Current Situation of Treated Wastewater Reuse in Golf Courses in Marrakesh (Morocco): Problems and Solutions

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Abstract
The region of Marrakesh, with a strong growth in urbanization, tourism, irrigation and population will suffer from increases in water demand. Therefore, a partnership between Moroccan Government , the State Board of Marrakesh (RADEEMA), the golf course developers, and the municipality launched a joint wastewater treatment and reuse project. This project was implemented with the aims to protect environment, to sustain tourism and urban development of the city and to satisfy the water requirements (24 000 m^3/day) of 18 Golf courses and city landscaping. However, so far only 8 golf courses are using treated 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 treated wastewater to irrigate golf courses was one of the reasons to conduct this survey.
This paper presents the results of a survey carried out in 2015, in six golf courses, out of the eight using reclaimed wastewater in this city. 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 including area, water consumption, water storage structures, soil type, irrigation systems, turfgrass varieties, and hygienic measures taken to protect public and employees, are reported. The survey showed a reluctance of golf courses managers towards the use of treated wastewater for irrigation, because it causes problems which are mostly related to irrigation system clogging and salinity affecting irrigation distribution and homogeneity and the green grass growth.
In the light of the results obtained, we suggested some practical solutions to promote treated wastewater reuse such as the use of efficient storage and filtration systems. In addition, some special amendments are recommended to cope with salinity damages in golf courses.

Keywords
Reclaimed wastewater; Marrakesh; Golf course; irrigation; turfgrass
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INTRODUCTION

Morocco has been facing a severe drought for the last twenty years; therefore, it was apparent for the decision-makers at the highest political levels that there is a need to find new solutions to the challenges of water resources management that are getting pressing. Within this framework, great efforts have been developed to reduce demand and search for new water supplies, to face drought and increased population growth. The reuse of treated wastewater could contribute to fill the gap, and reduce water resources pollution.
Within the context of increasing scarcity and degradation of water resources, wastewater reuse (WWR) appears as a good alternative for Morocco to reduce the gap. The WWR can indeed have several types of benefits, which vary depending on the circumstances, including: (i) the elimination of the impact of the waste water treatment plant effluent discharge into the natural environment, (ii) the recovery of an additional water resource for different possible reuses, and, consequently, (iii)conservation of fresh conventional water resources of the highest quality (required for demanding uses such as drinking water). Wastewater reuse possibilities in Morocco include

agricultural irrigation, watering golf course, municipal landscaping, ground water recharge and industrial uses (Bourziza & Makhokh 2011).

The golf sector is an important factor of national, regional and local economy. In the last decades, as a part of the National Tourism Strategy, golf courses development has been associated with mixed-use resort including residential complexes. As a consequence, a number of golf courses have emerged in many cities, and have made the country an important golf destination.

Marrakesh is a city located in a region suffering from water resources scarcity, and nowadays, it comprises eleven running golf courses and seven under construction. Clearly, in a region where water resources are already constrained, the rising demand for golf courses irrigation in conjunction with the continued expansion of the tourism sector will increase pressure on already limited water resources (Salama and Tahiri, 2013). The long-term threat of climate change with the likelihood of much drier summers and more frequent droughts would only exacerbate the current situation (Diaz et al., 2007). Therefore, the use of conventional water resources for golf courses irrigation is increasingly criticized and their replacement by reclaimed wastewater has become essential (Toze, 2006; Pedrero et al., 2010).

The promotion of golf courses as a pillar of touristic attraction in addition to the importance of reclaimed wastewater reuse in protecting the environment and preserving water resources are the driving forces of this research. We believe the findings of this survey are of interest for developers of future projects on the reuse of reclaimed wastewater in golf courses, as well as stakeholders (organizations and companies) that are involved or interested in the golfing sector in Morocco.

STUDY AREA

Marrakesh is part of the arid continental climate zone of Morocco. Climatic data obtained from FAO ClimWat database (data based on monthly average of a historical baseline of 30 years), show a monthly average temperature ranging from 4.4°C to 38.3°C. Monthly evapotranspiration ranges from 1.76 to7.01 mm/day with an average of 4.13 mm/day. Maximum precipitations occur in April and November while minimum rainfall is recorded in summer (June, July, August and September).

