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Current situation of reclaimed wastewater reuse in golf courses in Marrakech (Morocco): problems and solutions

H. Benlouali[a,*], M.C. Harrouni[a], M. Fallah[b], A. Hirich[c], R. Choukr-Allah[a,c]

[a]*Hassan II Institute of Agronomy and Veterinary Medicine, Complex of Horticulture, Agadir, Morocco, emails: h.benlouali@gmail.com (H. Benlouali), c.harrouni@gmail.com (M.C. Harrouni), redouane53@yahoo.fr (R. Choukr-Allah)*
[b]*Ibn Zohr University Faculty of Science, Laboratory of Biotechnology and Valuation of Natural Resources, B.P. 8106, Agadir, Morocco, email: m.fallah@uiz.ac.ma*
[c]*International Centre for Biosaline Agriculture, P.O. Box 14660, Dubai, UAE, email: hirich_aziz@yahoo.fr*

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ABSTRACT

Marrakech region is facing a strong growth in population, urbanization and tourism, inducing more demand for water. Therefore, a partnership between the Moroccan Government, the local agency dealing with wastewater reclamation in Marrakech (RADEEMA), the golf courses developers and the municipality, launched a joint wastewater treatment and reuse project. This project was implemented with the aim of protecting the environment, sustaining tourism and urban development of the city and satisfying water requirements (24,000 m^3/d) of 18 golf courses and city landscaping. However, so far only eight golf courses are using reclaimed wastewater. The absence of surveys related to golf courses irrigation with reclaimed wastewater and the lack of data on the constraints limiting the use of reclaimed wastewater to irrigate golf courses was one of the reasons to conduct this study. This paper presents the results of a survey carried out in 2015 in six golf courses out of the eight using reclaimed wastewater in Marrakech. It covers the political, regulatory and financial frameworks implemented to involve private stakeholders in water resources preservation and achieve the National Sanitation Plan goals. Moreover, an analysis of data about the golf courses is reported. It includes golf course area, water consumption, water storage structures, soil type, irrigation systems, turfgrass varieties and hygienic measures taken to protect users and employees. The survey showed a reluctance of golf courses managers toward the use of reclaimed wastewater for irrigation, because it causes problems which are mostly related to the clogging of the irrigation system affecting irrigation distribution, salinity, homogeneity and grass growth. Based on these results, we suggested some practical solutions to promote reclaimed wastewater reuse such as the use of efficient storage and irrigation water filtration systems. In addition, some special amendments are recommended to alleviate salinity damage to the turfgrass of these golf courses.

Keywords: Reclaimed wastewater; Marrakech; Golf course; Irrigation; Turfgrass

1. Introduction

Morocco has been facing a gradual reduction of rainfall and an increase in temperature for the last 20 years [1]. Therefore, it was clear for decision-makers at the highest political levels that there is a need to find new solutions to the challenges of water resources management. Within this framework, great efforts are developed to reduce water demand and search for new alternative water supplies in order to face drought and increased consumption.

* Corresponding author.

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Within the context of increasing scarcity and degradation of water resources, wastewater reuse (WWR) represents an alternative for Morocco to reduce the gap between water resources availability and water requirements. The WWR can indeed have several benefits which vary depending on circumstances, including: (i) the elimination of the impacts of wastewater treatment plant effluent discharge into the environment; (ii) the recovery of an additional water resource for different possible reuses, and consequently; (iii) the conservation of fresh conventional water resources with high quality (drinking water). Treated WWR possibilities in Morocco include agricultural irrigation, golf courses watering, municipal landscaping, groundwater recharge and industrial uses [2].

The golf sector is an important factor of the national, regional and local economy. During the last decades, golf business has gained a lot of interest as a part of the National Tourism Strategy. The reasons behind that are: (i) the golf courses provide high economic added value. Therefore, development of new courses has been, at a national level, associated with integrated resorts including residential complexes and hotels; (ii) the golf market is a niche that attracts high level tourists that usually spend more money than usual. Nowadays, a number of golf courses have emerged in many cities, and have made the country an important golf destination.

