Criteria and operational guidelines to increase wastewaters recovery in islands and rural areas

G. Mancini*, L. Cosentino** G. Signorello** A. Luciano*** and D. Fino****

*Department of Industrial and Mechanical Engineering, University of Catania, Viale Andrea Doria 6, 95125 Catania, Italy (E-mail: *gmancini@dii.unict.it* , *michelepanzica@alice.it*)
**Dipartimento di Agricoltura, Alimentazione e Ambiente (Di3A), University of Catania, Via Valdisavoia 5, 95123 Catania, Italy (cosentin@unict.it, g.signorello@unict.it)
***ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development – Casaccia Research Centre, Via Anguillarese 301, 00123, Rome, Italy (E-mail: *antonella.luciano@enea.it)*
****Department of Applied Science and Technology (DISAT), Polytechnic of Turin, C.so Duca degli Abruzzi 24, 10129 Turin, Italy. (E-mail: *debora.fino@polito.it)*

Abstract
Droughts, along with demand due to growth, effluent disposal issues, and ecological protection, are the principal driving forces behind reuse. However high quality for the wastewater to be reused in agriculture, required in many countries by too severe regulations, impose advanced treatments and related high costs that are hardly sustainable for the small-to-medium wastewater treatment plants (WWTPs) so significantly hampering a wider reuse diffusion.

Although the main function of reservoirs in agriculture is to allow the storage and temporal shifting of large volumes of waters, further benefits emerge from their application in wastewater reuse systems. As a result of the storage period significant improvement of the water quality for irrigation can occurs, under proper management conditions, thanks to concurrent physical, chemical and biological processes. Based on operational parameters optimization, criteria and specific operational guidelines are here proposed which, within a sustainable and cost-effective approach, integrate the main features of the reuse system and the proper management of the wastewater reservoirs (WWRs). These criteria are specifically applicable in semiarid areas where rotation-water distribution practice is implemented and many small farm reservoirs constitute the tail of the distribution network. Including these small capacities as an active part of the whole treatment process can allow further sanitary safeguards for both farmers and irrigated products consumers. Besides, the appropriate use of algal ponds in combination with the different wastewater reservoirs could allow to both avoid a specific phase for nutrient removal in the wastewater treatment plant while utilizing the harvested algae for bio-fuel or bio-fertilizer production.

Keywords
Wastewater reuse; operational index; microbiological; stabilisation reservoir, costs, bio-refinery approach.

INTRODUCTION

Globally, many countries struggle to cope with water resources that are increasingly limited in both quantity and quality. As a consequence, water utilities that manage potable water and wastewater treatment have begun to incorporate planned water reuse strategies as part of sustainable water resource management (Miller, 2006; Sun et al., 2016).

Whenever wastewater effluents are used, health protection measures must be carefully enforced. In the past it was widely accepted that wastewater treatment with some restrictions on crop types would provide enough health protection when using wastewater in agriculture (low risk). However World Health Organization indicates that effective health protection can also be achieved by the integration of various control mechanisms which include wastewater treatment, crop restrictions, control of wastewater application and human exposure controls.

Some countries (e.g. Italy) have however preferred to follow a quite restrictive approach, totally focused on the WWTP performance, by requiring quality standards for the reuse that, at least for some parameters, are surprisingly close to those applied for drinking water (Lopez and Vurro, 2008). This approach has often led to insuperable difficulties in promoting wastewater reuse, as the compliance with these very strict standards require advanced treatments and unaffordable costs to farmers, especially if compared with costs of waters from superficial water body of groundwater.

Also the overabundance of the required parameters (e.g. 54 parameters in the case of Italy) and their related monitoring protocols (Cirelli et al., 2008) have their important consequences on the economics of the reclamation and further hamper the chance of reusing wastewater as the final cost (construction, operation and maintenance) requested for reclamation, in addition to the costs for water distribution and reuse system monitoring, is hardly sustainable for the small-to-medium wastewater reuse systems (Ruiz-Rosa et al., 2016).

A new holistic multidisciplinary and sustainable approach to wastewater reuse for irrigation is thus needed, that must take place within an overall policy-making, engineering design, operation, monitoring, surveillance, management, administration, legal and environmental framework. It should involve a combined health, environmental and economical benefit to the urban communities (who gets rid of the wastewater) and critical economic and livelihood benefit to the rural community (who uses it) (Rice et al., 2016).

