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Study of the Effect of Chlorine on Maintaining the Safety of Drinking Water of Ain Temouchent City (Western Northern Algeria) during Distribution and Its Related Problems

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ABSTRACT

Access to all to safe drinking water affects significantly the health and wellness of different social groups, for this reason, the distribution of a good water quality remains one of the main objectives of the installations of production, treatment and distribution of water supply, depending to the risks associated to this quality and its serious impact on human health.

In this context, this study leads us to appreciate chlorine treatment effectiveness on the elimination of pathogens (coliforms total and fecal), and, consequently, on the guarantee of water disinfection. Also, this paper aims to identify the key constraints affecting the supply of safe water to the consumer.

To this end, a study was conducted in different points throughout Aïn Témouchent city, over a period of thirteen months to verify the bacteriological quality and some physicochemical parameters such as turbidity and residual chlorine.

The results obtained during this study bearing on Aïn Témouchent city's drinking water, revealed that they were beneficial bacteriologically, where, no signs of contamination of fecal origin was observed, while, certain parameters analyzed, showed results in excess of regulatory standards, and in this regard, high levels of turbidity of some sampled waters have exceeded 7 NTU. Furthermore, the experimental study revealed an instability of chlorine residuel levels.

Given these results, it appears that the qualitative aspect of water served to the consumer in this city, had been deteriorated in the distribution network, witch implies the establishment of preventive measures complemented by by corrective treatments, to get to meet the quality criteria of the water supplied and therefore, ensure safety to the consumer's tap.
KEYWORDS: Drinking water, Aïn Témouchent city, chlorine, quality control, preservation.

I. INTRODUCTION

The quality of drinking water is directly related to human health, where it is a major concern for consumers, for this reason, the main goal of each manager is to provide drinking water whose the quality must be conform to the standards, not only to satisfy the needs of consumers, but also to prevent of serious diseases caused by waterborne pathogens.

However, this supply is exposed to various threats that weigh on essentially on qualitative level and that have an negative impact on human health and the economy.

In this respect, and to better protect public health, it is imperative that the distributed drinking water stays safe, and to this end, an management focused primarily on maintaining water quality throughout different components of the distribution system from the source to the consumer's tap, must identify the causes that confront this quality, and implement network security actions in order to prevent sanitary constraints.

The objective of this article to appreciate the effectiveness of disinfection by chlorination of the water served to consumers, than to identify the harmful causes that confront safe water supply of Ain Témouchent city according to an experimental study, than, to propose a remedial actions to maintaining the safety of this water consumption.

II. MATERIAL AND METHODS

STUDY AREA

Ain Temouchent city is the capital of Ain temouchent area (Algeria North West), located 72 km south-west of Oran, 63 km west of Sidi Bel Abbes and 69 km north-east of Tlemcen (Fig. 1)

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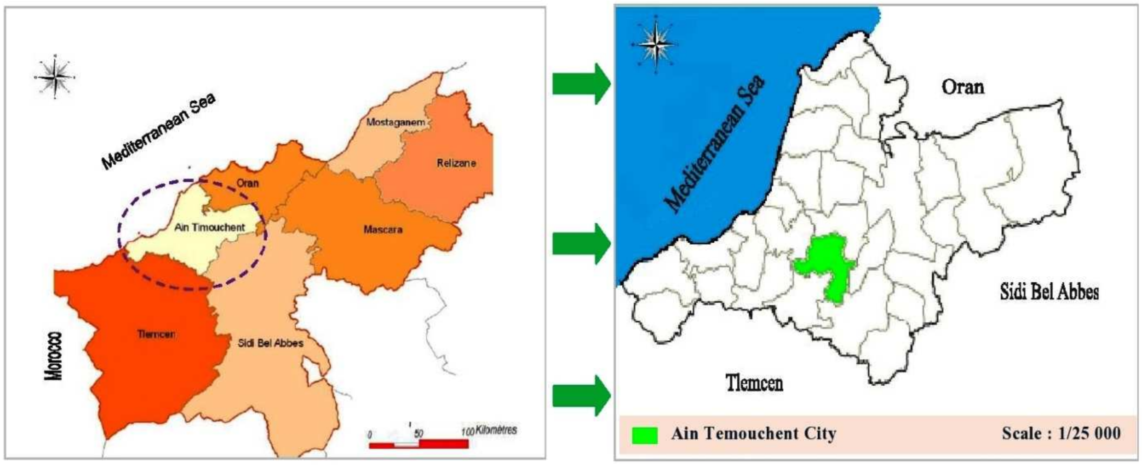

