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Impact of Waste on the Quality of Water Resources – Case Study of Taza City, Morocco

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ABSTRACT

The ultimate purpose behind this study is to assess the quality of water surface of Oued Inaouen and its tributaries and some underground stations before and after discharge of the city of Taza. It addresses the leachate of the unauthorized landfill of Taza which is a source of nuisance that adds to the many problems of contamination of the surrounding environment if they are not treated before discharge. This survey explains how the landfill can affect the quality of water resources near the city of Taza, represented by the main tributaries of the watershed of Oued Inaouen by determining the main parameters indicators of pollution, and to study the possibilities of contamination of groundwater and surface water by infiltration or flow of leachate. Physico-chemical results show high concentrations of organic matter, the BOD_5/COD ratio indicating a biodegradable organic fraction. As far as mineral pollution is concerned, high contents of NH_4^+, NO_3^-, total phosphorus and Cl^-, which explains the high conductivity values. Bacteriological analyses show significant quantities of coliforms and fecal streptococci. For the evaluation of the pollution of groundwater and surface water, the results obtained are translated by the presence of a significant contamination that differs from one point to another. To evaluate the pollution of groundwater and water surface, the results obtained are translated by the presence of a significant contamination that differs from one point to another.

Keywords: Taza landfill, impact, physico-chemical parameters, bacteriological parameters, statistical analysis.

INTRODUCTION

The physico-chemical quality of watercourses has always been the subject of a number of international and national investigations in the country of Morocco. Moreover, these investigations have revealed an alarming reality of the effects of pollution on the state of surface and groundwater. The demographic structure which is progressively increasing on the one hand and the evolution of the gross domestic product per capita has generated a massive production of solid waste (El Hammoudani, 2019, Abbou, 2020, Fernine, 2022). In this context, the production of leachate, which is one of the main consequences, remains one of the threats to the environment (Coffin, 2022), especially to water resources (El Hammoudani, 2021, Benaissa, 2022, Bouhout, 2022) (soil pollution, contamination of groundwater and surface water) (Abbou, 2014, Abbou et al., 2020, El Hammoudani, 2020, Al Raisi, 2022), which could have negative health effects on the population (Fekri, 2012, Dimane, 2021).

In this regard, the management of solid waste has always been an important issue for a number of Moroccan cities, in this case, Taza. In fact, the latter whose waste production is about 126,000 tons per week, for an estimated population of

154,496 inhabitants- is obliged to proceed to an unauthorized dump (domestic, industrial, hospital, agricultural waste). At a distance of 1.2 km is the dumping site, more precisely at the edge of Oued Larbâa. This reality is the cause of several evils whose consequences are harmful to the watershed of Oued Inaouen (Abbou et al., 2014).

This study has the primary purpose of evaluating the measurement, nature and behaviour of various physico-chemical parameters of effluents from the most polluted area in the city of Taza (Boutchich, 2015).

MATERIALS AND METHODS

The area under survey

For justifying the physico-chemical wellness of the waters of the Oued Inaouen watershed, we will first study the spatial-temporal evolution of these parameters. Then, we classified the waters of this catchment Oued Inaouen while proceeding to a comparison of the results retained to the national and international standards, which will moreover, allow us to hold a database deep enough to be able to carry out statistical tests to determine the correlation between the parameters and also to know the significant effect of the explanatory variables (samples of time and site) on the dependent variables (parameters of pollution: COD, BOD_5, NTK, ect). In this study, we relied on statistical test which is the principal component analysis (PCA), exploiting the XL-STAT 2016 software. Knowing about pollutant parts of the treated water helps to understand how these processes work. This leads to choose and apply these processes at low cost. It is efficient treatment method (Elabdouni, 2020, El Abdouni, 2021).

The Oued Inaouen watershed remains one of the large watersheds of Sebou. Indeed, its area is estimated at 3396 km². Therefore, it constitutes 8.3%. It is 20 km north-east of the prefecture of Fez. Thus, it is upstream of the Idriss I dam (Fig. 1). One of the main characteristics of Oued Inaouen is that it is surrounded from the North-West by the Upper Ouergha watershed, from the South by the Upper Sebou watershed and from the East by that of the Middle Mouloya. This basin drains mainly marly formations of the Pre-Rifain relief at the level of the right bank, while at the level of the left bank; it drains mainly the carbonate formations of the middle Atlasian Causse. The Middle Atlas Mountains concentrate the greatest variations in altitude. Moreover, the successive snowfall -especially in winter- in this region is due to this concentration.

The density of the hydrographic network in the basin is influenced by the lithological nature. In general, it is very dense in the marly soils of the Prerif and the South Rifain corridor and loose in the carbonate formations of the Middle Atlas Causse.

Sample sites

Generally, the sampling of the different types of samples was done in accordance with the ISO 5667/2-1982 standard [15 mer] on sampling techniques. Beforehand, there was a step of choice and definition of these sampling points according to the objective of the physico-chemical and bacteriological analysis, this study will focus on the evaluation of the impact of the load of the city of Taza on water resources: the upstream watershed of Oued Inaouen and its main tributaries (Oued Larbâa, Oued Lahdar and Oued Taza). Among the studied stations, eight were taken in the framework of this research. The choice of these stations was therefore made taking into account certain parameters, the situation in relation to the landfill, the diversity of biotopes and the upstream and downstream of the settlements in order to estimate the importance of the human impact. This choice is also subject to the difficulty of accessing the stations. To carry out the present study, monthly sampling campaigns were carried out in March, April and May at the Taza dump. All these samples were taken in 6 points of surface water numbered from O1 to O6 and 2 points of groundwater numbered from P1 to P2 (Fig. 2).

