The application of performance indicators for the management of sanitation systems; a good practice to generalize

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Abstract: In Algeria, little importance is given to sanitation services compared to drinking water services. From collection to treatment, the waste water route deserves to be diagnosed order to master the sanitation system and optimize its facies by prospecting and research performance indicators that identify gaps and to propose technical solutions for better wastewater management. This study defines the values of mean concentrations, ratios and ranges of variations associated wastewater characteristics. Subsequently, we calculated the ratios of pollution indicators that should enable us to highlight the optimizations necessary to the wastewater treatment plant of Médéa.

Key-Words— sanitation network, treatment plant, performance indicators, ratios.

I. INTRODUCTION

The sanitation problems remain a critical concern that requires significant care by taking appropriate measures to protect the environment [1].In Algeria, little importance is given to sanitation services compared to drinking water services [2]. The sanitation systems management has to face several facts such as physical infrastructure degradation due to its aging, lack of maintenance and pollution of natural environments by increasingly disturbing direct and indirect discharges from urban sanitation.

This situation inquires more research to improve this service. Therefore the search for performance indicators is compulsory to a better sanitation network management. These indicators will identify inadequacies and can be used to analyze the sustainability of sanitation service.

II. MATERIALS AND METHODS

In the framework of this work, we have proceeded to the control and monitoring of various measured and analyzed parameters of the raw and treated water of Medea city WWTP, during the period January 2013 - November 2015. The water analyses were made at the laboratory of WWTP.

III. RESULTS AND INTERPRETATIONS

III.1. Evolution of the hydraulic load and share of clear parasitic waters

The treatment plant of Medea was designed for a nominal flow of 26000 m^3/day. The overruns of recorded flows are given in the Table I.

Table I. Maximum flows recorded

Period	Flow max (m^3/d)	Overruns / nominal flow (26000 m^3/d)
September 2013	26280	1.1 %
October 2013	33540	29 %
December 2013	27000	3.84 %

The excess in flow represents the share of clear parasites waters (cpw) that have increased significantly during the rainy season (September, October and December). According to [3], the clear parasites waters (drainage water, fountains, cooling, etc.) also overload unnecessarily the network collectors. They dilute the waste water before treatment. They can cause the increase of upstream rejection into the network, involving an increase in operating costs of WWTP and preventing the achievement of required performance.

The share of clear parasites waters (cpw) is calculated by evaluating the effect of dilution of wastewater by clear waters on the DBO_5 parameter compared to theoretical undiluted wastewater [3] with an Inhabitant Equivalent (IE) corresponding to a daily pollution load of 60 g of BOD_5 and 150 l/day of consumed water [3].
Hence, we shall have an equation of the form as follows:

$$Y= a-bX.$$

with Y : the daily volume of clear parasites waters, a : the daily volume of wastewater, b = 150/60=2.5 and X : Incoming load in kg BOD_5/d.

The Clear parasite water volume is estimated from BOD_5 concentrations at the inlet of WWTP. The Cpw (BOD_5) is given by the equation of the form Y= a-bX, which confirms that less lower measured concentrations are, the more important the share of clear parasites water is.

The estimate of the average share of clear parasite waters for the study period from January 2013 to November 2015, with a daily average volume of 10,723 m^3/d and an BOD_5 average concentration of 352.33 mg/l, leading to an average daily load BOD_5 of 3778 kg/d, is estimated from the equation Y = a-bX. Therfore, we will have Y = 10723 - 2.5 x 3778 = 1278 m^3/d, representing 14% of the volume of the theoretical undiluted wastewater found of 9445 m^3/d.

III.2. Treatment performance obtained

III.2.1. Monitoring of nitrogen treatment

The Kjeldahl nitrogen TKN is the most representative parameter of the wastewater collection [4]. The average concentrations of Kjeldahl nitrogen at the inlet and outlet WWTP are respectively 55.5 mg/l and 5.20 mg/l, therefore the abatement is 91%.

Table II. Results of the nitrogen from inlet to the outlet of the WWTP

Parameters	Average Inlet Outlet	Max Inlet Outlet	Min Inlet Outlet
TKN mg/l	55.5	75	37
	5.20	11	3.70
NH_4-N	29.36	47.20	6.90
mg/l	3.46	26.96	0.03
NO_3-N	0.59	2.25	0.01
mg/l	10.61	27.11	0.02

The average concentrations of ammonia NH_4-N varies from 29.36 to 3.46 mg/l from the inlet to the outlet. However the nitrate concentrations NO_3-N at the inlet vary between 0.01 mg/l and 2.25 mg/l with an average of 0.59 mg/l. Their contents at the outlet vary between 0.02 mg/l and 27.11 mg/l with an average of 10.61 mg/l. Therefore an increase of 1698 % , from the inlet to the outlet which is due to nitrification.

