Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2020.26144

200 (2020) 74–81
October

Microbial quality assessment of Beni Aamir and Beni Moussa groundwater (Tadla plain-Morocco)

Fatima Zahra Hafiane[a,*], Latifa Tahri[a], Nordine Nouayti[b], Mohamed El Jarmouni[c], Rajaa Rochdi[d], Karim Arifi[a], Abdelkhalek Elamrani Idrissi[e], Mohammed Fekhaoui[a]

[a]*Mohammed V. University of Rabat, Scientific Institute, Geo Biodiversity and Natural Patrimony Laboratory GEOPAC Research Center, Ibn Battuta Av, B.P. 1040, Rabat, Morocco, Tel. +212 609350079; emails: f.s.h.hafiane@gmail.com (F.Z. Hafiane), tahrilat@yahoo.com (L. Tahri), arifi_karim@hotmail.com (K. Arifi), medfekhaoui@hotmail.com (M. Fekhaoui)*
[b]*Applied Science Laboratory, Water and Environmental Engineering Team, National School of Applied Sciences, Abdelmalek Essaadi University, B.P. 03, Ajdir, Al-Hoceima, Morocco, email: nordine.svt@gmail.com (N. Nouayti)*
[c]*National Graduate School of Geology, University of Lorraine, Doyen Marcel Roubault Av, B.P. 10162, Nancy, France, email: med.eljarmouni@gmail.com (M. El Jarmouni)*
[d]*Hydrology and Toxicology Laboratory of the Environmental and Industrial Hygiene, National Institute of Hygiene, Ibn Battuta Av, Agdal, Rabat, Morocco, email: rochdirajaa@gmail.com (R. Rochdi)*
[e]*Hydraulic Basin Agency of Oum Er Rbiaa, B.P. 511, Beni-Mellal, Morocco, email: elamranibiodifec@gmail.com (A.E. Idrissi)*

Received 22 December 2019; Accepted 14 May 2020

ABSTRACT

The groundwaters from the deep aquifers of the Tadla are mainly used for agriculture, industry, and drinking water. To assess the state of microbial contamination of the groundwater in the irrigated area, a study has been carried out over a 1 y period from March 2017 to May 2018. A total of 43 wells are selected and the water has been analyzed every 3 months to quantify the coliforms (TC), fecal coliforms (FC), and fecal streptococci (FS) using the membrane filter (MF) method, and also to perform a spatial-temporal mapping in order to clarify the concentration of pollution using the Surfer software. The result has revealed significant groundwater contamination by microbial agents. The analyzes of TC, FC, and FS indicated that 95.34%, 86.04%, and 55.81% of the wells tested to exceed 1,000 CFU/100 mL respectively, for each TC, FC, and FS group, where 100% of the wells have positive results, that is, having more than one colony-forming unit (CFU). However, spatial variation maps show concentrations of the microbial indicators, which are varied according to wells location, and due to the different sources of contamination. Fluctuations in microbial concentrations are probably influenced by the sampling season in both dry and rainy periods and also by anthropogenic activity. The study appoints a serious risk that threatens the environment and human life.

Keywords: Tadla plain; Pollution; Total coliforms; Fecal coliforms; Fecal streptococci; Irrigated perimeter

1. Introduction

The intensification of industrial and agricultural activities associated with the fast-paced urbanization of agglomerations in Tadla plain has led to a significant increase in water demand, with noticeable pollution of the wadis and groundwater. The Tadla plain is currently experiencing multiple pollutions due to unprocessed liquid discharges (urban and industrial) to the groundwater, as well as solid discharges to uncontrolled waste disposal sites [1]. In addition, the use of well water is varied among households; water is used for irrigation, livestock watering, household water, and sometimes as drinking water in some areas [2,3].

* Corresponding author.

This risk of urban groundwater pollution and its impact on the consumers' health, combined with the lack of studies on the microbiological quality of the region's groundwater, prompted us to assess the degree of microbial contamination in the groundwater.

The following indicators of fecal contamination are reported: total coliforms (TC), fecal coliforms (FC), and fecal streptococci (FS). TCs have been used as indicators of microbial water quality, for long time, because they can be indirectly related to fecal pollution [3,4]. Nearly all species in this group do not pose a direct health risk, except some strains of *Escherichia coli* [4]. TCs are defined as optional aerobic or anaerobic rod-shaped bacteria with the enzyme β-galactosidase, allowing hydrolysis of lactose at 35°C to produce red colonies with metallic sheen on an appropriate agar medium. Some opportunistic pathogenic bacteria can cause serious illness in debilitated patients. FCs (or thermotolerant coliforms), are a subgroup of total coliforms that are capable to ferment the lactose at a temperature of 44.5°C [5]. The *E. coli* is the most frequent associated species with this bacterial group, which presents 80%–90% of the detected fecal coliforms. Although the presence of these bacteria usually indicates contamination of fecal origin, many fecal coliforms are not of fecal origin, but rather come from waters enriched with organic matter, such as industrial effluents from the sugar industry or food processing (olive oil extraction) [6].