The choice of appropriate and sustainable wastewater reuse schemes should therefore derive from a careful analysis of all these elements, considered in their potential role to guarantee both the global financial soundness of the project, as well as the necessary environmental and sanitary requirements.

THE "OTHER" ROLE OF STORAGE IN WASTEWATER REUSE SYSTEMS

Among the functional elements of a wastewater reuse system, storage has an important role in allowing the continuously produced volumes of treated wastewaters to be utilised during the narrowest period of the irrigation season.

Several researches (Juanico and Shelef, 1991; Juanico and Shelef, 1994; Friedler et al., 2003; Mancini et al., 2007; Mannina et al., 2008) have however established that, under proper operations and conditions, storage inside a Wastewater reservoir (WWR), by itself, can lead to a significant improvement of the water quality for irrigation as a consequence of a complex system of physical-chemical and biological processes taking place in it, that is typical of hypertrophic water bodies with slow water turnover.

In particular, during the long detention periods of the non-irrigation season, processes of bio-antagonism yield to a progressive reduction in the number of indicator microorganisms and pathogens (Cirelli et al., 2008). Removal effectiveness are generally improved by a stable stratification determining a barrier between the upper aerobic layer (from which the effluent is usually withdrawn) and the lower anaerobic one in contact with the sediments (Llorens et al., 1992). The presence of a stable stratification can however causes hydraulic short circuits and the consequent reduction of ‘active’ volume and mean retention time (MRT) (Kellner and Pires, 2002). Curtis et al., (1992) identified the production of oxygen associated with high pH values as main parameters in the die-off of pathogens in stabilization ponds. Even in WWRs the polishing performance depends on establishing a positive balance between algal photosynthesis and oxygen demands exerted by bacteria during organic matter decomposition (Abeliovich and Vonshak, 1993). However the simple sedimentation process plays a key role in the reduction of suspended solids and attached microorganisms (included helminth eggs) that significantly improve the chemico-physical and microbiological quality of the stored wastewater.

Dor and Raber (1990), by stressing the non steady state characteristics of the stabilisation reservoirs, indicated PFEn (e.g., the percentage of effluent with a detention time of n days or less) as the main parameters linked to the removal of total coliforms and organic content. The role and importance of operational parameters such as the mean residence time (MRT) and the percentage of fresh effluents (PFEn), in governing wastewater quality within the reservoir is well established (Juanico and Shelef, 1991; 1994; Barbagallo et al., 2001; 2003; Mancini et al., 2007). When a reservoir operates as a cumulative batch reactor, during the non irrigation season, both MRT and

PFEn continuously vary during the year. MRT increases during the non irrigation period reaching the maximum towards the middle of the irrigation season. PFEn, with high value of n (≥30 days), decreases during the non irrigation season, because of the growing volume inside the reservoir, but greatly increases during the irrigation season due to the continuous reduction of stored volume (and limited dilution of the incoming treated wastewater). When the reservoir operates in a batch way (i.e., the case of small reservoirs), the volume is filled all at once, therefore decreasing the significance of the operational parameter PFEn and increasing that of MRT.

ISSUES TO SOLVE IN THE MANAGEMENT OF WWRs

Some important issues have to be faced in order to optimize the reuse system through the finishing role of the different storage capacities.

Excessive algal production and clogging issues

The planktonic community dynamics of wastewater reservoirs is of extremely importance in view of the destiny of stored water (i.e., irrigation). The input of fresh wastewaters in the reservoir, and related nutrients load can cause drastic changes in planktonic community with the substitution of many small-size organisms (chlorophyta-diatoms) with a lower number of larger size organisms (Cyanophyta-Euglenophyta) and a consequent sensible increase in VSS, chlorophyll and pH (Teltsch et al., 1992). The consequent development of large populations of cladocerans and copepods in reservoirs can dramatically increases the possibility of sprinkler clogging when drip irrigation is used. Milstein and Feldlite (2015) by studying relationships between clogging and particle size distribution in a range of secondarily treated wastewater reservoirs identified a strong correlation, during the irrigation season, between thermal stratification and the development of a planktonic community with a complex web of feeding interactions in which the organisms capable of clogging filters were mainly copepods. In spring and fall the organism capable of clogging filters were mainly cladocerans involved in a shorter food chain. Also organic loading, mostly related to the entrance of fresh wastewater into the reservoirs during the irrigation season, was found to have a negative effect on nitrification promoting blue green algae development and copepod reproduction (Milstein and Feldlite, 2014).