Experimental protocol

Physico-chemical analyses

Fifteen elements were measured. Within this framework, there are two types of physico-chemical analyses, Five parameters were recorded in the field: temperature (T), electrical conductivity (E.C), pH, dissolved oxygen (DO) and turbidity and the other parameters : Generally, biological oxygen demand after 5 days (BOD_5), chemical oxygen demand (COD), Orthophosphates and total suspended solids (TSS) are measured in the laboratory, Nitrate (NO_3^-), Nitrite (NO_2^-) ions and Ammonium (NH_4^+) (Table 1) are the methods most used within

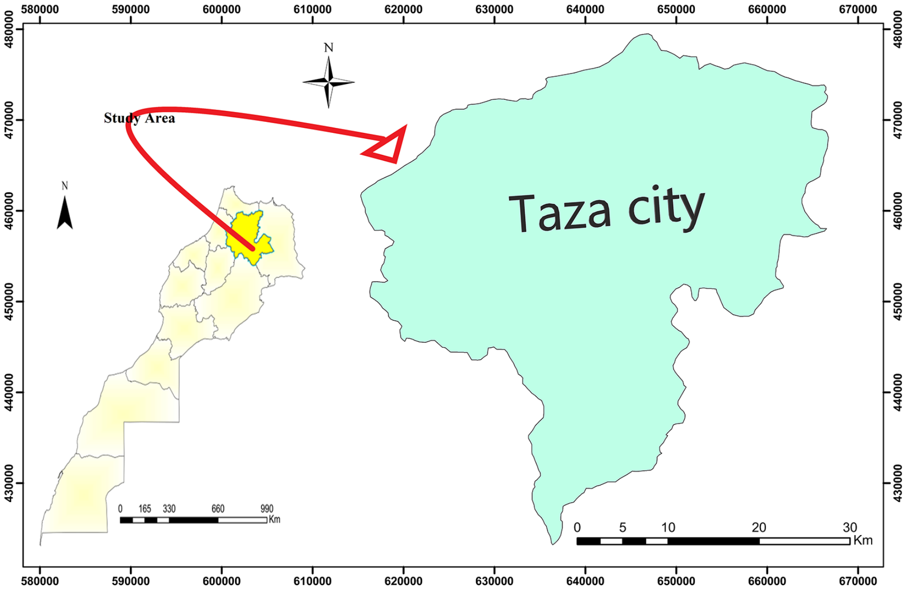

Figure 1. Geographical location of the Oued Inaouen watershed and sub-watershed

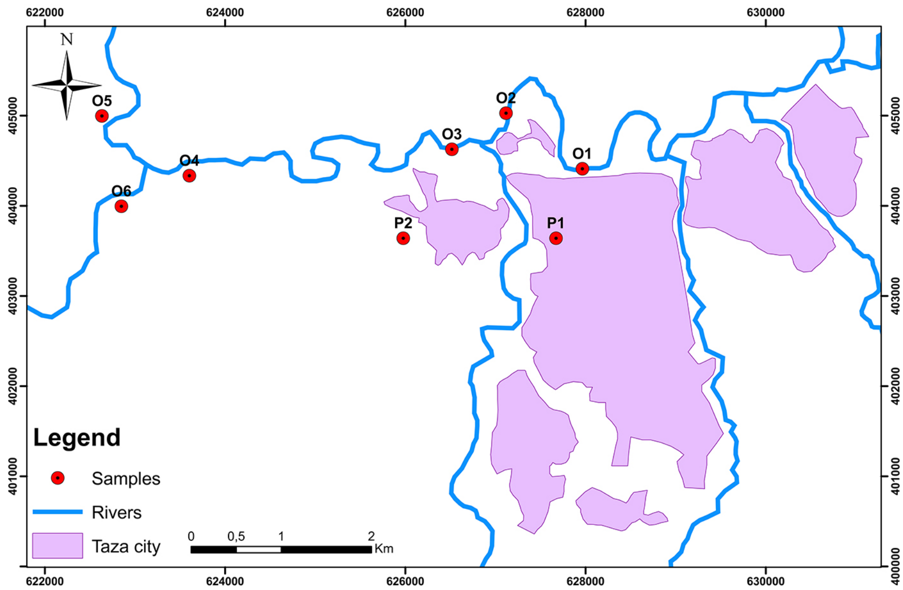

Figure 2. Representative map of the study stations

the National Laboratory of Studies and Monitoring of Pollution Rabat (LNESP) (Rodier, 2009).

Bacteriological analysis

The main objective of a bacteriological analysis of water is not to make an inventory of all the species present, but to look for indicators of fecal contamination: fecal coliforms and fecal streptococci. In our study we opted for the membrane filtration method to estimate the bacterial load in the study area. It consists in a filtration of water on membranes of porosity 0.45 µm likely to retain the bacteria with a grid on the surface facilitating the enumerations. During our work period we carried out the research of the following germs: Total aerobic mesophilic flora (FMAT); Total coliforms (TC); Fecal coliforms (FC); Intestinal enterococci (Faurie, 2011).