The reason to consider these coliforms as organism indicators is the fact that their survival in the environment is generally equivalent to that of pathogenic bacteria and that their density is generally proportional to the degree of pollution produced by the fecal matter [7]. Where the fecal coliforms can detect fecal contamination resulting, for example, from the infiltration of polluted water into the soil and then into the groundwater.

The FSs contaminate the supply water. They are rather typical of animal excreta, such as *Streptococcus bovis*, *Streptococcus equinus*, *Streptococcus gallolyticus*, and *Streptococcus alactolyticus*. These species colonize livestock, horses, and poultry, and they could also survive in human body, particularly *S. bovis* [8]. The detection of streptococci in groundwater, on the one hand, must give rise to serious suspicions of fecal contamination and the presence of enteropathogenic microorganisms [9]. On the other hand, this detection is highly associated with the presence of *E. coli*, in the water distribution networks [10].

The primary aim of this study is to assess the current state of wells in the irrigated perimeter and the risk of pollution of water resources, based on exogenous data (water quality). In order to achieve these aims, we have carried out a methodological and analytical approach in order to identify the microbial pollution in the selected wells.

2. Materials and methods

2.1. Application zone: case of the Tadla plain

The study area is a part of the Tadla Plain (Fig. 1), in Beni-Mellal province in Beni Mellal-Khenifra region.

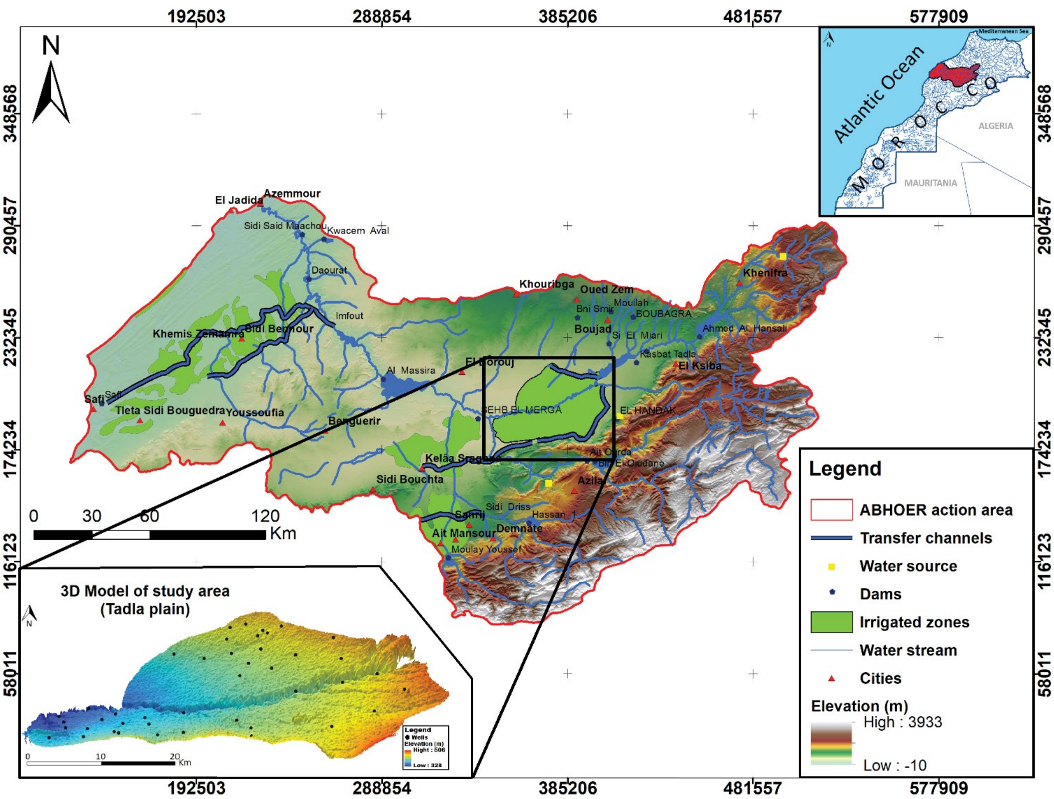

Fig. 1. Geographical location of the study zone/position of the wells under study in the perimeter at the level of the two groundwaters (Beni Moussa and Beni Aamir).

It extends over a large surface of 3,600 km², in the middle basin of Oum Er-Rbia between the High Atlas and the Phosphate plateau. The Oum Er-Rbia River across the plain along 160 km from east to west, and divide it into two vast hydraulically independent irrigated areas: the Beni Amir on the right side and Beni Moussa perimeters on the left side [2].

2.2. Characterization of the wells

Forty-three wells are selected, some are connected to the Beni Moussa groundwater and others are connected to the Beni Aamir groundwater (Fig. 2). The wells constitute the streamlined observation network in order to monitor the quality of the two groundwaters.

