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Contribution to the assessment of the health risks related to the reuse of treated wastewater in Oujda-Morocco

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ABSTRACT/RESUME

Abstract: *Wastewater reuse is to consider in Morocco, as rainfalls are irregular in time and space and because of the large amount of wastewater produced nowadays. Therefore, prior treatment is required to minimize health and environmental risks.*

Wastewater from the city of Oujda is treated by a lagoon system, discharged at the Oued Bounaim and partially reused by the neighboring farmers and for watering a 25ha ecological park.

The purpose of this work is to contribute to the assessment of the health risks of the treated wastewater reuse. This purpose has been done by the determination of the wastewater treatment plant (WWTP) performances, the evaluation the self-purification tendency of the outfall and the determination of the bacteriological quality of the water table around the outlet of the plant.

The physico-chemical purification performances of the Oujda's WWTP are satisfactory, but bacteriological elimination needs to be improved. The fecal coliforms density is 1.7 10^4 FCU/100mL. Wells' water showed also faecal contamination.

Purified water has a bacteriological quality that allows reuse for B and C category crops. A reuse for A Category crops and in green spaces could represent an important health risk.

I. Introduction

The reuse of wastewater in agriculture is a process that has been used worldwide for several decades. Raw or treated wastewater are reused in the United States, Mexico, Chile, Peru, Tunisia, Saudi Arabia [1], Australia, South Africa [2], China [3], Italy [4] and Spain [5]. The growth in the volumes of wastewater reused per year exceeds 30% in Europe and 40% in the United States and China [6].

In Morocco, this practice could be a possible response to the water deficit and to demographic and economic growth [7-9]. In this sense, the average annual production of wastewater in Morocco, which was about 370 Mm^3 in 1990 [1], and which increased to 600 Mm^3 [10], could have reached a volume of 900 Mm^3 in 2020 according to El Haité's forecasts [11]. However, the presence and content of chemical pollutants and pathogens in raw sewage represents both an environmental and health risk [12-16]. Monitoring of the quality of the soil irrigated by treated wastewater and of the groundwater is necessary, as continuous and uncontrolled reuse may itself be accompanied by serious risks [17].

In 2017, 60% of the wastewater was treated and only 20% reused in Morocco. The volume of treated wastewater that will be reusable by 2030 is estimated at 325 Mm^3 per year [18]. In Oujda, before the wastewater treatment plants (WWTP) was commissioned in March 2010, farmers in the Angad's plain (around the city of Oujda - North-East Morocco) used raw wastewater to irrigate and fertilize their land [1]. This illegal activity has left after-effects on the quality of the Angad's water table, which shows nitrate concentrations, particularly in the southern zone of the water table, exceeding 50 mg/L allowed by the Moroccan standards [19].

According to Rassam et *al*. [10], the Oujda's WWTP had, in its first years of operation, a satisfactory purification efficiency of about 80 to 90% for Suspended Solids (SS), biochemical oxygen demand in 5 days (BOD_5) and chemical oxygen demand (COD). In the case of Oujda's WWTP, the treated water is discharged at the Oued Bounaim, east of the city [15], and is unofficially used in the irrigation of the surrounding land.

Since 2017, part of the treated water has been used for drip irrigation of 25 hectares of green space in the ecological park of the city of Oujda [20]. The authorities plan to irrigate 1500 ha of agricultural land in Oujda with treated water by 2030 [21].

According to Moroccan standards, the wastewater treated and discharged at the Oued Bounaim or conveyed to the ecological park should not contain bacteria such as *Salmonella* or *Vibrio cholerae* or parasites such as hookworm larvae and furcocerciasis of *Schistosoma hoematobium* [22].

In this work, we sought to assess the quality of the wastewater treated by the Oujda's WWTP and its suitability for use, without chlorine decontamination, for agricultural purposes. The study was also interested by the self-purification ability of a river of Oued Bounaim downstream the WWTP. Furthermore, bacteriological monitoring has been conduced to determine the vulnerability of the aquifer in the area surrounding the WWTP.

II. Materials and methods

II.1. Study area

The Plain of Angads (460 km^2) located in the north of the city of Oujda (Figure 1), is bounded to the south by the Horst chain, to the north by the Bni Znassen chain, to the west by Jbel Megrez and to the east by the Algerian-Moroccan border [23].