RESULTS AND DISCUSSIONS

We determined the physico-chemical and bacteriological composition of groundwater and

Table 1. Methods of analysis of physicochemical components

Parameters	Analytical procedure	Unit
Conductivity	Type CONSORT – modelC535	µs/cm
pH	pH-meter Type CONSORT – model C535	1-4
Temperature	Mercury thermometer/multi-parameter analyser type CONSORT – modelC535	–
Dissolved oxygen	Winkler titration method	mg/L
Nitrates	Sodium salicylate	mg/L
Nitrites	Zamballi reagent method	mg/L
Ammoniums	Sodium phenol nitroprusside and chlorine solution	mg/L
Orthophosphates	Potassium antimony tartrate and ammonium molybdate solution	mg/L
TSS	0.45 um membrane	mg/L
BOD_5	OXITOP	mg/L
COD	Potassium dichromate at a temperature of 180°C	mg/L
Total Kjeldahl nitrogen	Mineralization of the sample by concentrated sulfuric acid in the presence of a selenium catalyst	mg/L

surface water in the watershed of Oued Larbaa in the city of Taza. For this we have carried out 24 samples (three samples for each station). The surface waters are numbered from O1 to O6 and the groundwater are numbered from P1 to P2.

Physical and chemical analyses

The pH

The pH is a parameter very sensitive to various environmental factors; it also depends on variations in temperature, salinity, the rate of dissolved CO_2. Moreover, it is determined by geological nature of the soil, it is also a function of chlorophyll assimilation, respiration of organisms and metabolism of bacteria and fungi (Azami Hassani, 1996). The pH values show that the waters are slightly alkaline (Fig. 3). This alkalinity is highly affected by the nature of soils and rocks which are made of Liassic dolomite. For the station O5 which is located downstream of the Oued Lahdar, the use of CO_2 during photosynthesis, which is accompanied by the precipitation of insoluble carbonates resulted in the alkalization of their waters (Bontoux, 1983, Lavandier, 1995). The groundwater studied has a pH that meets the Moroccan standards.

Electrical conductivity (EC)

The electrical conductivity of the water in the study area varies greatly between the left and right banks. On the right bank, the waters are characterized by a high mineralization, with a maximum

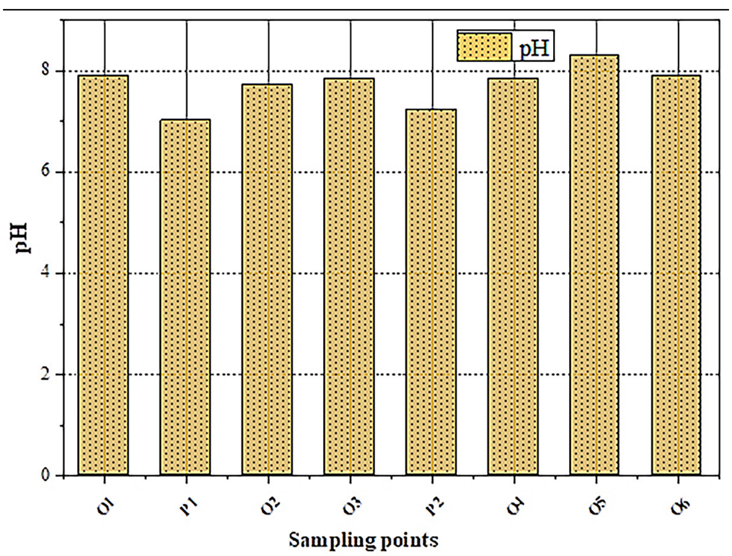

Figure 3. Variation of pH in the waters of the city of Taza

conductivity of 2,140 µs/cm downstream of Oued Lahdar. On the other hand, the waters of the tributaries of the left bank present a low mineralization, with a conductivity of 918 µs/cm downstream of Wadi Taza (Fig. 4).

Dissolved oxygen (DO)

The dissolved oxygen levels in the waters of the city of Taza show a decrease in the values recorded in the majority of stations jump the station O1 which is upstream of the Oued Labaa. The study conducted at the stations (O2, O4 and O6) showed a low rate of the dissolved oxygen. This fact occurred because of the organic load of urban waste from the city of Taza. In fact, decreasing in the dissolved oxygen occurred due to the activity of bacteria breaking down the organic matter present. The distance from the polluted site is a fundamental factor that determines the rate of concentration of the dissolved oxygen in a sampling point. For groundwater, the P2 sampling point does not match the Moroccan standard NM 03.7.001, but the P1 point has a varying concentration which is estimated between 5 mg/L and 8 mg/L (Fig. 5).

Total suspended solids (TSS)

A total suspended solid generally comes from erosion and discharge of waste and wastewater in the natural environment. They are a function of the nature of the land crossed, the season, the