Each of these wells has already been investigated based on some criteria:

- The wells are located in areas characterized by a significant presence of urban pollution sources (non-standardized septic tanks and their spillages, open dumped wastewater, household waste, slaughterhouse, and residential neighborhood discharges).
- The wells are located in areas where the sources of urban pollution are major, either with intensive pastoral activities or agricultural activities.
- The chlorination in the selected wells are strictly not practiced, and the water is used in agricultural fields.

2.3. Sample collection and transport

The sampling campaigns has been conducted during the period between March 2017 and May 2018. Samples have been collected, in sterilized vials, in an autoclave at 120°C for 1 h and 30 min. At the level of each well, a quantity of 1.5 L of water is collected every 3 months. All well samples are collected after three minutes of pumping in order reach deep water in the well. All precautions have been taken to avoid possible contamination. The transport of samples to the laboratory was in a clean refrigerated cooler (4°C). The analyzes of TCs, FCs, and FSs started in less than 24 h after sampling.

2.4. Sample analyzes

The density has determined using the standard membrane filtration methods [11,12]. A volume of 100 mL of the water sample is filtered and the membrane is incubated on a specific agar medium. In this study, TTC-Tergitol lactose agar medium is used for the enumeration of total coliforms and fecal coliforms (NM ISO 9308-1/2007), and Slanetz and Bartley agar for fecal streptococci (NM ISO 7899-2/2007). The incubation of this selective medium during 24–48 h allow us to count the total of coliforms and fecal streptococci at 37°C, and the total of fecal coliforms at 44°C ± 0.5°C. The enumeration of colonies has then carried out. The result is measured in colony-forming units (CFU) per unit volume. Thus, the spatial and temporal maps are compiled.

3. Results and discussions

The bacteriological quality of the groundwater is responsible for short-term health risks. The transmission of disease to humans and animals increases when consumers use the

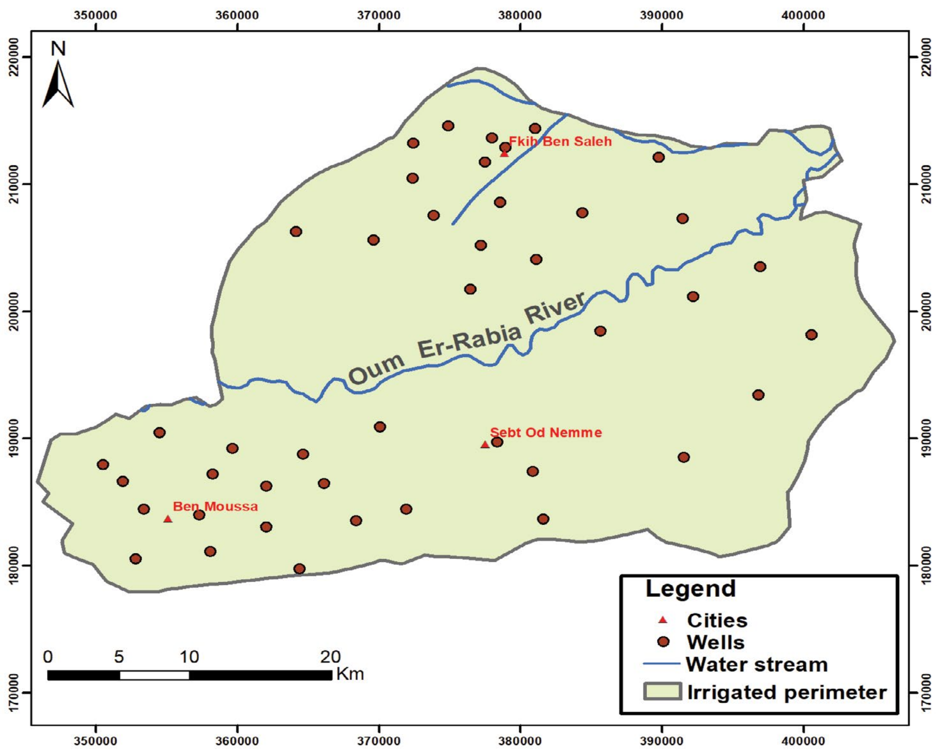

Fig. 2. Position of the wells under study in the perimeter at the level of the two groundwaters (Beni Moussa and Beni Aamir).