Marrakech city is located in a region suffering from water resources scarcity, and currently, it holds 11 running golf courses and 7 more are under construction. Clearly, in a region where water resources are already limited, the rising demand for golf courses irrigation in conjunction with the continuous expansion of the tourism sector will increase the pressure on water resources [3]. This situation is worsened by the threat of climate change with the probability of frequent droughts and drier summers [4]. Therefore, the use of natural water resources for the irrigation of golf courses is being gradually criticized and their substitution by reclaimed wastewater (RWW) has become a must [5,6].

RWW reuse has been widely applied for irrigation as it presents many advantages such as effluent disposal and reduction of the fertilizers use [7,8]. RWW is rich in nitrogen, phosphorus and other nutrients. Its reuse in irrigation will significantly reduce the amount of fertilizers applied. Golf courses are specifically suitable to be irrigated with RWW due to their dense plant canopy and active root system that remove excess nutrients, especially nitrogen [9]. In addition, golf courses are usually close to cities where treatment plants are located, which minimize water transport costs [10].

The promotion of golf courses as a tourist attraction and the importance of RWW reuse in protecting the environment and preserving water resources are the driving forces of this research.

2. Study area

Marrakech is located in an arid continental climate zone in Morocco [11]. Climatic data obtained from FAO ClimWat database (data based on monthly average of a historical baseline of 30 years) show that temperatures ranging from 4.4°C to 38.3°C (Table 1). Monthly average of evapotranspiration (ET_0) daily values ranges from 1.76 recorded in December to 7.01 mm/d in July. Yearly average precipitation is 236 mm. Precipitations are distributed from October to May with the maximum occurring in November (37 mm), whereas minimum rainfall is recorded from June to September.

3. Materials and methods

During the period of July and August 2015, a survey conducted at RADEEMA's (local agency dealing with wastewater reclamation) offices enabled to collect official data about political, regulatory, financial and technical frameworks related to the reuse of RWW in golf courses irrigation in Marrakech. Moreover, it allowed gathering data about RWW consumed by all eight golf courses during 2012, 2013 and 2014.

In addition to this survey, a self-administrated questionnaire was carried out in six of the eight golf courses that are using RWW for irrigation in Marrakech. The choice of the golf courses surveyed is based on their accessibility. Five were running golf courses while one was under construction. Answers were obtained on site and the golf courses managers were assisted to understand the questions in order to ensure the quality of the responses. The survey consisted of 32 questions divided into six main areas, namely, general information about the golf course, water consumption, irrigation system, soil nature, turfgrass varieties and hygiene measures. Questions were both open questions and multiple choice ones. Ambiguous responses were considered as unanswered. The average time used to complete the survey questionnaire was 30–40 min.

Respondents included four greenkeepers and two greenkeeper's assistants. All golf courses were connected to the RWW network in the year of 2012, except one that was connected in June 2013.

Data related to golf courses areas were checked using aerial views of each course using AutoCad software. The data were analyzed using descriptive statistics (means, maximum and minimum) by Microsoft Excel in order to get a general view of frequencies of variables.

Table 1
Climatic data for Marrakech [12]

	January	February	March	April	May	June	July	August	September	October	November	December
Rain, mm	27	34	30	33	20	4	1	2	5	18	37	25
Minimum T, °C	4.4	6.1	8.9	11.1	13.9	16.7	19.4	20	17.2	13.9	9.4	5.6
Maximum T, °C	18.3	20	23.3	26.1	28.9	33.3	38.3	37.8	33.3	28.3	22.8	18.9
ETo, mm/d	1.8	2.4	3.5	4.3	5.1	5.8	7.0	6.8	5.1	3.5	2.2	1.7

4. Results and discussion

4.1. Current state of the treatment and reuse of reclaimed wastewater in Marrakech

4.1.1. Political and financial frameworks

In 2006, Morocco launched the National Sanitation Plan which focused on water management and mobilization of unconventional water resources. Among the objectives of this plan, the reuse of RWW (300 Mm^3/year by 2030) in golf courses, landscaping and date-palm crop [13]. In this context, a project for the reuse of RWW in golf courses of Marrakech has been launched under a public–private partnership. In collaboration with the Moroccan government and golf courses owners, RADEEMA has initiated a one billion Moroccan Dirhams (105 million USD) project, which includes a wastewater treatment plant and an RWW distribution network across the city [14]. According to the technical office of RADEEMA, the project was financed up to 12% by the government through its Ministry of the Interior and the Secretariat in charge of Water and Environment, 40% by 15 golf courses promoters and 48% by RADEEMA. Specific contracts regulated the financial contributions of each golf course promoter, the regulations related to water allocations and quality, as well as the price of RWW that was set to 2.5 Moroccan Dirhams/m^3 (0.25 USD/m^3). The project started supplying six golf courses by the end of 2010 and actually, it supplies eight golf courses and the seven other signatory promoters will be connected in the future.

