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Zer0-M, sustainable concepts towards a zero outflow municipality

Martin Regelsberger[a]*, Ahmet Baban[b], Latifa Bouselmi[c], Hussein Abdel Shafy[d], Bouchaib El Hamouri[e]

[a]AEE INTEC, Feldgasse 19, 8200 Gleisdorf, Austria
Tel. +43-3112-5886 50; Fax +43-3112-5886 51; email: m.regelsberger@aee.at
[b]Tübitak — Marmara Research Center, Gebze, Turkey
[c]Centre de Recherches et des Technologies des Eaux,
Laboratoire Traitement et Recyclage des Eaux usées, Soliman, Tunisia
[d]Water Research & Pollution Control Department, National Research Center, Cairo, Egypt
[e]Institut Agronomique et Vétérinaire Hassan II, Rabat, Morocco

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Abstract

Zer0-M, short for "Sustainable Concepts Towards a Zero Outflow Municipality", is a project financed by the MEDA Water programme of the European Union (EU). This project aims at concepts and technologies to achieve optimised close-loop usage of all water flows in small municipalities or settlements (e.g. tourism facilities).

A key idea in Zer0-M is to integrate water supply, wastewater treatment and reuse. Actually it is about abandoning the concept of "waste" water, because on one hand there is no water to waste, and on the other disposal is a poor concept, which so far has proved very unsafe. From a disposal problem we should shift to an asset, which has to be developed.

In order to encourage implementation of this concept in real systems Zer0-M is presently building so-called training and demonstration centres on one side, with a great variety of different techniques to be shown and tested, and pilot plants to implement and demonstrate the same techniques under real conditions.

First results about greywater in MEDA countries will be discussed. Water demand and saving measures in rural areas of MEDA countries as well as simple potable water substitution techniques will be presented on the basis of studies and implementations of Zer0-M.

Keywords: Zer0-M project; MEDA water; Sustainability; Integrated water management; Ecosanitation

*Corresponding author.

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1. Introduction

Morocco is presently extending sanitation to the major part of its population. A total budget in excess of 4 billion euro is planned for sanitation until 2020 or almost 150 million euro a year. This dwarves the water supply programme running until the early 1990s which had less than half that yearly budget. Obviously enormous efforts are necessary to provide sanitation for all. On the other hand, by 2015 Morocco expects to dispose of 750 million m^3 of wastewater per year. For a country with limited water resources this represents a non-negligible volume of water. Even presently wastewater is reused for irrigation. It is sometimes done in a controlled way with the outlet of treatment plants, especially for the irrigation of golf courses. Quite sometimes reuse occurs in an uncontrolled way simply from the outlet of a sewer. No major negative effects have been reported so far due to this practice, which is actually what we should expect. Irrigation with raw wastewater is not limited to Morocco but is widespread in the Mediterranean area and, indeed, in most arid countries. However, from a sanitary and legal aspect the application of certain guidelines and minimum standards would certainly be welcome where wastewater is reused in a way where people can get in contact with it or with the subsequent products, e.g. crops.

Wastewater reuse is but one aspect considered in Zer0-M. It is part of what we think is a sustainable approach to wastewater, or ECOSAN approach, as it is widely called, which should integrate water supply and treatment of wastewater for its further intended purpose. Zer0-M is about abandoning the concept of “waste” water altogether, because there is no water to waste. From a disposal problem we shift to an asset, which has to be developed. We have to face the fact that in dry climates with a high pressure on water resources wastewater is reused anyhow if possible, whether it is allowed or treated to the necessary quality or not. Anyhow, treatment only considers a narrow set of parameters, their negative impact having already been established, whereas a wide range of other pollutants is released unattended. In the closed system of the earth there is always somebody on the receiving end, however. Some have thus replaced the concept of disposal by unplanned reuse, as opposed to planned reuse, which Zer0-M is advocating together with other organisations and projects working at the ECOSAN concept. The far end of the process would be to design substance flow cycles which allow up-cycling of water and nutrients, instead of down-cycling especially water until it cannot be further used.