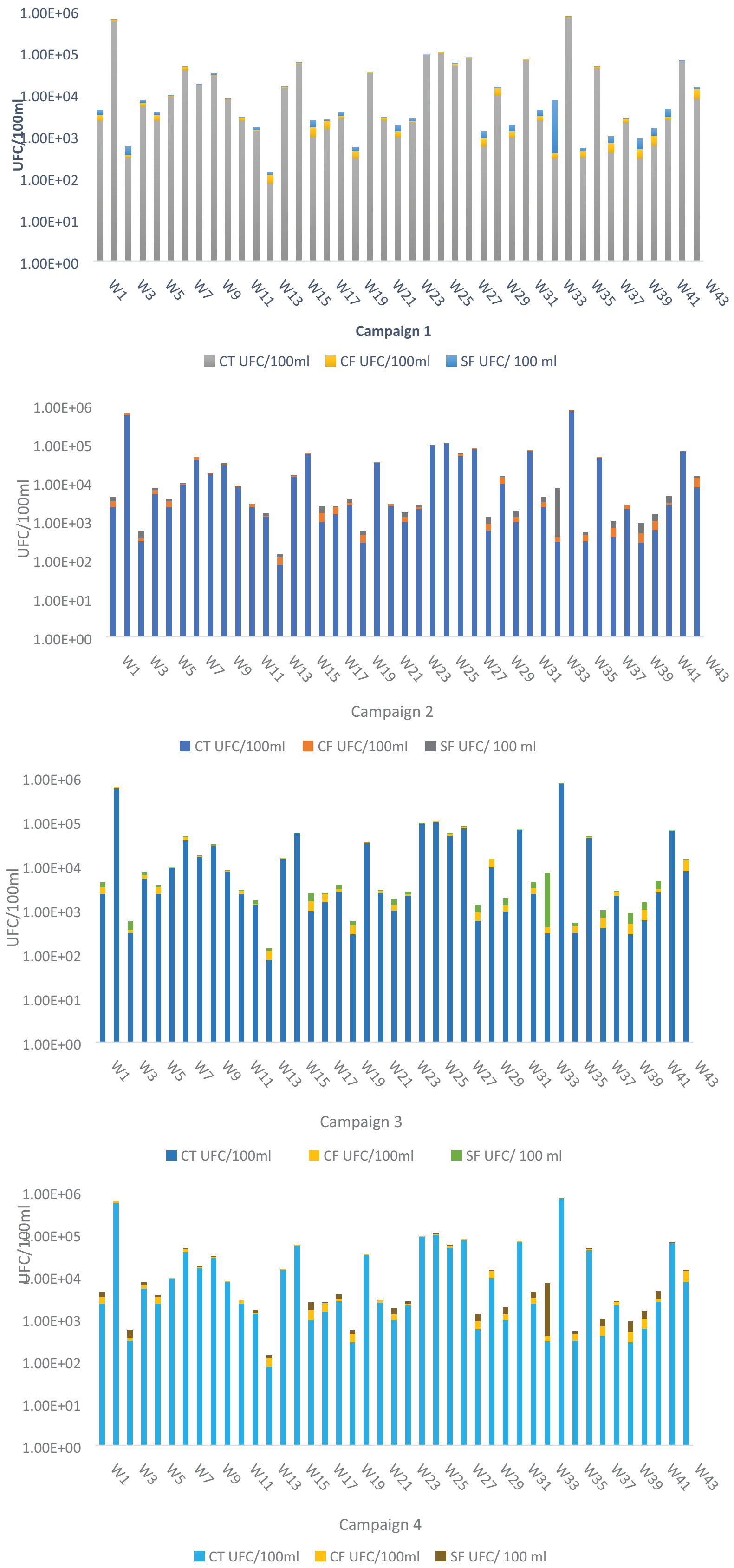

Fig. 3. Concentration of total coliforms/fecal coliforms/fecal streptococci in CFU 100 mL of well water during the analysis period of Beni Aamir and Beni Moussa groundwaters.