The Angads aquifer system is a "transboundary aquifer". It extends over the plains of the Angads and Maghnia. The aquifer system is characterized by a bending (Oued Isly) separating the northern part of the Angads (200 km^2) from its southern part (260 km^2) [23]. The city of Oujda, characterized by a semi-arid climate, is equipped since 2010 with a wastewater treatment plant (WWTP) capable of treating a volume of water of 40 000 m^3/day. The volume of treated water will increase to 65 000 m^3/day in 2030. The WWTP has 43 basins: 10 anaerobic, 12 aerated and 21 maturation ponds. Theses basins are arranged in a series of 5 purification stages [16].

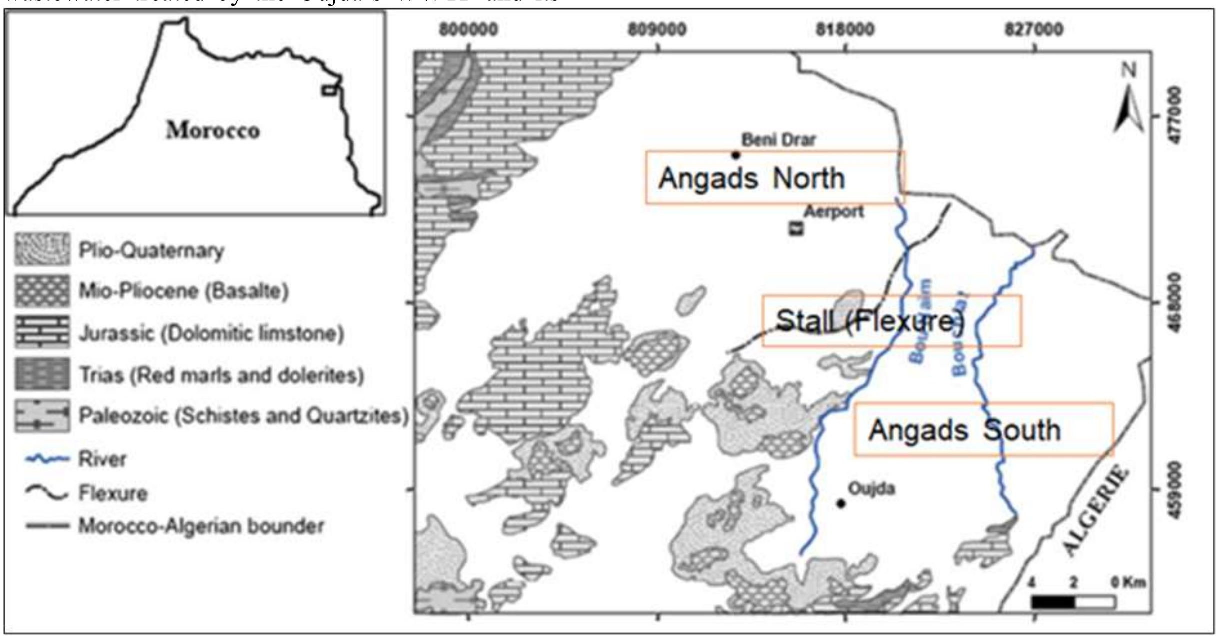

Figure 1.*Localization and geological characteristics of the study area [23]*

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Figure 2. *The localisation of the wastewater treatment plant (WWTP) and the sampling points (P1 to P6 for wells' water and N1 to N3 for the downstream water)*

II.2. The study of the wastewater treatment plant's performances

Two sampling campaigns were carried out in April 2018, including 5 sampling points of the WWTP : the plant's inlet (In), outlet of the anaerobic basins (A), of the aerated basins of the first stage (E_1) and of the second stage (E_2) as well as the outlet of the maturation basins which corresponds to the plant's outlet (Out).

The physico-chemical parameters measured *in-situ* were temperature (T°), pH, dissolved oxygen (O_2) and electrical conductivity (EC). Suspended Solids (SS), biochemical oxygen demand for 5 days (BOD_5) and chemical oxygen demand (COD) were carried in the laboratory according to the standards NF EN 872 for the SS, and EN ISO 15705 for COD. The BOD_5 mesurment has been done according to the manometric method using the equipment *velp-scientifica BOD sensor*.

