MADFORWATER

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MADFORWATER

DevelopMent AnD application of integrated technological and management solutions FOR wasteWATER treatment and efficient reuse in agriculture tailored to the needs of Mediterranean African Countries

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Public abstract relative to the results obtained in WP2 on the wastewater treatment technologies

WP2 of the MADFORWATER project aims to develop and/or adapt to the local conditions of the 3 target Mediterranean African countries (Morocco, Tunisia and Egypt) technologies for the treatment of different types of wastewater, in order to obtain effluent compositions complying with the quality standards set by international and national guidelines for reuse in irrigation. The considered wastewaters were i) municipal wastewater (MWW), ii) drainage canal water (DCW, in the Egyptian context only), iii) agroindustrial WWs (olive mill WW, OMWW, and fruit and vegetable packaging WW, FVPWW) and iv) textile WW (TWW).

With the exception of drainage canal water, for which a single treatment technology has been proposed (canalized facultative lagoons), different technologies have been investigated for each WW type, in order to identify the most suitable treatment trains.

Municipal wastewater treatment technologies included secondary treatment in trickling filters filled with innovative high specific-surface carriers, and tertiary treatments aimed specifically at further N, P and pathogens removal (canalized facultative lagoons), at the removal of emerging organic pollutants and heavy metals (constructed wetlands, in combination or not with the application of plant growth promoting bacteria), at the removal of pharmaceuticals (immobilized laccase reactors) and at disinfection (TiO_2-coated catalytic disinfection beds). Traditional and advanced methods for monitoring pathogens and viruses removal, as well as antibiotic resistance, have been also tested and further developed.

For olive mill wastewater, a secondary treatment in aerobic sequenced batch reactors (SBRs) was developed and compared with a combined treatment and valorization option based on microfiltration, polyphenols recovery via adsorption/desorption and anaerobic biomethanation.

Technologies investigated for fruit and vegetable packaging wastewater treatment included a dissolved air flotation/flocculation integrated process, to be used either as primary treatment or donwstream the biological treatment in moving bed biological reactors, as well as immobilized laccase bioreactors as a tertiary treatment specifically aimed at the removal of residual fungicides.

Finally, technologies investigated for textile wastewater included coagulation-flocculation as primary treatment, moving bed biologial reactors and granulated sludge aerated bioreactors as secondary treatment options, immobilized laccase bioreactors and dyes adsorption/desorption with innovative resins as tertiary treatments aimed at the specific removal of residual dyes. An alternative approach consited in decolorization through adodyes reduction with zerovalent iron, followed by enzymatic (immobilized laccase reactors) or microbial degradation of the reduction products.

The investigated technologies were evaluated and optimized in terms of removal performances in relation to the main target pollutants. Overall, the results obtained provided the technical elements to be used, along with the LCA, CBA and the stakeholders feedback, for the selection of the most suitable treatment trains to be implemented in the MADFORWATER pilots for the treatment of the target wastewaters. In particular, the most promising train for municipal wastewater consisted in biological treatment in trickling filters followed by chemical disinfection and tertiary treatment in constructed wetlands. Canalized facultative lagoons proved very promising for the in-stream treatment of drainage canal water, provided that the depth of the existing drainage canals is increased to approximately 2 m. As regards agro-

industrial wastewaters, effluent water qualities suitable for reuse in irrigation could not be achieved for olive mill wastewater, despite both technologies investigated were able to remove a large fraction of polyphenolic compounds and BOD. Conversely, a promising treatment train was identified for fruit and vegetable packaging wastewater, consisting in biological treatment in a moving bed bioreactor followed by adsorption of residual dyes with powdered activated carbon combined with dissolved air flotation. Finally, the most promising treatment train for textile wastewater consisted in a pre-treatment via coagulation-flocculation with polyaluminium chloride, followed by biological treatment in moving bed bioreactor and a post-treatment for residual dyes removal with anions exchange adsorption resins.

The results of the LCA conducted for each technology indicate that most technologies have positive environmental benefits when applied for the treatment of the wastewater. Only fruit and vegetable packaging wastewater, when treated in Morocco, does not show an actual environmental benefit. In all cases the avoided water abstraction due to water reuse for agriculture is the most significant contribution to the positive environmental impacts, reinforcing the importance of water reclamation and reuse. The results of the cost-benefit analysis show that, while some treatment trains are characterized by an acceptable discharge price required for financial stability, or even by a net gain (municipal wastewater treatment with constructed wetlands as tertiary step, textile wastewater treatment with dyes adsorption, drainage canal water treatment by means of lagoons), several other treatment trains need a further optimization in order to find an actual implementation. Moreover, the 2 treatment trains that include an enzyme bioreactor are characterized by an excessively high cost. The economic assessment of the canalized lagoons for the treatment of drainage canal water has a positive outcome, mainly because of the very low investment cost associated to this technology.

Public abstract relative to the results obtained in WP3 on the irrigation technologies

Work Package 3 of the MADFORWATER project aims to investigate several technological and non-technological solutions to reduce water vulnerability and the impact of water scarcity on agriculture in Egypt, Morocco and Tunisia. Activities have been addressed both to enhance the reuse of treated wastewater and to attain a consistent increase in agricultural water use efficiency, that could potentiate the contribution of reused treated waste water as per the communication from the Commission to the Institutions COM (2012)673.

