quality data of both raw wastewaters and treated effluents over a period of six years (1991-1996). Poor performance was shown to be attributed to raw wastewaters quality, expansion of the population and its activities, rainwater, bad functioning of the grit chamber and ventilation conditions. Furthermore, the influence of other factors related to the industrial atmospheric contribution appeared to be non-negligible.

Key words: Aerated lagoon, wastewater, water quality parameters, statistical analysis, industrial fallouts, deposits.

Introduction

High urbanisation and industrialization rates as well as the rapidly increasing population growth rates over the last few decades have been responsible for the production of huge quantities of wastewater, often disposed off in the environment without any particular treatment (Beaudry, 1992; Edeline, 1998). This usually results in affecting water quality of the receiving water bodies bringing in different types of pollutants (physical, chemical, biological, etc.). Excessive amounts of organic matter in receiving waters cause rapid growth of bacteria, which reduces the overall level of dissolved oxygen, resulting in fish kills and septic conditions in the vicinity of the area of disposal and often for several kilometres downstream.

Tunisia was engaged in large scale investments for the collection and safe disposal of wastewater (Arar, 1991). The ever-increasing development of urbanization, tourism and industrial activities resulted in undertaking the necessary measures to protect wastewater receiving sites from eventual pollution. The number of wastewater treatment plants increased from 26 in 1989 to 61 in 2000 and is expected to exceed 120 plants by 2010 (Kouri, 1992). The annual treated wastewater volume produced by treatment plants spread all over the country is estimated to be 170 millions of cubic metres, 25% of which are used in agriculture (Asano and Mujeriego, 1988; Bahri, 1991; Grabi, 2001). However, compared to the produced treated wastewater volumes, the rate of reuse is still low and important quantities of treated effluents are still rejected in water receiving bodies. An increase in the rate of reuse can be achieved by maintaining a good quality of the treated effluent, which could help convince local farmers with its use in irrigation. This demonstrates the need for systematic controls of effluent quality to evaluate the treatment plant performance and make the necessary changes in order to improve its efficiency. Furthermore, Azov et al. (1992)

*Corresponding Author

found routine monitoring and specific research studies to be beneficial in solving specific problems arising during the operation of large wastewater reclamation systems.

In this context, the present study deals with the evaluation of the performance of the wastewater treatment plant of Sfax city (Tunisia) and retails the influence of multiple intrinsic and extrinsic factors on its characteristics.

Material and Methods

The quality of raw and treated wastewaters of Sfax city is investigated over a period of six years (1991-1996) in order to identify the plant treatment efficiency and evaluate its performance. The adopted methodology consists of the use of:

- Descriptive analysis of monthly data: the parameters, characterizing wastewaters, that were considered, were flow rates, captured detritus and sand volumes, 5-day Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD) and Suspended Solids (SS). The bacteriological aspect was not considered in the present work; it has already been dealt with and published elsewhere (Maalej et al., 2003). Because of the absence of data, pollution by nitrogen and phosphorous compounds was also not considered in this study;
- Complementary statistical analysis: the objective of this second phase of the study was to refine the descriptive analysis and identify the principal factors affecting the characteristics of the plant. Multivariable analysis of data was performed using the I.T.C.F. statistical software package (STATIT-CF, 1987). Two statistical operations were considered: the principal component analysis (PCA) and the automatic cluster analysis. For additional details on these operations, the reader is referred to basic textbooks such as Foucart (1985) for PCA and Roux (1985) for cluster classification.

The following abbreviations are adopted in this study:

Raw wastewater: **w**; Removal efficiency: **r**; Treated effluent: **t**; Water temperature: T_{Water}; Rainwater: R_{Water}; Volume of wastewater: V_{Water}; Volume of detritus: $V_{Detritus}$; Volume of sand: V_{Sand}

Description of the Wastewater Treatment Plant

The wastewater treatment plant considered is that of Sfax city (Tunisia), characterized by a semi-arid Mediterranean climate. The plant, which has been operational since 1983, was designed for raw sewage treatment. Its average and maximum daily capacities are 24,000 and 32,000 m^3 respectively. The plant is composed of a screening system, a grit chamber, an oxidation basin, two secondary clarifiers, two sludge thickeners and sludge drying beds. It is devoid of a primary clarifier. The biological treatment is of the aerated lagoon type based on micro-organisms action to treat wastewaters. Residence time in lagoon was estimated to be around 5.2 days for dry weather conditions (Allani, 1993). Raw sewage is mainly composed of domestic and industrial wastewaters. The treatment plant received wastewater volumes corresponding to 269,114 equivalent-inhabitants in 1991, which represent 89.7% of the total recommended population to be eventually connected to the plant (300,000 equivalent-inhabitants). This percentage remained below 100% until 1993, after which it reached values of 118% and 124% in 1995 and 1996 respectively.

Results and Discussion

Performance Evaluation of the Plant

Wastewater Volumes

In Figure 1, monthly evolutions of wastewater volumes show irregular variation depending not only on water consumption rates of the population but also on the precipitation inflow in the city combined sewer system. The average monthly wastewater volume increased from 6×10^5 m^3, in 1991 to 7.5×10^5 m^3, in 1996. The corresponding average daily volume varied between 20,000 and 25,000 m^3, which is comparable to the plant capacity (24,000 to 32,000 m^3). Over the period 1994-1996, despite the relatively high number of equivalent-inhabitants (more than 100% of the total recommended value), the wastewater volumes did not exceed the plant capacity, implying little water consumption rate. This rate has an average value around 75 litres per equivalent-inhabitant per day.

Extreme monthly wastewater volumes show, in general, small differences:

- The largest monthly volumes of wastewater are observed in the fall season (September, October and November) of 1992 and 1995 (between 8×10^5 and 15×10^5 m^3), characterized by important storm runoff discharge rates (Figure 2);
- In winter season, despite the importance of precipitations, wastewater volumes are relatively small. This is due to the character of regional precipitations (weak downpours spread out over prolonged periods) (Bousnina, 1990). However, one

