APOC technology as an eco-innovative decentralized sanitation system for wastewater treatment and reuse facilities in the rural locality of Bent Saidane-NE Tunisia

CHAABANE S.[1,*], GHATTASSI A.[1], MENSI K.[1], M'HIRI F.[1] and PLAKAS K.[2]

[1] Direction of Transfer and Technological Innovation, Tunis International Center of Environmental Technologies (CITET), Boulevard of leader Yassar Arafat, ZI Charguia, 1080 Tunis-Tunisia

[2] Chemical Process and Energy Resources Institute, Centre for Research and Technology-Hellas, 6th km Charilaou-Thermi Road, 57001, Thermi-Thessaloniki, Greece

*corresponding author:
e-mail: chaabane.safa.esim@gmail.com

Abstract. Decentralized wastewater treatment systems (DEWATS) in rural areas can be a smart alternative that helps communities to strengthen rural sanitation in improving clean water and sanitation management. To address these challenges, AquaCycle project, funded by the European Union under the ENI CBC MED Program, aims to bring an eco-innovative APOC system that combines anaerobic digestion (AD), constructed wetland (CW), and solar photocatalytic oxidation (SPO) for decentralized wastewater rural sanitation in a cost-effective, economic, green, sustainable, and environmental healthy, manner. The APOC system will be established in the rural locality of Bent Saidane (Governorate of Zaghouan, Northern East of Tunisia) as an appropriate implementation site with a 90.12 km^2 area and a flow capacity of 5 to 25 m^3/day. About one hectare will be planned for treated wastewater irrigation purposes. Based on the annual average values of the physicochemical and bacteriological raw wastewater quality, a spontaneous biodegradability was noted. Compared to conventional wastewater systems, APOC system will provide reliability, affordability, environmental and financial benefits, that make such system particularly appropriate for rural sanitation in relation to the transition to the circular economy.

Keywords: decentralized wastewater treatment, anaerobic digestion, constructed wetland, solar disinfection, Bent Saidane Tunisia.

1. Introduction

Improvement in sanitation, global health and consequent reduction in the spread of disease depends largely on the availability of health facilities, good hygiene practices and reliable collection, treatment and reuse of wastewater. The World Health Organization (WHO) estimates that 2 billion people lack access to any type of sanitation equipment and wastewater collection systems where 673 million still defecate in the open, for example in street gutters, behind bushes or into open bodies of water. At least 10% of the world's population are thought to consume food irrigated with wastewater (WHO/UNICEF, 2019). Water resources in the Mediterranean countries, are subjected to many pressures related to water quality pollution, anthropogenic activities, urbanization and climate change (Bahri et al., 2016). These pressures reached the UN-Sustainable Development Goal 6 (SDG 6) and Goal 13 (SDG 13) to strengthen the rural sanitation in improving clean water and sanitation management that build local economic growth, address a range of social needs, while tackling climate change and environmental protection (UN, 2018). DEWATS can provide a smart green alternative solution for small communities to tackle climate change impact on water resource, if properly designed, maintained, and operated to provide optimum benefits of sustainability. Today, decentralized wastewater treatment can also provide the safety and reliability of conventional large-scale wastewater treatment, and can also offer many additional benefits to communities (USEPA, EPA)

Water resources in Tunisia are subjected to many pressures related to urbanization and anthropogenic activities which will be exacerbated by climate change. In spite efforts of Tunisian governments who struggle to prioritize rural sanitation in the national agenda and make progressive financial commitments (75% urban vs. 25% rural WASH funding), the sanitation crisis is still acute in rural areas. According to WHO reports, 82 diarrhea deaths attributable to WASH were identified. The use of improved sanitation facilities (2012) for 88% of urban and only 10% of rural population (2014) was declared by WHO/UNICEF (2014).

The main objective of the AquaCycle project is to provide research and development support for sustainable non-conventional water resources management (NCWR) through participatory governance and low-cost eco-innovative technology to enhance rural sanitation in the Mediterranean's Regions especially for Tunisian rural localities. The eco-innovative APOC System stands for "AD", "SPO" and "CW" for sustainable WWTR in the rural locality of Bent Saidane. The attributes of the implementation of the WWTP demonstration unit in Bent

Saidane case study, would support decentralized sanitation facilities to achieve equitable and sustainable sanitation in Tunisian rural areas.