4.1.2. Regulatory framework

The contractual regulations of the reuse of RWW in golf courses in Marrakech are governed by the Order 1276-01 enacted on the 17th of October 2002, related to irrigation water quality standards. This order indicates that the minimum number of water samples to be analyzed for conformity with irrigation standards must be as follows:

- One analysis per quarter to control heavy metals (i.e., 4/year);
- One analysis for every 15 d to control bacteriological, parasitological and physicochemical parameters (i.e., 24/year).

As a result, every 15 d samples are taken in each golf course in order to evaluate BOD_5, suspended matter (SM), total Kjeldahl nitrogen (TKN), total phosphorus (TP), chloride (Cl) and fecal coliforms. Analyses are performed by RADEEMA in its laboratories. However, when comparing the standards mentioned in the contracts between RADEEMA and the golf courses promoters, we can note that chloride and fecal coliforms rates permitted in the project are higher than the standards set by the 1276-01 Order (Table 2).

4.1.3. Wastewater treatment

The wastewater treatment plant provides 33 Mm^3/year of RWW. It is connected to golf courses through a supply network of 80 km, using four pumping stations. A fifth pumping station is under construction. The pre-treatment consists of screening as well as grit and grease removal from wastewater. The primary treatment consists of sedimentation. In the secondary treatment, activated sludge is applied as biological treatment. At last, the tertiary treatment uses various processes such as coagulation and flocculation, sand filtration and disinfection by ultraviolet lamps and chlorine.

4.2. General data of the surveyed golf courses

4.2.1. Golf courses areas

The total surface of the surveyed golf courses is 349 ha. All golf courses are integrated in residential complexes. Four of them are 18 holes with areas ranging from 43 to 60 ha. The two others are 27-hole golf courses with 70 ha each.

Total greens surfaces ranging from 1.3 to 1.7 ha for 18-hole courses and reach 2 ha in 27-hole courses. Average surface of greens is 800 m^2. Average surface of fairways is 6.1 ha and the number of lakes ranges from 3 to 6 ha for each golf course. Table 3 shows the average percentage of each component in the surveyed golf courses.

4.2.2. Irrigation system

The survey has shown that the six golf courses studied run their irrigation through a centralized management system. Moreover, in order to adapt irrigation to turfgrass requirements, four of them use agro-meteorological stations and two are equipped with soil humidity sensors.

After its delivery from the treatment plant to the golf course through the main pipeline, the RWW is stored in

Table 2
Comparison of regulations adopted in the project and regulations set by the Order 1276-01

	Regulations adopted in the project	Regulations adopted in the 1276-01 Order
BOD_5, mg/L O_2	10	–
SM, mg/L	5	100
TKN, mg/L	5	–
TP, mg/L	10	–
Cl, mg/L	<500	15
Fecal coliforms, cfu	2,000	200

Table 3
Percentage of surveyed golf courses components based on their average areas

	Average area (%)
Greens	3
Bunkers	3
Roughs	35
Lakes	8
Fairways	44
Tees	3
Practices	4

lakes with volumes ranging from 50,000 to 92,400 m^3, with an average depth of 7 m.

RWW is transported from lakes to underground reservoirs from which it is pumped before passing through the filtration system and getting distributed through pipelines to sprinklers. Two of the four 18-hole golf courses are equipped with six pumps while the two others have five pumps. Five golf courses use screen filtration and the sixth uses disc filters. All surveyed golf courses have a drainage system. Drainage water is evacuated in sanitation network by all golf courses.