Samples for bacteriological analysis were collected at the inlet and the outlet of the WWTP. The Bacteria sough are total (TC) and *Faecal Coliforms* (FC), *Faecal Streptococci* (FS) and *Salmonella*, following Moroccan Standards (ISO 9308-1 for TC and FC, ISO 7899-2 for FS and 03.7.050 of the year 1995 for *Salmonella*).

II.3. Self purification ability

In order to get an idea of the self-purification of the treated wastewater that is discharged into Oued Bounaim, three samplings points were carried out at the discharge point of the WWTP (N_1), 0.5 km (N_2) and 3 km (N_3) downstream (Figure 2) in May 2019. The samples were analysed bacteriologically (TC, FC, FS and *Salmonella*) and physico-chemically (pH, EC, SS, NO_3^-, NH_4^+ and PO_4^{3-}). The dosage of orthophosphates was carried out according to the standard ISO 6878 and that of nitrates according to ISO 7150/1 using the method of sodium salicylate [25].

II.4. Bacteriological quality of wells' water

In order to check the groundwater contamination by infiltration, water samples were taken from 6 wells (P1 to P6) located around the WWTP (Figure 2) and have undergone bacteriological analysis (TC, FC, FS, Sulfite-Reducing Anaerobic bacteria [SRA]).

The samples were taken during the month of May 2018.

III. Results and Discussion

III.1. The wastewater treatment plant's performances

The characteristics of the raw wastewater received at the WWTP at an average temperature of 16 °C are pH =7.5, EC = 2500 µs/cm and $[O_2]$ = 0.2 mg/L. SS, BOD_5 and COD are 266, 455 and 792 mg/L, respectively.

The passage of water through the different treatment stages is accompanied by a slight increase in the temperature due to the influence of sunlight and external temperatures, an increase in pH values and electrical conductivity, a significant increase in the oxygenation rate, especially in the last two stages (E_2 and Out), and a clear decrease in SS, BOD_5 and COD values, with reductions of about 75 to 87% (Table 1).

It should be noted that the removal of the polluting material is essentially done at the first treatment stage (In and A). Indeed, at the outlet of the anaerobic basins, a reduction of about 52% for the SS and 35% for the BOD_5 and COD is already noted. This is explained by the settling phenomenon, as found in our results on the Hammam Fokani lagoon station in Figuig [15] and in other works [26, 29]. The reductions of these 3 parameters remain low, even negative in the levels of the plant (E_1, E_2, Out). This could be explained by the restitution of organic matter through the decomposition of living matter, notably through the production of phytoplankton [15, 29].

An important elimination of COD is noted at the level of the maturation ponds, the explanation for which remains unclear.

The bacteriological analysis at the inlet of the WWTP revealed TC, FC and FS contents of 1.4 10^8 FCU/100 mL, 1.1 10^7 FCU/100 mL and 10^7 FCU/100 mL, respectively. Bacterial elimination is between 3 and 4 log units (Table 2). *Salmonella*, present at the entrance of the station is not detected at the outlet. However, the FC rate at this sampling point is higher than the reuse standards recommendation of 1000 FCU/100 mL [22, 30].

III.2. Downstream physico-chemical and bacteriological quality

The physico-chemical study of the effluent (Table 3) revealed a trend towards eutrophication (SS ranging from 12 mg/L at the WWTP outfall to 65 mg/L at a distance of 3 km downstream). This can be seen by a naked eye observation, as water becomes gradually greener in colour from sampling point N1 to N3 (Figure 2). This would indicate a proliferation of microalgae in the water, which would explain both the increase in pH values from 8.03 to 8.25 and the slight decrease in electrical conductivity due to the photosynthetic activity of phytoplankton.

Table 1. *Physico-chemical parameters evolution in the WWTP*

Parameters	**In**	**A**	**E1**	**E2**	**Out**	**Morrocan irrigation standards** **[**Arrêté, 2002]
T° (°C)	16.2	17.8	17.3	17.2	17.3	35
pH	7.5	7.4	7.8	7,8	8.4	6.5 – 8.4
EC (µs/cm)	2 500	2 300	2 300	2 350	2 700	12 000
O_2 (mg/L)	0.2	0.24	1.75	4.82	7.6	
SS (mg/L)	266	128	129	115	66	2000 (gravity irrigation) 100 (Sprinkler or localized)
BOD_5 (mg/L)	455	294	200	148	73	
COD (mg/L)	792	517	360	360	100	

E : Inlet of the WWTP ; A : Outlet of the anaerobic basins ; E1 : Outlet of the first stage of the aerated basins ; E2 : Outlet of the first stage of the aerated basins ; Out : Outlet of the WWTP ; EC : Electrical conductivity ; SS : Suspendend Solids ; BOD_5: Biochemical Oxygen Demand in 5 days ; COD : Chemical Oxygen Demand.

