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PERFORMANCE-BASED CONTRACTING FOR IMPROVEMENT OF DRINKING WATER TREATMENT EFFICIENCY

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ABSTRACT

Problem statement: In the water treatment processes, the efficiency is a good indicator of the WTP management (water quantity and quality). The operators are the main responsible to improve the plant performances regarding the relationship between them and the hierarchy. Many fields are now heading towards performance-based contracting in order to improve the efficiency of the installation. A very interesting approach that has been deployed rapidly in the water field especially in water infrastructure management.

Approach: In this study, the effectiveness of performance based contracting approach was evaluated in order to find optimal operational conditions and relationship between operators. Many indicators related to the WTP management was also studied in the objective to reduce the cost of treated water while the performances are improving in terms of quantity and quality. **Results:** Results demonstrated that the approach application improve the plant efficiency and the coordination between all the operators. The approach permit to control the key performances indictors. It offers a clear understanding of benefits and risks.

Conclusions/Recommendations: Results show that the approach is very beneficial to improve the treated water quality and reduce water cost. This approach contributes in enhancing the human resources organization, offers information that is more detailed and resources pertaining to WTP management improving.

Key Words: Performance based contracting, Efficiency, water treatment, water quality, cost, Human resources, management.

I. Introduction

The demand on water supply is increasing over the last century due to improved lifestyle, industrial development and population growth. This increased demand is facing a paradox to produce treated water with high quality at lower cost. In order to reduce the water cost, it is very important to optimize the operating expenses in the water treatment plant (power, chemicals, operator's expenses…) and many measures should be taken in this vision [1].

The treatment of drinking water comprises the aeration, coagulation, sedimentation, filtration and disinfection of raw water produced by the springs. During the rainfall period, the water's turbidity increases, colloidal particles are separated in the treatment plant by means of a chemical coagulation process: consisting in the charge destabilization of the suspended particles by adding coagulant.

The performance based contracting is guided by the contract's terms and conditions between the operators of different hierarchy levels. It is achieved with the support of the professional relationships, organization and communications between the contractor and his hierarchy according to the contract's terms [2], [3],[4].

In the WTP, there three main activities realized by the operators: maintenance, managing, and water quality control. The performance based contracting is based on some indictors related to those activities. The key performances indictors are mainly defined to reduce the operating costs (Energy and chemicals), improve the maintenance level and to enhance the water quality control in the water treatment plant [5].

This paper addresses the problem of improving WTP performances by using performance based contracting. This paper is organized as fellows. After an introduction of the objective of this study, the experimental section is described in section II, also, the methodology used to assess the approach impacts is explained. In section III, the results are presented and discussed.

II. Experimental section

a/ Water treatment operation

This study was developed in a water treatment plant located in Meknes in the middle of Moroccan Kingdom, whose source is two big springs Bittit (630 l/s) and Ribaa (400l/s). The quality of water produced by the springs changes according to the rainfall in the region. Sometimes, it can be affected by the snow in the Atlas Mountain. The treatment water plant, as part of other water resources, water to more than 700.000 inhabiatnts of Meknes city, Morocco and has a nominal capacity of 600 l/s of treated water. Figure 1 presents a schematic overview of the various operations necessary to treat the water.