4.3. Water management in golf courses irrigated with reclaimed wastewater

4.3.1. Reclaimed wastewater consumption

Since its beginning in April 2012 until December 2014, the project of RWW reuse in golf courses in Marrakech has saved a total of 11.3 Mm^3 of freshwater resources. Although volumes of RWW used vary from a golf course to another, obtained results showed correlation between seasons and water consumption. From November to April, low consumptions were recorded due to rainfall and low evapotranspiration rates. During the period between May and October high water consumption was recorded due to high evaporative demand and low rainfall (Fig. 1). Analysis of RWW consumption data in 2014, when all the surveyed golf courses were supplied by the treatment plant, shows that courses monthly peak consumptions ranged from 45,164 to 147,175 m^3 with an average of 110,212 m^3. When analyzing the relationship between RWW consumption and number of holes in golf courses, it was found that 27-hole golf courses consumed less RWW than 18-hole golf courses (Fig. 1). This is unreasonable since the area of the latter is bigger than the former. Lower consumption in the 27-hole courses can be explained by the potential use of other water resources (underground water and dam water).

The obtained data also indicate that golf courses consumed on average 15,671 m^3/ha year of RWW, ranging from 5,945 to 28,836 m^3/ha year. The findings indicate that water use in the surveyed golf courses was higher than water consumption in golf courses in Spain which is on average of 8,200 m^3/ha year according to a general survey conducted by Diaz et al. [4] using the same methods (i.e., visiting courses and greenkeeper interviews). The difference is probably a result of climatic differences, since the Spanish survey included golf courses from North of Spain where the evapotranspiration is lower and rain is more important than in Marrakech.

To summarize, differences in volumes of water consumption vary based on: (a) management practices such as the conjunctive use of RWW with other water resources, (b) technical knowledge of the golf course manager, (c) market positioning and budget allocated to irrigation water and (d) golf course's equipment (e.g., humidity sensors, agrometeorological station).

4.3.2. Irrigation and water storage

Clogging of irrigation system and eutrophication of lakes is the major issues faced by the golf courses (Fig. 2). Eutrophication is ultimately caused by excessive inputs of nutrients. In lakes, it is mostly a result of high rates of phosphorus that is assimilated by bacteria and algae. This leads to phytoplankton proliferation as well as algae and bacteria growth [15]. Consequently, this causes bad odors and mosquito proliferation which disturb players and impact properties sales. Clogging reduces the uniformity of water emission and decreases the irrigation efficiency [16].

A report by HYGIUP laboratory [17] for the benefit of a surveyed golf course showed the occurrence of biological clogging in a high rate due to proliferation of bryozoans and the presence of bacterial biofilm. However, it reported very low rates of chemical clogging. The actions undertaken by golf courses managers aimed mainly at reducing lakes eutrophication in order to prevent irrigation system clogging (Fig. 3). Aeration of lakes is the major action done to cope with this problem. However, although it is recommended to clean reservoirs for every 3–5 years in order to avoid sludge accumulation in the bottom [18], no reservoir cleaning has ever been performed. As an alternative, lakes in golf courses were in second case manually cleaned on the surface in order to remove algae. The cleaning of the filtration system

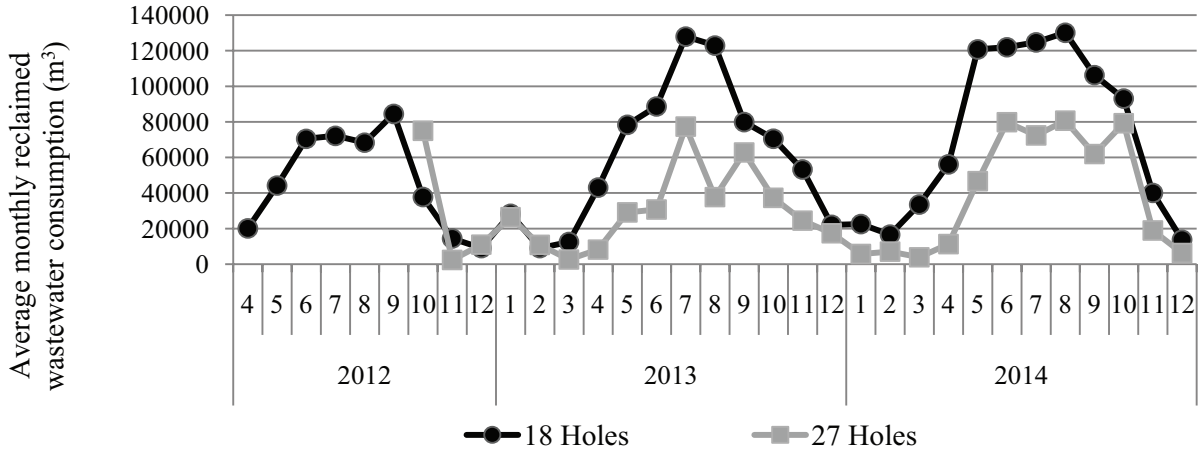

Fig. 1. Average reclaimed wastewater consumption in 18- and 27-hole golf courses in Marrakech.

