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Analysis of the Production and Treatment of Wastewater in the Southeast of Coahuila, Mexico

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Abstract

This paper deals with the study of wastewater production, municipal treatment plants performance, and utilization of treated wastewater in the southeast of Coahuila, Mexico. The objective is to identify the status of wastewater in order to propose alternatives to increase the use of treated wastewater. Influent and effluent on three municipal wastewater treatment plants were analyzed considering four parameters. Results show that the wastewater presents a high concentration of total suspended solids; nevertheless the effluents meet the current environmental standards. Then the treated wastewater requires additional treatment before to be applied in industrial processes, but it can be used for irrigation purposes.

Keywords: wastewater, treatment, reutilization, irrigation, environment

1. Introduction

According to the law of conservation of matter, water is not created or destroyed only transformed; however human is able to use it and to pollute it reducing the availability of this essential resource. Most of human activities require water, either in transformation processes or in urban applications; then the production of wastewater is implicit to human settlements. For this reason, the wastewater should be treated and adapted to be used in adequate applications in order to keep on the natural equilibrium between the human and the ecosystem. The treatment at different levels improves the wastewater quality and allows the use in several applications. Nowadays, the reuse of municipal wastewater is an extended practice all around the world, especially in arid and semiarid countries. It implies that treated wastewater is a part of the actual water hydrological cycle; it is considered as an alternative source of water and should be included in all balance studies. The quality of the treated wastewater depends on the water source and also on the treatment level and/or the depuration process; this quality is also an important aspect to define the reutilization alternatives. On the other side, the wastewater treatment plants must to remove both biological and physicochemical pollutants which are accumulated by the first user of water and to reach the requirements of the second user. The most common applications for treated wastewater are agriculture and industrial activities, watering of green areas and aquifers refill (Arreguín et al., 1999). Many studies concerning different aspects of treated wastewater reuse have been reported. For example, on a review of the situation in South Africa, including potential and challenges of treated wastewater reuse it is concluded that there exist an important potential of wastewater reuse in applications such as landscape irrigation and industrial processes in arid areas (Adewumi et al., 2010). Besides, an evaluation of technical, legal, social and economic challenges concerning the reuse of treated wastewater in the West Bank at the Palestinian territory, as an example of arid and semi-arid areas, has been reported (Mizyed, 2013).

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A relevant conclusion of the study is that the participation of farmers in developing guidelines, standards, policies and plans for agricultural reuse is very important for the sustainability of treated wastewater reuse. A feasibility study for the application of treated municipal wastewater in agricultural irrigation on the island of Crete was developed (Agrafioti and Diamadopoulos, 2012); three types of crops were evaluated (olive trees, vineyards and lettuce) considering the Greek water reuse criteria. Another study has been addressed in order to evaluate the application of treated wastewater on agriculture irrigation considering new standards in Riyadh, Saudi Arabia (Al-Jasser, 2011); the effluent quality from the six largest sewage treatment plants was monitored during 10 months; all of the studied plants produce effluents with minor violations for restricted agricultural irrigation; but, they do not meet the unrestricted agricultural irrigation standards. Besides, an important study related to the status of treated wastewater applications in Jordan is reported (Ammary, 2007); in this region, waste stabilization ponds (WSP) to treat wastewater for reuse in agriculture has been employed; the effluent from these plants are mixed with freshwater resources and stored before being used. The expected quality of the effluent from some of the new plants is very high. In addition, the volume of treated wastewater will increase as a result of high population growth and increased sewered areas. Also, a systematic framework to evaluate the possible wastewater reuse quantities under technological, economic and physical conditions in China has been proposed by Chu et al., (2004); based on the regional disparities in China, a linear programming optimization model is developed to explore the potential wastewater reuse under different scenarios; the study concludes that proper designing of regional or national policies will provide new opportunities of wastewater treatment and reuse infrastructure construction, and further promote regional or national economies. Another study reports the results of a reuse scenario where tertiary-treated municipal wastewater was supplied for vegetable crop irrigation, specifically, eggplant and tomato (Cirelli et al., 2012); tomato crops were successfully grown on treated wastewater-supplied plots, with higher yields (approximately 20%) than on plots supplied with fresh water. Moreover, an integrated strategy for reuse of treated municipal wastewater for irrigation of urban green areas has been proposed (Kalavrouziotis and Apostolopoulos, 2007); the strategy take into consideration the appropriate selection of species to be irrigated with the treated water, as well as several parameters relative to qualitative characteristics of the wastewater; the analysis of physical–chemical and environmental properties of all applications on soil, plants, building installations, and pipes are also included; the authors conclude that the adequate implementation of the proposed plan requires the responsibility of municipalities in cooperation with the private sector, and that it is possible to solve the environmental problem of management of municipal wastewater.