WP3 is the main pillar of the water demand approach of the MADFORWATER project, that recognizes the crucial role of treated wastewater reuse as an answer to the water crisis in the selected Mediterranean African Countries (MACs). In these countries, agriculture accounts for 80-85% of freshwater consumption and is mostly based on inefficient irrigation and agricultural practices, causing high water losses. On the other hand, only 54% of produced wastewater is currently treated in these countries, and only 7% of the produced wastewater is reused.

Technologies have been developed and tested at laboratory scale during months 1-19. Then they have been tested at pre-pilot scale. Conditions and scenarios similar to those of the 3 selected basins in the 3 target MACs have been simulated to be adapted to the local context of the target countries.

The main results obtained in WP3 for the different irrigation technologies tested can be summarized as follows:

1) The screening of plant growth promoting bacteria led to select biological resources having the potential to improve crop growth and to increase productivity under water deficit. The experiment carried out in the greenhouse on tomato crop showed an increase of plant biomass and fruit productivity under water deficit conditions confirming that all the selected bacteria resources are good candidates as biostimulants form MAC crops. Field experiments are being carried out in WP4 using the most efficient bacterial consortia. Two types of plantations have been chosen and are currently under test, namely durum wheat (Triticum durum) and maize (Zea mays). Several factors will be tested including bacterisation, irrigation water (tap water/treated wastewater), devices used for irrigation (commercialized/ innovative nozzles), irrigation controlled or not by SIM software.

2) The development of an innovative tensiometer suitable for dry and highly saline soils is progressing. The results obtained so far indicate some difficulty in the obtainment of a unified calibration curve valid for different types of sensors. The manufacturing process of the porous media needs to be improved.

3) Results obtained by means of the Safe Irrigation Management (SIM) model indicate that the management strategies typically adopted by farmers in Morocco do not induce water stress or yield reduction, but consume considerable amounts of water and induce important drainage volumes. The irrigation management using treated wastewater and based on the SIM model did not have a significant effect on crop yield (4% decrease), but it allowed great savings in terms of fertilizers. These fertilizer savings have both economic and environmental impacts, as they lower the production costs and reduce chemical effects on the local environment.

4) A low-cost mini-sprinkler was produced, having high resistance to clogging related to the use of treated wastewater and minimizing pathogen risk dissemination to farmers and consumers via aerosols. This was obtained by managing the size of droplets and minimizing the generation of droplets of less than 500 µm at low operating pressure (<200 kPa). The development of an optimized prototype is in progress.

5) Experimental prototypes of calibrated nozzle have been produced and tested regarding their anti-leakage capacity, to minimize pressurization time of the distribution system and hence allow short irrigation time with high discharge emitters without generating runoff. The objective has been reached with a pressure equal to around 0.4 bar. Numerical modeling has been operated to better understand the hydraulic behaviour of the nozzle. Simulations clearly show that the membrane doesn't have any effect on the discharge but effectively closes the inlet of the emitter at low pressure values and maintains the anti-leakage capacity. The next step will consist in the addition of the hydraulic pressure compensation properties to the calibrated nozzle.

6) Modified gated pipe systems, with proper management, can significantly enhance the irrigation performance in terms of Application Efficiency (AE) and Distribution Uniformity (DU). Furthermore such system consumes less energy with respect to any other pressurized irrigation. In the experimental field test, the modified gated pipe raised the performance by 11% in terms of AE and 17% in DU. The proposed system could also be a winning alternative in regions distinguished with seasonal water availability or rotational schedules (high fixed discharges and small fixed durations), flat topography and traditional legacy of surface irrigation, where low

irrigation performance can mainly be ascribed to mismanagement rather than water scarcity. In addition, it is expected that the system will have a positive environmental impact by reducing the drainage of polluted water due to the improvement of the application efficiency and distribution uniformity. This leads to a reduced application time. In fact, the drainage volume measured in the field test with gated pipe was less than half of the value obtained with traditional surface irrigation, for a comparable Distribution Uniformity. Finally, the total amount of irrigation water supplied by the gated pipe system was 34% lower than the amount of water supplied with the traditional furrow irrigation. In the framework of WP4, the application of the gated pipe in a pilot farm selected inside the Lake Manzala Engineered Wetland research station (Egypt) is in progress.

7) The software package OptGate proved to be very useful and relevant for the optimal design of complex irrigation systems. Therefore, it could be effectively used to optimize the design of new modern systems in the Nile Delta, currently under development in Egypt. It can also be used to analyze existing irrigation systems for identifying failures in terms of discharge and/or pressure at the nozzles. OptGate has been applied in order to design the irrigation system of field test in the Menzala Lake station (Egypt). The results allowed to obtain a set of pipe diameters having minimum cost and fully satisfying both the upstream constrains (discharge and pressure at the pumping station) and the downstream constrains (minimum presser and discharge at the nozzles).