JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2022, 23(11), 33–40
https://doi.org/10.12911/22998993/153397
ISSN 2299–8993, License CC-BY 4.0

Received: 2022.07.26
Accepted: 2022.09.14
Published: 2022.10.01

Monitoring of Faecal Contamination and Physicochemical Variables in Surface Waters in Oued Inaouène (Upper Sebou, Morocco)

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ABSTRACT

The study aimed to evaluate the spatiotemporal variation in the physico-chemical and bacteriological quality of Oued Inaouène water in relation to urban discharges that remain the main sources of pollution in the Inaouene basin. During the period from May 2019 to March 2020, seven stations were sampled, six of which are spread along the Inaouène Oued in addition to one reference station that is less affected by urban pollution. The indicators used were: temperature, pH, electrical conductivity (EC), turbidity and dissolved oxygen (OD), biological oxygen demand (BOD_5), chemical oxygen demand (COD), Kjeldahl nitrogen (TKN), E coli, IE and TC. The quality data obtained were analysed using multivariate statistical methods (the CPA) and the correlation matrix. The results showed that with the exception of the O_T station located upstream of urban discharges, the majority of stations downstream of urban discharges have poor quality during both wet and dry seasons, according to the Moroccan standards.

Keywords: Inaouène basin, water quality, bacteriological quality, CPA.

INTRODUCTION

Rivers are the easiest water resources to use for domestic, agricultural and industrial needs. However, these waters are exposed to anthropogenic and natural threats (Carpenter et al., 1998). This situation is all the more critical in semi-arid countries such as Morocco, the water resources of which are limited and difficult to renew (Jarvie et al., 1998). Oued Inaouène, plays a crucial regional and national economic role, these waters feed one of the largest dams of Morocco; Idriss I with a capacity of 1,186 Mm3. The latter is used to irrigate Rharb's plans with an area of 72,000 ha and to produce electricity 40 MW. The watershed of the Oued Inaouène is home to rural and urban populations of 559,486 habitants (DRT., 2014), spread over the city of Taza, Bab merzouka and Oued Amlil, which produce more than 4,650,000 m^3 /year of raw wastewater discharged directly into rivers, to which is added the leachate from landfills and the margin (STMT., 2005). The objective of this study was to determine the effect of urban pollution on water through the analysis and interpretation of the impact of this pollution on the hydrosystem.

MATERIAL AND METHODS

Study area

The study area extends over the watershed of the Inaouène Oued, the total measured area of which is of the order of 3396 km² (Figure 1). The river is located on two slopes with very different geological structure: marl formations of the Pre-rif at the level of the right bank and carbonate formations of the Middle Atlas Causse at the level of the left bank (Rachid A., 1997). In this watershed, drought can occur on a year-wide scale as it can last two or more years (El garouani et al., 2006). The average precipitation is characterized