As can be seen from the previous literature review, the reuse of treated wastewater in agriculture is basically for irrigation of different kind of crops; the urban reuse concerns landscape and green areas irrigation; in industrial sector, the treated wastewater can be used for cooling and processes which do not require water with high quality, and then this is a very interesting potential market in industrialized cities. An important issue is the need of adequate plans and strategies for a better utilization, as well as a careful evaluation of the potential applications of treated wastewater. Concerning the case of study presented in this paper, the southeast region of Coahuila, Mexico, is situated in a semiarid area with low precipitation, and in general, with few water resources. This region includes 5 counties: Saltillo, Ramos Arizpe, Arteaga, General Cepeda and Parras de la Fuente; but the population is mainly concentrated at Saltillo, Ramos Arizpe and Arteaga. In these 3 counties, there is a population of 850,000 which consumes around 51,500,000 m^3/year of water approximately. According with the National Water Board (CONAGUA, 2011), this volume corresponds to 20% of the water extraction from the aquifers in the southeast of Coahuila. The municipal wastewater produced is almost the same than the consumed water; however only 65% is collected by the sewage network and sent to the wastewater treatment plants. The treatment processes are designed in order to reach the Mexican official standards NOM-002-ECOL-1996 (1998) and NOM-001-ECOL-1996 (1998), which are related to wastewater and treated wastewater. The objectives of these standards are: i) to avoid the dispersion and multiplication of pollutants (mainly biological), ii) to avoid the proliferation of illness, and iii) to return the water to the hydrological cycle in order to maintain the natural equilibrium (Arreguín et al.,1999; Escalante et al., 2003). From this perspective, the reutilization of treated water is done during its whole natural cycle, which includes: extraction, return to sea, evaporation, precipitation, refill of water bodies such as aquifers, lakes and rivers. Also, it is required to do some studies to evaluate social, economic and environmental impacts; the goal of these studies is to determine the investment for infrastructure either to the reutilization (processes for tertiary or higher treatment, treated water network distribution, etc.) or to an optimal use of the water naturally purified (aqueducts, dams, better distribution networks, efficient refill of aquifers).

In this work it is presented an analysis of the situation of the influent and effluent on the wastewater treatment processes which operates in the metropolitan area of Saltillo, Ramos Arizpe and Arteaga, in Coahuila, Mexico. The main contribution of the study is the identification of the status of wastewater and treatment plants efficiency, and the formulation of potential strategies in order to increase the use of treated wastewater. The first activity was to analyze the physicochemical characteristics of the influent and the effluent on the three municipal wastewater treatment plants situated in this region. The considered parameters on this analysis are: biochemical oxygen demand (BOD), total suspended solids (TSS), heavy metals concentration (HMC) and conductivity (C).

2. Methodology

2.1. Status of the Municipal Wastewater Treatment Processes

The information was obtained through the technical reports provided by the enterprises which operate three WWTP: Planta Principal de Saltillo (SPP: Saltillo Principal Plant), Planta del Gran Bosque Urbano (BUFP: Big Urban Forest Plant) and Planta Municipal de Ramos Arizpe (RAMP: Ramos Arizpe Municipal Plant). The available information corresponds to the years 2008 to 2013 (Ideal, 2006; Ramos Arizpe, 2013).