Figure 1: Geographical location of Ain Temouchent city (North-West of Algeria)

SAMPLING AND ANALYZE

The study bearing on the conformity of the quality of water used to supplying Ain Temouchent city was carried out monthly during thirteen month (from November 2012 to November 2013).

Samples of consumer water were expressed at points of use of water (famous civic address of consumers) and we had tried to take care of the sampling points according to different urban areas of the city (Table 1)

Table 1: Geographical coordinates of sampling points

Dates		Latitude (North)	Longitude (West)
S_1	November 2012	35,31° 51′73″	1,12° 97′ 79 ″
S_2	December 2012	35,30° 41′ 59″	1,13° 94′ 28″
S_3	January 2013	35,28° 84′ 61″	1,14° 06′79″
S_4	February 2013	35,30° 21′19″	1,13° 04′13″
S_5	March 2013	35,29° 19′28 ″	1,13° 94′99″
S_6	April 2013	35,29° 68′ 47″	1,14° 02′19″
S_7	May 2013	35,30° 67′ 27″	1,14° 95′41″
S_8	June 2013	35,29° 13′ 50″	1,13°11′52″
S_9	July 2013	35,29° 70′ 42″	1,14°47′29″
S_{10}	August 2013	35,30°41′ 22″	1,13° 86′89″
S_{11}	September 2013	35,30° 91′ 46″	1,14°13′66″
S_{12}	October 2013	35,30° 53′20″	1,14°28′09″
S_{13}	November 2013	35,29° 39′ 86″	1,13°55′19″

First, the detection and enumeration of bacterial indicators of fecal contamination were been made, where, different indicators of safe drinking water had been defined for assessing the bacteriological quality of the water as the total and faecal coliforms [1].

On the auther hand, the analyzes had been focused on other bacteriological parameters, such as total aerobic bacteria at 37 °C, total and faecal streptococci and sulphite-reducing anaerobes. Similarly, the study on the verification of the safety of this water distributed was based on other parameters which are the most commonly followed like chlorine residual and turbidity that is often used as an indicator of the performance of treatment [2,3].

Taking a sample of water is a delicate operation, and for this reason, the material should be take a particular attention.

For bacteriological analyzes, the glass bottles (1 liter) used must ensure total protection against contamination. Before use, these flasks were thoroughly rinsed with distilled water, then they are dried then sealed and sterilized by an autoclave at 170 ° C for one hour.

After, the collected samples were transported in refrigerated coolers (temperature less than 4 ° C) to ensure a satisfactory conservation.

The bacteriological analysis consists of an enumeration of germs at 37 ° C on tryptone glucose extract agar (TGEA), using a colony counter (FUNKE mark) ;

Searching of sulphite-reducing clostridia, had been made by inclusing in meat – liver glucose agar ; Other bacteriological parameters had been determined by the method of Most Probable Number [4, 5, 6]. This method consists in seeding, using appropriate dilutions of the sample that will be analyzed, a series of tubes containing nutrient broth medium. After incubation for 24 hours at 37 ° C, the tubes having a disorder will be considered as positive.

The measuring of turbidity had been done by using a nephelometric turbidimeter (HACH mark), which measures in nephelometric turbidity units (NTU) and allowing immediate reading of the result. The residual chlorine had been determined using a disc comparator (LOVIBOND mark) by the DPD method (diethyl-p-phenylenediamine), wherever, the present chlorine in the sample as an hypochlorous acid form or as hypochlorite ion, reacts with the DPD to form a red color which is proportional to the concentration of chlorine.

III. RESULTS AND DISCUSSION

BACTERIOLOGICAL STUDY

The bacteriological quality of water is the key parameter of drinking water because the presence of germs in it constitues a risk factor for the occurrence of gastrointestinal disorders such as diarrhea, vomiting… The presence of total coliforms is often due to bacterial proliferation, however, their measure serves primarily to verify the presence of fecal contamination in the distribution network.