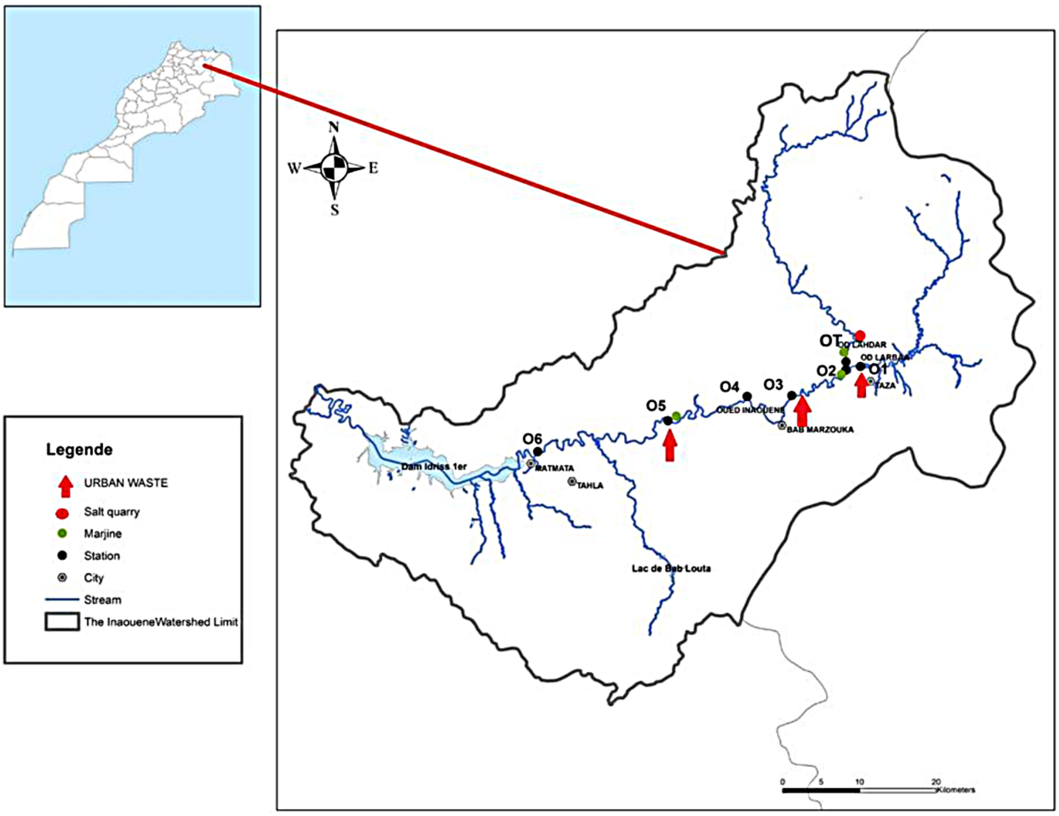

Figure 1. Study area and sampling stations

by the existence of two distinct seasons, during the year 2019 the precipitations reach 377 mm in the station of Taza. They are concentrated from October to April with a maximum volume in December 105 mm. The temperature varies between 10 (January) and 31°C (August) (DRAT., 2019).

Choice of stations

To determine the impact of the pollution, on the Inaouène river, an O_1 station that receives wastewater discharges and leachate from the landfill of the city of Taza and a referencial O_T station located far from any sources of anthropogenic pollution were chosen. In addition, in order to follow the evolution of pollution at the level of the watercourse, stations O_2, O_3, O_4, O_5 and O_6 which follow one another from upstream to downstream according to the longitudinal profile of water streams were chosen.

Sampling method

The physico-chemical characterization of the waters was based on the measurement of 11 parameters. The sampling, transport and storage of water samples refer to the protocol defined by Rodier (Rodier et al., 2004). Some parameters were performed directly in situ: Temperature (T), pH, Electrical Conductivity (EC), Turbidity (Tur) and Dissolved Oxygen (DO) using a Multi-parameter CONSORT Model C535 Type, while the other parameters were analyzed in the laboratory according to Rodier standard methods, BOD5 was determined by an OXITOP, the COD was evaluated by oxidation with potassium dichromate at 148°C, Kjeldahl nitrogen (TKN) was determined by mineralization with the sulfuric acid (distillation at Buchi Distilation Unit B-324). The study of bacteriological parameters focused on the quantification of parameters of faecal origin: E coli, total coliforms and intestinal enterococci. Enumeration was carried out using the indirect method of fermentation in multiple tubes in a lactose broth; the number was then deduced statistically using the most probable number method. The data obtained were compared to the Moroccan quality standards.

Statistical analysis methods

In order to facilitate the consistent evaluation of all the data of these variables, multivariate statistical methods were applied using the XLSTAT

2018 software: principal component analysis (PCA) and the correlation matrix, these analyses allow identifying the possible relationships between physico-chemical and bacteriological variables as a function of water quality.

RESULTS

Physico-chemical parameters

In the present study, the temperature values recorded (Figure 2a) vary between 13.7±4.07°C at the station (O_T) and 16.3±3.35°C at O1 in the wet season, those of the dry season are higher and oscillate between 24.6±0.48, and 25.4±2.08°C at OT and O_1, respectively, noting that the seasonal averages recorded in the reference station are still lower than those of the stations downstream of Inaouène. In general, temperatures show a decreasing gradient according to the longitudinal profile as they move away from station O_1.

On the basis of the surface water quality grid (NMQES), the average temperatures in all the stations qualify the water of good quality, In addition, these average temperatures are well below the limit value of 35°C set by the NMDEI and allow the reuse of this water in irrigation. The hydrogen potential values observed indicate a pH close to neutrality in the stations studied (Figure 2b), albeit with slight nuances depending on the stations and the seasons. In general, the most important values are obtained in the dry season. This alkalinity is related to the nature of the soils and rocks crossed, formed mainly of liasic dolomite. For stations located on the Inaouène river, the alkalinization of their waters would be the result of the use of CO_2 during photosynthesis which is accompanied by the precipitation of insoluble carbonates (Riad, S. 2003). The pH values obtained classify the waters of the stations in a good to medium quality class. In turn, the average pH approaches the upper limit value of 8.4 set by the NMEDI.