2. Geographic localization of Bent Saidane locality

The locality of Bent Saidane is a rural community belonging to the delegation of El Fahs, Governorate of Zaghouan. It is an agricultural area located in the North East of Tunisia (Figure 1). It lies between latitudes 36° 11' 42.774" N to 36° 19' 53.956" N and longitudes 9° 53' 21.322" E to 9° 59' 53.997" E. The total area is approximately 90.12 km^2. This area is mountainous with heights between 186 and 932 m above sea level and majority of the slope is lower than 15°. It is crossed by temporary Wadi El Gouissate where the wastewater is discharged. From a geological point of view, 32.8% of the area are lower cretaceous, 26% Quaternary and the rest is mainly Lias-Dogger and Vraconian-Turonian. According to the map of groundwater resources of Tunisia, the locality of Bent Saidane has a water table at a depth of 30 m. The region's natural vegetation is mainly cereals, shrubland, forest and olive trees. The totality of this area presents healthy soil.

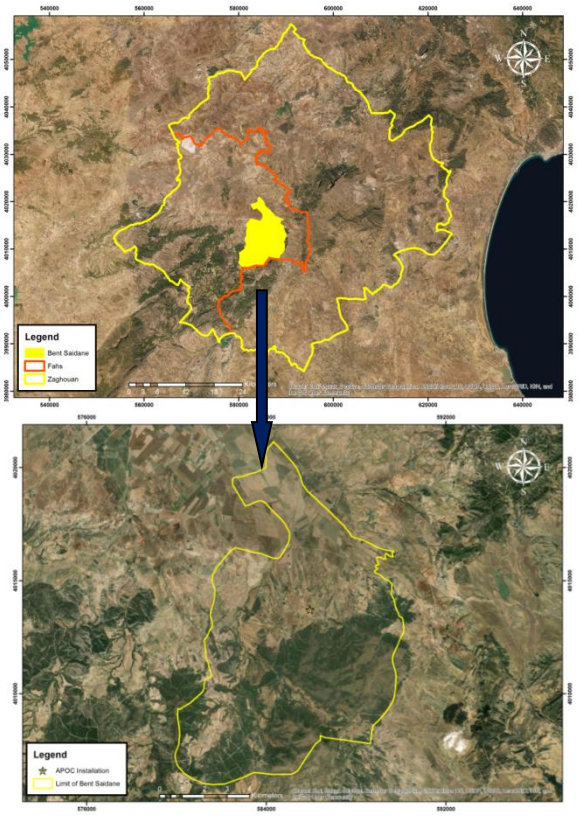

Figure 1. Site localization of the APOC system

The average annual precipitation is of the order of 682.55 mm in 2019. The bioclimate of Bent Saidane locality is Mediterranean semi arid, characterized by the predominance of drought in summer and the regime of concentrated rains in winter. The annual average temperature is about 17.69 °C, maximum temperatures are around 36.8 °C in July and August. However, minimum temperatures are around 4.5 °C in January and February (LaRC-NASA, 2019). The wind regime in terms of direction is globally constant throughout the year, North-North East/South-South West. To achieve sustainable treatment and reuse of wastewater in the Mediterranean region, Bent Saidane locality was selected as an appropriate site for the implementation of APOC system. The surface area of APOC installation, located in degrees, minutes seconds (WGS84) Latitude (9°57'24.6"), Longitude (36°15'52.6") is about 863 m^2. The area of 860 m^2 will be planned for TWW reuse tests.

3. Raw wastewater quality characteristics

The number of houses connected to the unit sewerage network in the locality of Bent Saidane locality is approximately 160 houses. The collected wastewater is conveyed by gravity to the new APOC system. After APOC unit treatment, wastewater will be discharged into temporary Wadi El Gouissate. The average daily flow of wastewater in Bent Saidane varies between 5 and 25 m^3/day. The annual average values of the physicochemical and bacteriological characterization of the discharged raw wastewater from the Bent Saidane locality are described in the table 1.