In reviewing our results, and according to standard set by theWorld Health Organization (WHO, 2004)and the Algerian legislation on the quality of drinking water which stipulate zero faecal coliforms per 100 ml of sampled water, our bacteriological analyzes were predominantly negative, where, no faecal contamination had been detected , however, total aerobic bacteria had been found eight times on a total of thirteen water samples.

The quantitative difference of germs to one ml of sample water can be explained by the non-homogeneous apportionment of bacteria inside the distribution of drinking water network. Also, the collected amount varies considerably from one sample to another, depending to the detachment or not to biofilm during sampling. The figure 2, below, shows that the count of total germs contained in our samples water supply collected, had not exceed 10 germs per ml of water, during all the tests.

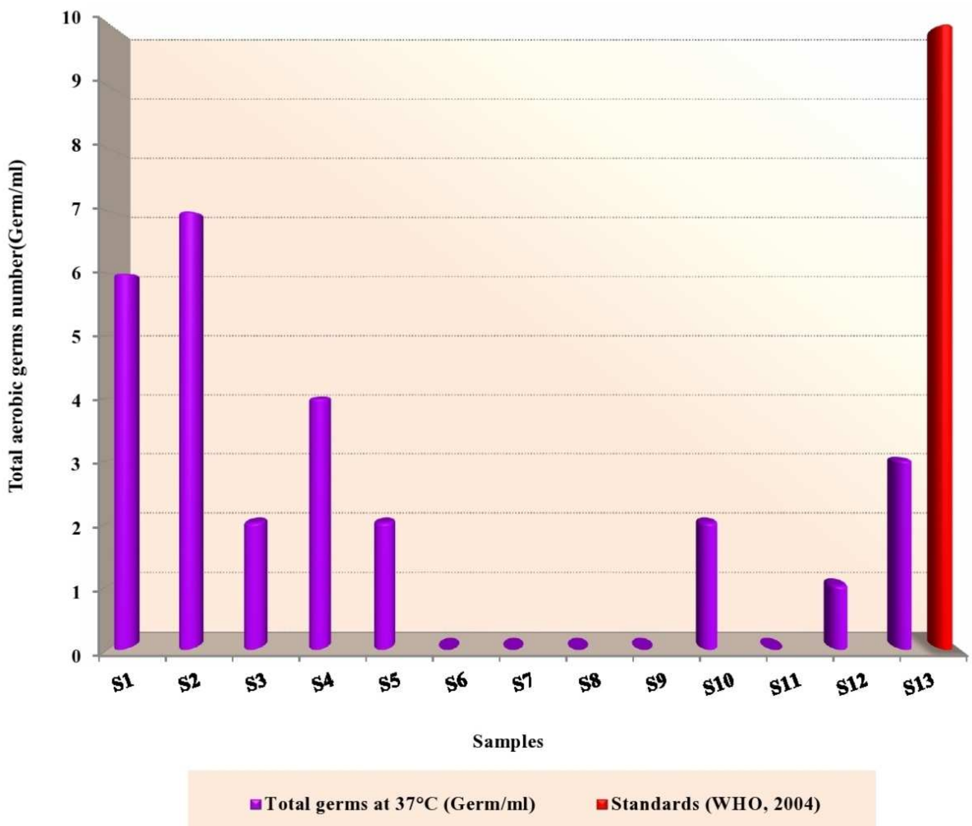

Figure 2 : Number of total aerobic count of drinking water during testing

CHLORINE RESIDUAL STUDY

Chlorination is the most popular disinfection process for the treatment of water allocated to human consumption, and the examination of residual chlorine concentrations is a valuable approach on the water quality.

It is obvious that an residual disinfectant (free chlorine) must be maintained in the distribution system to minimize bacterial growth [7,8]. However, the results of the analyzes had shown some instability of residual chlorine levels in water, where, its were in some ways very low and even null (0 mg/l), but, in other points, high residual levels of chlorine in drinking water (inducing to poor gustatives quality very pronounced in distributed water, having reached the 0.4 mg / l) were recorded.