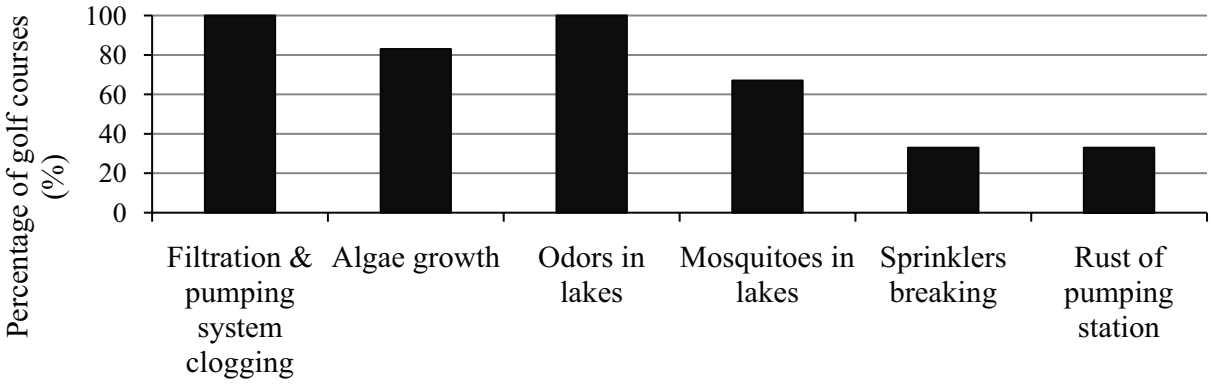

Fig. 2. Effect of RWW on storage lakes and irrigation systems in golf courses.

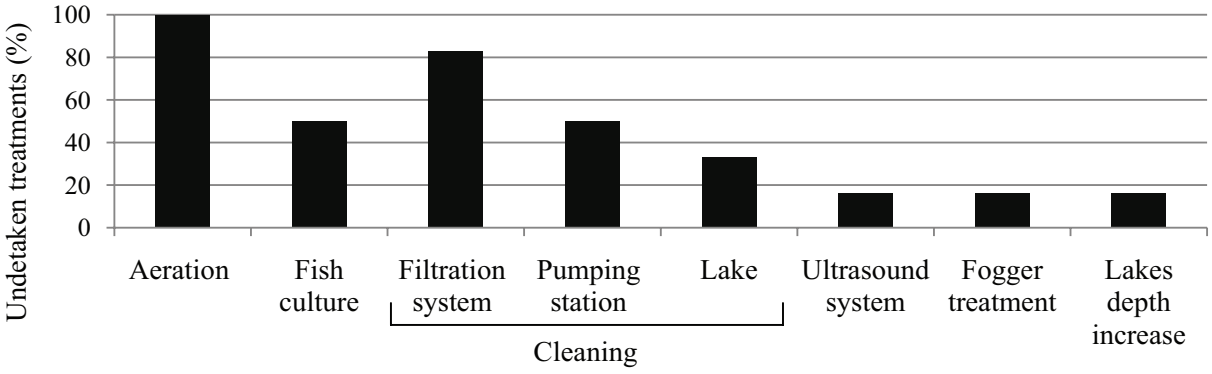

Fig. 3. Actions undertaken by Marrakech golf courses managers to overcome irrigation and water storage issues.

was automatic in third case. One golf course performed one cleansing per month while two performed 3–4 cleansings per year. However, pumping stations cleaning did not occur in fourth case. One golf course performed one cleaning per month and the last one cleaned it three to four times per year.

4.4. Turfgrass varieties

Riviera Bermuda grass (*Cynodon dactylon*) is the main turfgrass variety used in fairways. It is planted by five golf courses. Only one golf course's manager considers that its growth has been affected by RWW quality. Only one golf course uses *Paspalum pentium* in its fairways, and the golf course's manager was very satisfied with the performance of this turfgrass.