Table 1: Climatic data for Marrakesh (ClimWat, 2015)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain	mm	27	34	30	33	20	4	1	2	5	18	37	25
Min 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
Max 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/day	1.82	2.45	3.56	4.34	5.1	5.84	7.01	6.8	5.12	3.56	2.26	1.76

MATERIALS AND METHODS

In July and august 2015, an investigation conducted at the RADEEMA (Local agency dealing with wastewater treatment) offices, has enabled to collect official data about political, regulatory, financial, and technical frameworks related to the reuse of reclaimed wastewater in golf courses irrigation in Marrakesh. Moreover, it allowed gathering data about reclaimed wastewater consumed by all eight golf courses during 2012, 2013, and 2014.

In addition to that, a self-administrated questionnaire was carried out in six of the 8 golf courses that are using reclaimed wastewater for irrigation, which represent 75% of golf courses using reclaimed wastewater in Marrakesh. The choice of the golf courses surveyed was based on their accessibility. Five were running golf courses while one was under construction. Answers obtained were on site and the golf courses managers were assisted to fill up the form to ensure quality of responses.

The survey consisted of 32 questions subdivided into 6 main areas, including general information

about the golf course, water consumption, irrigation system, soil nature, turfgrass varieties, and hygiene measures. Some of the questions were open questions while others were multiple choices. Ambiguous responses to any questions have been recorded as unanswered. Estimated average time to complete the survey questionnaire was 30 to 40 minutes.
Respondents included 4 green keepers and 2 green keeper's assistants. All golf courses were connected to the reclaimed wastewater network in different months of 2012, except one that has been connected in June 2013. It is to mention that 67% of the golf courses surveyed were irrigated by reclaimed wastewater since their openings while 33% were supplied by *Zaraba* channel (surface water from a dam) and groundwater, before their connection to the treatment plant.
Data related to areas of golf courses were checked using aerial views of each course using AutoCad software. Data were analyzed using descriptive statistics (e.g. means, max., min.), using Microsoft Excel, in order to get a general view of frequencies of variables.

RESULTS AND DISCUSSION

Current state of the treatment and reuse of reclaimed wastewater in Marrakesh

Political and Financial Frameworks: In 2006, Morocco launched the National Sanitation Plan (NSP), which aimed for an integrated water management and the mobilization of unconventional water resources. Among the objectives of this plan is to raise the use of treated wastewater in golf courses, green spaces and irrigated crops to 300 million m^3/year by 2030 (FAO, 2011). In this context, a project for the reuse of reclaimed wastewater in golf courses of Marrakesh has been launched under a public-private partnership. The RADEEMA as a concessionaire, in collaboration with the Moroccan government and golf courses holders, have initiated a one billion Moroccan dirham (120 million USD) project, which includes a wastewater treatment plant and a treated wastewater distribution network across the city (Klingbeil *et al.*, 2014). According to the technical office of RADEEMA, the project was financed up to 12%, 40% and 48% by respectively, the government through its Ministry of the Interior and the Secretariat in charge of Water and Environment, fifteen golf courses promoters and RADEEMA. The financial contributions of each golf course promoter, the regulations related to water allocations and quality, added to the price of reclaimed wastewater that was set to 2.5 MAD/m^3 (VAT free), was governed by specific contracts. The project started by the end of 2010, supplying six golf courses. To date, it supplies eight golf courses and the seven other signatory promoters will be connected in the future.

Regulatory framework: As part of the Decree No. 2-97-787 (4 February 1998) on water quality standards, the contractual regulations of the reuse of reclaimed wastewater in golf courses in Marrakesh are governed by the regulations of the Order 1276-01 enacted on the 17th of October 2002 dealing with the quality standards for irrigation water. Thus, the minimum number of water samples to be analyzed for conformity with irrigation standards shall be as follows:
- 4 per year at the rate of 1 per quarter to analyse heavy metals;
- 24 per year at a rate of 1 every 15 days to analyse bacteriological, parasitological and physicochemical parameters.