The majority of these concentrations are reassuring, but they had exceeded the levels of residual chlorine that are really necessary to preserve the bacteriological water quality during its transport to the consumer's tap, which at this point, the residual chlorine concentration must be between 0.1 and 0.2 mg/l [9]. This situation may be explained by assaying of sodium hypochlorite, which is effected with a non proportional dosage pump to flow rate, making it difficult to maintain a more stable free residual chlorine on the network.

STUDY OF THE TURBIDITY OF DRINKING WATER

The guarantee of water disinfection is no longer based only on the research of indicators germs, but also on a range of parameters, in particular, those physicochemical which are added to the research of germs and more particularly the turbidity [10].

The turbidity of the water withdrawn from this urban area had averaged 2,21 NTU. During the study period, some samples showed a turbidity exceeding the recommended standard which is limited at 5UTN.

These except standards values could be explained by a deterioration of the water quality by handing of suspending matter deposited in the canalisations. In addition, these results indicate a failure of the treatment system, a corrosion problem, or a low level of residual chlorine.

Turbidity may contribute to the proliferation of bacteria where drinking water systems are continually exposed to a flux of biodegradable organic matter, plankton and other microorganisms as well as particulate matter consisting of silt, clay as well as particulate matter consisting of silt, clay coming from the treatment plant, or during repairs occurring on the network, breaks, and which are deposited in pipes.

Some of these micro organisms (heterotrophic bacteria in particular) fits to this oligotrophic environment and can colonize the whole of a water distribution network.

In addition, colloids responsible of turbidity can protect bacteria against chemical treatments.

Our experimental results show that the proportion of the number of total germs increases gradually as turbidity increases, and to better assess the relationship between these two parameters, a correlation statistical treatment was applied.

This statistical analysis had given us a positive coefficient of correlation (r = + 0.87) which means that the turbidity is positively correlated with the number of total germs.

The graphical representation (Fig. 3) below, exposes this relationship.

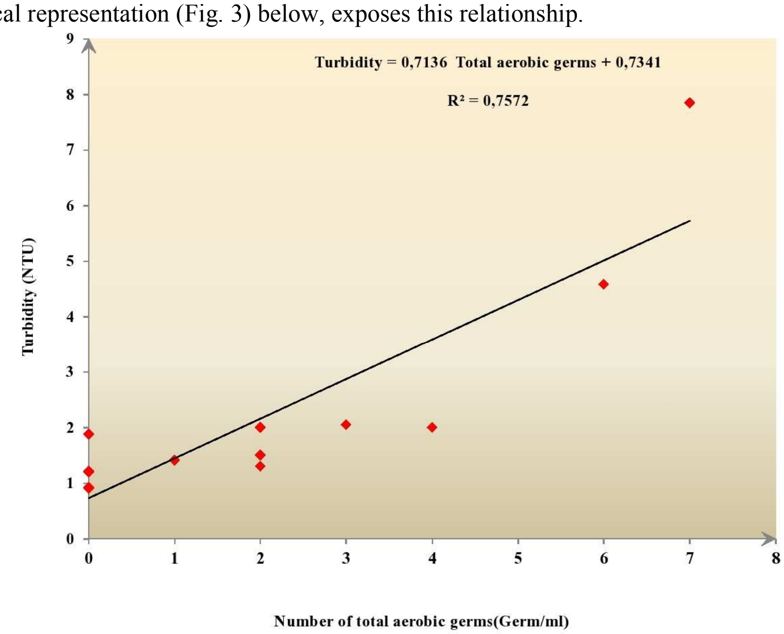

Figure 3: Evolution of the turbidity level of drinking water from Ain Temouchent city depending to the total aerobic germs

Also, high turbidity may constitue a gene against the effectiveness of water disinfection, because its growth can result in increased levels of chlorine required [11].

The obtained results of our samples had shown that untill turbidity values of 4.85 and 7.85 NTU registed during the two first samples (S_1 and S_2), we had obtained a perfect disinfection, where, national standards concerning bacteriological quality had been respected.

Therefore, these results confirm the beneficial effect of disinfection with sodium hypochlorite on reducing turbidity of water, where, we were able to observe that the increase in chlorine residual is associated with a decrease of the turbidity level.