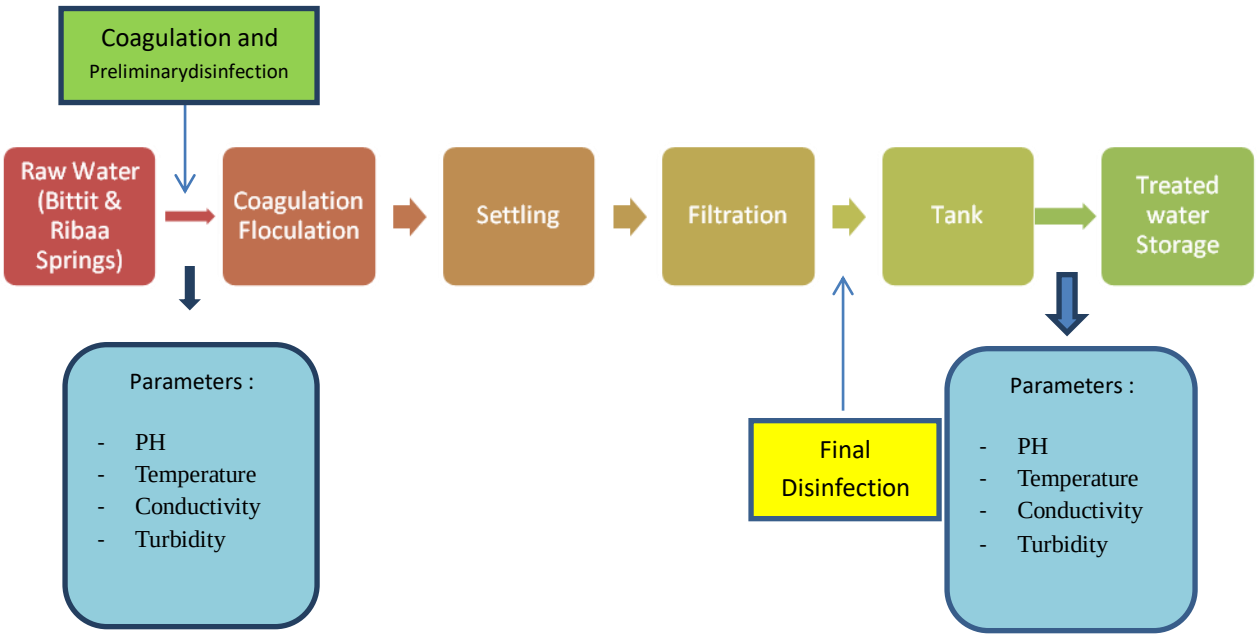

Figure 1: simplified synopsis of the water treatment plant.

Many measurements of variables such as turbidity level, PH, conductivity, temperature is needed to carry out the jars test in order to determine the optimal dose of the aluminum sulfate. The raw water variables used in this study present the following variation intervals [6]:

Table1: statistical summary of raw water conditions from 01/01/2013 to 31/12/2016

(ONEE, 2016)

Variables	**Min**	**Max**
Turbidity: Bittit (NTU)	**1.7**	**850**
Turbidity: Ribaa (NTU)	**1.62**	**960**
PH	**6.80**	**7.74**
Temperature: (°C)	**14**	**24.70**
Conductivity micro s/cm	**509**	**624**

The chemicals used in the water treatment process consume about 50% the total operating expenses of the water treatment. The energy cost is between 10 to 15% related to the total cost in 2013, 2014 and 2015 as shown in the Figure 2.