2.2. Evaluation of the Water Quality

The considered parameters for the evaluation are:

- Biochemical oxygen demand (BOD) on the influents and effluents
- Total suspended solids (TSS) on the influents and effluents
- Heavy metals concentration (HMC)
- Conductivity (C)
- Influents and effluents flow rates.

2.3. Alternatives for Utilization of Treated Wastewater

The alternatives for utilization of treated wastewater were proposed considering the quality of the effluents and the potential users.

3. Results

3.1. Saltillo Principal Plant

Figure 1 and Figure 2 shows the obtained results for BOD and TSS corresponding to the influent and the effluent of the Saltillo Principal Plant.

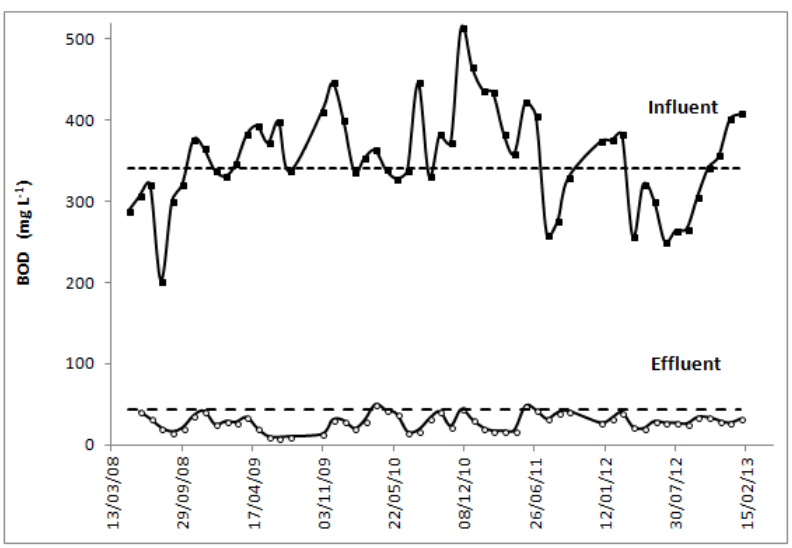

Figure 1: BOD in the Influent and Effluent of the Saltillo Principal Plant

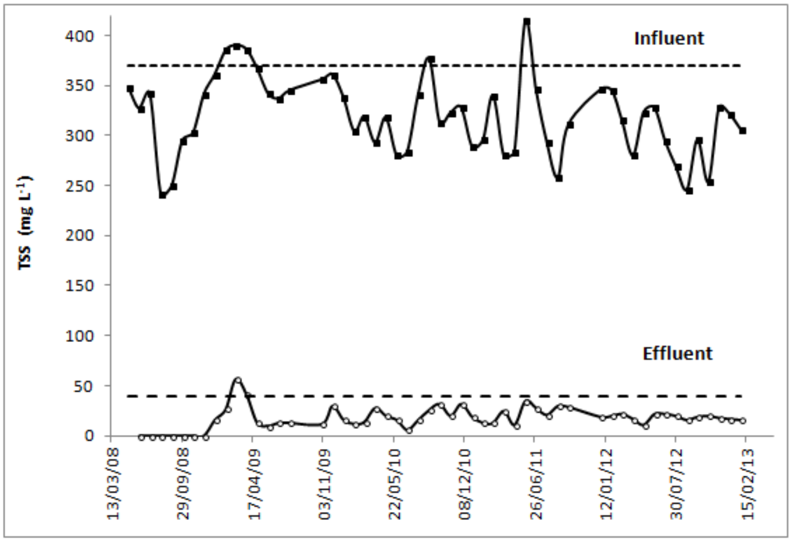

Figure 2: TSS in the Influent and Effluent of the Saltillo Principal Plant

As can be seen, the obtained values for BOD (353 mg L^{-1}) and TSS (319 mg L^{-1}) in the influent correspond to typical levels of these parameters on urban wastewater. In addition, both parameters reach the permissible interval considered in the original conditions of the plant design (Ideal, 2006; Saltillo, 2013). On the other side, it is important to remark that these parameters have values over the stated by the official standard NOM-002-ECOL-1996, which indicates that the maximal level permissible of pollutants on the wastewater discharges on the municipal sewage system is 150 mg BOD L^{-1} and 150 mg TSS L^{-1}. Concerning the effluent, the parameters BOD (28.2 mg L^{-1}) and TSS (17.6 mg L^{-1}) are below the values considered in the plant design, which are 44 mg BOD L^{-1} and 40 mg TSS L^{-1}. A removal of 92 % and 94 % respectively is obtained for these parameters. It implies that the treatment process reach the corresponding official standard NOM-001-ECOL-1996 (1998); this standard determines the pollution maximal level on the wastewater to discharge it on rivers which are used as source of water for irrigation of crops. Besides, the quality of the treated wastewater meets some other stricter environmental standards, such as the levels for discharges on natural and artificial water reservoirs which protect aquatic life; also, it reaches the national standard NOM-003-ECOL-1997 (1998), which states the maximal permissible levels of pollutants on treated wastewater used for public services with either indirect or direct humancontact.