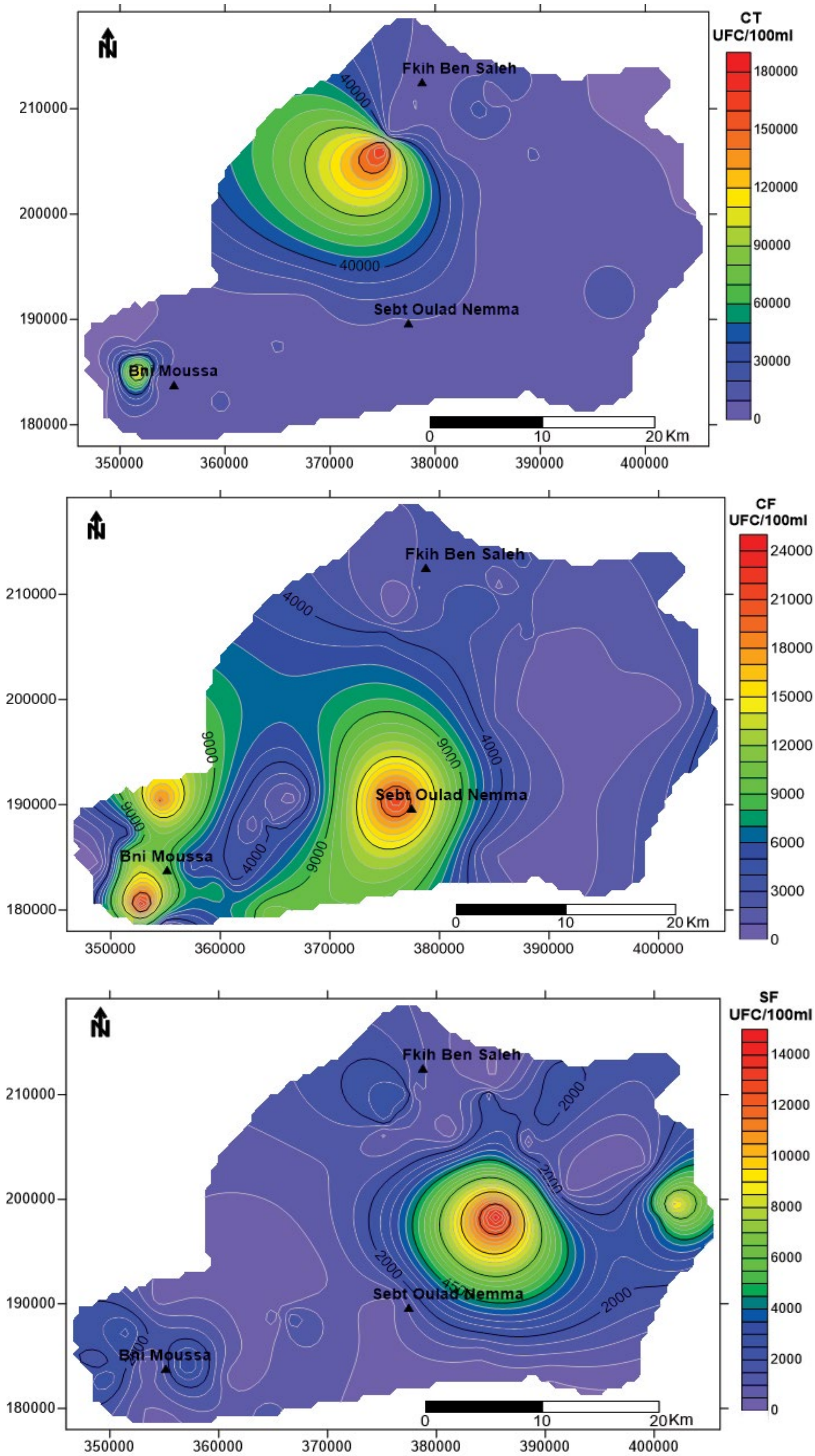

Fig. 4. Spatial distribution maps of total coliforms (CT), fecal coliforms (CF), fecal streptococci (SF) in CFU 100 mL of well waters from the Beni Aamir and Beni Moussa groundwaters.

contaminated water. Diarrheal diseases from the contaminated water continue to be a serious problem in developing countries and a chronical problem in Morocco. Our results of the groundwater quality show that fecal coliforms (FC), total coliforms (TC) and fecal streptococci (FS) are widely distributed in the studied wells water. These wells are an important natural resource, which are used as drinking water in certain localities, and also used in domestic activities by rural and suburban populations. This fact indicates a potential health effects on populations in this region. According to WHO standards, these wells are not entirely suitable for drinking water and other domestic uses.

On the basis of our results, we can conclude that the groundwater can play an important role in bacteriological transmission, such as total coliforms (TC), fecal coliforms (FC), and fecal streptococci (FS). Fig. 3 shows the concentration of pollution in the surveyed wells water, which exceed 1,000 CFU/100 mL. According to our survey, many households use water from these wells for washing, and even for drinking. Fig. 3 shows also that the water is contaminated by total coliforms, fecal coliforms, and fecal streptococci, which have a prevalence of 95.93%, 93.02%, and 87.79%, respectively, throughout the follow-up period. The analysis revealed relative differences among the different analyzed samples, where in all samples the concentrations of bacterial groups detected greatly exceed the standard prescribed for drinking water (0 CFU/100 mL). This difference is probably due to their location and to the season (wet or dry) during which the analyses have been carried out.

Because of that, an arbitrary benchmark concentration of 1,000 CFU/100 mL is used in order to clarify the results of different groups of samples (Fig. 3). The percentages are calculated on the basis of 43 samples analysed for each group of screened bacteria (TC, FC, and FS). The Wells P3, P23 have concentrations which do not exceed the threshold of 1,000 CFU/100 mL, with a prevalence of 4.65% for the bacterial groups (TC, FC) in P3,and with a prevalence of 2.35% for the three bacterial groups (CT, CF, and SF) in P23.

The Wells P3, P12, P19, P23, P32, and P36 have concentrations which do not exceed 1,000 CFU/100 mL only for fecal coliforms with a prevalence of 13.95%. While 95.34% of TC, 86.04% of CF, and 55.81% of FS in the analyzed samples have a concentration above 1,000 CFU/100 mL.

The analysis and interpretation of the maps of the spatial distribution of the bacteria groups (TC, FC, and FS) (Fig. 4) showed spatial variations. These variations indicate the concentrations of each indicator in urban and rural agglomerations, in relation with the factors of pollution and contamination of the water and also according to the direction of flow in both aquifers.