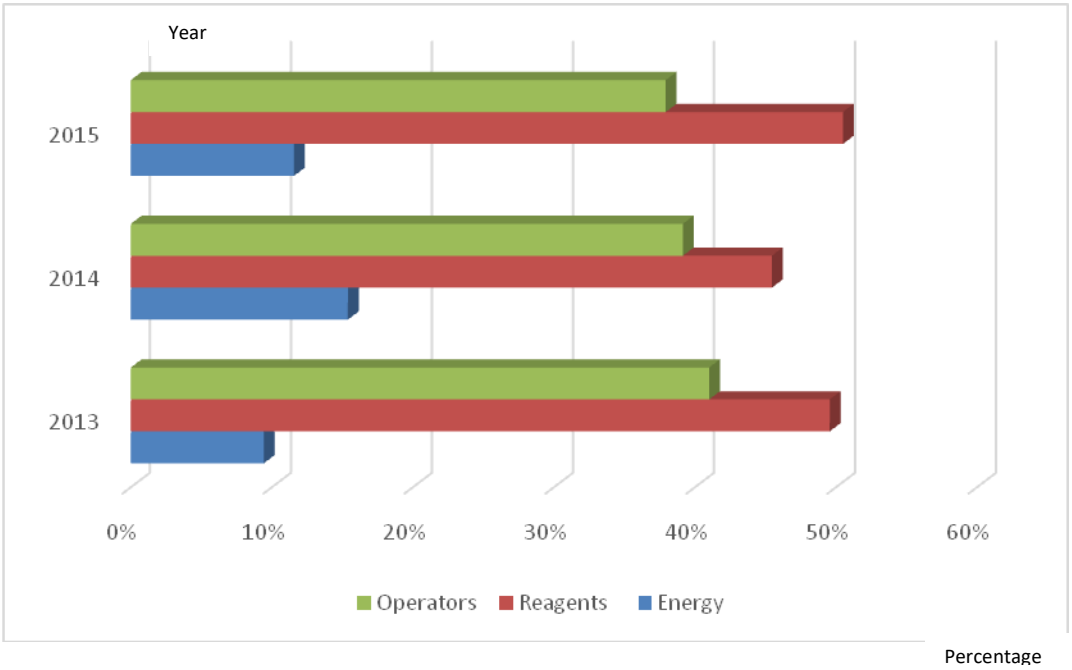

Figure 2: Operations expenses of the water treatment plant in 2013, 2014 and 2015 (National Office of Electricity and Drinking Water ONEE, 2016).

In addition, used as coagulant, the aluminum sulfate (Alum) consumption is more than 70% of the total chemicals consumption in the water treatment plant. Le polyelectrolyte (Poly) consumption is less than 10% and the chlorine is between 16 and 26% of the total chemicals used in the water treatment plant according to the water quality as shown by the figure below:

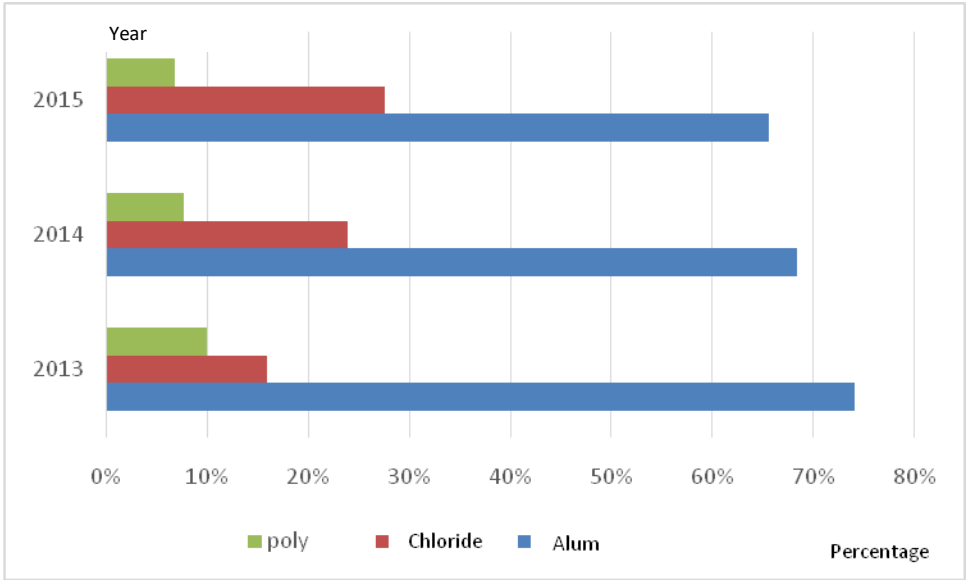

Figure 3: Percentage of chemicals expenses consumed by the water treatment plant in 2013, 2014 and 2015 (National Office of Electricity and Drinking Water ONEE, 2016).

b/ Operations data

b.1 Energy and chemicals consumption indictors:

The table 2 gives some indicators about the energy and chemicals consumption in the water treatment plant (year 2015) [7]:

Table2: Energy and chemicals indictors in 2015 (ONEE, 2016)

Key Indictor	**value**
Energy consumption kwh/m3	**0.012**
Chlorine consumption g/m3	**0.84**
Aluminum sulfate consumption g/m3	**9.82**
Polyelectrolyte g/m3	**0.12**

b.2 Maintenance:

The table 3 gives the maintenance operations number in 2015:

Table 3: Maintenance operations in 2015 (ONEE, 2016)

Key Indictor	**value**
Maintenance operations per year	**245**

b.3 water quality control:

The table 4 gives the rate of water quality control realization in 2015:

Table4: Water quality control rate in 2015 (ONEE, 2016)

Key Indictor	**percentage**
Chlorine control	**100%**
Turbidity control	**100%**
pH control	**100%**
Bacteriological control	**80%**

c/ Human resources

A staff composed of nine people manages the WTP. The plant head is responsible of the management and monitoring of the infrastructure. Eight people help him to achieve the activities related to maintenance managing and control of water quality.

The WTP is managed as follows:

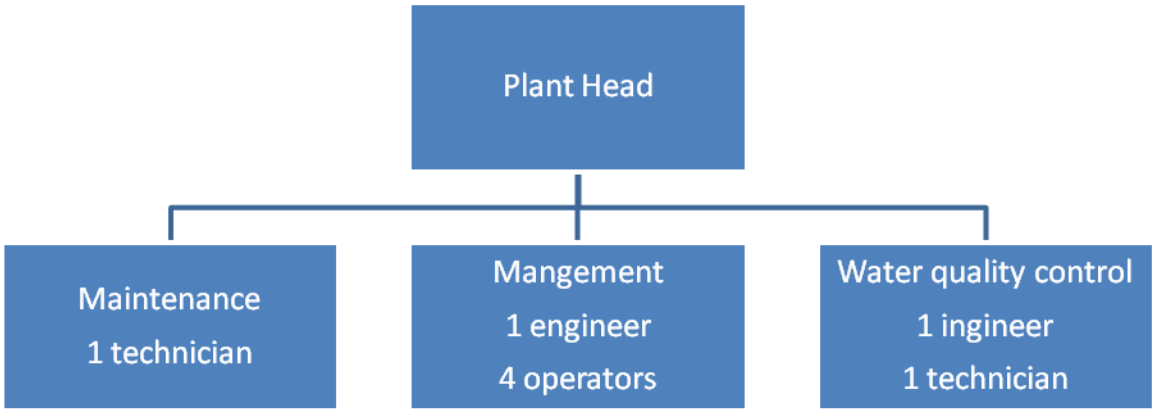

Figure 4: Human resources managing the WTP

The plant head is hierarchically depending on the head of production unit who depends on the water production department.

d/Research methodology:

Performance based contracting is based on some key indicators related to energy and chemicals consumption, the plant efficiency and the rate of water quality control. Three contracts was established in 2015 to assess the performances of the WTP in 2016. The first between the head of water production department and the production unit head. The second is signed between the unit head and the plant head and the last contract is established between the plant head and each operator representing one of the three activities in the WTP.

The key indicators used to assess the efficiency of WTP are:

- Efficiency
- Energy ratio
- Chlorine consumption ratio
- Aluminum sulfate consumption
- Rate of water quality control
- Maintenance operations number.