Following this observation, and after calculating the correlation coefficient (r) which can detect the presence or absence of a linear relationship between variables, it appears to us that there is an inverse relationship between the turbidity and residual chlorine.

This statistical treatment gives results as a matrix of correlations between variables whose data of this analysis are summarized in table 2 below.

Table 2: Correlation matrix between variables

	Residual chlorine	Turbidity
Residual chlorine	1	
Turbidity	- 0,26	1

The graphical representation (cloud of points) of the turbidity values recorded at different sampling points of drinking water samples from Ain Temouchent city depending on the residual chlorine values gives us a correlation coefficient of $r^2 = 0.0677$ (Fig. 4).

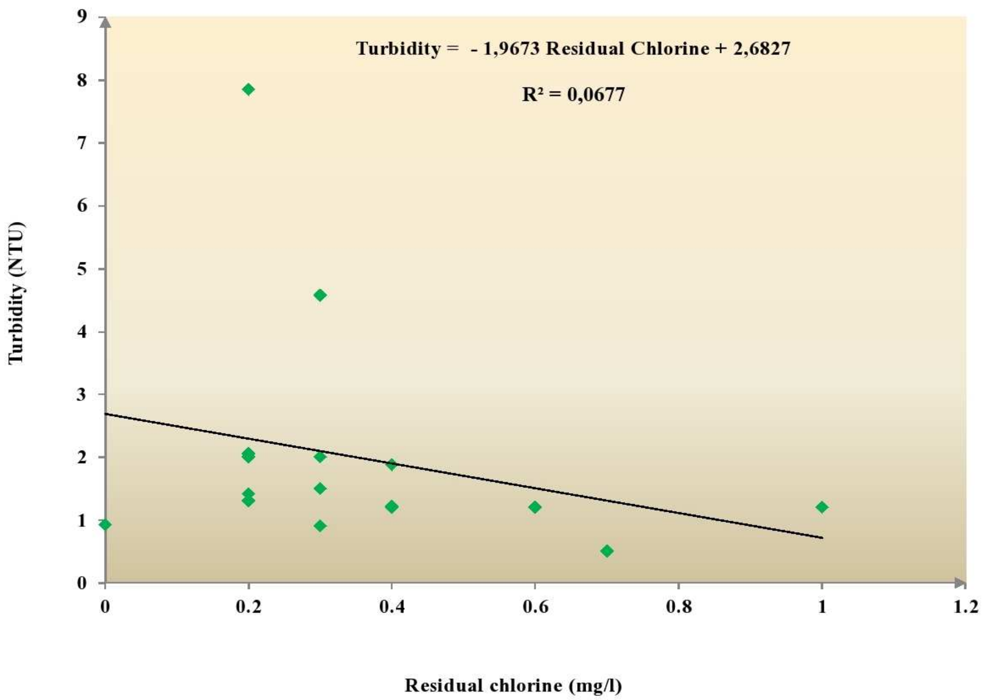

Figure 4: Evolution of the turbidity level of drinking water from Ain Temouchent city depending to the residual chlorine concentration

Moreover, the work of Graveland (1998) and Kaneko (1998) have shown that the effectiveness of disinfection by chlorination in surface water supplies was closely related to turbidity where the disinfecting power of chlorine is even more important when the turbidity of the water is low.

Under the light of these results, it appears that the water supplied to consumers in this city is good bacteriologically. However, it remains poorly for some parameters especially turbidity. This can be explained by the treatment goal which is not to produce sterile water, but water that does not present a risk to public health; without forgetting the drinking water system, that can be not considered like a simple water transport tool to consumers, where within which is set up a development of microorganisms.

Therefore, it can be said that the distribution of safe water is subject to various hazards, where any unit system (capture, production, storage, distribution) is not safe from failure.