We can consider that the nitrification only works well if the concentration of ammonia nitrogen in the treated water is less than 1 mg NH_4-N /l, conversely, if the concentration of nitrate nitrogen in the treated water exceeds, in dry weather, 3 to 5 mg NO_3-N /l [5]. The increase in the daily duration of aeration helps to speed up the restoration of good nitrogen processing performance, but it is not imperative for the viability of nitrification [5]. For the Medea WWTP, it is necessary to reduce the daily duration of aeration.

III.2.2. Monitoring of phosphorus treatment

At the intake to the WWTP, phosphates oscillate between 0.73 mg/l and 7.85 mg/l with an average of 2.29 mg/l. At the outlet, the average residual content of orthophosphate is 0.63 mg/l.

These values are very high compared to the tolerable limit of 0.1mg/l total phosphorus for the discharge of effluent into a sensitive medium at eutrophication [6]. However, they are lower than 10 mg/l, in ortho-phosphates, this limit being acceptable for a direct discharge into the receiving environment [7]. The level of phosphorus elimination is unstable and weak with an elimination average yield of 72 %.

III.2.3.Nutritional balance

The bacterial metabolism is accompanied by nitrogen needs in the form of ammoniacal nitrogen ,and phosphorus needs in the form of orthophosphates, in the following proportions BOD_5/NH_4-N/PO_4-P: 100/5/1 [8].

For an average BOD_5 of 352.33 mg/l (see table III) and for to respect that theoretical ratio, the concentrations of NH_4-N and PO_4-P must be respectively 17.61 mg/l and 3.52 mg/l. However, the average values recorded (29.36 mg/l NH_4-N and 2.29 mg/l PO_4-P) indicate a deficit of 35% for PO_4-P and an increase of 67% for NH_4-N relative to the respective theoretical ratios. This imbalance into nutrients can constitute a handicap at the level of biological treatment.

III.2.4.Monitoring of organic loads treatment

The TSS represents 109% of the nominal value (Figure 1), with a frequency of excess of 63% and an abatement yield of 95.35%.

Table III. Results of global parameters of raw and treated wastewater

Parameters	Average Inlet / Outlet	Max Inlet / Outlet	Min Inlet / Outlet	Nominal value
TSS mg/l	479.44	733.71	211	438
	22.31	175.11	6.57	
COD mg/l	624.97	846.16	351.09	675
	55.10	290	31.20	
BOD_5 mg/l	352.33	548.67	206.25	338
	13	150	2.67	

The BOD_5 equal to 104% of the nominal value (Figure 1) and records an exceedance frequency of 62% and a 96.31% removal efficiency.

The COD yield removal is 91%. This is a sharp reduction of the COD, which according to [9] is related to a better oxygenation that enables aerobic bacteria to proliferate and to assure accordingly, better mineralization or oxidation of the organic matter. The maximum value (846.16 mg/l) is increasing by 35% compared to the average concentration (624.97 mg/l).

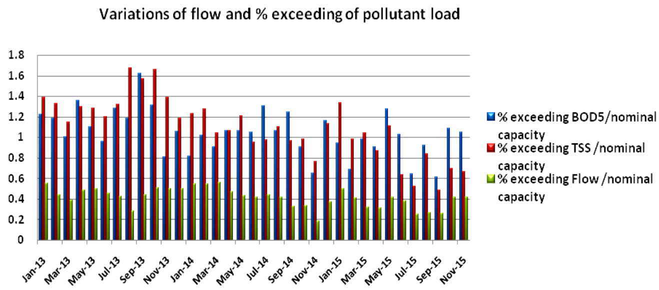

Fig1. Variations of flow and % exceeding of BOD_5 and TSS relative to the nominal capacity

III.2.5. Ratios

The use of these characterization parameters is a good means for giving a picture of the degree of pollution of raw effluent and also to optimize the physicochemical parameters of the waste water in order to propose a suitable mode of treatment.

COD/BOD_5 (Raw water): The biodegradability coefficient is calculated by the ratio COD/BOD_5 and depends on the nature and origin of the wastewater which may be domestic or industrial, and requires different treatments according to [9]. The ratio COD/BOD_5 for raw waste water is generally between 1.25 and 2.5. This ratio was found of 1.77, which is characteristic of a domestic effluent. A value less than 2 confirms the biodegradability of the waste water. Therefore, the biological treatment is adequate for these effluents.