Compliance with stringent standards required for unlimited irrigation

Besides to the increase in algal production, the addition of fresh wastewaters during the filling of WWRs also cause a severe worsening of the stored water quality with respect to microbiological parameters (Juanico and Dor, 1999; Mancini and Vagliasindi, 2006). Other researchers (Liran et al., 1994; Cirelli et al., 2008; Mannina et al., 2008) confirmed as, in spite of the WWR efficiency in removal of several physical-chemical pollutants and microbiological ones (Salmonella and Helminth eggs), the effluent in the continuous operational regime rarely match the more restrictive standards (e.g. Italian ones) for Escherichia Coli. By reviewing and evaluating for statistical data 60 WSRs in Israel, a country where the storage of treated wastewater is widespread from the early 1970s, Kfir et al., (2012) found that most WSTRs met the BOD and TSS requirements for unlimited irrigation (65% and 80%, respectively) according to the standards in place at the time of the study but most of them fail to meet several of the new quality parameters requirements set by the new, more stringent “Inbar” regulations, such as E.C., TSS and BOD, and, to a lesser extent, FC, chloride and sodium. However it should be observed that most of the studied WSTRs operate under a continuous flow regime with 49 out of the 60 based on seasonal storage-single WSTR concept, while only 11 are based on a multi-seasonal, multiple WSTRs concept (i.e.relying on two WSTRs working in tandem).

Costs (and benefits) of WWRs within the wastewater reuse framework

European Union, through the Water Framework Directive (Directive 2000/60/ EC), stipulates that the price of water should include all the costs of the service (including environmental costs). Sipala et al. (2003) obtained the unit cost of treated water from several different treatment processes and regeneration options; Lazarova et al. (2006), indicated a range 0.4-1.2 €/m^3 as treatment cost for the reuse of wastewaters in irrigation without restriction (coagulation/filtration/disinfection). Similar value (0.36 \$/m^3) were reported by Fine et al. (2006) while lower costs (0.2 €/m^3) were indicated by Gomez et al. (2007) for a larger scale plant. These costs can be however still far from the groundwater costs (0.1 €/m^{3}or even less) No detailed information were found from the scientific literature on the cost of wastewater storage in reservoirs although this phase, conceived as a part of the treatment, appears to be the a cost-effective option for both construction and O&M, because of the low energy and maintenance requirements. On the other hand these systems require the availability of large areas so they represent a sustainable alternative to more intensive treatments mainly in rural areas, where sufficient land at low cost is generally available.

The main advantage of storage in stabilization reservoirs remains the chance to recover high volumes of wastewaters produced during the non-irrigation seasons, avoiding direct discharge to water bodies or to coastal waters. Especially in the islands and coastal areas (e.g. in Sicily) the compliance with bathing standards would be more easily achieved and maintained by transferring large volumes of treated water from coastal areas (most populated) to inland ones allowing the resources to be available where more needed and at the same time shifting storage to areas with lower land price. However construction and O&M costs (e.g. pumping) of transferring might be largely variable and even unsustainable depending of the morphological features of the coast-inland areas and distance from the irrigated one (Cirelli et al., 2008). In order to distribute the economic burden of reclamation and reuse, it could be established that construction, operation and maintenance costs of reclamation must be added to WWTP's treatment costs, while monitoring and distribution costs can be charged to final users (farmers, golf courses, etc).

SUGGESTED LAYOUT AND MANAGEMENT CRITERIA

Within the holistic approach necessary to identify appropriate and sustainable wastewater reuse schemes, treated wastewater storage, through all the available capacities, can play an important role. Monitoring of phenomena involving wastewater stored in a small farm reservoir, subjected to variable operating conditions, (Mancini et al., 2007) have confirmed what was observed in many larger wastewater stabilisation reservoirs (Juanico and Shelef, 1994) in terms of water quality changes and improvements. High removal efficiencies were observed (up to five log units with a 31-day mean retention time) during the batch operating condition, thus highligting the further sanitary barrier role that farm reservoirs can play.

Therefore, it is here suggested, especially in islands and semiarid rural areas, where farm property is particularly fragmentised, a rotation-water distribution practice is often adopted and, consequently, many small reservoirs are already available, to conceptually and physically include these capacities in the reuse system, as a part of the whole treatment process, so taking into account their potential role to further guarantee sanitary safeguards for both farmers and irrigated products consumers.