Regarding to the conductivity, the influent has a mean value of 1744 mhos cm^{-1} between 2008 and 2013. An important remark is that the conductivity of the water supplied by the potable network is around 800 mhos cm^{-1}; then, the increase of the conductivity by the addition of dissolved solids and the concentration of salts due to the evaporation is higher than the expected value. Related to the effluent, the mean value of the conductivity is 1853 mhos cm^{-1} which is 6% more than the one in the influent. A possible reason of this situation is that the evaporation of water allows the dissolved solids to be concentrated during the treatment process. It is worth to mention that the treated wastewater with this quality can be used for cooling in different industrial processes; however, the efficiency on this application is low and implies a high cost on the equipment maintenance which should be compensated by a low price of the treated wastewater. Other alternative for the high conductivity is a tertiary treatment by a desalination process. On the other side, the treated wastewater with high conductivity such as the obtained from the SPP can be appropriate for irrigation of green areas as well as a large variety of crops. Related to the SPP input flow rate, it was observed that the mean value is 698.7 lps. This value is low considering that 1200 lps, approximately, are injected to the water system by the Operator Organism and some other users. This situation is due to either a low efficiency on the recollection of wastewater or that the network of the municipal sewage system is incomplete. Finally, the results of the analysis of heavy metals show that the metals found in the influent are between 10 and 100 times lower than the ones stated by the NOM-002-ECOL-1996 (1998); even, in many cases they cannot be detected by the analytical instruments. This is an expected situation since the wastewater are composed of 85% from household activities and 15% from industrial, commercial and services sectors which do not incorporate processes related to heavy metals Concerning the use of the treated wastewater, 20 lps are sold to an enterprise which applies the treated water in its industrial processes.

The remainder water is discharged in a natural stream water; besides the treated wastewater, this small river collects the rainwater and provides the liquid resources for agriculture activities in the county of Ramos Arizpe.

3.2. Big Urban Forest Plant (BUFP)

The same analyses as for the previous case were performed for the BUFP. This Plant is located near to a big green area inside the Saltillo city. In the Figure 3 and Figure 4, the obtained results for BOD and TSS are presented.