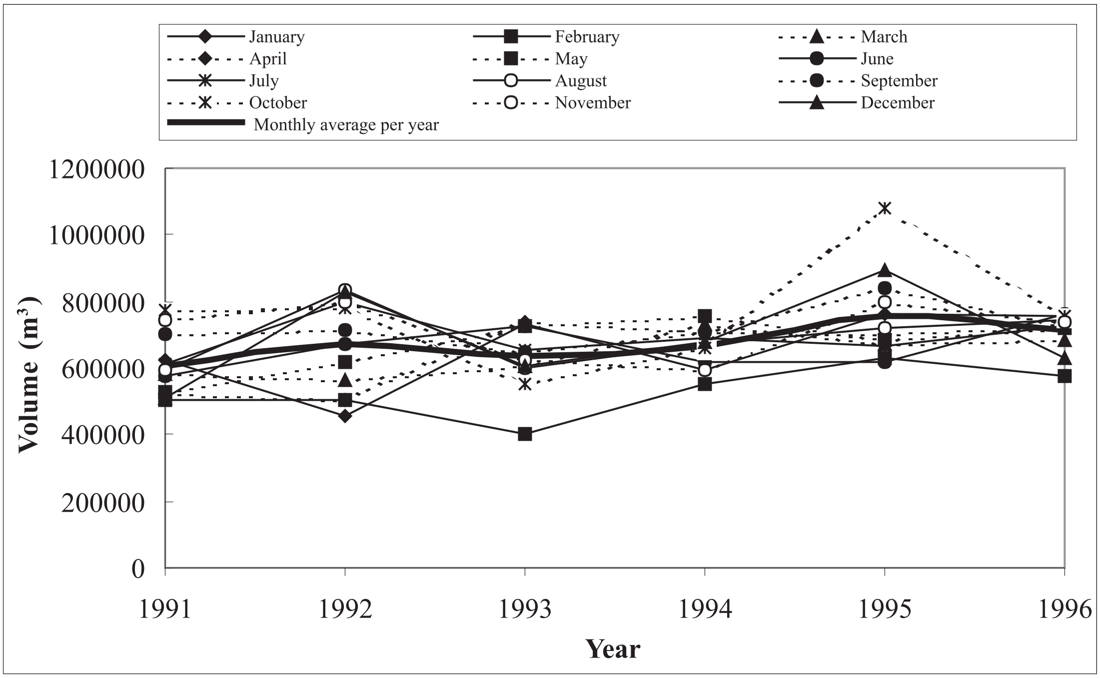

Figure 1: Evolution of wastewater volumes.

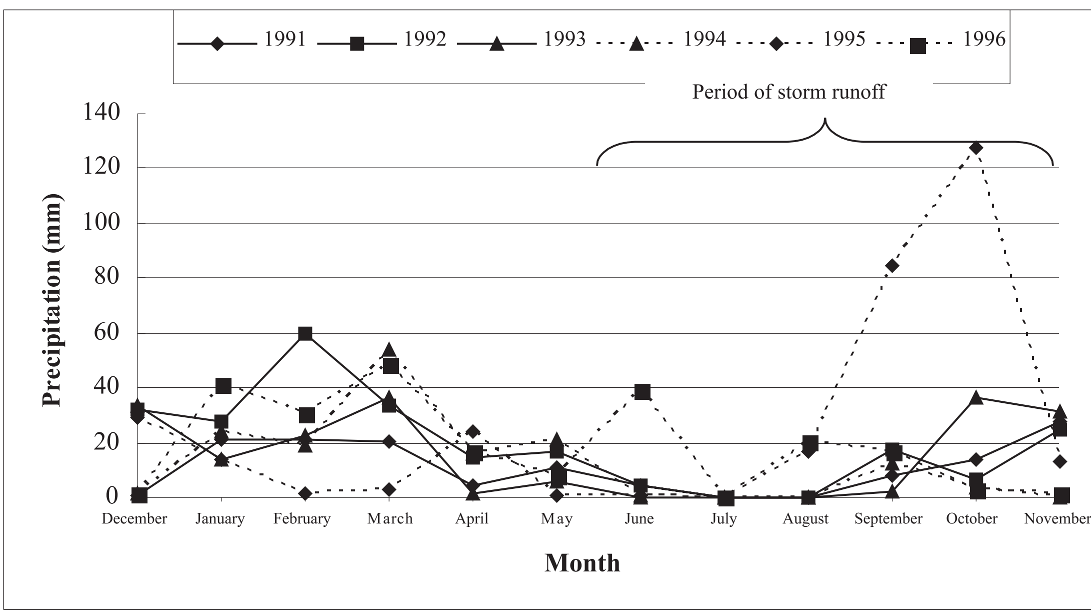

Figure 2: Precipitation variability over the selected period.

cannot exclude the relatively low water consumption rates of the population over this period;

- In summer season, where precipitations are very limited and despite the more important water consumption rates, wastewater volumes remain below registered volumes in the fall season.

Detritus Captured by Screening

Coarse screening of detritus, over the study period (1991-1996), was shown to increase with an increase in connected population and an increase in precipitations (Figure 3). Its average monthly evolution is characterized by values oscillating between 5 and 15 m^3. The highest values were observed in the period (1994-1996), with marked differences from a month to another (6 and 35 m^3). The largest monthly average rates were recorded in the months of September of 1994, 1995 and 1996, October 1995 and November of 1992 and 1993. They can be explained by the important detritus quantities

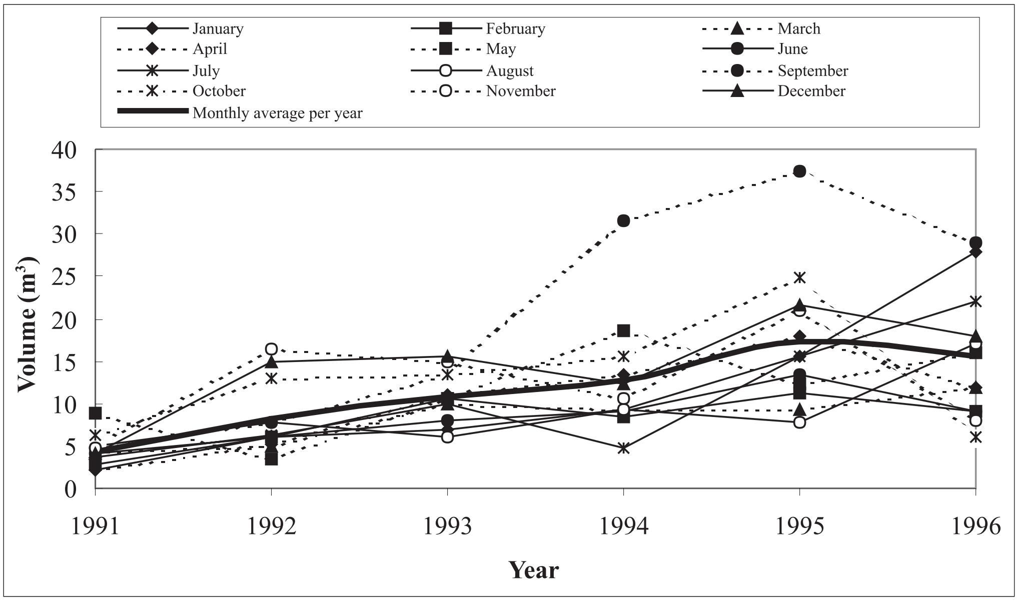

Figure 3: Evolution of detritus captured by screening.

associated with storm runoff, frequently occurring in the fall season. In winter, detritus volumes in December are shown to be important even without precipitations. This might be related to a deposit accumulation in the sewer system after the precipitations of the fall season. Through the screening system, the average detritus volume retention fluctuates between 0.2 and 0.5 litres per equivalent-inhabitant per year. It remains less than the recommended value (5 to 10 litres).