Table 1. Annual values of the physicochemical and microbiological wastewater quality (MC/MLAE) (2018)

Parameter	Value	Tunisian Decree N° 2018-315
T (°C)	16	< 35
pH	7.5	6.5 - 8.5
SS *(mg/l)*	400-500	40
COD (mgO_2/l)	1000-1500	160
BOD_5 (mgO_2/l)	500-600	40
COD/BOD_5	2-2.5	-
Chlorides (mg/l)	220	700
Sulphate (mg / l)	300	500
Nitrates (mg/l)	< 0.5	50
Nitrites (mg/l)	0.12	0.5
NTK (mgN/l)	70-200	5
Phosphorous (mg/l)	10 to 30	2
Iron (mg/l)	0.5	5
Copper (mg/l)	< 0.05	2
Manganese (mg/l))	< 0.05	1
Zinc (mg/l)	0.8	5
Arsenic (mg/l)	0.2	0.1
Aluminium (mg/l)	0.179	5
Cadmium (mg/l)	0.005	0.01
Lead (mg/l)	<0.05	0.1
Nickel (mg/l)	<0.05	0.2
Chromium (mg/l)	0.05	0.5
Oil and Fat (mg/l)	150-250	10
Total coliforms /100 ml	1-3×10^7	-
Feacal coliforms /100 ml	5-9×10^6	2000
***E. Coli* /100 ml**	5-9×10^6	-
Feacal streptococcus /100 ml	2-3×10^6	1000

In fact, the characterization of this raw wastewater was performed in accordance to the Standard Methods (USEPA, 2004) for the examination of wastewater discharge particularly, in temporary Wadi El Gouissate in terms of its main contaminants which may have negative

impacts on the aqueous environment of discharge. The values resulting from this evaluation show a variation from 1000 to 1500 mg/l for Chemical Oxygen Demand (COD), from 500 to 600 mg/l for Biochemical Oxygen Demand (BOD_5) and from 400 to 500 mg/l for Suspended Solids (SS). The COD/BOD ratio with a value of 2 to 2.5 confirms the type spontaneous biodegradability of domestic wastewater. The character of this wastewater is slightly stronger in terms of organic content reflected by the concentrations of Total Kjeldahl Nitrogen (TNK) varied from 70 to 200 mg/l and concentrations of Total phosphorus (Pt) varied from 10 to 30 mg/l. The up-scaling values of Pt and TKN suggest that agricultural activities and the use of fertilizers influence their concentrations in raw wastewater polluted with nutrients. In what refers to heavy metals, they do not constitute an evident problem of contamination in the wastewaters. The low concentration of heavy metals in the wastewater of Bent Saidane locality remains below 1 mg/l, also confirming an agricultural region where the industrial activity is rather limited and the discharges of contaminants have not yet caused a serious effect on the sewerage network and the receiving environment. Table 1 also evidences that the microbiological parameters are not subject to any recommendations to be respected for discharge into the sewerage network (MC/MLAE) (2018).

4. Description of an eco-innovative APOC system

The acronym APOC stands for "AD", "SPO" and "CW", the three components of the eco-innovative wastewater treatment system (WWTS) proposed by the AquaCycle project (Figure 2). In order to solve the problems of obstruction of pipes and mixing systems, a good pretreatment with a screen will be used to remove all large objects and control the dry matter content of the reactor. The secondary treatment is based on the AD process composed by two delivery pumps with timer, an AD reactor with a flow capacity of 5 to 25 m^3/d and a settling tank at the outlet of the digester with the possibility of recycling or extraction. Anaerobic treatment will reduce organic matter in the wastewater, but the quality of the effluent is not sufficient to meet the requirements for discharge or reuse. Therefore, two basins of sub-surface vertical flow CW followed by one basin sub-surface horizontal flow CW and two manholes is the system chosen to improve the quality of the effluent from the anaerobic reactor. The post treatment of the CW effluent in a novel solar Raceway Pond Reactor (RPR) consists a feasible option for treating substantial amount of wastewaters by the Solar Photo-Fenton (SPF) process and a distinctive feature of the APOC system. The phase of storage and recovery of the by-products of the APOC WWTP requires a storage basin for TWW with a volume of approximately 50 m^3, a basin for drying and treating sludge, a delivery pump to the irrigation network with a drip network, a technical room and a fence for the irrigation area.