As a result, every 15 days, samples were taken in each golf course in order to evaluate BOD5, Suspended Matter (SM), Total Kjeldhal Nitrogen (TKN), Total Phosphorus (TP), Chloride (Cl) and fecal germs. Analyses are performed by RADEEMA in its laboratories. However, comparison between standards mentioned in the contracts between the concessionaire, the golf courses promoters and standards set by the Order 1276-01 showed differences presented in table 2.

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

	BOD 5	SM	TKN	TP	Cl	Fecal Germs
	Mg/L O_2	Mg/L	Mg/L	Mg/L	Mg/L	U/L
Regulations adopted in the project	10	5	5	10	<500	2000
Regulations adopted in the 1276-01 Order	-	100	-	-	15	200

The wastewater treatment: The wastewater treatment plant provides 33 million m^3/year, and is connected to golf courses through a supply network of 80 km, using 4 pumping stations. A fifth pumping station is under construction. The pre-treatment consists of grit and grease removal from wastewater. The primary treatment consists of water decanting, and the secondary treatment employs sludge to degrade biological matter from sewage. It is based on aeration in biological activation basins. At last, the tertiary treatment consists of coagulation and flocculation, sand filtration and disinfection by ultraviolet lamps and chlorine.

General data of the surveyed golf courses

Golf courses areas: The total area of the golf courses surveyed is 349 ha. All golf courses are integrated in residential complexes. Sixty-six percent of them are 18 holes with a total course area ranging from 43 to 60 ha. The 27-holes golf courses have in average, an area of 70 ha.
Total greens areas range from 1.3 to 1.7 ha for 18-holes courses and reaches 2 ha in 27-holes courses. Average area of greens is 800 m^2. Average area of fairways is 6.1 ha and the number of lakes ranges from 3 to 6 for each golf course.

Table 3: Average percentage of components areas in the surveyed golf courses

	Green	Bunker	Rough	Lake	Fairway	Practice + Tee
Average area percentage	3	3	35	8	44	7

Irrigation system: The survey has shown that all golf courses run their irrigation through a centralized management system: 83% use TORO irrigation system, while 17% are using Rain Bird equipment. Moreover, in order to adapt irrigation to turfgrass requirements, 67% use agro-meteorological stations and 33% a sensor for measuring soil humidity.
After its delivery from the treatment plant to the golf course through the main pipeline, the reclaimed wastewater is stored in lakes with volumes ranging from 50 000 to 92 400 m^3.
Afterwards, it is pumped, filtrated and distributed through pipelines to sprinklers. The group of 18-holes golf courses is equipped at equal halves with 6 and 5 pumps. However, in the 27-holes group, 50 % is equipped with 6 pumps while the other half is equipped with two pumping stations: A five pumps station for 18-holes and a 4 pumps station for the remaining 9 holes.
The flow rate with 6 pumps ranges from 50 to 70 m^3/h. It ranges from 70 to 500 m^3/h for five pumps system, and it is equal to 135 m^3/h for the 4 pumps one.
The study has shown that in terms of filtration, 83% of the golf courses surveyed are equipped by a screen filtration station while 17% have a disc filtration station. In terms of drainage, the drainage system in use evacuates water to sumps (66%), lakes and sanitation network.

Water management of golf courses under irrigation with reclaimed wastewater in Marrakesh

Reclaimed wastewater consumption: Since its beginning in April 2012 until December 2014, the project of reclaimed waste water reuse in golf courses in Marrakesh has saved a total of 11.3 Million $m^3$of fresh water resources. Although volumes of reclaimed wastewater used vary from a golf course to another, results have shown correlation between seasons and water consumption

(Figure1). Low consumptions were recorded every year, between November and April due to precipitations occurrence, low evapotranspiration rates and turf dormancy. However, the hot season (May to September) corresponds to the period of greatest water use due to high evaporative demand and rare precipitations (Table 1).