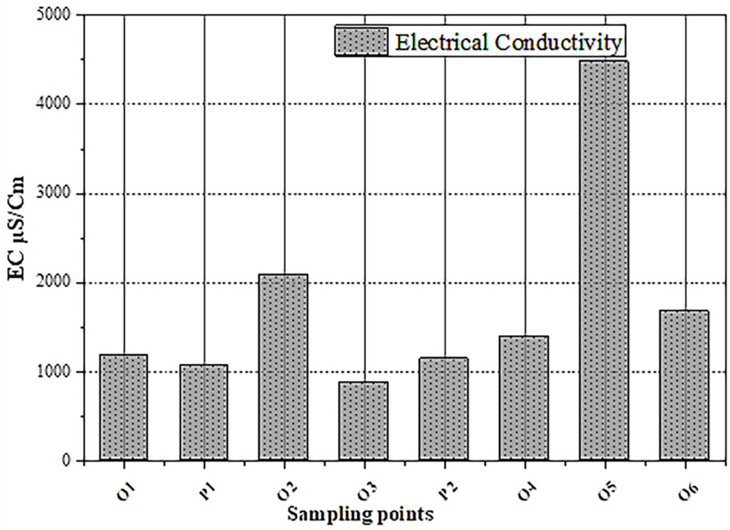

Figure 4. Variation of electrical conductivity in the waters of the city of Taza

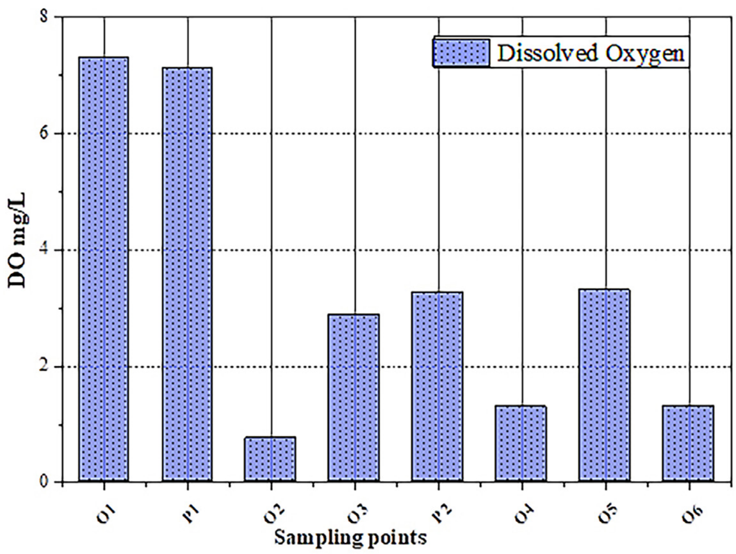

Figure 5. Variation of dissolved oxygen in the waters of the city of Taza

rainfall, the flow regime of water and the nature of the discharges (Belles-Isles, 2004). High suspended solids levels can be seen as a form of pollution. This increase can cause the warming of water, which can be resulted in reduction in habitat quality for cold-water organisms. In the streams of the Oued Inaouen watershed, TSS fluctuates greatly from season to season (Fig. 6).

For the station O2 and O6, the value of the TSS oscillates between 1 mg/L and 267 mg/L. The evolution of the TSS of the studied waters, during the study period shows very distinct values in the point that receives wastewater from the city of Taza and the other point far from pollution. This variation in values due to domestic discharges or agriculture.

Chemical oxygen demand (COD)

COD levels increase from one station to another. Indeed, minimum values of the order of 14.56 mg/L (Station O5), and maximum values of the order of 1,613 mg/L (Station O2) next to the dump of the city of Taza.With the exception of stations located upstream of the basin (O1) which show an average content greater than 40 mg/L (Fig. 7), the concentrations observed in other stations of the upstream during the study period are clearly low. In addition, the levels recorded in the stations that cross the city of Taza and are located downstream of the agglomerations of rural and urban centers to exceed 40 times and more the average value set at 40 mg/L.

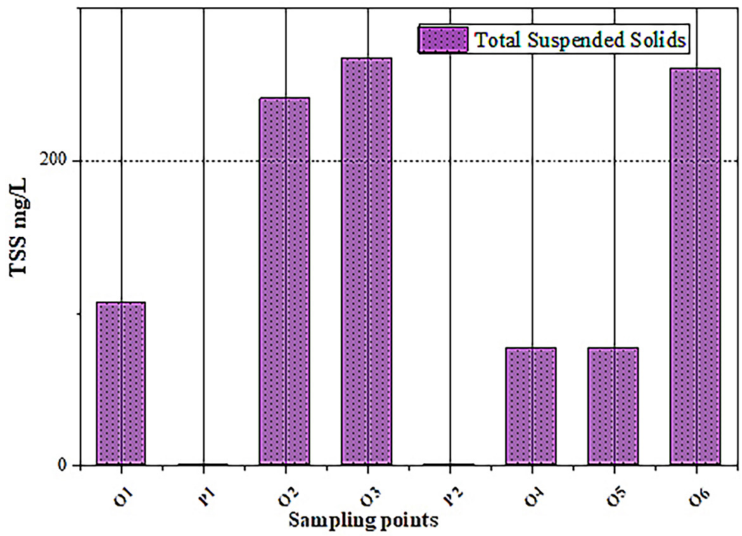

Figure 6. Variation of the total suspended solids in the waters of the city of Taza

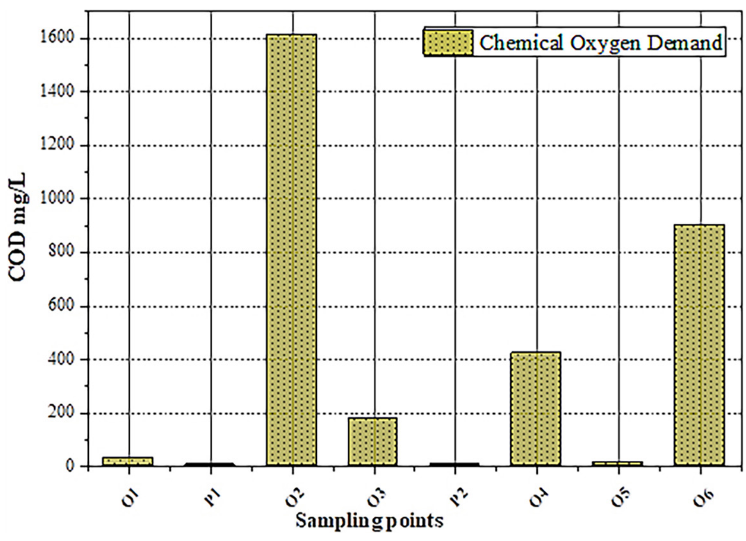

Figure 7. Variation of COD in the waters of the city of Taza

Biological oxygen demand (BOD_5)

BOD_5 varies irregularly – ranged from 1.33 mg/L at Station O5 to 1,126 mg/L at Station O2. The recorded values (Fig. 8) show an increase in BOD_5 of surface waters of the city of Taza downstream of the watercourses that receive raw water which consists of organic matter and nutrients from urban and rural mass. This leads to a noticeable raise in the organic load of surface waters in limited area. However, the other stations, which are generally far from any external influences, still have water of acceptable quality.