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Table 2. Bacterial elimination in the WWTP

Sampling points	TC (FCU/100mL)	FC (UFC/100mL)	FS (UFC/100mL)	*Salmonella* (/60mL)
Inlet of WWTP	1.4 10^8	1.1 10^7	10^7	Presence
Outlet of WWTP	3 10^4	**1.7 10^4**	10^3	Absence
Morrocan irrigation standards [Arrêté, 2002]	-	1000	-	Absence in 5L

TC : Total Coliforms ; CF : Faecal Coliforms fécaux ; FS : Faecal Streptococci

Nitrate contents are below the detection limit of the measurement. This is commonly observed in wastewater treatment plant effluents [31-32] where nitrogen is mainly present in ammoniacal or even amonifiable form [33].

Bacteriological parameters of the effluent showed high values ranging from 1.5 10^4 to 8.5 10^4 FCU/100mL for TC, 10^4 to 2.5 10^4 FCU/100 mL for FC and 9 10^2 to 4.2 10^3 FCU/100 mL for FS (Table 4). These values, which are sometimes higher than those observed at the outlet of the WWTP, could be due to a source other than treated wastewater, like an uncontroled discharge of raw wastewater or contamination from an animal origin.

At sampling point N3, the FC/FS ratio is less than 4, suggesting that this increase may be related to animal contamination [34]. Indeed, the field visit revealed frequent livestock grazing in the study area. The study of Bou Saad et *al*. [35] indicated the same finding of increased FS density when cattle have free access to the watercourse or when their droppings are used as fertilizer on surrounding land.

As for the SRA, their density is higher than 2 10^3 FCU/100mL in each of the three sampling points. This indicates an old contamination.

Ministerial Order 1276-01 limits the number of faecal coliforms to less than 1000/100 mL in samples taken at the exit of wastewater treatment plants for the irrigation of public green spaces [22]. We found levels ranging from 10^4 to 2.5 10^4 FCU/100mL which are very high levels compared to the legal limit indicated above. This quality of water allows a reuse for B and C category of crops [22]. A better microbial quality is required for the irrigation of a category of crops that are intended for raw consumption.

The value of detecting faecal coliforms, also known as thermotolerant coliforms, as indicator organisms lies in 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 faeces [36]. *Escherichia coli* accounts for 80-90% of the thermotolerant coliforms generally detected in water [37]. The rhizosphere, a layer of soil about 1 mm thick around the roots, represents a nutrient-rich habitat and is a permanent environmental reservoir of Escherichia coli [38].

III.3. Wells' water physico-chemical and bacteriological quality

Bacteriological analysis of the wells' water revealed TC contamination in all 6 wells, ranging from 550 to 2700 FCU/100mL. FC were found in 4 wells with densities ranging from 350 to 1500 FCU/100 mL, while FS ranged from 1 to 68 FCU/100 mL in 5 of the 6 wells, with a most notable presence in two wells (P1 and P4). SRA were found at the P2 with a density of 4 FCU/100 mL (Table 5).

The 4 wells with FC contamination show a FC/FS ratio greater than 4, which indicates that the contamination has dominant human origin [34].

Well P5, however, which does not show recent faecal contamination, shows evidence of SRA, indicating that it is also affected by older or intermittent contamination [25]. This presence of SRA would indicate ancient contamination probably related to the discharging of raw wastewater in the area before the commissioning of the WWTP.

It should be noted that a parallel study of physico-chemical parameters [19] revealed nitrate levels higher than 50 mg/L in several wells in the vicinity of the WWTP, with maximum values downstream of the WWTP of up to 240 mg/L.

According to the physico-chemical and bacterial parameters reveled by the present study and Es-sousy et *al*. results [19], the quality of wells' water is unfit for human consumption.