Moreover, when analysing the relationship between reclaimed wastewater consumption and number of holes in golf courses, similar volumes have been found for the 27-holes group and the 18-holes one. However, volumes of reclaimed wastewater used in 27-holes golf courses were significantly lower than those used in 18-holes ones (Figure 2). This was contradictory to results found in a survey in the United States in 2006 (Throssell *et al.*, 2009), that found that average water consumed in 18-holes golf courses represented 39.5% of the water used in 27-holes ones.

On the other hand, analysis of water consumption data in 2014 when all the surveyed golf courses were supplied by the treatment plant showed that courses consumed an average of reclaimed wastewater equal to 15,671 m^3/ha/year ranging from 5,945 to 28,836 m^3/ha.year. Although this average is believed to be higher due to the use of other water resources (groundwater), comparison with average irrigation water used in Spain have been found lower (Diaz *et al.*, 2007). Indeed, a general survey done by Diaz *et al*. in 2004, using the same methods, i.e. visiting courses and green-keeper interviews, found an average water consumption equal to 8,200 m^3/ha (Diaz *et al.*, 2007).

To summarize, differences in volumes of water consumption varies based on:

- Management practices like the conjunctive use of reclaimed wastewater with other water resources, or cultivating Ray Grass that has shown significantly higher water requirements especially in cold seasons.
- Technical knowledge of golf course's manager.
- Market positioning and budgets allocated to irrigation water.
- Golf course's equipment.

Irrigation and water storage: Clogging of irrigation system and eutrophication of lakes are the major issues faced by the golf courses (Figure 3). This causes a reduction in emission uniformity and consequently decreases the irrigation efficiency (Capra and Scicolone, 2004). Furthermore, it causes bad odors and proliferation of mosquitoes that disturb players and impact properties sales.

A report by HYGIUP laboratory, made in 2014 for the benefit of a surveyed golf course showed the occurrence of biological clogging in a high rate, chemical clogging in low rates, and no mineral clogging. The same report showed a strong proliferation of filamentous species that were mainly bryozoans and bacterial bio-films.

The actions undertaken by golf courses managers aimed mainly at removing organic clogging from lakes and irrigation systems (Figure 4). Aeration is the major action done to cope with this issue. Indeed, it has been found to reduce odors and increase dissolved oxygen (Carrow et al., 2008). However, although it is recommended in the literature to clean reservoirs every 3 to 5 years in order to avoid sludge accumulation in the bottom (Lazarova and Bahri, 2004), no reservoir cleaning has ever been performed. Lakes were in 33% of the cases cleaned manually on the surface in order to remove algae.

The filtration system cleaning was automatic in 50% of the cases. Seventeen percent performed one cleansing per month and 33% performed 3 to 4 cleansings per year. However, pumping stations cleaning did not occur in 67% of the cases, while 33% performed by half respectively, 1 cleaning per month and 3 to 4 cleanings per year.

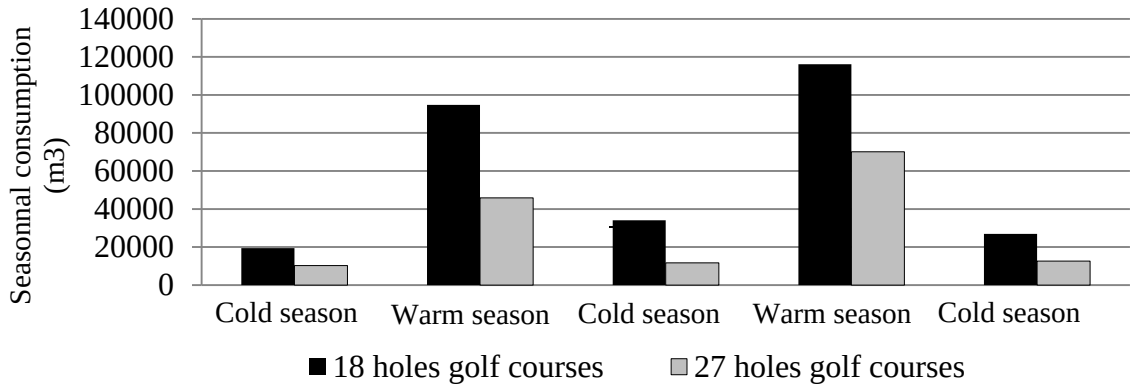

Figure 1: Average seasonal consumption of reclaimed wastewater in 18 and 27-holes golf courses in Marrakesh from April 2012 to December 2014.