The highest values of electrical conductivity are at the level of the OT station which means the mineralization of its waters is impacted by the geological nature of the crossed terrain to a much greater degree. The EC shows a slight decrease downstream (Figure 2c) the averages recorded are 1735.41 µs/cm at O_1, 1798 µs/cm at O_2 1758.8 µs/cm at O_3 1191.55 µs/cm at O_4 1527.75 µs/cm at O_5

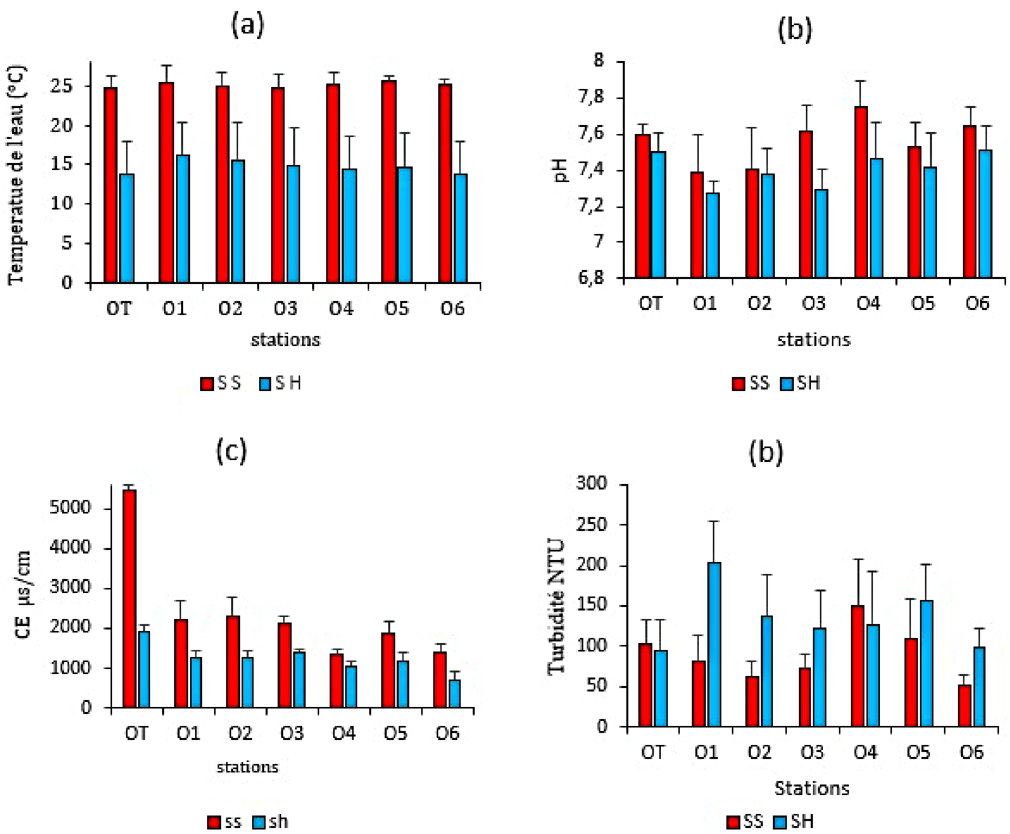

Figure 2. Variation of temperature (a), ph (b), electrical conductivity (c), turbidity (d) depending on the sampling points and during the wet and dry seasons

and 1046.29 μs/cm at O_6. The high average values of electrical conductivity during the dry period compared to the wet period would be related to the decrease in water flow in favor of the predominance of highly mineralized discharges and the acceleration of the bacterial process of mineralization of organic matter (Makhoukh et al,. 2001). According to the Moroccan surface water quality standards (NMQES), the average EC concentrations at the majority of stations classify water in the category of medium quality with the exception of the O_T station which is of poor quality.