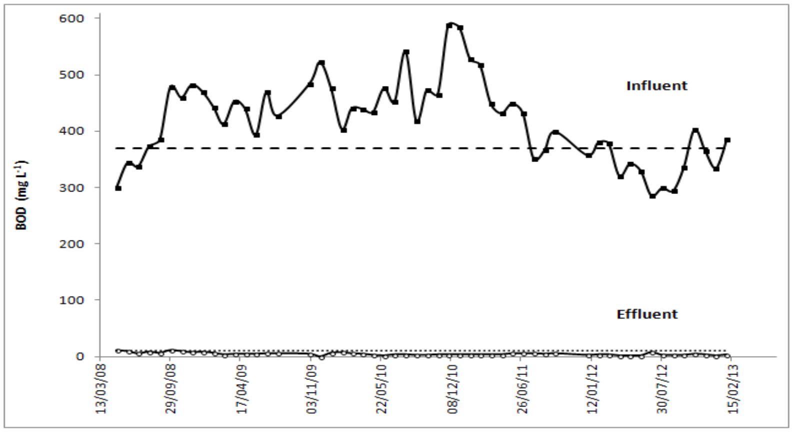

Figure 3: BOD in the Influent and Effluent of the BUFP

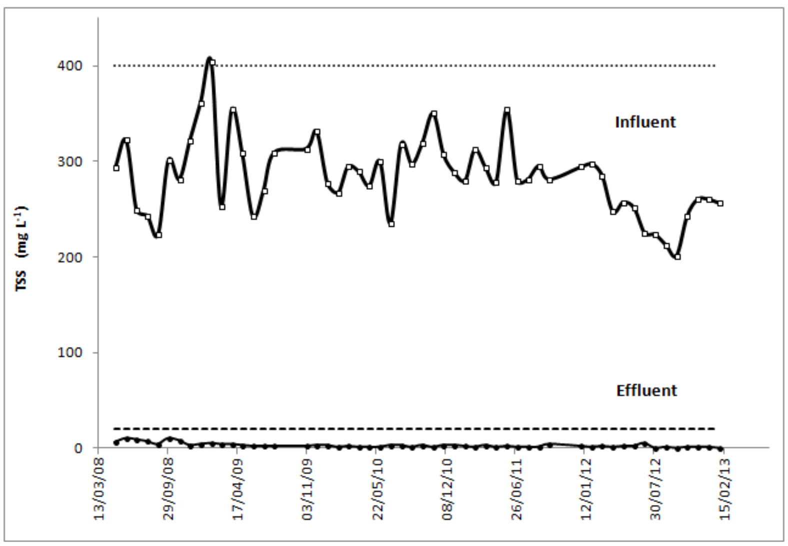

Figure 4: TSS in the Influent and Effluent of the BUFP

For the influent, the mean value of BOD is 418 mg L^{-1}, which is bigger than the obtained value for the Saltillo Principal Plant. The TSS is 285 mg L^{-1} (slightly lower than TSS on the SPP). Both parameters (BOD and TSS) have values higher than the stated by the official standard NOM-002-ECOL-1996 (1998) as well as the SPP. Concerning the effluent, a removal of 98.8 % and 98.7 % for BOD and TSS has been obtained; the corresponding values are 5.1 mg BOD L^{-1} and 3.7 mg TSS L^{-1}. It implies that the treated wastewater reach all the specifications of the official standards NOM-001-ECOL-1996 (1996) and NOM-003-ECOL-1997 (1998). The process presents a high efficiency and the wastewater quality is adequate for different applications, especially that of irrigation of cultures and urban green areas. The qualitative behavior of the conductivity is opposite to the one of the SPP since a decrease of 300 mhos cm^{-3} is remarked: the mean value of the conductivity in the effluent is 1391 mhos cm^{-3}, and in the influent is 1692 mhos cm^{-3}.

This situation is likely due to: a) the influent composition in the BUFP is entirely domestic and the TSS are very low, which allows the process to reach a higher performance; meanwhile the SPP influent includes some industrial wastewater and the TSS are bigger; b) the evaporation effect influencing the SPP does not apply for the BUFP since this is situated inside a forest area where the temperature is lower in comparison with the SPP. Related to the input flow rate, the available information shows an average flow rate of 41.5 lps, reaching only 70% of its design capacity. In the case of heavy metals, as for the SPP, the contents on the influent and effluent are very small; the parameter meets perfectly the official standards. It is worth to mention that, at present time, around 20 lps (40%) of the effluent is used to watering urban green areas. The other 60% is re-integrated to the ecosystem by discharges in a natural stream which provides water for some agriculture activities.