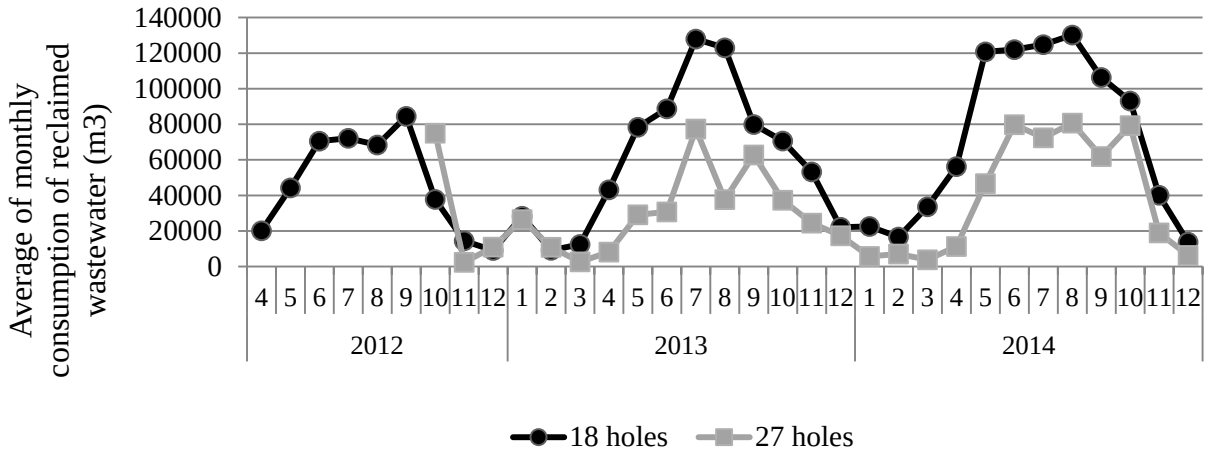

Figure 2: Average reclaimed wastewater consumption in 18-holes and 27-holes golf courses in Marrakesh (2012, 2013, 2014)

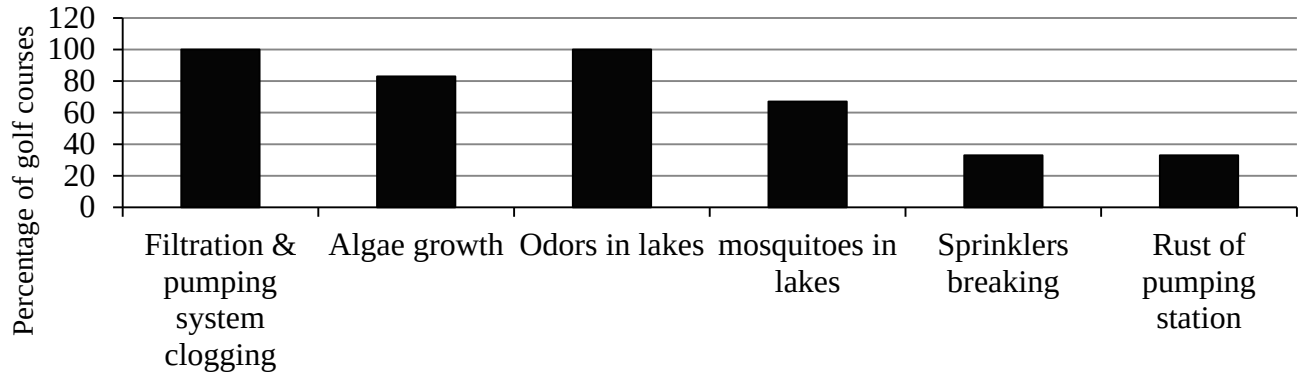

Figure 1: Percentage of golf courses surveyed facing negative impacts of reclaimed wastewater on storage lakes and irrigation system in Marrakesh