Sand Removal by Decantation

Over the period 1991-1996, sand removal volumes vary in two different fashions (Figure 4):

- 1991 to 1994: monthly average volume is maintained approximately constant at 60 m^3;
- 1995 to 1996: the monthly average volume increased to reach values around 80 m^3. Marked differences in monthly values (40 to 160 m^3) were particularly recorded in 1995. The maxima were observed in fall season (September, October and November), showing again the effect of storm runoff.

The general trend of sand retention volumes (Figure 4) is not very consistent with that of captured detritus. The difference is attributed to:

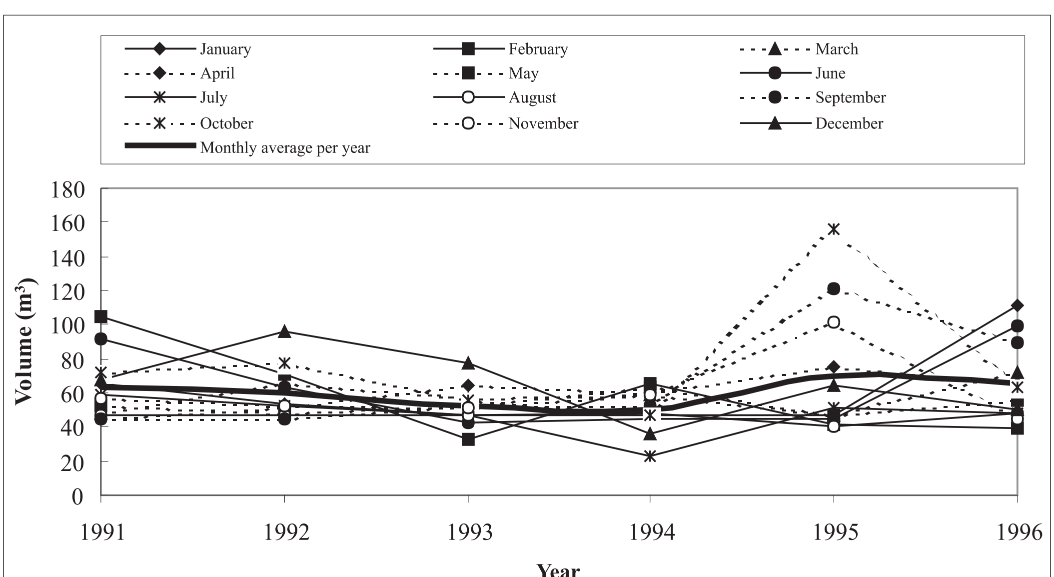

Figure 4: Evolution of sand volumes accumulated at the bottom of the grit chamber.

- The different carrying conditions of sand and detritus in raw wastewaters upstream;
- Their capturing and removal conditions within the wastewater treatment plant.

The average sand retention volume fluctuates between 2.7 and 3.2 litres per equivalent-inhabitant per year. It is less than the recommended value (5 to 10 litres). Studies based on short period sampling at the grit chamber confirmed the bad functioning of this latter (Allani, 1993; Taktak and Trabelsi, 2001). Inside the chamber, sand particles were shown to be re-suspended by the effect of pumping, which limits the decantation process. The escaped sand particles reach the lagoon, thereby increasing not only the accumulation at the bottom but also the water turbidity close to the aerators. These phenomena result in disturbing the ecology of waters (biomass disturbance and improved quantities of sludge in the bottom).

Biochemical Oxygen Demand (BOD_5)

Average Biochemical Oxygen Demand (BOD_5) values in raw wastewaters also varied between 1991 and 1996 (Figure 5a):

- From 1991 to 1993: the monthly average reached values close to 400 mgO_2/L;
- From 1994 to 1996: this period is characterized by a high increasing rate reaching BOD_5 values of 700 mgO_2/L. The representative BOD_5 daily average load, computed over this period, was shown to be much higher than the recommended value of 12,300 kg per day. This is the result of the rapid expansion of new zones connected to the city sewer system. The important monthly fluctuation of BOD_5 values, independent of the season, testifies an anarchical variability of the agglomeration wastes.

In treated effluents, the monthly average BOD_5 values show, in general, the same increasing trend as in raw wastewaters (Figure 5b). However:

- Monthly values in treated effluent are independent of upstream conditions and show a more pronounced variability;
- The increasing rate of values is much more important in treated effluents, especially during the second period (1994-1996);
- Over the first period (1991-1993), despite the conformity of upstream values to the

