Performance of Urban Wastewater Treatment of Four Activate Sludge Treatment Plants in Tunisia

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Abstract

In water-scarce regions, such as Tunisia which is known by the vulnerability of its water resources, national policy encourages and imposes laws opting for environmental sustainability and the preservation of water resources. The current study aims to determine the occurrence and removal of protozoan cysts, helminthes eggs, fecal bacteria, organic load and chemical pollution in the urban wastewater of activated sludge plants in Tunisia. The results show that the absence of primary sedimentation and operation of organic and fluid overload appears to be the main causes of the poor quality of the treated wastewater. The presence of protozoan cysts, helminthes eggs and bacteria as well as the high content of organic matter and nutrient elements greatly limits the reuse of wastewater in agriculture, in particular.

Keywords: Activated sludge; Wastewater; Constraints reuse; Protozoan cysts; Helminthes eggs; Fecal bacteria

Introduction

Tunisia belongs to the category of the least developed countries endowed with water resources in the Mediterranean Sea [1]. The Tunisian strategy in the medium term is to use non-conventional water resources such as the reuse of the treated wastewater, desalinization of brackish water and artificial recharge of groundwater [2].

The National Sanitation Utility (ONAS) [3] collects on 2010, 246 Mm3 of wastewater and manages 109 wastewater treatment plants (WWTPs) that can handle a volume of 240 million m3 of which 28% is used for irrigation of 8065 hectare of irrigated agricultural schemes, 1040 hectare of golf courses, and about 450 hectare of green spaces, in addition to the recharge of aquifers and wetlands.

Almost all WWTPs treat wastewater to a secondary biological stage. For urban WWTPs, there are about 82 activated sludge mainly at low load, 13 lagoons and 2 WWTPs trickling filter. It is worthwhile to note that treated wastewater has to meet Tunisian standard published in 1989: NT 106.02 and 106.03 before discharging it into the receiving environment and before reusing it in agriculture, respectively. Although the use of water and sludge in agriculture is an interesting alternative in water poor countries, public health risks associated with microbiological, organic and mineral burden can be relatively high [4,5].

The World Health Organization considers the presence of helmint eggs, especially intestinal nematodes as the main constraint for the reuse of wastewater in agriculture due to their higher resistance in the environment, simple life cycle, and low minimal infective doses [6,7]. As for the content of micropollutants in domestic waters, it is rather random because it is derived from daily household activities, originating, on the one hand, from the corrosion of drinking water pipes and, on the other hand, the use of metals in household activities and household products [5].

Metals can be a significant health risk to humans and animals and can also affect, in the long term, irrigated by the accumulation in the soil [8,9]. Nutrients not only are found in large quantities in the wastewater, but they are also important quality parameters that enrich these waters in agriculture and landscape management [10].

The current study aims to determine the occurrence and removal of protozoan cysts, helminthes eggs, fecal bacteria, organic load and chemical pollution in the urban wastewater in four activated sludge plants under the semi-arid climate of Tunisia. Therefore, the evaluation of purification yield gives an idea about the health risks for the population during its reuse in agriculture.

Materials and Methods

Physicochemical analyses

The pH and electrical conductivity of wastewater were determined according to the protocols of AFNOR (NF T 90-008 and NF EN 27888) using a pH meter and a conductivity-type Meter Toledo HANNA INSTRUMENTS HI type 9900. The chemical oxygen demand (COD), suspended solids (SS) and biochemical oxygen demand (BOD) were measured according to the protocols of AFNOR (NFT 90-018, NF T 90-103, NF EN 1189). The concentrations of nitrite, ammonium nitrate and orthophosphate were measured by a colorimetric method using Nessler reagent, sulfamidic acid, and sodium salicylate and ammonium molybdate, respectively. Regarding metal determination, it was performed by atomic emission spectroscopy with inductive current plasma (ICP-AES).

Bacteriological analysis

Bacteriological analysis is the germ count of fecal pollution indicators: thermo tolerant fecal coliforms and Escherichia coli. Thermo tolerant coliforms are commonly used to control the relative quality of water.

The numeration was performed using the static method of seeding in liquid medium (MPN). The sample preparation was performed according to the technique of suspension-dilution (ISO9308-2 and ISO 7899-1, 1990).
Parasitological analyses

Samples were examined for parasites according to the modified Bailenger method [11]. Briefly, each sample was allowed to settle over 24 h in the laboratory at room temperature. Then, the recovered sediment was centrifuged for 15 minutes. The resulting pellet was mixed with an equal volume of buffer-acetic acid pH 4.5. Besides, one equivalent volume of ether twice the volume of the resulting solution was then stirred for 10 minutes. The sample was then centrifuged at 1000 g for 6 minutes. The obtained sediment was resuspended with approximately 5 mL of a solution of zinc sulphate (33% density 1.18). The volume V of the product was measured. P a volume of 0.3 mL was collected on the surface after flotation microscopic observation.