In their greens, golf courses use creeping bentgrass (*Agrostis stolonifera*). The cultivar PN A4 is the most common, whereas other cultivars are used such as PN G2 and T-1. It was noticed that some golf courses managers tended to change cultivars when extending golf courses. This was the case of a 27-hole course that used Bermuda grass when building an 18-hole course in 1992, but used creeping bentgrass for the construction of its 9-hole extension in 2006.

The use of *Agrostis stolonifera* is chosen for its tolerance to various stresses, including heat, drought, frost and resistance to low mowing heights (3 mm) [19]. Half of respondents stated that RWW did not affect directly *Agrostis stolonifera* and the other half claimed it caused longer germination periods, fungal diseases and rooting problems. Finally, four golf courses overseeded their fairways with rye grass (*Lolium perenne*) starting from October. This turf species did not show any particular problem regarding irrigation water quality.

4.5. Effect of RWW on soil in golf courses

Soils of the golf courses are clayey but in greens the texture is sandy. The RWW's pH and electric conductivity were on average of 8.1 and 2.4 dS/m, respectively. The major problems faced by golf courses managers were soil compaction and black layer formation. Respondents were asked to expose problems that they judged related to RWW quality (Fig. 4), and the actions they undertook in order to cope with those problems (Fig. 5). The main action was soil aeration (creating macropores in the soil) followed by a topdressing (adding sand), from two to four times a year, in order to increase infiltration, diminish black layer and improve soil texture.

4.6. Hygienic measures

Apart from signs that prohibit swimming in lakes without mentioning the source of the water and irrigation during closure time, no hygienic measures are taken by golf courses to protect players and resorts users. Two respondents said that they ask workers to put protection when they are in contact with RWW.

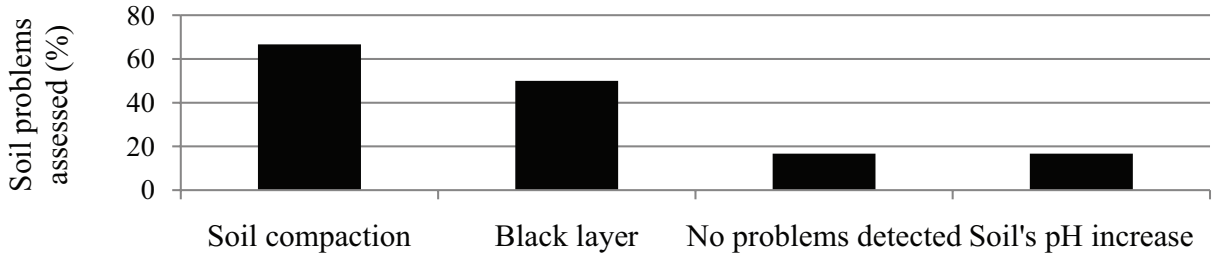

Fig. 4. Effect of RWW on soil according to golf courses managers.

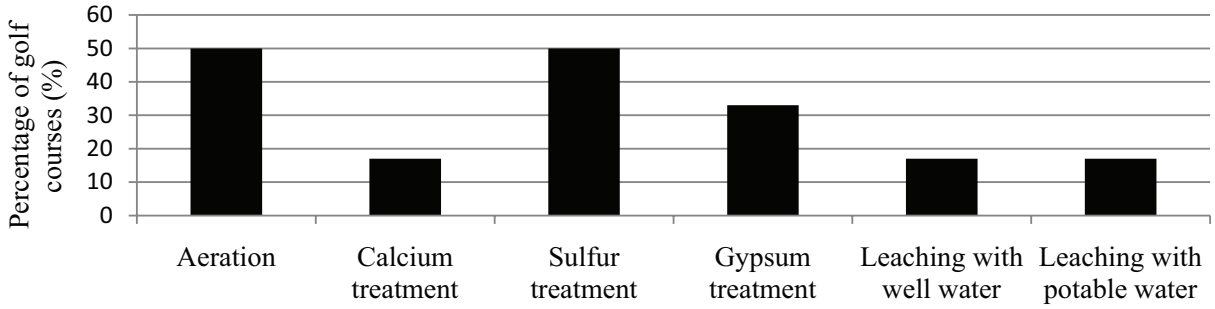

Fig. 5. Actions undertaken to overcome soil problems caused by irrigation with RWW.