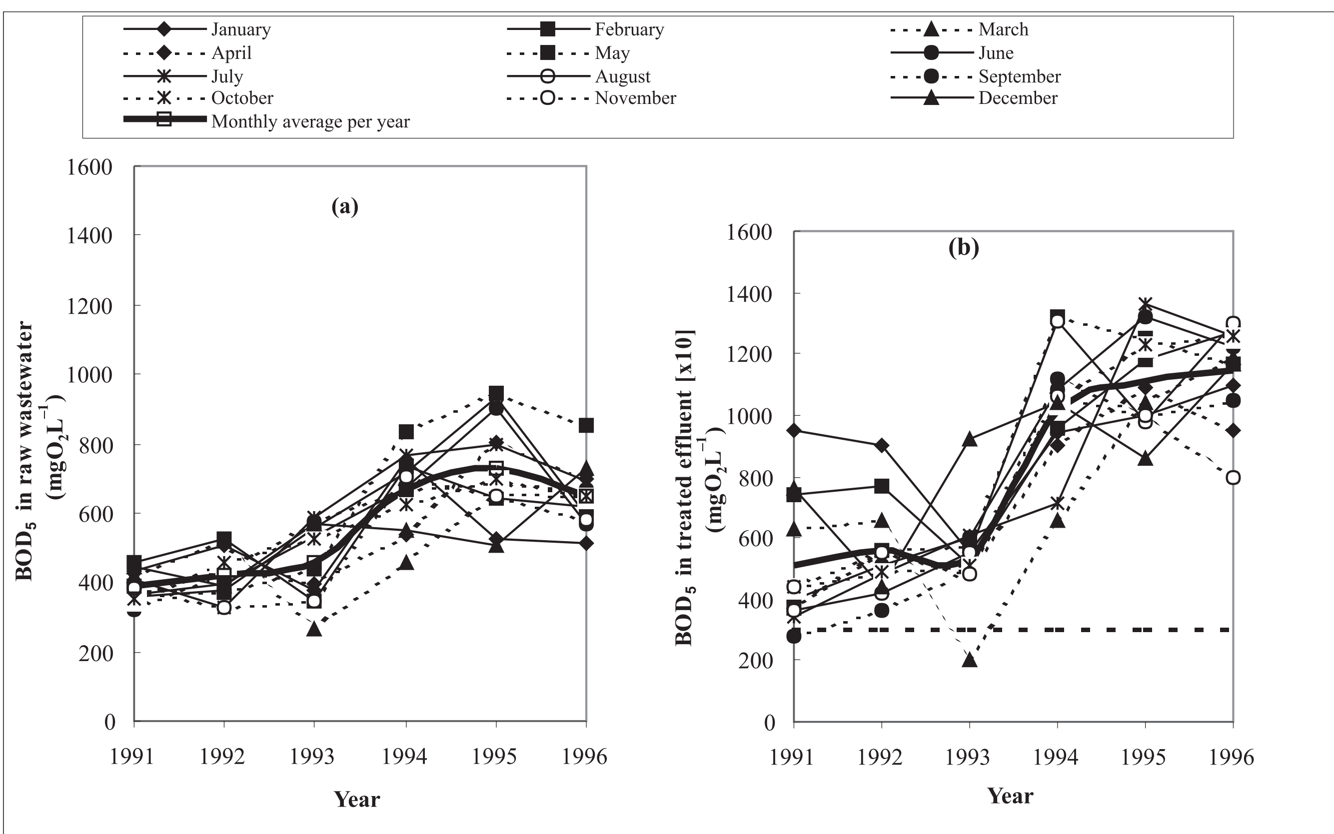

Figure 5: (a) Evolution of BOD_5 in raw wastewater; (b) Evolution of BOD_5 in treated effluent.

recommendations, the downstream values are higher than Tunisian standards (30 mgO_2/L).

All these results show, besides the plant overexploitation, a particular behaviour of organic matter in the wastewater treatment plant. This situation may cause massive production of biomass in the lagoon, which affects overall levels of dissolved oxygen. Through the overall plant, a relatively important BOD_5 removal efficiency fluctuating between 80 and 90% was recorded. It is exaggerated by the screening and decantation systems, through which a 30% BOD_5 removal efficiency was reached.

Chemical Oxygen Demand (COD)

The monthly average evolution of Chemical Oxygen Demand values (COD) in raw wastewaters, during the period 1991-1996, is presented in Figure 6a. Its general trend is not similar to that of BOD_5. It is characterized by two antagonistic evolution phases: the first is represented by a decreasing rate and monthly average values close to 800 mgO_2/L while the second shows an increasing rate and relatively important monthly average values around 1,000 mgO_2/L. The important variability of monthly values is recorded in 1991 and 1993. Maximum values of 1,400 and 1,200 mgO_2/L are observed in January and July 1991 and in September 1993 respectively. Without precipitations, in July 1991, one can deduct that these maxima are independent of the rainwater effect. They can be probably attributed to a dumping of particular industrial wastes. It is important to note that over the period 1991-1996, the representative COD daily average load was shown to be lower than the recommended value of 33,500 kg per day.

The variation of monthly average COD values, in treated effluents shows a trend which is not consistent with that of raw wastewaters (Figure 6b). This could be explained by a particular behaviour of oxydable matters in the plant. This fact could be assigned to an irregular work of aerators functioning. Despite the conformity of upstream values, the monthly COD values largely exceeding Tunisian standards (90 mgO_2/L) confirm a chemical disequilibrium of the system. Through the overall plant, the COD removal efficiency is low, varying between 65 and 75%. A removal efficiency of 15% caused by screening and decantation confirms the very low reduction of COD values through the lagoon.

Suspended Solids (SS)

Over the period 1991-1996, the evolution of monthly average suspended solid (SS) concentrations in raw