However, in driving the choice of farm reservoirs, type, volume, shape and management criteria, beside economical and boundary condition (climatic characteristics, existing distribution system features), design efforts must be addressed to minimise the fresh effluent input to volume ratio inside each of these small capacities (Mancini and Vagliasindi, 2006).

Wastewater reuse system layout

A set of design and management criteria was specifically conceived to limit the deterioration of the stored water caused by the fresh effluents input into the reservoir. The proposed solution was targeted to the case of Mediterranean regions and Islands (e.g. Sicily), where small reservoirs, already present in several farms, are candidate for inclusion in the "traditional"reuse system layout. The proposed reuse scheme involves the insertion of two "new" reservoirs in the reuse system (Figure 1), and specifically:

- ✓ a large wastewater stabilisation reservoir (WSR)
- ✓ a buffer reservoir (BR).

It is also proposed to shift the disinfection after an algal pond treatment to help reducing nutrients and improve microbiological quality (Tarayre et al., 2016) and a filtration phase (to remove residual organic matter and allow the harvesting of the algal biomass) relying on the following storage phases as a further microbiological barrier (i.e., use as a stabilisation reservoir).

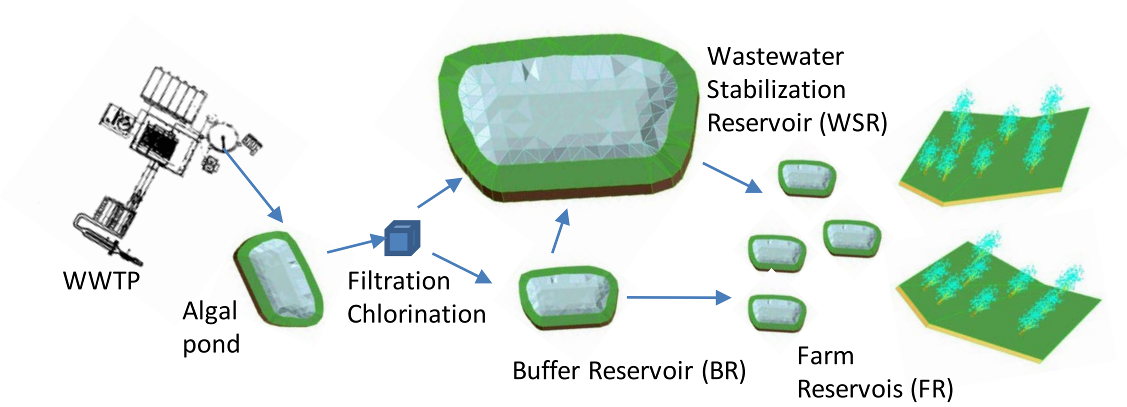


Figure 1. Sketch of the wastewaters reuse system with the proposed modifications.

Management and operational criteria

The suggested operational management for the ‘modified’ reuse system include the following steps.
Step I January, February and March. As of January 1st the wastewater stabilisation reservoir (WSR) is almost full and the buffer reservoir (BR) starts to store the wastewater coming from the treatment plant. After fifteen days without ‘fresh’ inputs, wastewaters inside the waste stabilisation reservoir, with a volume equal to 2.5 (0.5 October + November + December) months of mean flow, are distributed to the farm reservoirs (FRs). By the end of January the waste stabilisation reservoir is emptied and it starts to receive the wastewater previously stored in BR as well as the wastewaters from the plant.
Step II Early April. Starting April 1st, wastewaters from the treatment plant are stored inside the BR (it will be full by the end of the month). WSR has been filled from January the 1st (including the time-shifted BR contribution) with a volume of wastewater equal to three months (January + February + March) of mean flow. Water in farm reservoirs can be used for irrigation.
Step III Late April. Starting April 15th, as soon as the farm reservoirs are emptied for irrigation they start to be filled with wastewaters from WSR. Farmers are however warned to wait three days before using the water for irrigation to reduce fast filling effects. By the end of the month all the wastewaters of the WSR are transferred to the farm reservoirs.
Step IV May–June. Starting May 1st, the buffer reservoir (BR) is emptied transferring the stored wastewater to WSR while the ‘fresh’ wastewaters are (again) directed to WSR. Meanwhile farmers carry on the irrigation with water from FR.
Step V July. Starting July 1st, ‘fresh’ wastewaters are stored into the BR. Starting July 15th:

wastewaters from WSR with a volume of wastewater equal to three months (April + May + June) of mean flow are used to fill up the empty farm reservoirs. Farmers are asked to wait three days before irrigating. By July 31st BR is full and WSR is empty.