The highest values of turbidity (Figure 2d), were recorded during the wet season resulting from brutal hydrological manifestations (floods), during which the high turbidities could be attributed to an intense erosion of the watershed characterized by the dominance of marly soils, following stormy rains (Kazi et al., 2009), and during the summer in stations near the confluence of Oued Inaouène with their effluents which could be attributed to urban wastewater discharges as well as solid waste randomly deposited on the banks for stations O_1 (80.3 NTU), (located after the uncontrolled landfill of the city of Taza) and O_5 (109.78 NTU), (located after the Oued Amlil landfill). The average DO concentrations (Figure 3a) are generally less than 6.5 mg/l and vary according to the season, they oscillate between 1.54 to 5.53 mg/l in the summer season and 2.51 to 6.31 mg/l in the wet season. The concentration in DO also varies according to the degree of pollution thus the maximum value was recorded at the level of the referential station O_T it is 6.31 mg/L during the wet season against the minimum value of 2.45 mg/ L which was recorded at the O_1 station located near the town of Taza and suffered pollution from the landfill in addition to untreated wastewater. Furthermore, a significant improvement in DO values moving away from O_1, from upstream to downstream was observed(3a). According to the Moroccan surface water quality standards (NMQES), the average DO concentrations at the majority of the stations classify these waters in the poor to average quality category. BOD_5 and COD are two parameters used to quantify the organic contamination load (HÉBERT et al,. 2000). The highest values of BOD_5 (Figure 3b), are recorded at the level of the most polluted station O_1, it is of the order of 311.4 mg/L in summer, on the other hand the lowest value is that noted at the referencial station OT. A longitudinal

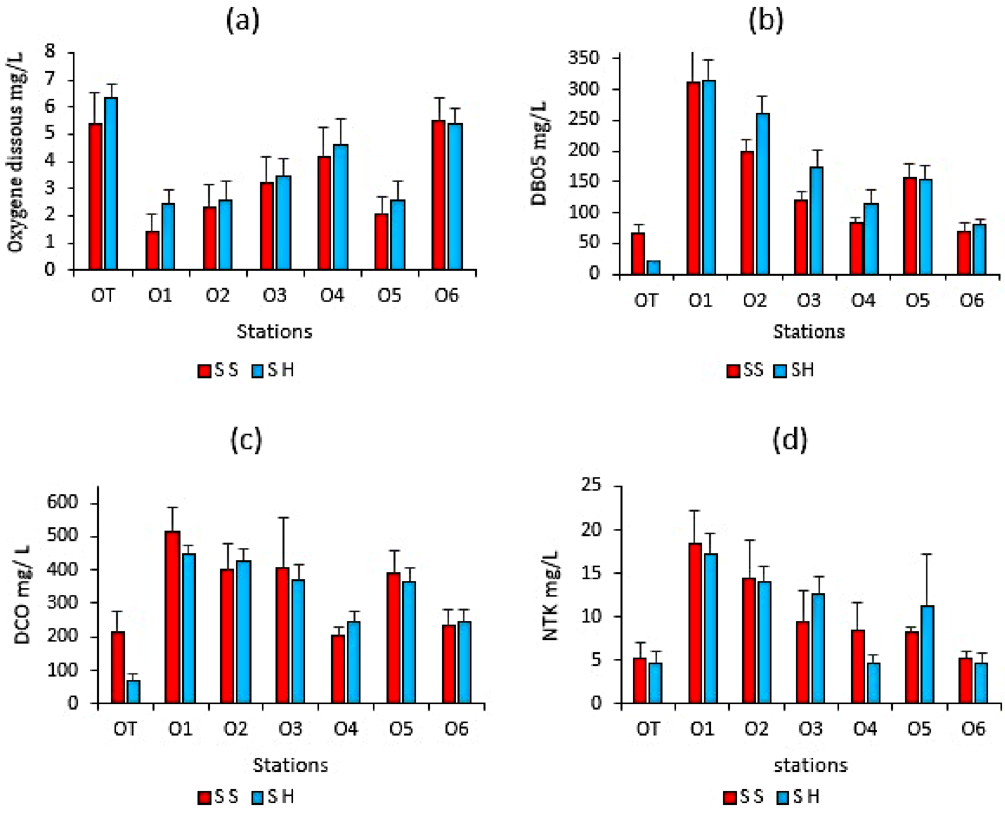

Figure 3. Variation of dissolved oxygen (a), BOD_5 (b), COD (c), and Kjeldahl nitrogen (d) depending on the sampling points and during the wet and dry seasons

gradient in the evolution of this parameter was observed, the averages of BOD_5 decrease away from the O_1 station, from upstream to downstream to go from 311.4 mg/l at O_1 until 68.8 mg/l at O_6. This testifies to the effect of the self-purification of the waters of the Inaouène Oued before joining the Idris 1 dam. The low COD value was recorded at O_T of about 71 mg/l. On the contrary, the highest value was observed at the level of the O_1 station which receives organic pollutants related to domestic discharge and wastewater from the city of Taza. Like the BOD5, the COD decreases according to the longitudinal profile while moving away from the O1 station downstream (Figure 3c), to pass from 447.93 mg/l at O_1 to 243.83 mg/l at O_6 located at the entrance of the dam. Indeed, according to the NMQES, the waters of this environment are of poor quality.