Nitrates (NO_3^-)

The nitrates in the waters of the city of Taza are very high in groundwater, show levels rising from 59.7 to 63.07 mg/L as maximum concentration in P1 and P2 (Fig. 9). The lowest values of surface waters due to the activity of aquatic plants transforming nitrates into organic molecules.

The nitrate content in the groundwater analyzed exceeds 50 mg/L. According to the Moroccan standard which sets 50 mg/L as the limit concentration of nitrates in water for human consumption, these waters analyzed do not meet the

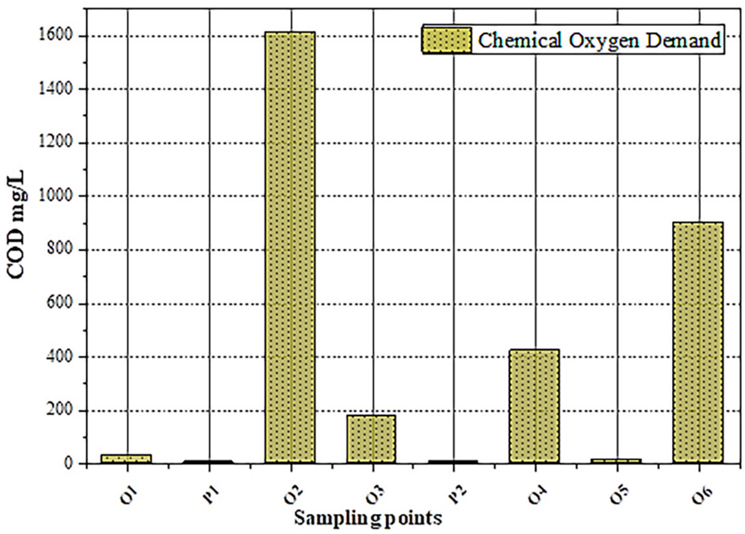

Figure 8. Variation of BOD_5 in the waters of the city of Taza

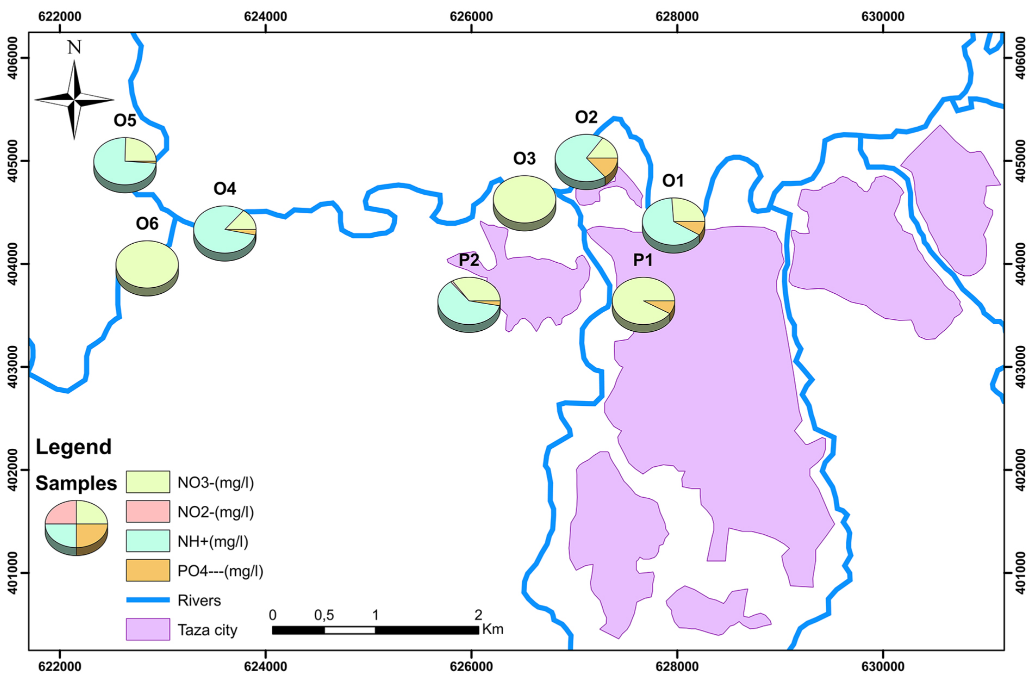

Figure 9. Variation of NO_3^-, NO_2^-, NH_4^+, and PO_4^{3-} in the waters of the city of Taza

standards. This increase would testify to a recent contamination resulting from the infiltration of wastewater (Hakkou, 2001). In general, when the organic matter is released by bacterial oxidation of nitrites, nitrates are produced. Therefore, we can assume that titrates are the output of nitrification (Derwich, 2010, Derwich, 2011).

Nitrite (NO_2^-)

Nitrite is an intermediate ion between nitrate and ammoniacal nitrogen, which is why it is found in low concentrations in water. According to NM 03.7.001. 2006 a concentration of 0.5 mg/L nitrite should not be exceeded. The concentration values of nitrite in the studied points do not exceed the limit value of 0.5 mg/L (Fig. 9). On the other hand in surface waters there is an increase would testify to a recent contamination resulting from wastewater a deficit of the environment in oxygen (3.86 mg/L at this point) or a reduction of nitrates by organic matter.