This study also shows that the Beni Aamir groundwater is seriously contaminated by total coliforms with concentrations ranging between 30,000 and 200,000 CFU/100 mL. Concerning fecal coliforms and streptococci, they are well-concentrated at the level of the Beni Moussa groundwater (South West), where values are varied between 3,000 and 25,000 CFU/100 mL and between 2,000 and 15,000 CFU/100 mL.

Our results are compared with published data on bacterial concentrations in groundwater from all over the world. Where the authors have studied the water quality in urban and rural area, and have identified the presence of the microbiological contamination in distilled water produced from solar stills. In general, our conclusions are in agreement with previously reported studies [2,13–20,26].

According to Ghazali et al. [21], Haijoubi et al. [5] and Haissoufi et al. [22]. the origin of water pollution can be natural or anthropogenic, and based on our study, we can conclude that the main factors that control the bacteriological quality of water are anthropogenic activities, the fact that is as well mentioned by Mfonka et al. [23], Mbwala et al. [24] and Mustapha et al. [25].

The study of Yuan et al. [26] and Benajiba et al. [27] come with the same conclusion that we present in this study, where the industry is the main sources of anthropogenic pollution, which cause a very diversified discharges. Also, the need to perform a pre-treatment before evacuation, which is also mentioned by Sabbahi et al. [28] who has conducted a study on the high inactivation of fecal indicators [fecal coliforms (FC), *E. coli*, and fecal streptococci (FS)] using a combination of methylene blue (MB) with natural sunlight or artificial visible light. As well as in the study of Gholami et al. [17], which has been conducted to compare the electrochemical removal of *E. coli* and spores of *Bacillus subtilis* as indicative and resistant bacteria in drinking water.

Several authors have noted factors such as activities around the wells, the lack of development of wells, the proximity of sources of pollution like urban waste, dumping of wild garbage, individual sanitation works (latrines, sumps, and septic). The degree of concentration of FC, TC, and FS in groundwater are, in general, similar to results from other studies [29,31].

In this study, the results show that the domestic sewage and livestock farming have a great effect on water quality. Where the bacterial pollution is principally derived from anthropogenic point source pollution in the upper areas, which included domestic sewage and livestock farming, with higher concentrations in surface water compared to groundwater. The same results are found in previous studies [1,32–36,38–41].

4. Conclusion

The data collected during this survey allow us to draw a spatio-temporal portrait of the microbiological quality of well waters for domestic and agricultural use on both sides of the Oum Er-Rbia River (the Beni Aamir and Beni Moussa groundwater). The waters from the sampled wells are of poor quality and do not meet drinking or irrigation water quality standards. The presence of total coliforms, fecal coliforms, and fecal streptococci, in 100% of the analyzed wells water shows a high contamination by germs, where this contamination is caused by the absence of sanitation and household waste collection services. Therefore, without prior treatment the water still present high risk to human life.

Acknowledgments

Authors are especially grateful to acknowledge the Department of agricultural development (DDA) of Tadla and Department of irrigation and drainage network management (DGRID) of Tadla for his assistance in this study. Authors also would like to acknowledge the staff for their kind help in sampling collection.

References

[1] F.Z. Hafiane, L. Tahri, N. Nouayti, M. El Jarmouni, K. Arifi, A. Idrissi Elamrani, M. Fekhaoui, Assessment of spatial and seasonal nitrate variation of groundwater in the irrigated perimeter (Tadla Plain-Morocco), Agric. For., 66 (2020) 203–214, doi: 10.17707/AgricultForest.66.1.19.

[2] F.Z. Hafiane, L. Tahri, N. Ameur, R. Rochdi, K. Arifi, M. Fekhaoui, Antibiotic resistance of *Pseudomonas aeruginosa* in well waters in irrigated zone (middle atlas Morocco), Nat. Environ. Pollut. Technol., 4 (2019) 1193–1200.

[3] K. Arifi, L. Tahri, A. El Abid, F.Z. Hafiane, S. Elblidi, A. Yahyaoui, M. Fekhaoui, Impact of wastewater from the rural commune of Jmaa Moulblad on the physico-chemical quality of the waters of the Grou River (Rabat region, Morocco), E3S Web Conf., 37 (2018), doi: 10.1051/e3sconf/20183701008.

[4] T.A. Edge, I.U.H. Khan, R. Bouchard, J. Guo, S. Hill, A. Locas, L. Moore, N. Neumann, E. Nowak, P. Payment, Occurrence of waterborne pathogens and *Escherichia coli* at offshore drinking water intakes in Lake Ontario, Appl. Environ. Microbiol., 79 (2013) 5799–5813.

[5] E.H. Haijoubi, F. Benyahya, A. Bendahou, F.Z. Essadqui, M.E. Behhari, N.N. Ghailani, M.B. Mechita, A. Barakat, Study of the bacteriological quality of water used in the agro-food industry in the North of Morocco, Pan Afr. Med. J., 26 (2017), doi: 10.11604/pamj.2017.26.13.10591.