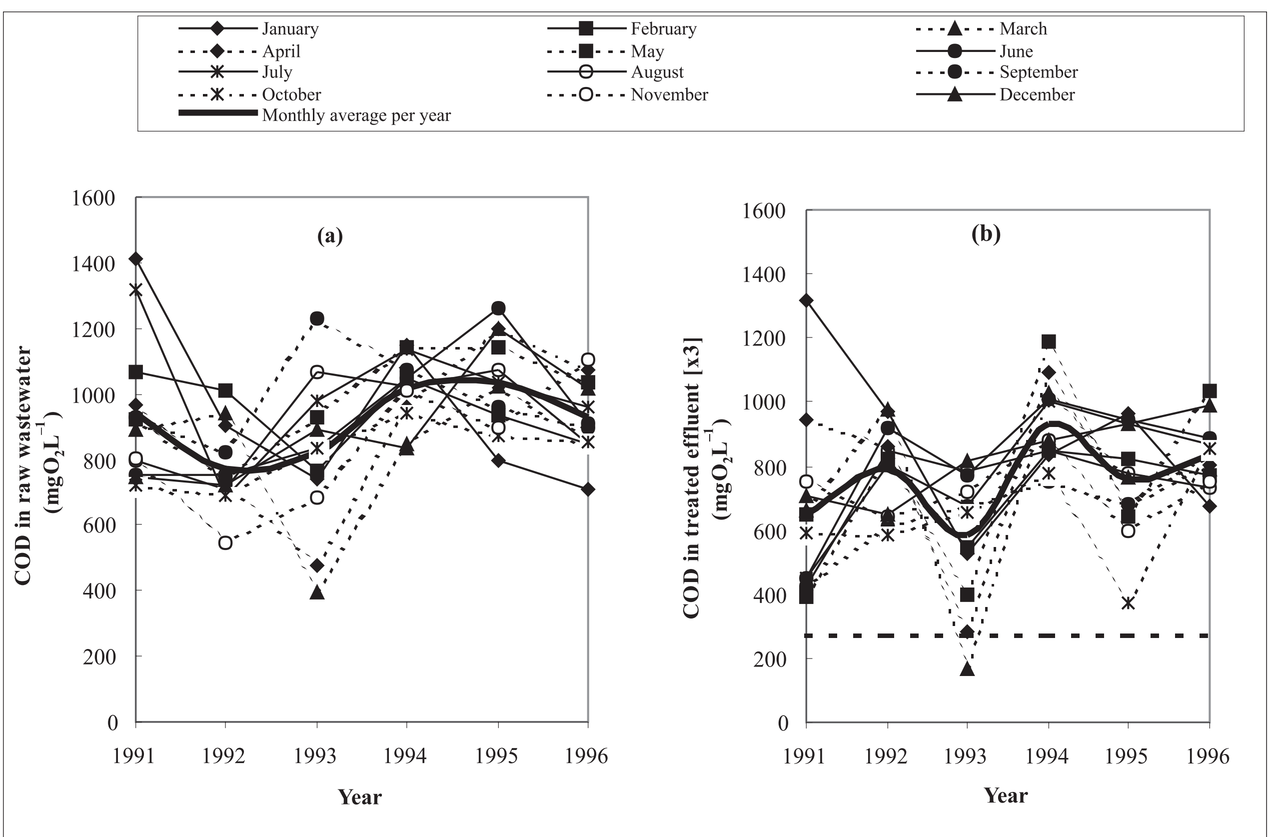

Figure 6: (a) Evolution of COD in raw wastewater; (b) Evolution of COD in treated effluent.

wastewaters shows a fluctuating trend, with values varying between 300 and 500 mg/L (Figure 7a). The computed representative daily average of SS loads showed values fluctuating between 7,000 and 11,000 kg per day, which are lower than the recommended value of 12,200 kg per day.

SS concentrations in treated effluents show a marked variability from a month to another (Figure 7b). Maxima appeared independent of upstream values. This testifies also a particular behaviour of SS in the plant. The aeration conditions of wastewaters in the lagoon as well as the rising of the mud to the water surface, which was proved elsewhere (Allani, 1993), are probably the main factors of this SS behaviour. According to the aforementioned study, the mud rising is a result of an expansion of anaerobic conditions in the lagoon waters. The overall plant efficiency in terms of suspended solids retention was shown to be around 90%, with relatively high concentrations downstream compared to Tunisian standards (30 mg/L). The removal efficiency in suspended solids reaches 30% through the screening and decantation systems, which clearly shows reduced removal rates through the lagoon.

From this descriptive study, it emerges that:

- The performance of the plant is affected by multiple factors such as the expansion of the population and its activities, the inlet wastes quality, the rainwater, the bad dimension of the grit chamber and the ventilation conditions.
- The BOD_5, COD and SS removal efficiencies through the screening and decantation systems can be explained by the enrichment of detritus and sand by mineral and organic matters.
- Through the lagoon, the relatively low BOD_5, COD and SS removal efficiencies testify a chemical and biochemical disequilibrium of the oxidation basin.

In the following, by using statistical analysis, one refines the impact of the above intrinsic and extrinsic factors on plant characteristics.

Statistical Analysis of Data

Table 1 displays the summary statistics of significant inter-wastewater quality parameters correlations. The threshold of significance resulting from a test of Pearson for $p<0.05$ was found to be equal to 0.23. This yielded a moderately significant distribution corresponding to 54 significant relationships out of 105 total relationships. The most important significant relationships indicated that:

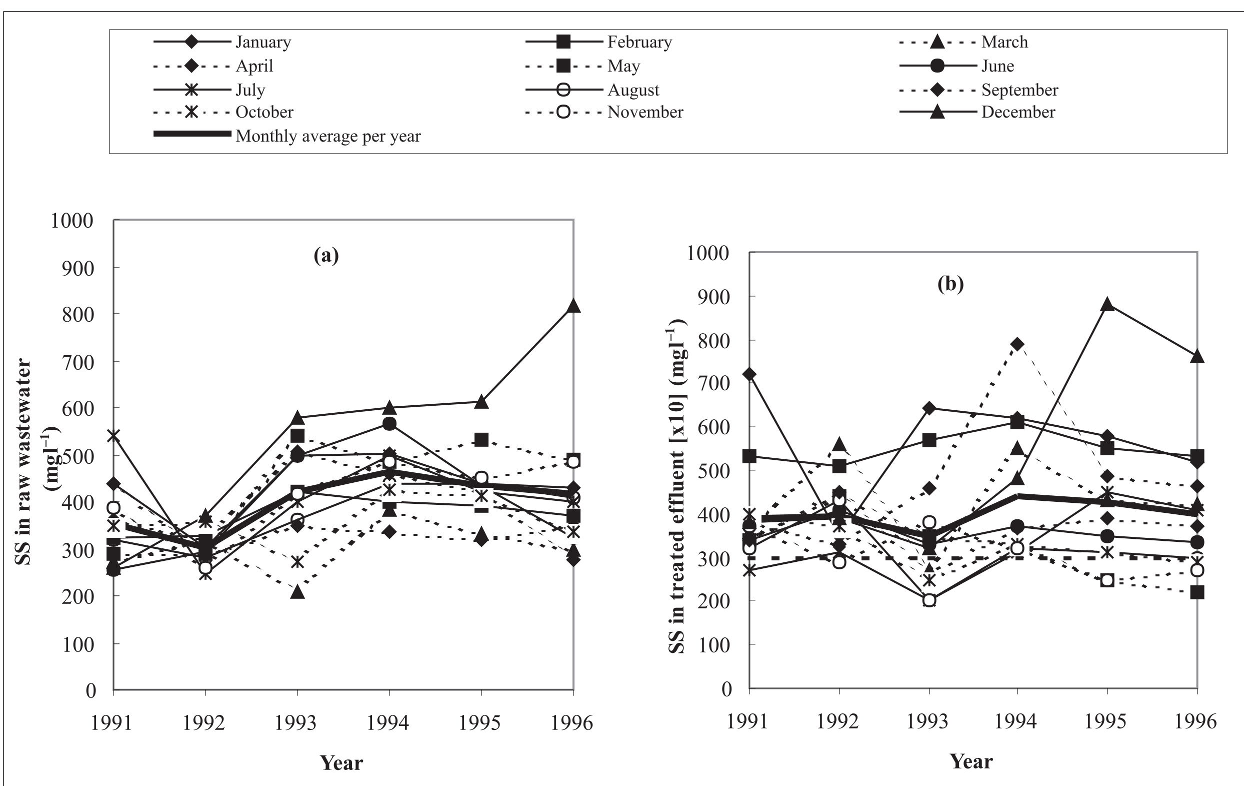

Figure 7: (a) Evolution of SS in raw wastewater; (b) Evolution of SS in treated effluent.