Kjeldahl nitrogen is considered a major indicator of organic pollution. This parameter presents well-marked spatiotemporal variations. Thus, the nitrogen values obtained in the wet period are significantly lower than those of the dry period, The OT station records the lowest averages, The maximum levels were recorded at the level of the most polluted station O_1, it reaches 15.93±1.3 mg/L in wet period and 22.31±1.19 mg/L in dry period, in addition to a decrease in concentrations moving away from station O_1 from upstream to downstream (Figure 3d), reflecting the effect of dilution and testifying to good oxygenation of the waters leading to the oxidation of nitrogen in winter. The relatively high levels recorded during the dry period reflect the process of incomplete degradation of organic matter, these values exceed 1 mg/L and classify these waters in the class of very poor to poor quality (NMQES).

Microbiological parameters

Faecal pollution is a primary health problem in the environment. The presence of faeces in water is an important indicator predicting the potential risks to public health. In the present study, microbial analysis revealed the presence of total coliforms, and E. coli and intestinal enterococci in all stations. The concentrations of E. coli (Figure 4a) are between 1.86 at O_T and 3.32 Log10NNP/100 ml at O_1 in the dry period, this water quality improves in winter and records 1.69 at O_T

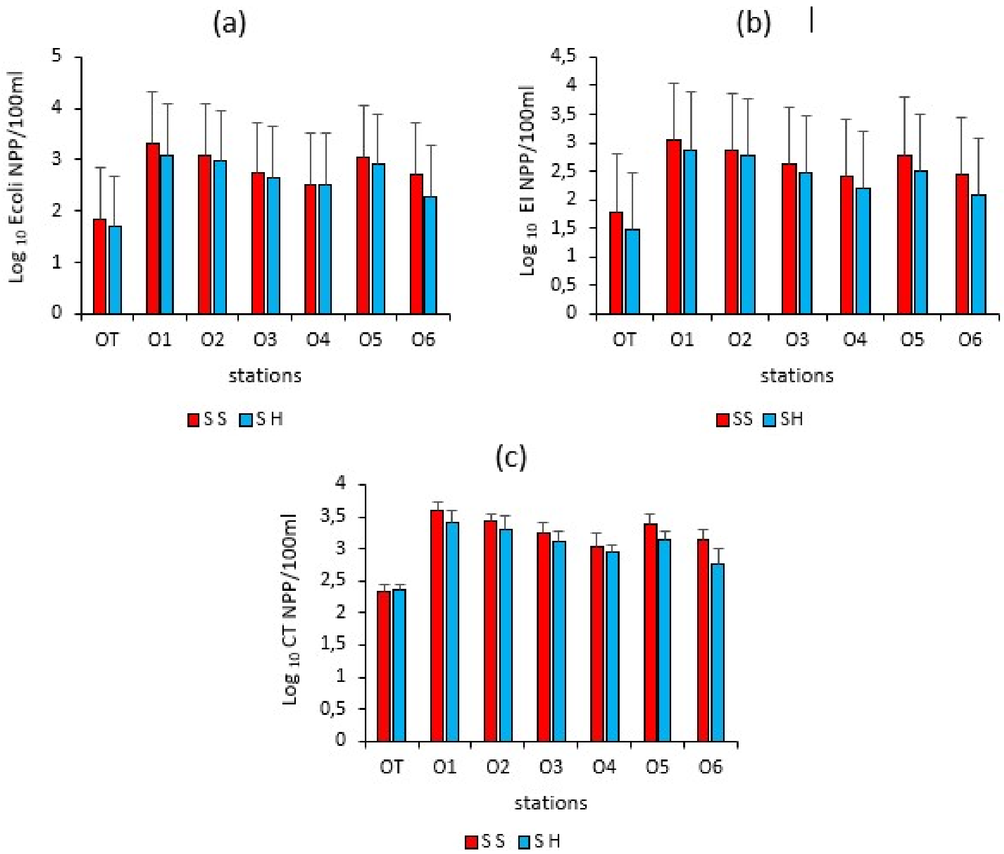

Figure 4. Variation of bacteriological parameters: E coli (a), intestinal enterococci (b), and total coliforms (c) according to the sampling points and during the wet and dry seasons

and 3.07 Log10NNP/100 at O_1. The abundance of E. coli was higher upstream than downstream. Indeed, the longitudinal evolution of contamination is characterized by a clear increasing gradient at station O_5 where its levels are abnormally high following the discharge of wastewater and the landfill of Oued Amlil.