Table 3. *Spatial evolution of the physico-chemical parameters in the Oued Bounaim*

Sampling points	**pH**	**EC (µs/cm)**	**SS (mg/L)**	**NO_3^- (mg/L)**	**NH_4^+ (mg/L)**	**PO_4^{3-} (mg/L)**
N1 (0km)	8.03	2 740	12	< 0.5	91.75	10.21
N2(0.5km)	8.09	2 680	14	< 0.5	103.64	10.05
N3 (3 km)	8.25	2 610	65	< 0.5	111.4	9.78
Morracan irrigation standars [Arrêté, 2002]	6.5 -8.4	1 200	2000 (gravity) 100 (sprinkler or localized)	30	-	-

EC: Electrical Conductivity, SS: Suspended Solids

Table 4. *Spatial evolution of the bacterial contamination in the Oued Bounaim*

Echantillon	**TC (FCU/100mL)**	**FC (FCU/100mL)**	**FS (FCU/100mL)**	**SRA (FCU/100mL)**	***Salmonella***
N1 (0km)	$8.5\ 10^4$	$2.5\ 10^4$	$9\ 10^2$	$>2\ 10^3$	+
N2 (0.5km)	$5.3\ 10^4$	$1.4\ 10^4$	$2\ 10^3$	$>2\ 10^3$	+
N3 (3km)	$1.5\ 10^4$	10^4	$4.2\ 10^3$	$>2\ 10^3$	+
Morracan irrigation standars [Arrêté, 2002]	-	10^3	-	Absent in 450mL	Absent in 5L

TC: Total Coliforms, FC : Faecal Coliforms, FS : Faecal Streptococci, SRA : Sulfit Reducing Anaerobic bacteria

Table 5. *Bacteriological wells' water quality*

Puits	**TC (UFC/100 mL)**	**FC (UFC/100 mL)**	**FS (UFC/100 mL)**	**SRA (UFC/100 mL)**
P1	573	346	59	0
P2	791	564	6	0
P3	2274	1518	1	0
P4	2690	573	68	0
P5	719	0	0	4
P6	555	0	1	0
Morrocan irrigation standards [Arrêté, 2002]	-	1000	-	0/ 5 L
Morrocan potability standards [Arrêté, 2006]	-	0/100mL	0 /100mL	0/100mL

P1 to P6 : Wells' water samples, TC : Total Coliforms, FC : Faecal Coliforms, FS : Faecal Streptococci, SRA : Sulfit Reducing Anaerobic bacteria

IV. Conclusion

The wastewater treatment plant (WWTP) in the city of Oujda, although it provides good purification yields with respect to parameters such as suspended solids (SS) BOD_5 and COD, requires additional treatment to achieve better bacteriological quality. However, the water treated by this WWTP could be reusable for category B or C crops according to the Moroccan standards.

The water quality of the Oued Bounaim, at the plant's downstream, showed signs of significant phytoplankton proliferation as well as high bacterial density, often exceeding that observed at the outlet of the WWTP, which could indicate other sources of contamination, particularly animal contamination.

The well's water around the WWTP has significant bacterial contamination making it unfit for human consumption. This contamination would be the result of an infiltration of treated wastewater (recent contamination), but also of raw wastewater that was discharging into the area before the commissioning of the WWTP in 2010, indicated by the presence of bacteria indicative of former contamination.

The use of treated wastewater with its current bacteriological quality in the irrigation of agricultural land and green spaces could constitute health risks for the population.