Different types of samples collected from each sampling station always include raw sewage collection and wastewater treatment. The samples were collected during the rainy season from November to March 2010, with two samples per month. The samples under investigation were collected from the WWTPs of Beja, Bizerte, Nabeul and Menzel Bourguiba. The characteristics of the four stations operating at Activated Sledges are shown in Table 1.

Results and Discussions

Determining the abundance of parasitic forms of resistance in treated and untreated wastewater from the cities of Bizerte, Beja, Menzel Bourguiba and Nabeul (Table 2) showed that all the raw wastewater samples were positive for helminthes eggs and protozoan cysts (Giardia sp, Entamoeba coli and Entamoeba histolytica cysts), which is in accordance with the research work of Ben Ayed et al. [12].

Moreover, helminthes eggs are predominant protozoan cysts. The average concentration of protozoan cysts is close to 2164 cysts/L against 705 eggs/L.

Entamoeba coli cysts are the most abundant (Table 3), their concentration varies from 741 to 1680 cysts/L, followed by Giardia cysts from 400 to 921/L and finally cysts of Entamoeba Histolytica (390-817 cysts/L). Regarding helminthes, two major classes were identified, the nematodes class represented by the Ascaris sp and pinworm and the cestodes one represented by Hymenolepis nana (Table 3). The scale of abundance of helminthes eggs ranges according to the following order: Ascaris sp (49.50 to 68.42%) > Enterobius vermicularis (21.15 to 44.55%) > Hymenolepis nana (0 to 11.50%).

In addition, the evaluation of the bacterial load of raw sewage at the studied WWTPs showed the presence of fecal coliforms and Escherichia coli, with concentrations ranging from 2.5 × 10^9 to 2.5 × 10^10/100 mL and from 4.10^3 to 5.10^7/100 mL (Table 2), respectively. However, the concentration of fecal coliforms in treated wastewater ranges from 4.5 × 10^2 to 1.1 × 10^3/100 mL.

Table 4 presents an overview of the mean physicochemical characterization of raw and treated wastewater. It appears that the WWTPs of Nabeul and Beja currently operate in organic overload (COD, BOD_5 and SS) which are not compliant to Tunisian standard of ONAS gathering network estimated at 1000, 400 and 400 mg/L, respectively. After treatment, the organic quality of Beja and Menzel Bourguiba wastewater met the Tunisian standard of irrigation and may be discharged/thrown out into the receiving environment set at 90 mg O_2/L for COD, 30 mg O_2/L for SS and 30 mg/L for BOD_5 (NT 106 002-1989).

The determination of nutrients (NH_4^+, NO_3^-, NO_2^- and PO_4^{3-}) at the outlet of the studied treatment plants shows that the oxidized forms of nitrogen do not cause problems while ammonia nitrogen and orthophosphate concentrations, estimated at 1 and 0.005 mg/L, respectively, exceed by far the Tunisian standards for the discharge into the receiving set.

Giardia sp, Entameaba coli, and Entamoeba histolytica cysts were detected in all the treatment plants, suggesting endemic levels of these parasites in the concerned Tunisian population. Together with epidemiological investigations [13,14], the order of frequency of protozoan cysts and helminthes eggs in wastewater corroborate the research work undertaken in Tunisia [15,16] and in the world in this field [17,18]. Generally, the concentration of nematode was higher than that of cestodes, and the abundance of protozoa cysts was higher than that of helminthes eggs [19].

<table>
<thead>
<tr>
<th>Commissioning</th>
<th>Capacity (equivalent inhabitant)</th>
<th>Sizing</th>
<th>Discharge day (m^2)</th>
<th>BOD_5 (kg/day)</th>
<th>Composition Eq. Hab connected (100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bizerte</td>
<td>1997</td>
<td>250 000</td>
<td>26600</td>
<td>10740</td>
<td>Domestic 96.7%, 2.9% industrial and 0.6% touristic</td>
</tr>
<tr>
<td>Beja</td>
<td>1979</td>
<td>144000</td>
<td>14000</td>
<td>7800</td>
<td>60% domestic and 40% industrial</td>
</tr>
<tr>
<td>Menzel Bourguiba</td>
<td>1997</td>
<td>91000</td>
<td>11065</td>
<td>4700</td>
<td>85.5% domestic, 12.76% industrial and 1.7% touristic</td>
</tr>
<tr>
<td>Nabeul (SE4)</td>
<td>1994</td>
<td>81400</td>
<td>9585</td>
<td>5870</td>
<td>83% domestic, 12.2% industrial and 4.44% touristic</td>
</tr>
</tbody>
</table>