Intestinal enterococci (IE) record in wet periods an average of 2.87 and 1.48 Log10NPP/100ml at O_1 and O_T respectively, the situation worsens in dry periods (Figure 4b). The total coliforms (TC) concentrations vary between 2.37 at O_T and 3.39 log10/100ml at O_1 for the wet season, respectively, and during the dry season an increase in the averages was recorded (Figure 4c).

The results of the bacteriological analyses of the water revealed an increase in bacteriological contamination during the dry season, resulting from the increase in temperature which causes the multiplication of germs, in addition to the reduction in flows in summer due to the drying of tributaries that feed Oued Inaouène and pumping for agricultural purposes, while a decrease in bacterial abundance is noted during the wet season due to the dilution of water following the fall of rains (Bousaab et al., 2007), which leads to a dilution bacterial contamination and increase the flow of the river, which discourages bacterial proliferation (Givord & JM. Dorioz,. 2010). The faecal contamination of the waters of the Inaouène presents a spatial variation with a decreasing gradient going from upstream to downstream. These results show an alteration in the bacteriological quality of the waters analyzed. This can constitute a health threat for local residents who use these waters for drinking, swimming and irrigating their crops.

Influence of physico-chemical parameters on indicators of faecal contamination

The PCA applied to the physicochemical and bacteriological data shows that the F1 axis explains 74.09% of the total variance of the data and that the F2 axis indicates 11.84% of this variability, i.e. a total of 85.93% for the F1*F2 factorial plane (Figure 5). The correlation circle enabled to positively correlate COD, BOD_5, TKN, T(water), TC, EI and E coli on axis 1. This factor is attributed to anthropogenic pollution sources (urban wastewater and leaching), contrasted to dissolved oxygen. This axis then defines a gradient of organic pollution. The position of the DO on the positive part of component 1 is justified by the fact that the waters are more oxygenated in the

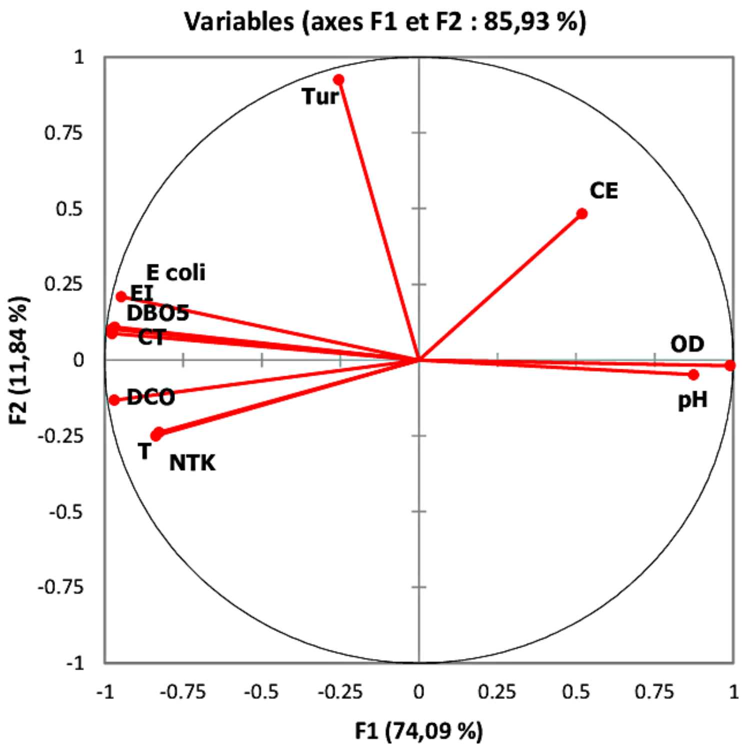

Figure 5. Representation of the PCA, carried out on the physico-chemical data: projection of the parameters on the factorial plane F1*F2. T – temperature, EC – electrical conductivity, DO – dissolved oxygen, Tur – turbidity, pH, COD, DOB_5, TKN – Kjeldahl nitrogen, E coli, TC, IE

Table 1. Correlation matrix (Pearson(n))

Variables	T	pH	Tur	OD	CE	DBO5	DCO	NTK	E coli	CT	EI
E coli	0.6895	-0.7415	0.4475	-0.9107	-0.5064	0.9617	0.8849	0.6773	1		
CT	0.6902	-0.7474	0.3412	-0.9416	-0.5201	0.9855	0.9301	0.7679	0.9855	1	
EI	0.7191	-0.7899	0.3188	-0.9516	-0.4709	0.9957	0.9212	0.8047	0.9817	0.9946	1

downstream part far from the impact of urban effluents upstream the watercourse. Axis 2 reveals a gradient of Tur and EC attributed to the erosion of the watershed characterized by the dominance of marly soils, following stormy rains and the natural alteration of the waters of the Inaouène watershed by contamination nature of very salty geological formations, in particular at the OT station.