Table 1: Inter-element correlations matrix (r = 0.2 3; p<0.05; n = 72)

		Raw wastewater								*Treated effluent*			*Removal efficiency*		
		T_{water}	R_{water}	V_{water}	$V_{Detritus}$	V_{Sand}	BOD_5w	$CODw$	SSw	BOD_5t	$CODt$	SSt	BOD_5r	$CODr$	SSr
Raw wastewater	T_{water}	1.000													
	R_{water}	–0.232	1.000												
	V_{water}	0.333	0.307	1.000											
	$V_{Detritus}$		0.383	0.501	1.000										
	V_{Sand}		0.670	0.413	0.439	1.000									
	BOD_5**w**				0.419		1.000								
	COD**w**						0.639	1.000							
	SS**w**						0.354	0.423	1.000						
Treated effluent	BOD_5**t**				0.470		0.806	0.425	0.265	1.000					
	COD**t**						0.439	0.437	0.256	0.521	1.000				
	SS**t**	–0.579							0.239		0.340	1.000			
Removal efficiency	BOD_5**r**	0.257			–0.281		–0.220			–0.738	–0.459	–0.341	1.000		
	COD**r**							0.272			–0.721	–0.265	0.450	1.000	
	SS**r**	0.416					0.275	0. 250	0.494			–0.697	0.243	0.301	1.000

Water temperature: T_{Water}; Rainwater: R_{Water}; Volume of wastewater: V_{Water}; Volume of detritus: $V_{Detritus}$; Volume of sand: V_{Sand}; Raw wastewater: **w**; Removal efficiency: **r**; Treated effluent: **t**.
Only variables with p<0.05 are listed. Blank = $p \geq 0.05$, n = 72 for all variables

- The rainwater is correlated with raw wastewater, detritus and sand volumes (r is respectively equal to 0.307, 0.383, and 0.670 for p<0.05). It contributes therefore to their increase in the sewer system. The high positive correlation coefficient between sand volume and rainwater confirms both its abundance in Sfax city (roofing, pavements, etc.) and its relatively easy transport by the surface water (compared to the detritus). A good positive correlation between detritus and BOD_5**w** (r = 0.419; p<0.05) is particularly noted, independently of rainwater. It testifies their enrichment by organic matter (organic fibers, greases, hydrocarbons, etc.). Compared to the sand, detritus have large contact surfaces and are therefore able to fix (by absorption, adsorption, etc.) greases and hydrocarbons in the sewer system.
- The quality parameters describing raw wastewater (BOD_5**w**, COD**w**, SS**w**) are positively correlated. This can be explained by the effect of their common transport mechanism in the sewer system. Their independence of raw wastewater volume is attributed to the irregularity of waste quantities, which are function of the population activities.
- The removal efficiencies of wastewater quality parameters are not correlated with the parameter values of raw wastewater, which are positively correlated with those of treated effluent (except for BOD_5). This confirms the abnormal functioning of the plant.

The application of simple correlation analysis is insufficient to evaluate the simultaneous effects of multiple factors on plant characteristics because this analysis tests the relationship between a single independent parameter and a dependent parameter at a time and consequently fails to elucidate combined effects of multiple factors. Therefore, multivariable analyses including a principal component analysis (PCA) and an automatic cluster classification were performed. In these statistical analyses, the lagoon water temperature was chosen as the seasonal reference parameter because of its good correlation with ambient temperature (r = 0.970; p<0.05).

The PCA applied to all data (monthly values of wastewater quality parameters) resulted essentially in three principal components (Table 2). The significant correlations between selected parameters (variables) and these components represent approximately 62% of the total variance. These components superimposed on an automatic cluster classification of data based on a division of three classes show distinguished chronologically disorganized periods (Figure 8):

(i) A first period (class 1), which is defined by the first component, is represented by the majority of

Table 2: Correlation between variables and principal components

		Component 1 (Axis 1)	Component 2 (Axis 2)	Component 3 (Axis 3)
	Variance %	25.9	18.9	17.0
	Selected variables	Correlation coefficients		
	Rainwater	0.238		0.704
Raw wastewater	Water temperature		0.677	
	Water volume	0.368	0.235	0.558
	Detritus volume	0.620		0.509
	Sand volume	0.226		0.774
	BOD_5**w**	0.810	0.389	
	COD**w**	0.396	0.372	–0.491
	SS**w**	0.364	0.259	–0.414
	COD**w**/BOD_5**w**	–0.684		
Treated effluent	BOD_5**t**	0.930		
	COD**t**	0.621	–0.279	–0.531
	SS**t**		–0.735	
Removal efficiency	BOD_5**r**	–0.653	0.459	
	COD**r**	–0.331	0.544	
	SS**r**		0.856	

Only variables with p<0.05 are listed. Blank = $p \geq 0.05$, n = 72 for all variables

selected water quality parameters (differed in Table 2) and explains 26% of the total variance of data. This component presented good positive correlations with parameters describing the raw wastewater quality and those of treated effluent. On the other hand, it is anti-correlated to parameters describing removal efficiencies. Furthermore, the good negative correlation between this first component and the COD**w**/BOD_5**w** ratio, which fluctuated between 2 and 3, confirms a good quality of wastewater for biological treatment. This situation implies normally a good functioning of the wastewater treatment plant. However, the absence of relationship between the SS removal and this first component shows a particular behaviour of particle matters in the plant, which is eventually attributed to ventilation conditions of wastewaters in the lagoon and the mud up-lifting to the water surface. This first component, which is independent of the lagoon water temperature (r = 0.019; p<0.05), shows a variance tendency independent of the season. However, it is dependent on precipitation effects (r = 0.238; p<0.05);

(ii) A second period (class 2), which corresponds to the second component, accounts for 19% of the total variance of data and is mainly represented by the wastewater temperature and some of the selected wastewater quality parameters. This second component depends on season effect, but, it is independent of the rainwater effect (r = 0.202; p<0.05). It explains another tendency for evaluating a second performance state of the plant. It is distinguished from the previous tendency by its independence of treated effluent parameters, especially BOD_5**t** (r = 0.023; p<0.05). It showed then a bad functioning of the plant. Besides, there is no significant relationship between parameters describing removal efficiencies and the COD**w**/BOD_5**w** ratio. This latter fluctuated between 1.5 and 2 and was shown to be influenced by an increasing rate of organic loads.