[6] A. Alhajoja, B. Alowaieshb, Innovative solutions for reduction of olive mill wastewater pollution, Desal. Water Treat., 155 (2019) 48–54.

[7] J. Voisin, B. Cournoyer, F.M. Blondin, Utilisation de billes de verre comme substrats artificiels pour la caractérisation des communautés microbiennes dans les nappes phréatiques: mise au point méthodologique, La Houille Blanche, 4 (2015) 52–57.

[8] C. Jans., L. Meile, C. Lacroix, M.J. Stevens, Genomics, evolution, and molecular epidemiology of the *Streptococcus bovis*/*Streptococcus equinus* complex (SBSEC), Infect. Genet. Evol., 33(2015) 419–436.

[9] A. Hammani, A. El Masri, A. Bouaziz, M. Kuper, Valorisation de L'eau Souterraine Par les Cultures Fourragères Dans le Périmètre Irrigué du Tadla, Maroc, Cirad, 2009.

[10] E. Djuikom, E. Temgoua, L. Jugnia, M. Nola, M. Baane, Pollution bactériologique des puits d'eau utilisés par les populations dans la Communauté Urbaine de Douala-Cameroun, Int. J. Biol. Chem. Sci., 3 (2009) 967–978.

[11] NM, Moroccan Standard of Water Quality-Counting *Escherichia coli* and Coliform Bacteria-Part 1: Membrane Filtering Method, ISO 9308, Vol. 1, 2007.

[12] NM, Moroccan Standard of Water Quality-Research and Counting of Intestinal Enterococci-Part 2: Membrane Filtering Method, ISO 7899, Vol. 2, 2007.

[13] M.H. Habibollahi, A. Baghizadeh, A. Sabokbara, K. Sharafi, Isolation and characterization of copper and cadmium resistant bacteria from industrial wastewaters and evaluating the biosorption of selected bacteria, Desal. Water Treat., 93 (2017) 139–144.

[14] K. Ouarrak, A. Chahlaoui, I. Taha, A. Taouraout, A. Kharroubi, Seasonal Variations of the Microbiological Parameters of the Quality of Water in Urban Oued Bouishak of the City of Meknes (Morocco), The Proceedings of the Third International Conference on Smart City Applications, Springer Cham, 2019, pp. 1211–1221.

[15] P. Hounsinou, D. Mama, F. Dovonou, A. Alasane, Seasonal evolution of the quality microbiological of the natural waters in the township of Abomey-Calavi (South Benin), Br. J. Earth Sci. Res., 3 (2015) 30–41.

[16] J. Zerhouni, F.R. Filali, A. Aboulkacem, Qualité et facteurs de risque de pollution des eaux souterraines périurbaines de la ville de sebaa ayoune (Meknes, Maroc), Larhyss J., 22 (2015) 91–107.

[17] S. Gholami, M. Naderi, M. Yousefi, M.M. Arjmand, The electrochemical removal of bacteria from drinking water, Desal. Water Treat., 160 (2019) 110–115.

[18] K. Soncy, B. Djeri, K. Anani, M. Eklou-Lawson, Y. Adjrah, D.S. Karou, C. de Souza, Évaluation de la qualité bactériologique des eaux de puits et de forage à Lomé, Togo, J. Appl. Biosci., 91 (2015) 8464–8469.

[19] S. Bricha, K. Ounine, S. Oulkheir, N. El Haloui, B. Attarassi, Etude de la qualité physicochimique et bactériologique de la nappe phréatique m'nasra (maroc), Afr. Sci., 3 (2007) 391–404.

[20] G.M. Ayoub, L. Dahdah, I. Alameddine, Transfer of bacteria via vapor in solar desalination units, Desal. Water Treat., 53 (2015) 3199–3207.

[21] D. Ghazali, A. Zaid, Etude de la Qualité Physico-Chimique et Bactériologique des Eaux de la Source Ain Salama-Jerri (Région de Meknès-Maroc), Larhyss J., 12 (2013) 2602–7828.

[22] H.E. Haissoufi, S. Berrada, M. Merzouki, M. Aabouch, M. Benlemlih, M. Idir, A. Zanibou, Y. Bennis, O. Lalami, Impact of treated wastewater on groundwater quality in the region of Tiznit (Morocco), Rev. Microbiol. Ind. San. Environ., 5 (2011) 37–68.

[23] Z. Mfonka, J.N. Ngoupayou, P.D. Ndjigui, M. Zammouri, A. Kpoumie, E. Rasolomanana, Hydrochimie et potabilité des eaux du bassin versant du Nchi dans le plateau Bamoun (Ouest Cameroun), Int. J. Biol. Chem. Sci., 9 (2015) 2200–2218.