3.3. Ramos Arizpe Municipal Plant (RAMP)

The obtained results for BOD and TSS are presented in Figure 5 and Figure 6. The influent contains 376 mg BOD L^{-1} and 237 mg TSS L^{-1}. On the other side, BOD and TSS in the effluent is 18.3 mg L^{-1} and 8.4 mg L^{-1}, respectively. All these values are similar to the respective ones for the other wastewater treatment plants; with efficiencies of 95.1% in BOD removal and 96.4% of TSS. With this efficiency, the treated wastewater meets the official standards as well as the other two treatment processes. Some periodic peaks of both BOD and TSS are obtained each month; this situation can be explained by illegal discharges from industrial activities.

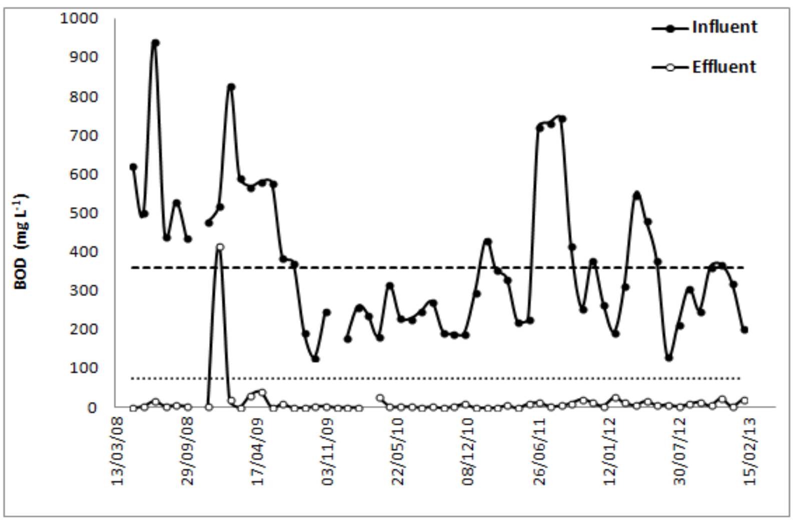

Figure 5: BOD in the Influent and Effluent of the Ramos Arizpe Municipal Plant

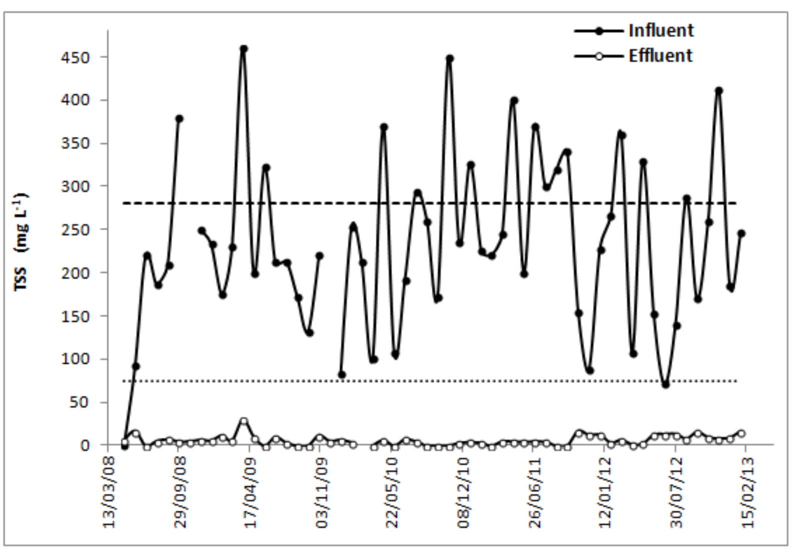

Figure 6: TSS in the Effluent and Effluent of the Ramos Arizpe Municipal Plant

Concerning the conductivity, it is important to mention that the water supplied to the Ramos Arizpe network distribution is higher than that provided in Saltillo. This is confirmed from the conductivity analysis on the influent and effluent of the RAMP where the obtained values are 2222 mhos cm^{-3} and 2331 mhos cm^{-3}, respectively. As can be deduced, the conductivity in this treated wastewater is 26% more than the corresponding one from the SPP, which is an important inconvenient for the use of treated water on industrial applications. Finally, the input flow rate represents only 54% of the volume provided by the organism which manage the water in the county; as for the case of Saltillo, this is due to either a low efficiency on the recollection of wastewater or that the network of the municipal sewage system is incomplete. Substantial leaks were detected in the main collector near the RAMP. On the other side, there is no evidence indicating the use of treated wastewater neither for urban nor industrial applications. The whole of the effluent is sent, at present time, to a natural stream water.

3.4. Alternatives for Utilization of Treated Wastewater

Nowadays, the treated wastewater is few reused. Only 20 lps from the BUFP is used for irrigation of urban green areas. Besides, 20 lps from the SPP are reused in a steel industry for cooling purposes and 40 lps from the RAMP are engaged for a future court term use in a steel industry in Ramos Arizpe. As said before, the remaining of the effluents from the wastewater treatment plants are discharged in a natural water stream which name is Arroyo La Encantada. It is worth to mention that the water of this small river is used for irrigation purposes by several farmers from many years ago, even when no wastewater treatment plants were implemented. Due to the water quality and especially because of the current regulations from the Ministry of Environment and Natural Resources and the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food, only few crops are authorized, such as plants used as fodder. The results of this study suggest that he treated wastewater could be used for more urban green areas irrigation, irrigation of crops with added value such as potato, tomato and other vegetables. Industrial applications are limited by the salt concentration