Compared to conventional wastewater systems, the combination of advantages of the three processes (AD, CW and SPF) allows more reliability, affordability and environmental-financial sustainabilities, makes them particularly appropriate for small communities applications and control of the spread of harmful substances in the environment.

Anaerobic treatment and CW are mature and commercialized technologies with wide applications in the WWT market, that are combined with a novel solar disinfection and photocatalytic oxidation process towards the treatment of municipal wastewater at a level that satisfies the most stringent standards for reuse. by promoting a sustainable practice in order to focus on energy efficiency of biogas production and utilization of the nutrient-rich by-product generated such solid digestate.

5. Prospects of APOC system implementation with regard to the circular economy transition

In comparison with conventional domestic WWTT and other tertiary water harvesting technologies, the APOC system exhibits salient attributes in terms of cost, cultural acceptability, hydro-geological conditions and local availability of materials and requires less specialized skills and maintenance than intensive techniques. The distinctive features of APOC technology make it eco-friendly, efficient and cost-effective as it is based on natural systems, it uses less chemicals, runs on renewable energy (Solar irradiation), produces biogas, solid fertilizer and clean water for reuse in agriculture, in domestic, industrial or other applications, and the CW thrives as habitat, an ecological tourist attraction aside from being a climate change mitigation measure. The investment cost of the three components consisting of the APOC system is generally low, and the operating conditions are simple, more flexible, and allow more energy to be saved (Plakas et al., 2020).

The demonstration APOC unit in Bent Saidane rural locality is set to improved water governance socio-economic, and environmental sustainability through the active involvement of the local communities. Indeed, the active engagement of local actors and stakeholders will effectively drive a new stakeholder responsibility to address public health and sanitation issues, water scarcity, climate change mitigation, and food security as a new, non-conventional water resource becomes available all year. The operational demonstration of this new eco-innovative water treatment technology in Tunisia will be illustrated with detailed documentation on the main performance objectives achieved with regard to the quality of the treated effluents, the recovery of valuable substances, the savings energy and energy recovery, the potential for reuse of treated effluents and the overall profitability of the new technology. In addition, municipal action plans based on the Public Participatory Geographic Information System (PPGIS) will be entirely owned by local communities with a target set for the reuse of 900.000 m^3 of treated effluent. Among the main expected achievements is the creation of MedAPOC, a Mediterranean wastewater reuse community that will adopt the AquaCycle Charter on the sustainable use of unconventional water resources and will serve to promote the transfer and sharing of knowledge of the research results at the operational level across borders.

6. Conclusion

The main objective of the AquaCycle project is to provide research and development support for sustainable NCWR management through participatory governance and low-cost eco-innovative technology to enhance rural sanitation in Tunisia. Bent Saidane WWTP case study was selected to support rural decentralized sanitation facilities in Tunisia. Results demonstrate an estimated surface area of APOC installation of 863 m^2. The APOC system will be established with a flow capacity of 5 to 25 m^3/day. The selected area of one hectare will be planned for TWW irrigation purposes. As the APOC technology will permit the recovery of valuable substances from the TWW such as fertilizer and biogas, sustainable WWTR in Bent Saidane rural locality is set to show a good example in relation to the transition to the circular economy.

7. Acknowledgements

This publication of APOC technology has been made possible through financial support by the European Union under the ENI CBC Mediterranean Sea Basin Programme.