Step VI August–Early September. Starting August 1st the buffer reservoir (BR) is emptied by transferring the stored wastewater to WSR while the ‘fresh’ wastewaters are again diverted to WSR. Wastewater stored in the farm reservoirs is used for irrigation.

Step VII Late September. Starting September 15th, ‘fresh’ wastewaters are stored into BR. Irrigation proceeds with high MRT waters from the farm reservoirs.

At the end of the month (September 30th), wastewaters from the WSR, with a volume equal to (July + August + 0.5 September) = 2.5 months of mean flow start to be transferred to the farm reservoirs. Farmers are warned to wait three days before using the water for irrigation to reduce fast filling effects.

Step VIII October–December. By October 15th the buffer reservoir is full. ‘Fresh’ wastewater is stored inside the WSR. Farmers continue to irrigate with water from farm reservoirs. At the beginning of December wastewaters stored in BR are transferred to farm reservoirs therefore restoring the initial BR empty-condition..

Suggested management procedures to avoid filter clogging are: 1) prefer pumping water out from the upper hypolimnion layer near the oxic epilimnion in order to reduce the smell nuisance while controlling the clogging impacts of anaerobic bacteria in the distribution network; 2) Using a bottom–up action to reduce phyto-plankton by controlling the entrance of nutrients and/or reducing light into the reservoir. Reducing light penetration is an option for which are available several floating cover technologies originally developed to control evaporation in ponds and reservoirs (Milstein et al., 2014). Their application would depend on cost/benefit considerations, taking into account that most probably this bio-manipulation would be an effective tool against spring filter clogging due to cladocerans but less efficient against clogging due to cyclopoid copepods occurring through the whole irrigation season. The nutrient levels depend on the quality of wastewater sources could be economically achieved by properly exploiting the removal efficiency of the algal pond (and related algal separation through filtration/centrifugation).

Wastewater provides a conducive growth medium for microalgae because the CO_2 balances the Redfield ratio (molecular ratio of carbon, nitrogen and phosphorus) of the wastewater allowing for faster production rates, reduced nutrient levels in the treated wastewater, decreased harvesting costs and increased lipid production. Microalgae, by removing nitrogen and carbon from water can significantly reduce the eutrophication in the WSR aquatic environment and constitute a base for bio-fuel or bio-fertilizer production (Suganya et al., 2016).

Simulation through the use of operational parameters

Figure 2 shows the dimensionless volume and inflow-outflow variations over the year inside the WSR according to the proposed management criteria. Figure 3a shows the corresponding simulation results in terms of MRT variation for wastewater stored in WSR and FRs, respectively. Since MRT is a measure of the overall ‘aging’ of the stored wastewater, it was decided to compute, in the analysis, the wastewaters detention time in the farm reservoirs. Under this assumption MRT values of wastewater inside the farm reservoirs can be calculated starting from the wastewater stabilisation reservoir ones (in the phase of transferring). MRT in wastewater stabilisation reservoir (Figure 3a) shows a constant increase rate during the non-zero input phases followed by a sharper increase as the flow is stopped. In the three phases of wastewaters transfer from the BR to the empty WSR, the MRT shows immediately a positive value (>13 day) thanks to the ‘aging’ of the wastewaters inside the buffer reservoir during the previous month. MRT of farm reservoirs starts to be computed when the FRs are empty and new wastewaters come from the stabilisation reservoir. However, as already mentioned, the initial values for this parameter depend on the previous storage inside the WSR. Therefore, minimum (cumulative) MRT values in the farm reservoirs are always at least equal to the maximum ones in wastewater stabilisation reservoir before the transfer starts. Specifically, minimum MRT values obtained in the farm reservoirs are 55, 60, 60.5 and 54 days respectively on January 16th (non irrigation period), April 15th, July 15th, and September the 30th.