on the treated wastewater; however, most of industries installed in the region do not require water with high quality, since the main application is for cooling purposes or activities without human contact. Nevertheless, for a more extended reuse of treated water on industrial applications, secondary or even tertiary treatment processes should be implemented. In general a deeper analysis of treated water demand is required. Besides, the increase of treated wastewater reuse could bring important benefits to the local government: additional revenues due to the sold of treated water, the possibility to reduce the extraction of water from the local aquifers allowing the conservation of water resources, and a reactivation of the agricultural sector if better crops are authorized to be irrigated with treated wastewater. Then a proper strategy concerning the management of the wastewater is a main issue in this region.

5. Conclusions

The physicochemical characteristics of the wastewater sent to the three municipal treatment plants correspond to typical household and commercial wastewater. Due to the source of the potable water which is transformed in wastewater, a high content of total dissolved solids is detected; in consequence high values of conductivity are observed in the wastewater and in the treated water. The highest value of this parameter is found in the wastewater produced in the county of Ramos Arizpe. The three municipal wastewater treatment plants considered in this study work in agreement with the design conditions. The effluents meet perfectly the official national standards which determine the level of pollutants in the discharged wastewater; this situation allows the treated wastewater applications to be diversified, such as irrigation of new crops and more urban green areas, as well as in some industrial activities. This last case requires special attention, since at present time few applications can be done; however, it is possible to incorporate secondary and/or tertiary treatment processes in order to either eliminate or minimize the contents of dissolved solids. This would allow the treated water to be used for cooling and/or steam generation, which is a demanded application in industrial activities. It has been detected that the collection of wastewater is not complete in the studied region since the volume arriving to the treatment plants is less than the volume injected to the water distribution network. An important task is then to verify the municipal pipeline systems in order to detect and eliminate eventual leaks. Also, it is important to increase the wastewater collection capacity. These actions could contribute both to treat a higher volume of water and to keep the natural equilibrium; in fact, the water could be reintegrated to the ecosystems with high quality avoiding, or at least minimizing, the dispersion and multiplication of pollutants (mainly of biologic nature) as well as the illness proliferation.

New researches are in progress in order to evaluate different scenarios of the demand of treated wastewater. The idea is to elaborate guidelines to diversify the reuse of treated water in order to take care of the water sources in the region.

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