Table 1: Main characteristics of the different treatment plants

I: Influent Station, E: Effluent the station, CF: fecal coliforms, EC: Escherichia coli

<table>
<thead>
<tr>
<th></th>
<th>Bizerte</th>
<th>Menzel Bourguiba</th>
<th>Beja</th>
<th>Nabeul (SE4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helminthes eggs/L</td>
<td>1010 ± 300</td>
<td>0 ± 70</td>
<td>200 ± 80</td>
<td>1089 ± 180</td>
</tr>
<tr>
<td>Protozoa cysts/L</td>
<td>3417 ± 600</td>
<td>2190 ± 450</td>
<td>1676 ± 240</td>
<td>2873 ± 360</td>
</tr>
<tr>
<td>FC/100 ml</td>
<td>2.5 ± 0.4 10^9</td>
<td>2.5 ± 0.7 10^9</td>
<td>4.5 ± 0.6 10^3</td>
<td>2.2 ± 0.8 10^3</td>
</tr>
<tr>
<td>EC/100 ml</td>
<td>4.0 ± 0.5 10^9</td>
<td>2.0 ± 0.3 10^9</td>
<td>9.0 ± 0.8 10^2</td>
<td>5.0 ± 0.7 10^8</td>
</tr>
</tbody>
</table>

Table 2: Microbiological characterization of raw and treated sewages

**Table 3: Composition and abundance of parasitic elements**

<table>
<thead>
<tr>
<th>Station</th>
<th>I (100%)</th>
<th>E. coli</th>
<th>Giardia</th>
<th>Hym. nana</th>
<th>E. Hyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bizerte</td>
<td>500 (49.50%)</td>
<td>450 (44.55%)</td>
<td>60 (5.90%)</td>
<td>920 (26.90%)</td>
<td>1680 (49.16%)</td>
</tr>
<tr>
<td>Menzel Bourguiba</td>
<td>350 (76.30%)</td>
<td>110 (21.15%)</td>
<td>60 (11.50%)</td>
<td>730 (33.41%)</td>
<td>1070 (48.85%)</td>
</tr>
<tr>
<td>Beja</td>
<td>390 (68.42%)</td>
<td>180 (31.57%)</td>
<td>0 (0%)</td>
<td>400 (23.85%)</td>
<td>741 (44.2%)</td>
</tr>
<tr>
<td>Nabeul</td>
<td>546 (50.13%)</td>
<td>543 (49.86%)</td>
<td>0 (0%)</td>
<td>760 (26.45%)</td>
<td>1345 (46.81%)</td>
</tr>
</tbody>
</table>

**Table 4: Physicochemical characterization of the average raw and treated wastewater**

<table>
<thead>
<tr>
<th>Station</th>
<th>pH</th>
<th>CE (µS/cm)</th>
<th>DCO (mg/L)</th>
<th>DBO (mg/L)</th>
<th>SS (mg/L)</th>
<th>NO3 (mg/L)</th>
<th>NO2 (mg/L)</th>
<th>NH4 (mg/L)</th>
<th>P (mg/L)</th>
<th>Zn (mg/L)</th>
<th>Ni (mg/L)</th>
<th>Cr (mg/L)</th>
<th>Cd (mg/L)</th>
<th>Cu (mg/L)</th>
<th>Pb (mg/L)</th>
<th>Hg (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bizerte</td>
<td>7.38</td>
<td>4.680</td>
<td>6.48</td>
<td>289</td>
<td>338</td>
<td>-</td>
<td>-</td>
<td>34.50</td>
<td>-</td>
<td>0.6</td>
<td>0.05</td>
<td>0.014</td>
<td>0.014</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
<td></td>
</tr>
<tr>
<td>Menzel Bourguiba</td>
<td>7.65</td>
<td>4.620</td>
<td>7.3</td>
<td>25</td>
<td>34</td>
<td>0.56</td>
<td>0.05</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>&lt;0.03</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Beja</td>
<td>7.24</td>
<td>2106</td>
<td>368</td>
<td>258</td>
<td>34</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>&lt;0.03</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Nabeul</td>
<td>7.78</td>
<td>2349</td>
<td>72</td>
<td>25</td>
<td>23</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>&lt;0.03</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Otherwise, the microscopic counting and recognition of eggs and cysts of parasites could be influenced by the following factors: the limitations of the Bailenger technique [11], the presence of impurities in the samples to be analyzed and the morphological characteristics of some forms of parasites and their low abundance.