[24] A. Mbawala, A. Abdou, M.B. Ngassoum, Evaluation de la pollution physico-chimique et microbienne des eaux de puits de Dang-Ngaoundéré (cameroun), Int. J. Biol. Chem. Sci., 4 (2010) 1962–1975.

[25] H. Mustapha, H. Cherifa, H. Abdelkrim, G. Abdellah, T. Abdelali, Assessment of water pollution in the semi-arid region: case watershed Wadi Saida (Northwest of Algeria), Desal. Water Treat., 52 (2014) 5995–6008.

[26] Z.W. Yuan, L. Wang, T. Lan, Y. Ji, H.Z. Zhao, Water quality assessment and source identification of water pollution in the Banchengzi reservoir, Beijing, China, Desal. Water Treat., 57 (2016) 29240–29253.

[27] M. Benajiba, Y. Saoud, A. Lamribah, M. Ahrikat, N. Amajoud, O. Ouled-Zian, Evaluation de la qualité microbienne des eaux de la nappe phréatique de Martil au Maroc, Rev. Sci. L'Eau, 26 (2013) 223–233.

[28] S. Sabbahi, Z. Alouini, L. Ben Ayed, M. Jemli, Inactivation of faecal bacteria in wastewater by methylene blue and visible light, Desal. Water Treat., 20 (2010) 209–219.

[29] P.K. Roy, M. Ghosh, Chlorine resistant bacteria isolated from drinking water treatment plants in West Bengal, Desal. Water Treat., 79 (2017) 103–107.

[30] F. Dovonou, Pollution Physico-Chimique et Bactériologique du lac Nokoué, Doctorat en Hydrologie et Gestion Intégrée des Ressources en Eau, Bénin, 2012.

[31] F.E. Dovonou, A. Alassane, V.N. Adjahossou, B. Agbodo, R. Djibril, D. Mama, Impacts de l'assainissement autonome sur la qualité des eaux de puits dans la Commune de Sèmè-Podji (Sud-Bénin), Int. J. Biol. Chem. Sci., 11 (2017) 3086–3099.

[32] P. Palma, P. Alvarenga, V.L. Palma, R.M. Fernandes, A.M. Soares, I.R. Barbosa, Assessment of anthropogenic sources of water pollution using multivariate statistical techniques: a case study of the Alqueva's reservoir, Portugal, Environ. Monit. Assess., 165 (2010) 539–552.

[33] R. Kumari, P.S. Datta, M.S. Rao, S. Mukherjee, C. Azad, Anthropogenic perturbations induced groundwater vulnerability to pollution in the industrial Faridabad District, Haryana, India, Environ. Earth. Sci., 77 (2018), doi: 10.1007/s12665-018-7368-8.

[34] O. Yapo, V. Mambo, A. Seka, M.J.A. Ohou, F. Konan, V. Gouzile, P. Houenou, Evaluation de la qualité des eaux de puits à usage domestique dans les quartiers défavorisés de quatre communes d'Abidjan (Côte d'Ivoire): Koumassi, Marcory, Port-Bouet et Treichville, Int. J. Biol. Chem. Sci., 4 (2010) 289–307.

[35] C. Degbey, M. Makoutode, V. Agueh, M. Dramaix, C. De Brouwer, Facteurs associés à la qualité de l'eau de puits et prévalence des maladies hydriques dans la commune d'Abomey-Calavi (Bénin), Cahiers d'étud. rec. Francophones Santé, 21 (2011) 47–55.

[36] M.L. Belghiti, A. Chahlaoui, D. Bengoumi, R. El Moustaine, Etude de la qualité physico-chimique et bactériologique des eaux souterraines de la nappe plio-quaternaire dans la région de Meknès (maroc), Larhyss J., 10 (2013) 21–36.
[37] L. Ran, A. Djikpo, Effets des pratiques agricoles sur la pollution des eaux de surface en republique du benin, Larhyss J., 14 (2017) 173–190.
[38] R.P. Schwarzenbach, T. Egli, T.B. Hofstetter, U. Von Gunten, B. Wehrli, Global water pollution and human health, Annu. Rev. Environ. Resour., 35 (2010) 109–136.
[39] M. Ouhsassi, E.O. Khay, N. Amajoud, J. Abrini, Etude de la qualité microbiologique des eaux Skundo, ancien réseau d'approvisionnement en eau (médina de Tétouan, Maroc), Sci. Lib Ed. Mersenne, 5 (2011) 2111–4706.
[40] Y. Mahfooz, A. Yasara, L. Guijianb, B. Yousafb, M.T. Sohailc, S. Khanb, M. Khana, An assessment of wastewater pollution, treatment efficiency and management in a semi-arid urban area of Pakistan, Desal. Water Treat., 177 (2020) 167–175.
[41] A.B. Hassane, C. Leduc, G. Favreau, B.A. Bekins, T. Margueron, Impacts of a large Sahelian city on groundwater hydrodynamics and quality: example of Niamey (niger), Hydrogeol. J., 24 (2016) 407–423.