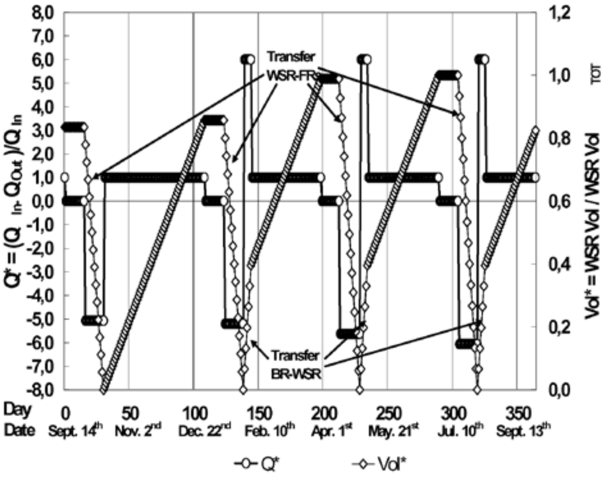
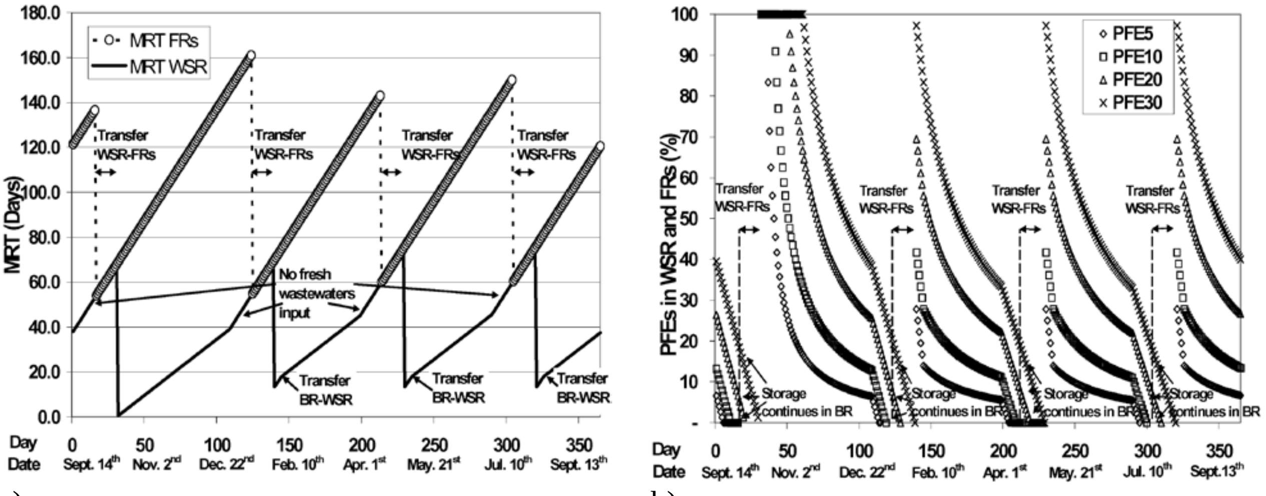


Figure 2. Dimensionless volume and inflow-outflow variation over the year inside the WSR.

Figure 3b shows the results of the simulation in terms of PFEn values (5, 10, 20 and 30 days) for wastewaters inWSR and FRs. To make the discussion straightforward it is useful to start observing values from October the 15th (day 32), when the wastewater stabilisation reservoir, just emptied to fill-up the FRs, starts again to receive ‘fresh’ wastewater. All PFEn parameters, at this date, show a value of 100%, as the volume inside the stabilisation reservoir is totally composed by ‘fresh wastewater’.

Later, (January the 1st) all the PFEn, starting from PFE5, start to decrease with a regular trend till the filling of WSR is completed (and the ‘fresh’ wastewaters are diverted to BR) and PFEn start decreasing in a faster way. When instead, the empty wastewater stabilisation reservoir also receives the high flow coming from the buffer reservoir (transfer BR-WSR, early February, early May, early August), initial PFEn values (with 5, 10 and 20 days) are significantly lower than 100% due to the dilution effect of the wastewaters previously stored in the BR. Specifically, already during the wastewater transfer from the buffer reservoir to the WSR, a sharp decrease of PFE5 and PFE10 is observed that slows down when the ‘fresh’ wastewaters are the only input to the WSR.



a)

b)

Figure 3. a) Comparison between WSR and FRs mean retention times over the year and b) simulated variability, over the year, of PFEn values in WSR and FRs, calculated for different numbers of days (n = 5, 10, 20, 30).

Rapid decreases can be observed for all the PFEn values as a consequence of diverting the ‘fresh’ wastewater to the buffer reservoir (early January, early April, early July). During retention inside WSR, PFE5 and PFE10 always reach the 0% value. Also PFE20 and PFE30 show quite low values (5–6 % and 16–18% respectively) by the end of the detention periods in the wastewater stabilisation reservoir, giving enough guarantees on the quality of the water for irrigation, even if the farmers, contravening a suggested rule to delay irrigation for other few days, immediately would utilize the wastewater coming from WSR.