Ammonium (NH_4^+)

Ammonium is produced due to the decrease in nitrogenous organic substances and inorganic particles in water and soil. In addition to this, there are other factors which lead to the production of Ammonium: disposal of living organisms, the biodegradation of waste, in addition to industrial and agricultural origin (Derwich et al., 2010). It stands as a signal of the pollution of waterways by urban effluents. In surface waters, it is generated from nitrogenous organic matter and from gas exchanges that occurs between water and the atmosphere (Chapman, 1996, Benaissa, 2020, El Hammoudani et al., 2020, Bourjila, 2021).

The analysis of the results shows a variation of ammonium contents from one station to another, recording maximum contents between 29.92 mg /L (Station O2) and 13.30 mg/L (Stations O1 and O3) (Fig. 9). This increase reflects the process of incomplete degradation of organic matter.

Orthohosphates (PO_4^{3-})

Phosphorus, a crucial nutrient, can emerge in distinctive oxidized aspects that are produced as result of the decomposition of organic matter and leaching of minerals from phosphate rocks. It is present in small quantities in unpolluted streams that can reach the level of concentration of 0.02 mg/L (Chapman, 1996, Benaissa et al., 2020). High levels of this element in surface waters are the sign of water pollution by domestic, industrial or agricultural effluents . They then favour the proliferation of plant populations in the aquatic environment and are, thus, at the origin of its eutrophication. Phosphate can be noticed in distinctive oxidized forms as Meta HPO_3, pyro $H_4P_2O_7$ and ortho H_3PO_4. In aqueous medium, the Meta and pyro forms tend towards the ortho form for pH 5 to 8. Results analysis reveals that orthophosphate concentrations in surface waters of the city of Taza, vary between 3.13 mg/L (Station O2) and 0.21 mg/L (Station O1). The question of why orthophosphates are available could be answered by referring to the urban discharges coming from nearby settlements, and the release of the abundant quantity of phosphorus in the sediments.

Bacteriological analyses

Enumeration of total aerobic mesospheric flora (FMAT)

All groundwater analysed are contaminated by the total aerobic mesophilic flora (FMAT). At 22°C, the minimum value is recorded in sampling point P1 with a concentration of 5×10^2 CFU/100 mL, while the highest value of FMAT is recorded in sampling point P2 with a concentration of 14.64×10^4 CFU/100 mL. At 37°C, the concentration of FMAT varies between maximum values of 9.36×10^3 CFU/100 mL recorded in the P2 sampling point and a minimum value of 3×10^2 CFU/100 mL recorded in the P1 sampling point. The total germs at 22°C are bacteria of residual (environmental) origin, while the total germs at 37°C are bacteria of intestinal origin (human or animal). The high contamination of wells by total germs can be caused by insufficient protection of wells (open wells), ignorance of hygiene rules, absence of liquid sanitation; cattle breeding next to wells, wells are located in agricultural land, false septic tanks and latrines and also the use of contaminated buckets.

Total coliforms (TC)

The total coliforms rate in the analyzed waters varies between a maximum value (8.3×10^2 CFU/100 mL) presented by the sampling point P2 and a minimum value (5×10^2 CFU/100 mL) presented by the sampling point P1. The high values of total coliforms could be explained by fecal pollution triggered by local disposals in the neighbouring areas, septic tanks or latrines in the surrounding areas.

Enumeration of Escherichia coli (E. coli)

Escherichia coli makes us spot the pollution of fecal origin, 100% of the water we analysed have a minimum value of 140 CFU/100 mL recorded in the station O1 and a maximum value recorded in the station O2 next to the dump of the city of Taza (Fig. 10). *Escherichia coli* was detected in all groundwater analysed. It is considered as an evidence of fecal contamination.We should refer to the sources of *E. coli*. They can be the intestines of warm-blooded animals and humans as well.

Nevertheless, it could entail that a well is having surface water through seepage and may be contaminated with fecal coliforms. In spite of the fact that the water with *E. coli* implies fecal contamination, it does detect the specific source of the fecal material. There various possible sources: manure, pasture, septic tanks, latrine and other factors such as wildlife. From a visit to some well sites, we noted the existence of manure, septic tanks and latrines in the surrounding area and an absence of sewage systems in some neighbourhoods.

Enumeration of intestinal enterococci (IE)

The research conducted on intestinal enterococci in the groundwater under study showed that 100% of the wells analysed were contaminated. The concentration of these bacteria in this water is estimated between a minimum concentration of 20 CFU/100 mL recorded in P1, and a maximum concentration of 40 CFU/100 mL recorded in P2. The high contamination of these waters by intestinal enterococci can find insightful explanation in fecal pollution of animal or human origin (latrines, septic tanks, sheep breeding, using fertilizers recycled from animal waste to be used for agricultural activities near the wells). The relationship between Escherichia coli and intestinal enterococci can indicate the origin of the contamination (Animal or Human).