In general, we can summarize these constraints affecting the provision of safe water to the consumer in:

Exceptional weather phenomena that may endanger the water supply (for example : flood risk of certain production sites);

A problem with the treatment system, including electrical failure which will make the distribution unit no able to provide a water that respects the healthy prerequisites of water quality and also the necessary volumes;

Several studies have documented a spatial variability of drinking water quality due to the dwell time of water, biofilm on the conduit walls [12, 13, 14, 15,16];

In addition, networks may encounter problems with leaks (risk of polluted water return, intrusion of contaminants, or, to water stagnation [17,18];

Additionelly, networks are exposed to many types of degradation,whose, the main ones are the corrosion and scaling, particularly if they are often badly controlled by the managers ;

The fluctuation of the bacteriological and physicochemical quality of raw water, will hardly affect the final quality of the water produced. However, some networks do not have an important financial resources, are often devoided of robusts installations, and must frequently have to be content with a simple disinfection step. Moreover, the high costs of maintenance of installations, limit those networks to use the appropriate means [19];

The drinking water operator ensures the proper functioning of the distribution water system, than, he is the responsible of water quality management and for all supplying system too.

It is knowned that due to a lack of qualified human resources, the manager must be use less experienced operators, therefore, introducing of a human factor in production of drinking water process, can add an additional source of error and risk also, which can weigh more on the quality of water produced [20]. In this context, several authors have studied the causes of waterborne illeness, where, a lot of accidents were due to the human error [21].

In addition, we must not forget that the final quality of water supply depends also to consumption habits and systems put in place by consumers in their homes [22,23].

Based upon the results of our study, in order to proposing solutions, and in the context of protection of public health, several recommendations were made ;

Improving the quality of the source of supply ensuring its protection, can help to treatment costs while improving the quality of the water produced;

The maximal reduction of the suspended matter of the raw water should be envisaged in order to minimize the risk of deterioration of the water quality;

The modernization of the treatment water system, specially of surface water, is the most effective strategy to reduce turbidity;

The presence of total bacteria was observed eight times of a total of thirteen tests carried out, for this reason, nanofiltration should be a barrier to any kind of bacteria for the pore size of the membranes which are in the nanometer range . On the other hand, the presence of these organisms in our samples could be due not to its passage through the membrane but also to their development in the network. Indeed, though the module was cleaned after each test, it was never disinfected propely. For this reason, the regular maintenance of filters (supply water pressure, air pressure when cleaning) is not sufficiently rigorous and the installation manager suggested circulating a disinfecting solution after each chemical wash series.

Also, the use of sterile disposable filter is designed to reduce the risk of deterioration of inner membranes of filters;

In addition, other approaches are necessary to do its, and in this sense, hydraulic design of networks must ensure a certain circulaion of water speed, in order to prevent stagnation phenomena that are favorable for the growth and development of bacteria ;

Similarly, the material must not be altered, however, water can be corrosive, which it is imperative to file a protective film on the inside of canalisations, which aims to form a barrier therebetween it and water, thus avoiding any adverse interaction between its;

A regular monitoring of residual chlorine needs to be reinforced in many possible points. The impact its variability on other water quality parameters (including specially bacteriological parametrs) must be taken into account by the operators;

Operator formation is paramount, where, conferences should be more accessible so they can participate. Also, some training should be garanted directly on site a special attention should be given of the on the management of the chlorine disinfection and its impact on the quality of drinking water ;

It is best to create a citizens' committee in order to more improving the communication between the residents and the operator. This committee could have an objectif to meet the requirements and demands of residents and also to informing them on water problems (failure of treatment system, deterioration of water quality).

IV. CONCLUSION

This study taken place in Ain Temouchent city, whose, drinking water supply is provided primarily by the Beni Saf desalination station, had bringing out many exceedances of standars of some parameters especially turbidity and residual chlorine.

These temporary exceedances of the limit value indicate that the situation is not completely satisfactored, which, water quality involves little or no risk to consumer health.

Any dysfunction in the distribution of water, as regards quality, quality, can have serious consequences for public health, and for this reason, the maintenance of good water quality during distribution requires monitoring control and prevention through periodical analyzes of the network, whose aim is to make sure the drinking water quality served to the consumer, based on various parameters, especially the residual chlorine, where, its supervision, provides a quick indication of the problems that affect the measurement of the bacteriological parameters, allowing to draw up a quality mapping.

Also, it is important to sensize the actors who are daily mobilizing to produce and control the quality of tap water, so they are aware of their responsibility within the service to deal with an important part of the problems that may be encountered.

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