V. References

1. El Halouani, H. Réutilisation des eaux usées en agriculture et leur impact sur l'environnement : cas de la ville d'Oujda.*Thèse de Doctorat ès-Sciences, Faculté des Sciences, Université Mohammed Premier* (1995) 193p.
2. Salgot, M. and Huertas, E. Integrated Concepts for Reuse of Upgraded Wastewater, Guideline for quality standards for water reuse in Europe, *AQUAREC* (2006) 128p.
3. Wang, J.F.; Wang, G.X. ; Wanyan, H. Treated wastewater irrigation effect on soil, crop and environment: Wastewater recycling in the loess area of China. *Journal of Environmental Sciences* 19 (2007) 1093-1099.
4. Lopez, A.; Vurro, M. Planning agricultural wastewater reuse in southern Italy : The case of pulina region. *Desalination* 218 (2008) 164-169.
5. Cazurra, T. Water reuse of south Barcelona's wastewater reclamation plant. *Desalination* 218 (2008) 43-51.
6. Lazarova, V.; Brissaud, F. Intérêt, bénéfices et contraintes de la réutilisation des eaux usées en France. *L'eau, l'industrie, les nuisances*. 299 (2007) 29-39.
7. El Addouli, J.; Chahlaoui, A.; Berrahou, A.; Chafi, A.; Ennabili, A.; Karrouch, L. Influence de rejets d'eaux usées sur les qualités physicochimique et bactériologique d'eaux utilisées en irrigation. *Revue francophone d'écologie industrielle* 56 (2009) 23-28.
8. Dadi, E. L'évaluation de la possibilité de réutilisation en agriculture l'effluent traité de la commune de Drarga. *Mémoire de maitrise en environnement, Centre Universitaire de Formation en Environnement, Université de Sherbrooke, Quebec, Canada* (2010) 70 p.
9. Legros, N. La réutilisation des eaux usées traitées en irrigation comme incubateur d'un processus de pérennisation et de bonne gouvernance des infrastructures d'assainissement : cas pratique de la station d'épuration de Tidili au Maroc. *Mémoire de Master, Université de Liège* (2017) 83 p.
10. Rassam, A.; Chaouch, A.; Boukhriss, B.; Boukhriss, M. Performances de la dégradation de la matière organique par lagunage aéré dans la station d'épuration des eaux usées de la ville d'Oujda (Maroc oriental). *Bulletin de la Société Royale des Sciences de Liège* 81 (2012) 121 – 125.
11. El Haité, H. Traitement des eaux usées par les réservoirs opérationnels et réutilisation pour l'irrigation. *Thèse de Doctorat, Ecole Nationale Supérieure des Mines de Saint-Etienne* (2010) 214p.
12. Deveaux, I.; Maranon, E.; Sastre, H.; Planchon, C.; Bontoux, J.; Glanddier, P.Y. Infections risk associated with wastewater reuse : an epidemiological approach applied to the case of clemont-Ferrand, France. *Water Science and* Technology 43 (2001) 53-60.
13. Amahmid, O.; Bouhoum, K. Assessment of the health hazards associated with wastewater reuse : transmission of geohelminthic infections (Marrakech, Morocco). *Journal of environmental health research* 15 (2005) 127-133.
14. Kadmiri, M.; Glouib, K.; Verschaeve, I.; Hilali, A. Cytogenetic monitoring of domestic mammals exposed to wastewaters from the localities of Dladla and Boukallou near Settat, Morocco. *Environment International* 32 (2006) 690-696.
15. El Hachemi, O. Traitement des eaux usées par lagunage naturel en milieu désertique (Oasis de Figuig) : Performances épuratoires et aspect phytoplanctonique. *Thèse de Doctorat. Université Mohammed Premier. Oujda* (2012) 122p.
16. RADEEO Dépollution des eaux usées, Document interne (2017) [visited in 5/2020]. URL : http://www.radeeo.ma/Accueil/D%C3%A9pollutiondeseauxus%C3%A9es/tabid/294/language/en-US/Default.aspx
17. Baumont, S. Réutilisation des eaux usées épurées : Risques sanitaires et faisabilité en Ile-de-France, *Observatoire régional de santé d'Ile-de-France* (2004) 176p.
18. Noratech, Ingénierie & Conseil Energie – Eau – Environnement. Formation sur le Changement Climatique au profit des opérateurs économiques, Engagement du Maroc dans l'accord de Paris: CDN Volet adaptation, Casablanca les 15 et 16 mars (2018).
19. Es-sousy, M.; Gharibi, E.; Ghalit, M.; Taupin, J.D.; Alaya, M.B. Hydrochemical Quality of the Angads Plain Groundwater (Eastern Morocco). In Advances in Sustainable and Environmental Hydrology, Hydrogeology, *Hydrochemistry and Water Resources* (2019) 99-102.
20. Assousy, M.; Gharibi, E.; Ghalit, M. ; Taupin, J.D.; El Hachemi, O.; El Halouani, H. Etude de la vulnérabilité de la nappe phréatique des Angads en tenant compte du recours à des ressources non conventionnelles d'irrigation (REUSE), 2nd *Conference on Econometrics for Environment.* December 19-20 (2018) Nador. Morocco.
21. Dahan, S. Gestion de la Rareté de l'Eau en Milieu Urbain au Maroc. *Banque mondiale, Washington, DC* (2017).
22. Arrêté conjoint du ministre de l'équipement et du ministre chargé de l'aménagement du territoire, de l'urbanisme, de l'habitat et de l'environnement n° 1276-01 du 10 chaabane 1423 (17 octobre 2002) portant fixation des normes de qualité des eaux destinées à l'irrigation.
23. Boughriba, M.; Barkaoui, A.E.; Zarhloule, Y.; Lahmer, Z.; El Houadi, B.; Verdoya, M. Groundwater vulnerability and risk mapping of the Angad transboundary aquifer using DRASTIC index method in GIS environment. *Arabian Journal of Geosciences* 3 (2010) 207-220.
24. Quang Trac, N.; Simonot, M. Le couloir Taourirt-Oujda in *Ressource en eau du Maroc* 1 (1971) 279-287.
25. Rodier, J.; Legube, B.; Merlet, N. L'Analyse de l'Eau, Eaux Naturelles, Eaux Résiduaires, Eaux de Mer (9th edn) 2009 Dunod. Paris.
26. Schneiter, R.W.; Middlebrooks, E.J.; Sletten, R.S. Cold region wastewater lagoon sludge accumulation. *Water Research* 17 (1983) 1201-1206.