In the contract, each operator define the objectives to be achieved in 2016 according to the data analysis, the means required , the budget and his involvement in the process of contracting. Thus, the table 5 gives the key indicators defined by each operator:

Table 5: Performances contracting in 2016 (ONEE, 2016)

Activity	Key Indictor	Engaged value
Management	Efficiency %	**98.5**
	Energy consumption kwh/m3	**0.01**
	Chlorine consumption g/m3	**0.86**
	Aluminum sulfate consumption g/m3	**10**
	Polyelectrolyte g/m3	**0.12**
Maintenance	Maintenance operations per year	**277**
Water quality control	Chlorine control %	**100**
	Turbidity control %	**100**
	pH control %	**100**
	Bacteriological control %	**100**

III. Results and discussions

III.1. Key indicators:

The analysis of data collected in 2016 gives the results figured in the table 6:

Table 6: key indicators collected in 2016 (ONEE, 2017)

Activity	Key Indictor	Contracted Value	Recorded value
Management	Efficiency %	**98.5**	**98.6**
	Energy consumption kwh/m3	**0.012**	**0.011**
	Chlorine consumption g/m3	**0.86**	**1**
	Aluminum sulfate consumption g/m3	**10**	**10.5**
	Polyelectrolyte g/m3	**0.12**	**0.12**
Maintenance	Maintenance operations per year	**277**	**230**
Water quality control	Chlorine control %	**100**	**100**
	Turbidity control %	**100**	**100**
	pH control %	**100**	**100**
	Bacteriological control %	**100**	**89**

The table 6 shows that the WTP performances are improved by using the performance contracting for many indicators such as efficiency, energy consumption and water quality control. However, Aluminum sulfate and polyelectrolyte consumption indicators are increasing due to the raw water quality.

III.2. Evaluation of operational impacts:

1/ Improvement of water quality:

Performance based contracting in water treatment process improve the water quality produced by the water treatment plant. Concerning the dose of chemicals, contracting is the best way to control the dose that the process requires and many problems of over or under dose are avoid. Thus, the quality of water is improved.

2/ Reduction of breakdowns and incidents:

The contract with the maintenance operators presents many benefits for the WTP. In fact, the breakdowns and the incidents number is going down by 50% in 2016 compare to 2015. In addition, the maintenance of the equipment's permit to reduce the energy consumption and chemicals. Thus, it contributes to improve the water quality. However, the maintenance allows reducing the rehabilitation budget to renew the infrastructure of the WTP.

3/ Reduction of operating costs:

The improvement of the WTP performances especially the efficiency, the chemicals and the energy consumption plays a great role in reducing the operating costs. Thus, the treated water cost is reduced and optimized by applying this approach.

III.3. Evaluation of approach impacts:

The approach based on performance contracting in water treatment plant can be widespread. The relevance of these approach findings for the challenge is appreciated at three levels [8]:

1/ The environmental level:

The application of this approach contributes to enhance and protect the environment and improve the water quality. The treated water quality is improved by increasing the turbidity removal percentage due to the rational use of chemicals and energy. However, the rejected water quality is improved by decreasing all of the chemicals residues.

2/ The economic level:

The application of this approach contributes:

- Reduce operating costs by mastering the chemicals dose contracted with the operators instead of usual method.
- Improve operator productivity and efficiency and increase company profits by decreasing the operating expenses.
- Optimize life-cycle economic performance: this approach improve the performances facilities.

3/ The Social level:

The application of this approach contributes to create a very professional climate in the WTP between all the operators. The organization of human resources in improved and each operator define the objectives and the means that he should carry out to achieve the goals in synchronization with the other operators. Also, this approach can enhance population health and comfort by improving water quality.

IV. Conclusions

This paper has presented some results concerning the improvement of the water treatment efficiency. It is based on performances contracting approach that include all aspects of the WTP management. This solution is very interesting because it can improve water use efficiency, improve the competitiveness of the water supply company and reduce environmental impact. This approach gets the water treatment process more efficient by reducing operating costs, enhancing the human resources organization, and improving water quality. The study findings show that the performances of the WTP water are improved. Thus, the treated water cost is reducing. In addition, this approach touches the environmental issue by decreasing the chemicals dose and the energy consumed in the process of water treatment. Finally, the approach can be generalized for water infrastructures all over the world.

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