Principal components analysis PCA

We conducted a statistical study using principal component analysis on the samples taken. The correlation coefficient indicates whether one variable is adequate to predict the other. Each cell in the table deals with the relationship between two factors. The range of values for the linkage coefficient (noted: r). A ratio of -1.0 indicates a totally poor relationship and a ratio of 1.0 indicates an ideal positive relationship. A value of zero indicates that there is no relationship between the two factors. Table 2 shows that there is a very strong correlation between:

$$\text{Fecal Coliforms (FC) – Fecal Streptococcus (FS) } (r = 0{,}997),\ BOD_5 \text{ – FS } (r = 0\ {,}967),\ BOD_5 \text{ – FC } (r = 0{,}948) \quad (1)$$

$$NH_4^+ \text{– TSS } (r = 0{,}906),\ \text{COD – FS } (r = 0{,}896),\ \text{COD – FC } (r = 0{,}892),\ PO_4 \text{–COD } (r = 0{,}873),\ NH_4^+ – BOD_5 (r = 0{,}872),\ BOD_5 – \text{COD } (r = 0{,}892),\ T – Cl^- (r = 0{,}859),\ \text{TSS – FC } (r = 0{,}848),\ \text{TSS – FS } (r = 0{,}838),\ NH_4^+ – \text{FS } (r = 0{,}819),\ PO_4 \text{–TP } (r = 0\ {,}813),\ NH_4^+ – \text{COD } (r = 0{,}812) \text{ and } NH_4^+ – \text{FC } (r = 0{,}801) \quad (2)$$

The principal component analysis yielded eigenvalues explaining 95.141% for the F4 design

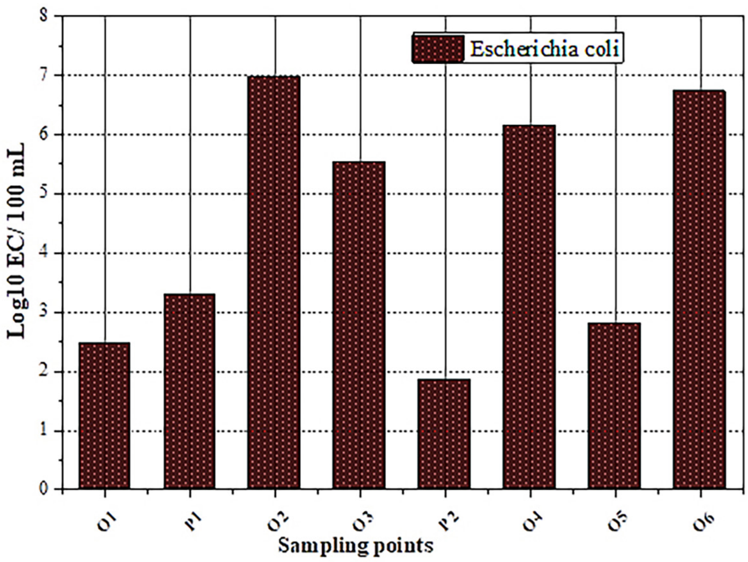

Figure 10. Variation of *E. Coli* in the waters of the city of Taza

Table 2. Presents the values of the correlation coefficients between two groundwater quality parameters in the study area for 15 parameter variables

Ref. Sample	CF/EI	Origin of the fecal contamination
O1	0.37	Fecal contamination of animal origin
P1	75	Fecal contamination of human origin
O2	2.07	Fecal contamination of human origin
O3	1.58	Fecal contamination of human origin
P2	5.25	Fecal contamination of human origin
O4	0.5	Fecal contamination of animal origin
O5	6.7	Fecal contamination of animal origin
O6	2.33	Fecal contamination of human origin

Table 3. Total variation explained by each parameter

Variables	Temperature	pH	E.C	DO	Chloride	NH_4^+	NO_3^-	NO_2^-	PO_4^{3-}	TP	BOD_5	TSS	COD	FC	FS
Temperature	1														
pH	0.505	1													
E.C	0.180	0.628	1												
DO	0.185	-0.392	-0.236	1											
Chloride	0.859	0.402	0.209	0.583	1										
NH_4^+	0.416	0.285	-0.164	-0.423	0.010	1									
NO_3^-	-0.535	-0.916	-0.374	0.386	-0.357	-0.569	1								
NO_2^-	0.403	0.373	-0.444	0.098	0.391	0.404	-0.563	1							
PO_4^{3-}	0.042	0.321	-0.047	-0.789	-0.395	0.740	-0.543	0.193	1						
TP	-0.042	0.009	-0.248	-0.804	-0.539	0.676	-0.163	0.023	0.813	1					
BOD_5	0.160	0.106	0.038	-0.545	-0.260	0.872	-0.306	-0.061	0.701	0.730	1				
TSS	0.441	0.392	0.071	-0.438	0.050	0.906	-0.622	0.222	0.683	0.598	0.804	1			
COD	0.174	0.182	0.050	-0.652	-0.295	0.812	-0.404	-0.071	0.873	0.798	0.871	0.861	1		
FC	0.236	0.055	0.111	-0.444	-0.174	0.801	-0.235	-0.213	0.601	0.661	0.948	0.848	0.892	1	
FS	0.227	0.064	0.102	-0.467	-0.189	0.819	-0.248	-0.191	0.628	0.679	0.967	0.838	0.896	0.997	1