Moreover, it appears that the activated sludge treatment is more effective in the removal of helminth eggs. Indeed, the average reduction of cysts and eggs are 99.70 and 95.36%, respectively (Table 5). Treated wastewater from sewage treatment plants (Menzel Bourguiba and Nabeul) remains partly contaminated by protozoan cysts. However, helminth eggs were detected only at the effluent of the WWTP Nabeul SE4.

Pollution in this context [12,15], found that more than half of the parasites are eliminated during the primary settling with a greater reduction of helminth eggs compared to cysts protozoa because of their large size and hence their high settling velocity. It was reported a settling velocity of 0.01 and 0.65 m/hour for *Giardia* cyst and *Ascaris* ova, respectively [20]. In our case, the WWTP of Bizerte and of Beja are not equipped with a primary clarifier.

With respect to the bacteria of fecal pollution, the best reduction rate of fecal coliforms and *Escherichia coli* were recorded at the WWTP Bizerte with the reduction rate of approximately 99.94 and 99.50% corresponding to 3.25 and 2.3 log unit, respectively. Nevertheless, the removal efficiency of WWTP of Nabeul, reduces fecal coliforms and *Escherichia coli* which did not exceed 95.11% and 94.20 (1.44 and 1.23 log unit).

The presence of these concentrations of bacteria in treated wastewater leads to the probability of the existence of pathogens for humans and animals [21].

Monitoring the evolution of the organic load (COD, BOD3, SS) in wastewater before and after treatment showed a reduction exceeding 80% (Table 5). The best treatment efficiency was observed at the WWTP of Beja.

Concerning parasitic and organic load, the WWTP of Nabeul is the least efficient one. It is manifested in the research work of Robertson et al. [22], which demonstrated a positive correlation between the elimination of parasites and the reduction of suspended solids due to the adhesion of the greater part of the microorganisms contained with the suspended matter.

Besides, the average concentration of NH4+ and PO4+3 in the treated wastewater of all studied stations are 29.76 and 3.52 mg/L, respectively. The rejection of these waters rich in eutrophying components into a receiving site could disrupt the ecological balance [8].

The evaluation of the chemical toxicity of both raw and treated wastewater via the analysis of heavy metals has shown a low concentration that does not exceed the Tunisian standards.

The WWTP of Beja (Table 1) assures the treatment for 40% of the industrial waters, coming from a plant of yeast in the region [23] which is characterized by a COD concentration of 27 g/L and a BOD\textsubscript{5} of 3.2 g/L [24].

It appears that most microbiologically contaminated raw sewage (helminthes eggs, protozoan cysts, fecal coliforms, and *Escherichia Coli*) are those of the WWTP of Bizerte and Nabeul, while the least contaminated ones are those of the station of Beja. This quality influent could be explained by the characteristics of the treatment plant (Table 1).

In fact, although the WWTP of Bizerte is the largest among the four plants, which is sized for 250 000 Eq. inhabitants, it works in organic overload during seasonal peaks [16]. The same thing is to Beja plant that operates in organic overload, however 40% of the collected industrial wastewater is lightly loaded microbiologically [25]. The poor quality of Nabeul plant treated wastewater is attributed, as shown by the research work of Maamri [26] not only to a fluid overload that sometimes attains 153% and 197%, but also to an organic overload in which SS can exceed 4 g/day in some conditions.

**Conclusion**

Monitoring the treatment efficiency of urban wastewater at four active-sludge stations shows that the quality of the treated wastewater exceeds the Tunisian standards for a possible reuse or a release into the environment without risk. Besides, it may have, in certain cases, some human health and ecological risks and perturbation of the ecological balance following the presence of high nutrient concentration, organic load and parasitic elements observed in the functioning of the overloaded plants.

However, the microbiological quality of all treated wastewater does not meet the standard of irrigation or discharge into a natural environment that is 2000 units of fecal bacteria per 100 mL.

Rehabilitation treatment plants are becoming increasingly necessary to solve the problems such as the lack of primary sedimentation and operation fluid and organic overload. The poor quality of the treated wastewater suggests greater caution management of water potential so as to preserve the safety of the population as well as the environment.

**References**