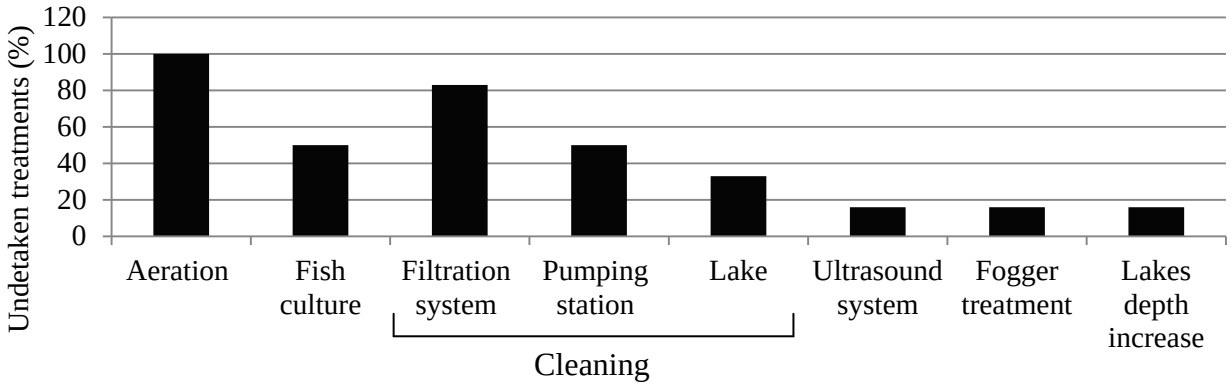

Figure 2: Actions undertaken by Marrakesh golf courses managers to overcome irrigation and water storage issues

Turfgrass varieties

Riviera Bermuda grass is the main turfgrass variety planted in fairways (83%). Seventeen percent consider that its growth and stolonisation has been affected by reclaimed wastewater quality while 83%consider it has not. Seventeen percent of golf courses use *Paspalum pentium* in their fairways, and assess that it is not affected by irrigation water quality.

In their greens, all golf courses use *Agrostis stolonifera*. However, it was noticed that a 27-holes course uses this variety in its 9-holes'extension constructed in 2006,while using Bermuda grass for the initial 18 holes constructed in 1992.This is explained by the fact that the 18-holes were built in 1992, while the extension was constructed in 2006. The use of *Agrostis stolonifera* was chosen for its tolerance to various stresses, including drought, heat, frost and withstanding low mowing heights (3 mm) (Valverde, 2007). Fifty percent of respondents stated that reclaimed wastewater did not affect directly *Agrostis stolonifera*. Others claim it causes longer germination periods, fungal diseases, and rooting issues. Finally 67% of golf courses over-seed their fairways with *Ray Grass* starting from October. This turf species did not show any particular problem regarding irrigation water quality.

Golf courses soils under irrigation with reclaimed wastewater

Soils of the golf courses are clayey, with specified sandy texture in greens. The reclaimed wastewater pH and electric conductivity were on average 8.1 and 2.4dS/m respectively. The major problems faced by golf courses managers were soil compaction and superficial black layer formation. Respondents were asked to expose problems that they judged were in relation with reclaimed wastewater quality (Figure 5), and actions they take in order to cope with those problems (Figure 6).The main action was soil aeration by creating macro-pores followed by a topdressing, from two to four times a year, in order to increase infiltration and improve soil texture.

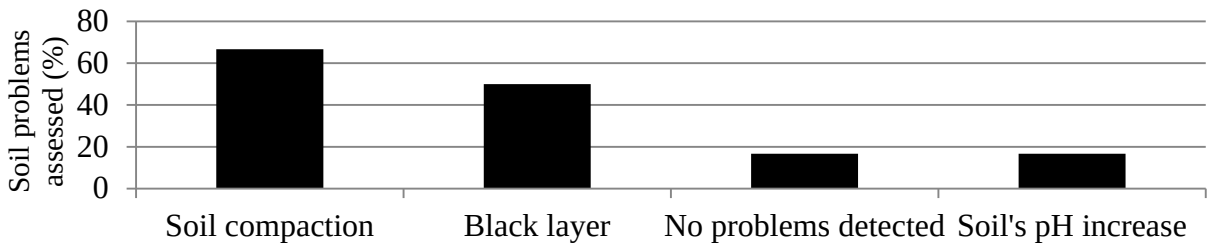

Figure 5: Responses of golf courses managers to negative impacts of reclaimed wastewater in golf courses in Marrakesh