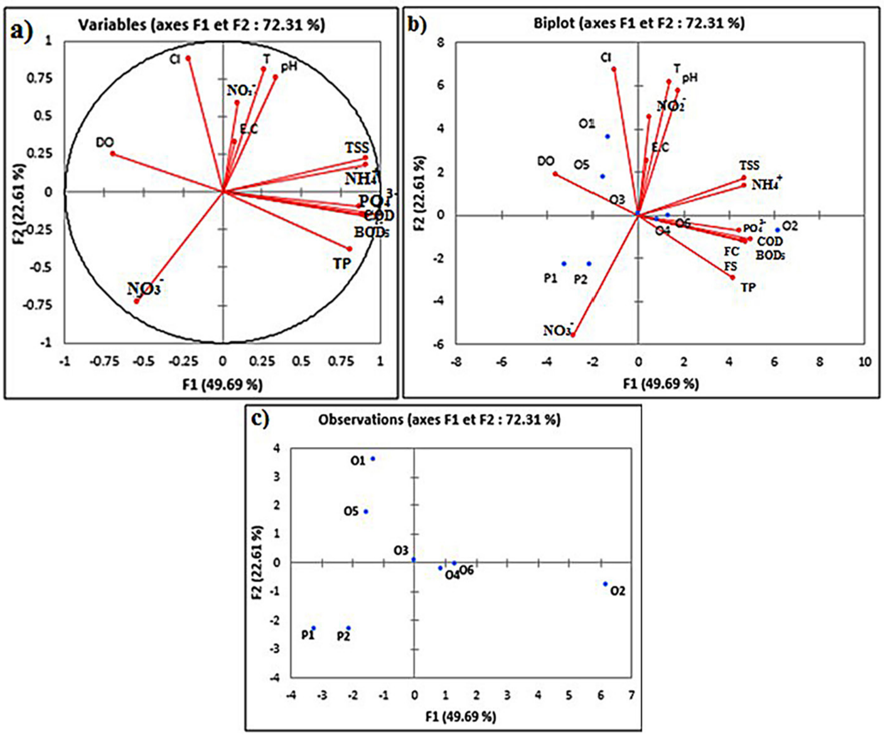

Figure 11. Graphical representation in the factorial plane: a) variables, b) biplot, c) observations

Table 4. Total variation explained by each parameter

Parameter	F1	F2	F3	F4
Eigenvalue	7.454	3.392	1.806	1.619
Variability (%)	49.695	22.613	12.042	10.791
Cumulative (%)	49.695	72.307	84.350	95.141

Table 5. Standards for drinking water at national and international levels

Parameters	Symbols	NM	WHO
pH	-	6.5–8.5	6.5–8
E.C	EC	2700	-
DO	O_2	5–8	-
COD	COD	-	-
BOD_5	BOD_5	-	-
TSS	TSS	-	-
Nitrates	NO_3^-	50	50
Nitrites	NO_2^-	0.5	-
Ammonium	NH_4^+	0.5	-
Orthohosphates	PO_4^{3-}	-	-

(Table 3). PCA is a method for reducing the number of variables (parameters measured in water samples). This approach was used to extract related variables and derive the processes that control water chemistry. Dissolved oxygen in water comes mainly from the atmosphere and from the photosynthesis of aquatic plants. At concentrations below 1 mg/L, the survival of all species, even in the short term, is threatened. The ionic strength of the water also affects the amount of O_2 that can be dissolved in the water, and decreases with increasing salinity of the water.

This high anthropogenic activity consisting of solid and liquid waste goes directly into the lake. The most important increase in COD and BOD_5 could be due to the discharges. The ratio COD/BOD_5 (Fig. 10) gives a first estimate of the biodegradability of the organic matter for a given effluent. At the plant inlet, the effluent has a COD/BOD_5 ratio of between 1.66 and 2 [17], describing an easily biodegradable effluent [20].

The analysis of the PCA variables in the F1-F2 factorial design is presented in Fig. 11 and Table 4. The result shows four groupings of the studied parameters. The first factor F1, with 47.7% of total variance, is related to electrical conductivity (EC) and concentrations. The F2 factor, which represents 24.1% of the total variance, is related to pH, salinity and Cl^-, SO_4^{2-} and NO_3^- ions, which are mostly from the same origin. Factor F3, which accounts for 11.3% of the total variance. The factor F4, which alone explains 10.2% of the inertia of the cloud of representative points, is determined by the electrical conductivity. The clustering of the obtained point cloud indicates that the associated parameters are brought into solution by the same phenomenon. They come from the surface and are brought by the discharge.

CONCLUSIONS

The assessment of the physico-chemical quality of surface waters of the city of Taza shows that the quality of these waters is influenced, on the one hand, by the nature of lithological formations drained by these tributaries. Indeed, the stations of the right bank and those of the southern part of the Rifa have a conductivity and high concentrations of Cl^- and SO_4^{2-} following the dissolution of marl and limestone formations of the Jurassic. As far as the left side of the Oued is concerned, the high concentrations of bicarbonates, calcium and magnesium reflect the effect of the limestones and dolomites of the Middle Atlas.

On the other hand, the anthropic action contributes to the degradation of surface water quality by unauthorized dumping, domestic, industrial (mainly margines) and agricultural discharges discharged without any prior treatment, particularly in the rivers that cross the city of Taza. These waters may constitute risks of pollution transfer and threats of contamination during agricultural uses.

At the end of our study, we can conclude that groundwater contamination is almost general in the districts of our study. This pollution is manifested by contents largely exceeding the Moroccan standards. Indeed, the analysed waters contain physico-chemical features which make them inappropriate for human consumption. In addition, bacterial pollution was very high and almost permanent in the groundwater studied during the entire duration of our study. The causes of this pollution are multiple; among them we can cite: poor protection of wells; non-application of basic hygiene measures; poor design of cesspools and latrines; poor drainage of waste water; presence of garbage deposits in the water table feeding zone.

Let us recall that our work took place during the rainy season. Whether chemical or bacteriological, pollution is accentuated during the rainy season. This is explained by the general rise in the water table level due to a stronger dilution because of the recharge of the water table on the one hand, and on the other hand because of the direct exposure of the wells to runoff water which falls there loaded with numerous contaminating substances. The nature of the germs encountered and their quantity exceeding the standards allowed for drinking water make the water of the wells studied unfit for consumption. All in all, it is not only a question of setting up drinking water supply structures, but also, it is necessary to put a particular accent on the behaviour, i.e. the assimilation and the respect of the rules of hygiene.

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