The study of the correlations between the physicochemical and bacteriological variables (Table 1) showed a negative correlation between the bacteria indicating contamination of faecal origin and the pH, Givord showed when the pH moves away from the neutrality the survival of bacteria is negatively affected. A negative correlation is observed between bacteria and electrical conductivity, which reflects the degree of overall mineralization and provides information on the salinity rate. Indeed, Bennani et al. and Chedad et al. have shown that salinity is a very important stress factor experienced by faecal pollution bacteria in the salty environment. A negative correlation was also observed between bacteria and dissolved oxygen, which reflects the lack of oxygen which increases the growth and multiplication of germs in the water. COD, BOD_5 and TKN showed a positive correlation with bacteria indicating that wastewater effluent contributes to the worsening of the averages of these parameters.

The Inaouène Oued presents a spatial variation with a decreasing gradient going from upstream to downstream of the polluted station O_1, which testifies to the self-purification effect of the Inaouene before joining the Idris 1 dam. Contrary to the results obtained by (Lamrani et al., 2011). In general, the highest values are recorded at stations O_1, O_2, O_3 and O_5 located downstream of the urban discharges of Taza, Bâb Marzouka and oued Amlil, while the lowest averages were noted at stations far from urban centres. Compared to other previous works carried out on the same site, the averages recorded are higher than those reported by ben Abou et al. in 2014, confirming the effect of the accelerated development of industrial and agricultural activities and the effect of population growth involving the appearance of new sources of pollution which directly affect the quality of surface waters. However, it should be noted that the obtained averages are higher than those reported by (Guellaf et al., 2020) at Oued Martil and lower than the averages reported by (Idrissi al., 2018) at Oued Fez and Sebou and the averages reported by Aboulkacem and Lamrani at Oued Boufekrane and Ouislane.

CONCLUSIONS

This study was conducted to assess the effect of urban discharges on the quality of the waters of the Inaouène Oued which receive the discharges without any prior treatment. The spatio-temporal monitoring of several parameters provided the image of a relatively intense pollution which results in a significant organic and faecal load downstream of the discharges. This requires constant monitoring and treatment process, especially since these waters are used for irrigation and watering. It was concluded that the management of domestic waste and the treatment of wastewater and margins are necessary to reduce the accumulated pollutants in water, and to minimize environmental degradation. This objective should be achieved by the installation of controlled landfills and by the adequate treatment of waste water before its discharge into the rivers, as well as the improvement of agricultural practices.

REFERENCES

1. Aboulkacem, A., Chahlaoui, A., Soulaymani, A., Rhazi-Filali, F., Benali, D. 2007. Etude comparative de la qualité bactériologique des eaux des oueds Boufekrane et Ouislane à la traversée de la ville de Meknès (Maroc). Rev. Microbiol. Ind. San. Environ, 1, 10–22.
2. Abbou, M.B., Bougarne, L., Zemzami, M., El Haji, M. 2018. Carte de synthèse de la qualité des eaux superficielles du bassin versant de l’Oued Inaouen (Maroc). International Journal of Innovation and Applied Studies, 25(1), 322–328.