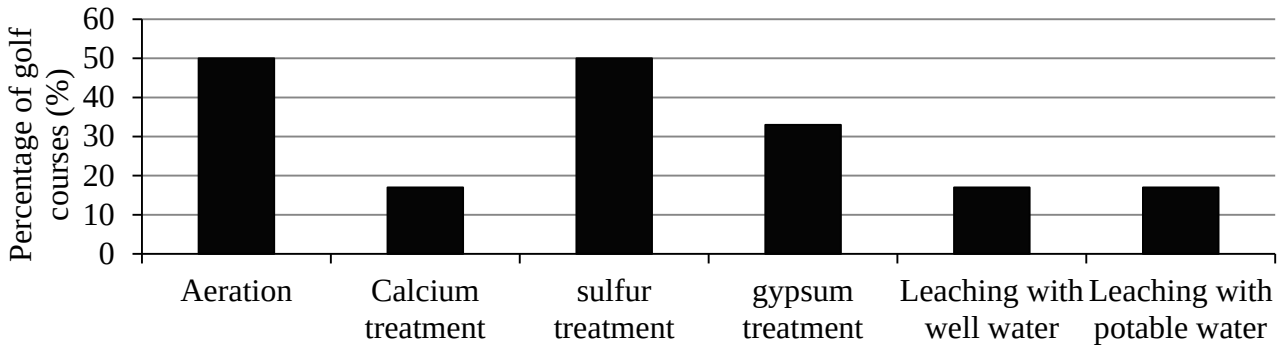

Figure 6: Actions undertaken to overcome soil problems caused by irrigation with reclaimed wastewater in surveyed golf courses in Marrakesh

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 clients. Thirty-three percent of respondents asked workers to put protection when they are in contact with reclaimed wastewater, but no hygienic measures were undertaken by employees.

RECOMMENDED MEASURES FOR WASTEWATER REUSE IN GOLF IRRIGATION

The study showed that golf courses managers using treated wastewater are having problems mainly related to the irrigation systems and soil structure. As regards to irrigation systems issues, clogging and development of algae were the main problems and occurred in storage lakes in 83% of the golf courses surveyed. To solve this problem, three approaches should be taken into consideration: (i) The first one is to use an efficient filtration system. Screen filtration is used with a rate of 83% of golf courses, according to our survey. However, aquatic algae in the water tend to cause screen blockage and can reduce the filtering capacity (Bucks *et al.*, 1979).Therefore, sand and gravel filters are recommended before screen or disc filtration in order to remove suspended inorganic and organic fines (Carrow *et al.*, 2008). Automatic flushing for filter cleaning is also essential for long-term operations (Capra and Scicolone, 2004), however it is used only by 50% of golf courses surveyed; (ii) The second alternative is to improve the quality of water before it reaches emitters (Tajrishy *et al.*, 1994). Many options are available like blending treated effluent with conventional sources of water (Lazarova and Bahri, 2004). This is the case of 17% of golf courses (Bensari *et al.*, 2014); (iii) The third approach is to improve conditions in storage facilities (Lazarova *et al.*, 2001). Indeed, aeration which is used in all reclaimed wastewater storages in the golf courses surveyed reduces odors and increases dissolved oxygen (Carrow *et al.*, 2008). In addition, storage of irrigation water in water tanks shows to be a good alternative for future golf courses constructions. The initial cost of constructing storage lakes with liners may be less than that of installing covered tanks, yet the maintenance cost of the lakes is generally higher (Harivandi, 2007). Moreover, chemical treatments to kill algae and prevent their growth is not recommended (Lazarova and Bahri, 2004). As it is the case for 17% of the golf courses, copper salts are used widely as an algaecide (Bucks *et al.*, 1979). However, it must be taken into consideration that copper sulfate is specifically toxic to fish (Schrader *et al.*, 1997), and that over several years, the repeated cycle of aquatic weed and algal blooms followed by copper-based chemical control can result in an organic sludge with high copper contents developing on the lake bottom (Lazarova and Bahri, 2004). Besides, it was also found in the literature that dredging shallow ponds to a greater depth that was undertaken in 17 % of golf courses is a good alternative (Carrow *et al.*, 2008).