(iii) A third period (class 3), which defines the third component, accounts for 17% of the total variance. It is represented by rainwater, wastewater volume, detritus and sand volumes. This period, which

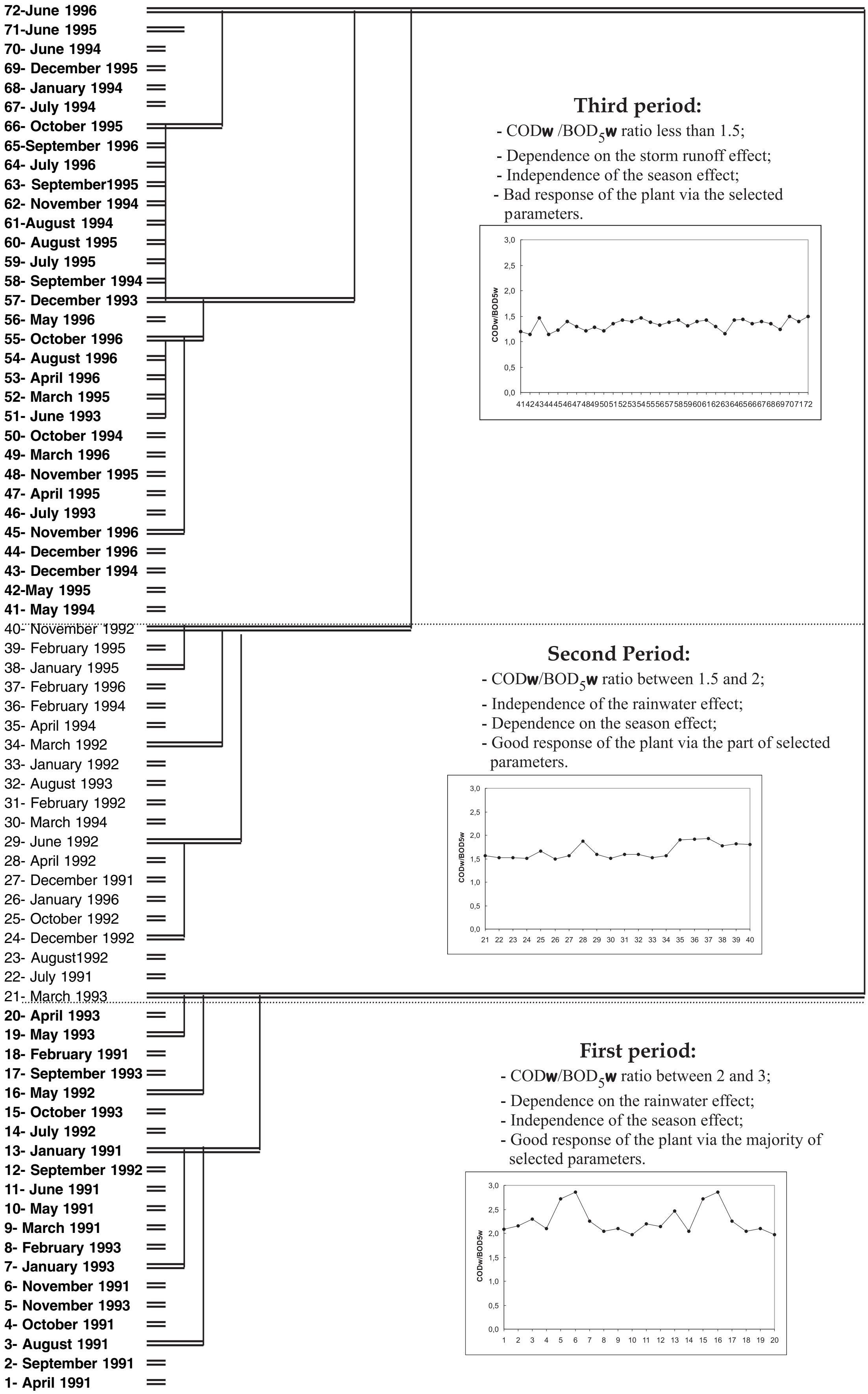

Figure 8: Cluster analysis results.

includes months characterized by torrential precipitations, shows the storm runoff effect, but, it is independent of the season. It represents a tendency for evaluating a third state of the plant performance, in which no correlations between water quality parameters and this component were noted. The $COD\mathbf{w}/BOD_5\mathbf{w}$ ratio is less than 1.5 and is influenced by an accentuated growth of the organic loads rate. Compared to the first period, this period is characterised by a decrease in removal efficiencies of both organic and mineral loads through the lagoon close to 10%. This relatively small decrease in the removal efficiency, despite the random change of the plant characteristics, proves the important role of the waters ventilation. The important waters ventilation was already confirmed by the maximum consumption rate of energy. It emerges that the plant, which did not preserve its characteristics during the three previous periods preserved, however, a nearly identical performance. This is attributed to the growth of ventilation which reinforces the survival of the biomass (notably the most resistant). This result was proved elsewhere (JICA, 1993).

The plant was installed more than 20 years ago in the vicinity of an industrial area characterized by various activities (lead secondary melting, chemical treatment of phosphate, municipal discharge, etc.). Therefore, besides the above mentioned intrinsic and extrinsic factors influences, the plant performance would be affected by the industrial fallouts and deposits. Different studies performed in the industrial zone showed high emission rates of SOx and dust, exceeding by far Tunisian standards (JICA, 1993; Azri, 2000). Indeed, through the chimneys of the phosphate treatment factory, average flow rates of 1,590 and 1,659 t/yr for dust (enriched by sulphate and phosphorous compounds) and SOx (expressed in equivalent SO_2) were registered respectively. These flow rates exceed 8 and 20 times respectively emission standards. Discharge rates of certain metals present in dust such as zinc, nickel, cadmium, copper and lead were evaluated as 3.01, 1.05, 1.07, 0.7 and 0.11 t/yr respectively. Dust discharge rates out of the lead secondary melting industry were found to be around 640 t/yr, which represent more than 160 times the acceptable standards. Lead concentrations originating from this industry were also found to be extremely high (72 t/yr).

Aerosol study conducted in the vicinity of the wastewater treatment plant area confirmed the air quality degradation and the pronounced influence of the aforementioned industrial sources (Azri et al., 2000). Compared with aerosols in other zones mildly affected by the industrial plumes, aerosol in the vicinity of the wastewater treatment plant was shown to be enriched in PO_4^{3-} (70%), Pb (60%), SO_4^{2-} (50%) and NH_4^+ (45%), compounds, which originate mainly from the industries involved in chemical treatment of phosphate, lead secondary melting and also municipal discharge (Azri and Medhioub, 2001). Atmospheric pollutant concentrations were shown to be accentuated by their poor diffusion in the atmosphere, the presence of obstacles and the importance of neutralisation processes (Azri et al., 2002).