3. Saab, H., Nassif, N., El Samrani, A., Daoud, R., Medawar, S., Ouaïni, N. 2007. Suivi de la qualité bactériologique des eaux de surface (rivière Nahr Ibrahim, Liban). Revue des sciences de l'eau/Journal of Water Science, 20(4), 341–352.
4. Carpenter, S., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N., Smith, V.H. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen.Ecological Applications, 8(3), 59–568.
5. DRAT: Direction régionale de l'office national du conseil agricole Fes-Meknes, SPMOCA de Taza). Rapport: Précipitations Campagnes 2019–2020/2020–2021. Taza: DRAT, 2021
6. El garouani abdelkader et abdellatif tribak. 2006. Relation entre hydrologie et climat dans le bassin versant de l'Oued Inaouène (pré-Rif marocain) Climate Variability and Change—Hydrological Impacts (Proceedings of the Fifth FRIEND World Conference held at Havana, Cuba, November 2006), IAHS Publ. 308, 2006.
7. Guellaf, A., Kettani, K. 2021. Évaluation de l'état écologique à l'aide de paramètres physico-chimiques, bactériologiques et d'indices biotiques du bassin de l'Oued Martil au nord-ouest du Maroc. Biologia, 76(2), 585–598.
8. Hébert, S., Légaré, S. 2000. Suivi de la qualité des rivières et petits cours d'eau, Québec, Direction du suivi de l'état de l'environnement, ministère de l'Environnement, envirodoq no ENV-2001-0141, rapport n° QE-123, 24 p. et 3 annexes.
9. Idrissi, N., Elmadani, F.Z., Ben Abbou, M., Taleb, M., El Rhazi, K., Nejjari, C., Rais, Z. 2018. Assessment of the physicochemical and bacteriological quality of oueds Fez and Sebou downstream of Fez after the launch of the wastewater treatmenplant: impact on health, Morocco. J. Mater. Environ. Sci., 9(4), 1182–1192.
10. Jarvie, H.P., Whitton, B.A., Neal, C. 1998. Nitrogen and phosphorus in east coast British rivers: Speciation, sources and biological significance. Science of the Total Environment, 210–211, 79–109.
11. Kazi, T.G., Arain, M.B., Jamali, M.K., Jalbani, N., Afridi, H.I., Sarfraz, R.A., Shah, A.Q. 2009. Assessment of water quality of polluted lake using multivariate statistical techniques: A case study. Ecotoxicology and Environmental Safety, 72(20), 301–309.
12. Chedad, K., Assobhei, O. 2007. Etude de la survie des bactéries de contamination fécale (coliformes fécaux) dans les eaux de la zone ostréicole de la lagune de Oualidia (Maroc). Bulletin de l'Institut Scientifique, Rabat, Section Sciences de la Vie, 29, 79.
13. Givord, L., Dorioz, J.M. 2010. La survie des microorganismes d'origine fécale dans les effluents et les sols. INRA thonon Umr carrtel. Etude réalisée dans le cadre du projet CasDAR Territ'Eau, 23.
14. Lamrani H., Chahlaoui A., El Addaouli J., Ennabili A. 2011. Evaluation de la qualité physicochimique et bactériologique de l'Oued boufekrane au voisinage des effluents de la ville de Meknès (MAROC). Science Lib, Editions Mersenne, 3(111112).
15. Bennani, M., Amarouch, H., Boukanjer, A., Nadre, H., Lalaoui, M., Allali, M., Cohen, N. 2012. Influence des facteurs environnementaux sur les charges des bactéries fécales dans le littoral méditerranéen du Maroc.
16. Makhoukh, M., Sbaa, M., Berrahou, A., Van Clooster, M. 2011. Contribution a l'étude physico-chimique des eaux superficielles de l'Oued Moulouya (Maroc oriental). LARHYSS Journal, (9), 2521–9782.
17. Rachid, A. 1997. Les bassins néogènes du sillon Sud rifain et Rif Nord oriental (Maroc). Sédimentologie, paléogéographie et évolution dynamique. Thèse d'Eat, Univ. Sidi Mohamed Ben Abdellah, Fès, 333.
18. Riad, S. 2003. Typologie et analyse hydrologique des eaux superficielles à partir de quelques bassins versants représentatifs du Maroc. Thèse en cotutelle. Université des Sciences et Techniques de Lille (France), Université Ibnou Zohr d'Agadir (Maroc), 147.
19. Rodier et al., 2004. Rodier, J., Legube, B., Merlet, N. 2009. L′Analyse de l′Eau Dunod, Paris Rudolph, A., Ahumada, R., Perez, C. 2002. Dissolved oxygen content as an index of water quality in San Vicente Bay, Chile" (36◦45_s). Environmental Monitoring and Assessment, 78, 89–100.
20. Royaume du Maroc Haut-commissariat au plan Direction régionale de Taza Al-Hoceima Taounate, 2014.
21. Secrétariat d'Etat auprès du ministère de l'Energie des Mines, de l'Eau et de l'Environnement. 2007. Fiche Sur le nouveau système d'évaluation de la qualité des eaux. Direction de la Recherche et de la Planification de l'Eau. Rabat, Maroc, 5.
22. Service technique de la municipalité de Taza STMT. 2005. Etude de choix d'un site pour l'implantation d'une décharge contrôlée des déchets ménagers et assimiles de la ville de Taza. Mission, 1(2), 1–19.
23. State Secretariat for the Ministry of Mining, Water and Environment Energy, Fiche on the New Water Quality Assessment System, Morocco. 2008. 5.
24. Moroccan Standards for surface water Quality. 2002.