Furthermore, problems reported in soils were expected. In the literature, it was found that soil issues

are prevalent in sites irrigated with reclaimed wastewater (Harivandi, 2007; Carrow *et al.*, 2008, Duncan *et al.*, 2000). The occurrence of black layer in 50% of cases is a proof of the presence of one or more of its causes. Black layer can be induced by migration of colloidal particles (clay or organic material), salt deposition, naturally occurring sulphur-containing organic matter layers or irrigation water sources that are high in sulphur as a secondary contributor, and biological contributors (Cyano-bacteria that produce gel-like substances and other bacteria that produce bio-films that plug pore spaces, creating anaerobic subsurface conditions) (Carrow *et al.*, 2001). It can be avoid by positive surface and subsurface drainage (Carrow *et al.*, 2008).

Furthermore, in all the golf courses surveyed, special consideration was given to aeration. Indeed, it is an integral part of regular management in salt-affected environments (Duncan, 2000). In addition, amendments were the secondly rated approaches taken by golf courses to cope with soil problems. Indeed, a number of chemical and physical amendments have been discussed for use on salt-affected soils, in order to improve soil physical conditions as (Carrow *et al.*, 2011): (i) Applying soil and water amendments, such as gypsum (calcium sulphate) and calcium chloride can reduce the negative effects of sodium and bicarbonate and improve water/soil pH and partially help with salinity control (Harivandi, 2007); (ii) Applying organic matter as a secondary amendment to assist in stabilizing aeration and moisture dynamics in the soil and to provide nutrients for microbial activity (Carrow *et al.*, 2011); (iii) Wetting agents are surface active agents that reduce tension of water up to 50%–60%, enhance the wettability of soil particles and organic matter (Karnok *et al.*, 2004), and increase the infiltration rate (Morgan *et al.*, 1966).

To sum up it is recommended to implement strict hygienic measures to protect clients and workers. Public exposure to recycled water may induce health hazards due to inhalation, contact, or accidental ingestion. Thus, firm regulations are highly recommended (Lazarova and Bahri, 2004).

CONCLUSION

The Moroccan Government decentralized responsibility for water supply and sanitation services to the municipalities, and left to them the right to choose how to manage service provision from a menu of several choices. Morocco has introduced autonomy and privatization to urban water supply and an ambitious sanitation national plan with an objective to reduce total water pollution by 60% was developed. This is achieved through working with stakeholders and local agencies government to address and formulate the national policy on the role of reuse in Morocco. Until 2014, the project of reclaimed wastewater reuse has saved up to 11.3 Million m^3 of fresh water resources. Hence the importance of an assessment of the current situation in the golf courses reusing this unconventional water resource, in order to determine the limits and the benefits of such projects.

The survey we have done has revealed an average of reclaimed wastewater consumption equal to 15,671 m^3/ha.year with a high variability from a golf course to another (from 5,945 to 28,836 m^3/ha.year). The survey showed the occurrence of development of algae and irrigation system clogging. This can be limited by proper storage structures and a suitable filtration system which includes sand filters, that are highly recommended in cases where clogging is caused by organic components. Problems in soil such as soil compaction and black layer were also reported to be prevalent.

Reuse of reclaimed wastewater offer multiple benefits but present also some limits that needs appropriate management. As the golf industry tends to expand in Morocco, and more golf courses will have to switch to reclaimed wastewater for irrigation, further investigation must be undertaken in order to have a national guidelines and best practices of reusing reclaimed wastewater in the golf industry.

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