COD/TKN: Equal to 11.26 and according [10], for a strict urban effluent, this ratio is between 8.8 and 12, and indicates the mixity of the effluent and has an influence on the denitrification. In the case of a waste water with a low COD/TKN ratio, organic carbon content of the digested effluent may be insufficient to achieve complete denitrification [10]. But too high ratios COD/TKN risk also to disturb the nitrification because COD/TKN has a direct effect on the autotrophic biomass concentration of sludge and thus on the maximum speed of nitrification [5].

NH_4/TKN: This ratio will indicate the degree of ammonification realized during the transfer of the effluent in the network [10].The proportion of Ammoniacal nitrogen at the inlet of the treatment plant varies between 50% (short networks) and 75% (very long networks) [5]. Therefore a ratio value NH_4/NTK found of 0.53 translates a flow of the raw water through a network relatively short.

TSS/COD: The average value recommended by the authors is 0.5 [3]. The found value of this ratio, 0.77, is high. [11] showed that the increase TSS/COD ratio is an index that allows us to suspect a phenomenon of resuspension of deposits (phenomena of sedimentation - erosion during transport into network).

BOD_5/TSS: found 0.73, comparable to 0.75 found by [11]. The extreme values of this ratio vary between 0.45 and 1.24 and are attributable to the sedimentation-erosion phenomenon in the network. It is therefore important to retain that, at some sludge age, the applicable maximum mass load depends on the BOD_5/TSS ratio of the input for which, an average value of 1.0 is generally retained for urban wastewater [5].

III.3.Electrical energy consumed

The average value of the electrical energy consumed is 3210 kWh/d. The mass of pollution eliminated in terms of the BOD_5 and COD is respectively 3638.67 and 6562 kg/d.

The amount of energy required to eliminate the pollution rises to 0.88 kWh/kg of BOD_5, yet it is 0.49 kWh/kg of COD. The maximum value of EE/DBO_5-eliminated ratio (Electric Energy /BOD_5 eliminated) of 3.85 recorded during the month of November 2014 and the values of 2.07 and 2.10 respectively recorded during the months of July and September 2015 (Figure 2) , are excessive and exceed the usual values for the spinneret of activated sludge that are of 2 kWh/kg BOD_5 eliminated [12].

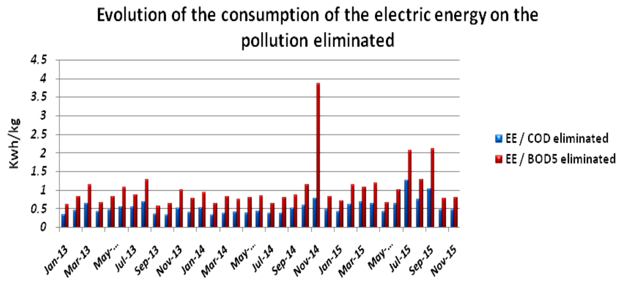

Fig 2. Variations of reports EE/BOD_5 eliminated and EE/COD eliminated

Because of the high specific consumption, it is recommended to perform an energy diagnosis of the WWTP.

IV. CONCLUSION

This study helped to determine the range of pollution parameters variation and the various relationships that exist between them. The analyzes results have identified gaps and helped to improve evacuation yields and wastewater treatment installations of Medea.

At Hydraulic level, the dilution rate of wastewater found of 14% caused by the clear parasites waters requires significant care to improve the city sewerage network performance and reduce the cost of exploitation. Good management of WWTP must go in the future through better knowledge and control of the water evacuation network.

To better control and mitigate the nitrates at the outlet of the city WWTP, it is necessary to reduce the daily aeration duration, increasing the denitrification duration in anoxic.

For a BOD5 of 352.33 mg/l, the average values recorded of NH4-N and PO4-P indicate a deficit of 35% for PO4-P and an increase of 67% for NH4-N, This imbalance into nutrients can be an obstacle at the level of biological treatment.

With regard to the ratios, it is observed similar average values and sometimes comparable to those of the literature .The particularity comes from the high values of the ratios TSS/COD and TSS/BOD5 found respectively 0.77 and 1.36, thus translating pollution of a particulate character. A quantitative study would be carried out to complete these results, in particular to evaluate the influence of collection networks on the quality of raw domestic sewage.

The high values of the electrical energy required for the elimination of pollution recorded, causing exceedances in specific energy consumption, require to perform a diagnostic analysis of the facility.

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