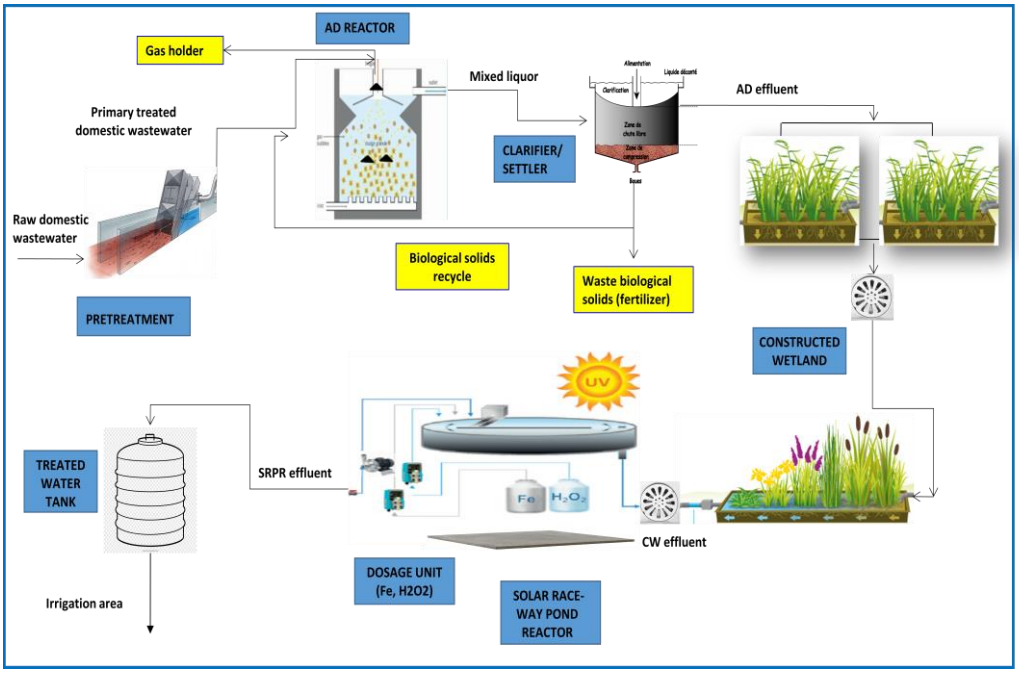

Figure 2. Global diagram of APOC system to be implemented in Bent Saidane locality

References

Bahri A., Brikké F. and Vairavamoorthy K. (2016), Managing Change to Implement Integrated Urban Water Management in African Cities, *Aquatic Procedia*, **6**, 3-14.

Plakas K., Chatzis V., Takavakoglou V.., Karabelas A., Oller-Alberola I., Polo I., Kallali H., Wahab M.A., M'Hiri F., Mensi K., Simon Andreu P.J. and Lopez R. (2020), Towards Sustainable Treatment and Reuse of Wastewater in the Mediterranean Region, *APOC technical guide Adapted to small and medium sized communities*, ENI CBC MED A_B41_0027_AQUACYCLE project, Deliverable 4.1, available in http://www.enicbcmed.eu/projects/aquacycle/.

Langley research Center-National Aeronautics and Space Administration (LaRC-NASA) (2019) https://power.larc.nasa.gov/data-access-viewer/.

Ministry of Commerce and Ministry of Local Affairs and Environment of Tunisia (MC/MLAE) (2018), Government decree N° 2018-315 of March 26, *Official Journal of the Republic of Tunisia*, **26**, 823-838.

United nations (UN) (2018), Sustainable Development Goal 6, *Synthesis Report 2018 on Water and Sanitation*, 199 pg. ISBN 978-92-1-101370-2.

United States Environmental Protection Agency (USEPA) (2004), Guidelines for Water Reuse. EPA/625/R-04/108, U.S. Environmental Protection Agency, Washington, DC.

World Health Organization and United Nations Children's Fund (WHO/UNICEF) (2019), Joint Water supply and Sanitation Monitoring programme (JMP), *WASH in health care facilities: Global Baseline Report 2019*, 132 pg.

World Health Organization and United Nations Children's Fund (WHO/UNICEF) (2014), Joint Water supply and Sanitation Monitoring programme (JMP), *Progress on drinking water and sanitation: 2014 update*, 78 pg.

www.un.org/sustainabledevelopment/water-and-sanitation/

www.epa.gov/owm/onsiteWater Environment Research

www.werf.org/i/a/k/DecentralizedSystems.aspx