SO_2 and dust deposit flows estimated at the water total surface of the plant, were shown to be around 5 and 15 t/yr respectively. These data clearly show the importance of the industrial atmospheric contribution, which clearly affects the ecology of waters in the wastewater treatment plant. Because of its location in the vicinity of industrial sources and its prolonged exposition (more than two decades) to their plumes, the plant was the dump site for important fallouts highly enriched in acidic substances (SO_2, sulphate), in phosphorous, in metals and ammonium. These compounds were already proved to be toxic and inhibitors of certain biochemical processes such as nitrification. Negative impact of these compounds on vegetation near the plant was shown by Ben Abdallah et al. (1990 and 1994). Sensitive species such as blackberry and apricot trees completely disappeared in a radius 1 km long from the phosphate treatment factory.

Conclusions

The descriptive study based on the water quality parameters evolution showed, besides the plant overexploitation, a particular behaviour of mineral and organic matter in the wastewater lagoon, testifying its ecological disequilibrium. It is affected by multiple intrinsic and extrinsic factors such as the raw wastewater quality, the expansion of the population and its activities, the rainwater, the bad functioning of the grit chamber and the ventilation conditions. In spite of the large variability of its characteristics via the selected factors, the plant maintained almost a nearly identical performance in terms of organic and mineral loads removals. This is attributed to the high waters ventilation, which reinforces the matter oxidation and the biomass survival.

Statistical analysis surrounded the impact of the aforementioned factors and proved the influence of others. The influence of industrial atmospheric fallouts, which has not been considered in the impact study for the plant implantation appeared to be non-negligible. By its proximity to polluting industries, its prolonged exposition (more than two decades) to their plumes and the effect of artificial obstacles, this plant has been proven to be the dump site of important fallouts highly enriched in acidic substances (SO_2, sulphate), in phosphorus, in metals and in ammonium. These compounds, which have been proved responsible for the vegetation decay close to the plant, are also able to damage the ecology of its waters.

In order to avoid high additional energy costs and improve the plant performance, the following recommendations may be considered:

- Adequate treatment of the industrial atmospheric emissions and removal of the artificial obstacles;
- Better design the grit chamber in a way to improve sand retention;
- Evacuate sludge deposits out of the lagoon to avoid their re-suspension to the surface and the extension of anaerobic conditions in wastewaters;
- Install water retention basins upstream of the plant to improve decantation of storm water runoff; and
- Install an activated sludge circuit to optimize degradation processes in the lagoon.

This study can be adopted as a model to improve the performance of treatment plants elsewhere with parallel environmental conditions.

Acknowledgements

Data used in this study were provided by the Wastewater Treatment Division of the Tunisian Ministry of Environment.

References

Allani, M. (1993). Epuration des eaux résiduaires urbaines par lagunage aéré et désinfection par rayonnements ultraviolets. Thèse de Doctorat de l'Université Paris VII, 189 p.

Arar, A. (1991). Wastewater Reuse for irrigation in the Near East Region. *Journal of Water Science and Technology*, **23:** 2127-2134.

Asano, T. and R. Mujeriego (1988). Tunisia: Institutional Aspects of wastewater Reuse. Report prepared for UNDP-WB water and sanitation program. UNDP Project RAB/88/009.

Azov, Y., Juanico, M. and G. Shelef (1992). Monitoring Large Scale Wastewater reclamation Systems—Policy and Experience. *Journal of Water Science and Technology*, **26:** 1444-1453.

Azri, C. (2000). Contribution des sources mobiles et fixes à la pollution atmosphérique dans la région de Sfax (Tunisie). Thèse de Doctorat de l'Université de Tunis II, 234 p.

Azri, C., Maalej, A. and K. Medhioub (2000). Etude de la variabilité des constituants de l'aérosol dans la ville de Sfax (Tunisie). *Pollution atmosphérique*, **165:** 121-129.

Azri, C. and K. Medhioub (2001). Caractérisation physico-chimique de l'aérosol urbain dans la ville de Sfax (Tunisie). *Pollution atmosphérique*, **170:** 279-291.

Azri, C., Maalej, A., Tlili, A. and K. Medhioub (2002). Caractérisation du niveau de pollution atmosphérique dans la ville de Sfax: Influence des sources et des facteurs météorologiques. *Techniques, Sciences, Méthodes* (*TSM*), **1:** 78-92.

Bahri, A. (1991). Present and future state of treated wastewaters and sewage sludge in Tunisia. Research Center for Rural Engineering, Tunis.

Beaudry, J.P. (1992). Traitement des eaux: Edition de Griffon d'Argile, 187-206.

Ben Abdallah, F. and M. Boukhris (1990). Action des polluants atmosphériques sur la région de Sfax (Tunisie). *Pollution atmosphérique*, **127:** 292-297.

Ben Abdallah, F., Belgacem, H. and M. Boukhris (1994). Réponses des végétaux d'une région aride à une pollution atmosphérique double (SO_2 et composés fluorés). *Pollution atmosphérique*, **143:** 117-122.

Bousnina, A. (1990). Le climat de Sfax. Rapport n°1, INM, 61 p.

Edeline, F. (1998). L'épuration biologique des eaux (Théorie et technologie des réacteurs). 4ème édition CEBEDOC, Lavoisier, 297 p.

Foucart, T. (1985). Analyse factorielle: Programmation sur Micro-ordinateur. Masson, Paris.

Grabi, A. (2001). Eaux usées, quel traitement pour quel usage ou quel usage pour quel traitement? *Revue de l'environnement en Tunisie*, **8:** 36-38.

Japan International Cooperation Agency (JICA) (1993). The study on waste water treatment and recycling of selected industries in the region of Sfax in the republic of Tunisia. Printed in Japan.

Kouri, N. (1992). Wastewater Reuse Implementation in selected countries of the Middle East and North Africa. *Canadian Journal of Development Studies*, Special issue on sustainable water resources management in arid countries. International Water Resources Association, 131-144.

Maalej, S., Mahjoubi, A., Azri, C. and S. Dukan (2003). Simultaneous effect factors on motile Aeromonas dynamics in an urban effluent and in the natural seawater. *Water Research*, **37:** 2865-2874.

Roux, M. (1985). Algorithmes des classifications. Masson, Paris, 1985.

STATIT-CF (1985). Services des études statistiques de l'I.T.C.F.

Taktak, G. and R. Trabelsi (2001). Etude des performances épuratoires de la station d'épuration des eaux usées de la ville de Sfax par l'emploi des méthodes descriptives et des analyses multivariables. Mémoire de maîtrise. Faculté des Sciences de Sfax, 55 p.