PFEn patterns in FRs are obtained according to the previously discussed idea of cumulative ‘aging’ of wastewaters, that is to say, starting from the values corresponding to the previous storage inside the wastewater stabilisation reservoir and calculating PFEn as if the water would continue to be stored inside the WSR with no input of ‘fresh’ wastewaters.

As a matter of fact, WSR water is simply distributed to the farm reservoirs and no ‘fresh’ wastewater is added to the water stored in the FR, therefore not interfering with the ‘contamination’ process expressed in terms of PFEn values. As it can be observed by the simulation (Figure 3b, values after each transfer), PFEn values, calculated for 5 and 10 days, are always zero while no more than 5 and 15 days are necessary for PFE20 and PFE30, respectively, to reach 0% starting from the 1st day of WSR-FRs transfer. After just five days from the transfer, very little fraction of the water inside the farm reservoirs, generally less than 12%, has an age lower than 30 days. Based on the experimental results previously described, as well as those, reported in (Juanico and Shelef, 1991, 1994; Azov et al., 1992; Barbagallo et al., 2003; Mancini et al., 2007; Kfir et al., 2012) is estimated that farmers could rely on stored water of high quality for the irrigation.

CONCLUSION

A wastewater reuse layout including different storage volumes storage scheme was proposed and simulated in the present work, based on PFE_n and MRT optimisation. The storage phase is here envisioned as a finishing treatment of secondary municipal effluents after a tertiary treatment performed through an algal pond and a filtration phase. The proposed two-reservoirs-based procedure specifically aims at reducing the effects of the input of fresh effluents on the stored water, particularly critical during the irrigation period. The adopted solution is particularly well fitted in areas (like Mediterranean regions and islands) where lot of farms have their own reservoir that can therefore be managed as a component of the reuse system.

High MRT and low PFEn values were obtained in the conducted simulations as a consequence of the adopted layout and management criteria. These results, along with the high microbiological removal efficiency, observed (under a wide range of MRT and PFEn values), during a monitoring activity, carried out in a full scale farm wastewaters reservoir, demonstrate the possibility to obtain stored waters of high quality for irrigation at affordable costs for the users.

REFERENCES

Abeliovich, A.,Vonshak, A. 1993 Factors inhibiting nitrification of ammonia in deep wastewater reservoirs. *Water Research* **27**, 1585–1590.

Azov, Y., Juanico, M., Shelef, G. 1992 Monitoring large scale wastewater reclamation systems-Policy and experience. *Water Science and Technology* **26**, 1545–1553.

Barbagallo, S., Cirelli, G.L., Indelicato, S. 2001 Wastewater reuse in Italy Water Science and Technology 43, 43–50.

Barbagallo, S., Cirelli, G., Consoli, S., Somma, F. 2003 Wastewater quality improvement through storage: a case study in Sicily. *Water Science and Technology* **47**, 169–176.

Cirelli, G.L., Consoli, S., Di Grande, V. 2008 Long-term storage of reclaimed water: the case studies in Sicily (Italy). Desalination 218, 62-73.

Curtis, T., Mara, D., Silva, S. 1992 Influence of pH, oxygen and humid substances on ability of sunlight to damage coliforms in waste stabilization pond water. Appl. Envir. Microbiol., 58(4) 1335– 1343.

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

Dor, I., Raber, M. 1990 Deep wastewater reservoirs in Israel: empirical data for monitoring and control. *Water Research* **24**, 1077–1084.

Fine, P., Halperin, R., Hadas, E. 2006 Economic considerations for wastewater upgrading alternatives: An Israeli test case. *Journal of Environmental Management* **78**, 163-169.

Friedler, E., Juanico, M., Shelef, G. 2003 Simulation model of wastewater stabilization reservoirs. *Ecological Engineering* **20**, 121-145.

Gomez, M., Plaza, F., Garralon, G., Perez, J., Gomez, M.A. 2007 A comparative study of tertiary wastewater treatment by physico-chemical-UV process and macrofiltration–ultrafiltration technologies. *Desalination* **202**, 369-376.

Juanico, M., Dor, I. 1999 Reservoirs for Wastewater Storage and Reuse. Springer, Environmental Science Series, Germany, pp.394.