27. Marin, M. Accumulation de boues dans les étangs aérés facultatifs. *Sciences et Techniques de l'Eau* 20 (1987) 303-308.
28. Hammou, N.; Picot, B. ; Bontoux, J. Les dépôts sédimentaires en lagunages à microphytes : évolution des quantités, des caractéristiques physico-chimiques et des charges en métaux lourds. *Environmental Technology* 13 (1995) 647-655.
29. Bouarab, L. Dynamique et rôle des algues phytoplanctoniques dans le traitement des eaux usées (station pilote de lagunage naturel de Ouarzazate - Maroc*). Thèse Doctorat d'état essciences. Faculté des sciences Semlalia Marrakech* (2000) 207p.
30. OMS. Directives OMS pour l'Utilisation sans risque des eaux usées, des excreta et des eaux ménagères (2012).
31. El Hachemi, O.; El Halouani, H.; Torrens, A.; Salgot, M. Wastewater treatment in the oasis of Figuig (Morocco) by facultative lagoon system : physico-chemical and biological aspect. *Journal of Life sciences* 6 (2012) 543-549.
32. Torrens, A.; Alcalde, L.; Salgot, M.; Casanova, P.; Querlat, E.; Elhachemi, O.; Elhalouani, H.; Gonzalez, C. Sustainable water resources management in the Oasis of Figuig - Morocco. *Sustainable Sanitation Practice* 11 (2012) 11-19.
33. FNDAE Traitement de l'azote dans les stations d'épuration biologique des petites collectivités. Document technique. *Ministère de l'agriculture et de la pêche. Cemagref. France* (2001) 79p.
34. Borrego, A.F.; Romero, P. Study of the microbiological pollution of a Malaga littoral area II. Relationschip between fecal coliforms and fecal streptococci. *VIᵉ Journée Étude Pollutions, Cannes, France* (1982) 561-569.
35. Bou Saad, H.; Nassif, N.; El Samrani, A.G.; Daoud, R.; Medaouar, S. ; Ouaïni, N. Suivi de la qualité bactériologique des eaux de surface (Rivière Nahr Ibrahim – Liban) *Revue des sciences de l'eau / Journalof Water Science* 20 (2007) 341-352 [visited in 6/2020]. URL : http://id.erudit.org/iderudit/016909ar
36. Centre d'expertise en analyse environnementale (CEAEQ), Recherche et dénombrement des coliformes fécaux; méthode par filtration sur membrane., Gouvernement du Québec, (2000), 24p.
37. Dorioz, J.M.; Trevisan, D.; Texier, S.; Prigent-Combaret, C.; Gourdon, M.H.; Joncteur-Monrozier, L.; Moenne-Loccoz, L.; Faivre, P. ; Qietin, P.; Poulenard, J. Rapport du Programme Gestion du Patrimoine Sol (GESSOL), (2008), 122. [Visited in 6/2020], URL: https://hal.inrae.fr/hal-02823449/document
38. Texier, S. Dispersion et survie des populations de bactéries fécales bovines dans le sol des écosystèmes pâturés subalpins : conséquence sur le transfert bactérien dans les bassins versants. *Thèse de doctorat, Université de Savoie* (2008) 170p. [Visited in 6/2020], URL : https://hal.inrae.fr/tel-02822460

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