5. Recommended measures for wastewater reuse in golf irrigation

The study showed that golf courses managers who are using RWW are having problems mainly related to irrigation systems and soil structure. Regarding irrigation systems issues, clogging was the major problem and was mostly induced by eutrophication occurring in storage lakes (five out of six surveyed golf courses). To solve this problem, three approaches should be taken into consideration:

- *Use of efficient filtration system*: According to our survey, all golf courses suffered from the clogging of the filtration system and the sprinklers, as a result of lakes eutrophication. In all studied cases, only screen or disc filters were used. Therefore, it is highly recommended to use pre-filtration using sand and gravel filters to remove suspended inorganic and organic fines [20]. In the surveyed golf courses only 50% use automatic flushing for filter cleaning and we recommend to use it for long-term operations to prevent clogging [17].
- *Improvement of water quality before it gets to emitters* [21]: Many options are available such as blending treated effluent with water having better quality [18], which is the case of one of the golf courses.
- *Improvement of conditions in storage facilities* [21]: Aeration which is used in all RWW storages in the golf courses surveyed reduces odors, increases dissolved oxygen [20], induces bacteria elimination and accelerates organic matter decomposition [22]. However, it can lead to more eutrophication as it induces the resuspension of phosphorus from the lake's bottom [23]. As a matter of fact, storage of RWW in water tanks tends to be a good alternative for future golf courses constructions. The initial cost of installing conventional storage lakes could be less than that of constructing covered tanks, yet the costs for lakes maintenance are generally higher [24]. Moreover, chemical treatments to eliminate algae and prevent their growth are not recommended [18]. As it is the case for 17% of the golf courses, copper salts are used widely as an algaecide [25]. It must be taken into consideration that copper sulfate is toxic to fish [26], and that over several years, the repeated cycle of algal blooms and aquatic weed followed by copper-based chemical treatments can result in an organic sludge with high copper contents developing on the bottom of the lake [18]. Finally, dredging shallow ponds to a greater depth is a good alternative [17]. This was undertaken by one golf course.

Furthermore, problems reported in soils were expected. According to authors in references [20–24,27], soil problems were declared to be prevalent when RWW was used. The occurrence of black layer in 50% of cases can be explained by anaerobic conditions of soil that permit the activity of anaerobic bacteria which metabolizes carbon using sulfur [28]. One way to deal with it is to have an effective surface and subsurface drainage [20].

To cope with soil problems, special consideration was given to soil aeration which is an important management practice in salt-affected environments. Amendment application was the second rated approach taken by golf courses managers. Physical and chemical amendments have been recommended by many studies to improve conditions of salt-affected soils, for example: (i) applying organic matter as a secondary amendment to supply nutrients for microbial activity, and induce soil aeration by improving its structure [29]; (ii) applying wetting agents which are surface active agents that reduce tension of water up to 50%–60%, improve the wettability of soil particles and organic matter [30], and increase the infiltration rate [31]. Furthermore, special

attention should be given to irrigation scheduling. A leaching fraction should be planned in order to leach salts near the turfgrass root zone and to avoid salt build up to toxic levels [32,33].

Finally, it is recommended to implement strict hygienic measures to protect players, resort users and workers [34]. Public exposure to RWW may induce health hazards due to inhalation, contact or accidental ingestion [35,36]. Thus, hygienic regulations should be firmly applied [37].

6. Conclusion

This study enabled us to assess the current situation of RWW reuse in golf courses in Marrakech and determine its constraints and benefits. The reuse of RWW offers multiple benefits as saving natural water resources and reducing fertilizers costs, but it also presents some limits that need appropriate management. Special attention should be given to storage facilities as their eutrophication causes serious problems of clogging. Therefore, we recommend the aeration of lakes, and the use of sand filters at the head station to prevent the clogging of the irrigation system. Furthermore, we believe that appropriate scheduling of both irrigation and cultivation operations (e.g., soil aeration) along with the use of salt tolerant turfgrasses are key solutions to salinity hazards.

The findings of this survey are of interest for current golf courses and for developers of future projects on the reuse of RWW, as well as stakeholders (organizations and companies) that are involved in wastewater production and reclamation in Morocco. As the golf industry tends to expand in Morocco and more golf courses will have to switch to RWW for irrigation, further studies must be undertaken in order to establish guidelines for the reuse of RWW in the golf industry at the national level.

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