Juanico, M., Shelef, G. 1991 The performance of stabilization reservoirs as a function of design and operation parameters. *Water Science and Technology* **23**, 1509–1516.

Juanico, M., Shelef, G. 1994 Design, operation and performance of stabilization reservoir for wastewater irrigation in Israel. *Water Research* **28**, 175–186.

Kellner, E., Pires, C. 2002 The influence of thermal stratification on the hydraulic behaviour of waste stabilization ponds. *Water Science and Technology* **45**, 41–53.

Kfir, O., Tal, A., Gross, A., Adar, E. 2012 The effect of reservoir operational features on recycled wastewater quality. *Resources, Conservation and Recycling* **68**, 76-87.

Lazarova, V., Rouge, P., Sturny, V., Arcangeli, J. 2006 Evaluation of Economic Viability and Benefits of Urban Water Reuse and its Contribution to Sustainable development. *Water Practice & Technology* **1(2),** 1-11.

Liran, A., Juanico, M., Shelef, G. 1994 Coliform removal in a stabilization reservoir for wastewater irrigation in Israel. *Water Research* **28**, 1305–1314.

Llorens, M., Sàez, J., Soler, A. 1992 Influence of thermal stratification on the behaviour of a deep wastewater stabilization pond. *Water Research* **26**, 569–577.

Lopez, A., Vurro, M. 2008 Planning agricultural wastewater reuse in southern Italy: The case of Apulia Region. *Desalination* **218**, 164-169.

Mancini, G., Vagliasindi, F.G.A. 2006. Issues and guidelines for treated wastewater reservoirs design and operation. *International Journal of. Environment and Pollution* **28**, 128-143.

Mancini, G., Barone, C., Roccaro, P., Vagliasindi, F.G.A. 2007 The beneficial effects of storage on the quality of wastewater for irrigation: a case study in Sicily. *Water Science & Technology* **55**, 417-424.

Mannina, G., Mancini, G., Torregrossa, M., Viviani, G. 2008 Wastewater modification processes assessment in a stabilization reservoir. *Water Science & Technology* **57**(7), 1037-1045.

Miller, W.G. 2006 Integrated concepts in water reuse: managing global water needs. *Desalination* **187**, 65-75.

Milstein, A., Feldlite, M. 2014 Relationships between clogging in irrigation systems and plankton community structure and distribution in wastewater reservoirs. *Agricultural Water Management* **140**, 79-86.

Milstein, A., Feldlite, M. 2015 Relationships between thermal stratification in a secondarily treatedwastewater reservoir that stores water for irrigation and filter clogging in the irrigation system. *Agricultural Water Management* **153**, 63-70.

Rice, J., Wutich, A., White D.D., Westerhoff, P. 2016 Comparing actual de facto wastewater reuse and its public acceptability: A three city case study. *Sustainable Cities and Society*. http://dx.doi.org/10.1016/j.scs.2016.06.007

Ruiz-Rosa, I., García-Rodríguez, F.J., Mendoza-Jimenez, J. 2016 Development and application of a cost management model for wastewater treatment and reuse processes. *Journal of Cleaner Production* **113**, 299-310.

Sipala, S., Mancini, G., Vagliasindi, F.G.A. 2003 Development of a web-based tool for the calculation of costs of different wastewater treatment and reuse scenarios. *Water Science and Technology: Water Supply* **3(4)**, 89-96.

Suganya, T., Varman, M., Masjuki, H.H., Renganathan, S. (2016) Macroalgae and microalgae as a potential source for commercial applications along with biofuels production: A biorefinery approach. *Renewable and Sustainable Energy Reviews* **55**, 909–941

Sun, Y., Chen, Z., Wu, G., Wu, Q., Zhang, F., Niu, Z., Hu, H.Y. 2016 Characteristics of water quality of municipal wastewater treatment plants in China: implications for resources utilization and management. *Journal of Cleaner Production* **131**, 1-9.

Tarayre, C., De Clercq, L., Charlier, R., Michels, E., Meers, E., Camargo-Valero, M., Delvigne, F. 2016 New perspectives for the design of sustainable bioprocesses for phosphorus recovery from waste. *Bioresource Technology* **206**, 264-274.

Teltsch, B., Azov, Y., Juanico, M., Shelef, G. 1992 Plankton community changes due to the addition of treated effluents to a freshwater reservoir used for drip irrigation *Water Research* **26**, 657–668.