Zer0-M is carried out by a consortium of 10 partners from 7 countries. One partner comes from each of the project MEDA countries. These partners are either research institutes or universities (Morocco). The European partners are each contributing a particular know-how to the project, be it sanitation or mapping or dissemination of know-how. Table 1 lists the partner organisations.

2. Approach

In practice the paradigm change of sustainable water management or Ecosanitation involves combining traditional, conventional and a new set of techniques and being flexible on the scale, i.e. combining solutions from a very local, small scale, so-called decentralised systems, up to very large scale or centralised systems, if they present an advantage. Systems are being developed that minimise potable water consumption but make best-quality freshwater available for high-grade use, e.g. for drinking. This approach shall be presented together with the procedures to implement the corresponding systems. Instead of just solving the two issues of where the drinking water comes from and how the wastewater is disposed of there is a new decision structure to be followed.

The first question to be asked when designing the aforementioned sustainable systems is: “*what uses do we need water for*?” Thus we can possibly

Table 1
List of Zer0-M partner organisations and their expertise/contribution to the project

Partner	Expertise/contribution to the project
(1) AEE — Institut for Sustainable Technologies, Austria	Applicant, constructed wetlands, sustainable water techniques, low-cost solutions
(2) Associazione Ambiente e Lavoro Toscana — O.N.L.U.S. (ALT), Italy	Constructed wetlands, life cycle analysis
(3) Tübitak-Marmara Research Center (MRC-ESERI), Turkey	Expertise in wastewater reuse, especially with industrial wastewaters, implements training and demonstration centre (TDC)
(4) Water Research & Pollution Control Department, National Research Centre, Dokki, Cairo, Egypt (NRC), Egypt	Expertise in wastewater treatment and reuse in Egypt, implements TDC and pilot plant
(5) Centre de Recherches et des Technologies des Eaux Laboratoire Traitement et Recyclage des Eaux usées (CERTE), Tunisia	Expertise with constructed wetlands, with solar disinfection of water and wastewater, officially responsible for research on rural wastewater systems, implements TDC and pilot plant
(6) Institut Agronomique et Vétérinaire Hassan II, Wastewater Treatment and Reuse Unit (WTRU), Morocco	Expertise with constructed wetlands, wastewater ponds, and anaerobic treatment systems, implements TDC and pilot plant
(7) Institut für Geographie und Regionalforschung, Universität Wien (IGR), Austria	GIS and digital cartography
(8) TU Berlin, Zentraleinrichtung Kooperation and Fakultät III, Fachgebiet Verfahrenstechnik I (TUB), Germany	Bio-membrane filtration, treatment of greywater
(9) Universität Hannover, Zentrale Einrichtung für Weiterbildung (weiterBILDUNG), Germany	Continuing education, preparation of didactic material, ECOSAN, e.g. dry toilets, urine diversion toilets
(10) Fachvereinigung Betriebs- und Regenwassernutzung e.V. (fbr), Germany	ECOSAN, e.g. rainwater harvesting, greywater treatment

substitute techniques presently consuming water with others not needing any water at all. A classical example is replacing flushing toilets with modern composting toilets. On the other hand wastewater shall be treated specifically for the planned purpose of reuse. All resources that are found in the wastewater, namely water and nutrients, shall be reused. In order to best achieve this goal, it could be advantageous to collect different fractions of wastewater separately, something undisputed in solid waste collection. The aim is to introduce "*low tech - high concept*" solutions developed for small communities because planning, even if complex, is a lot less expensive than construction or operation over the lifetime of a plant. Table 2 summarises some of those techniques to save water.

Zer0-M aims to transpose such techniques, which have been developed in countries like Germany, Sweden, Austria or Italy to the situation of the southern and eastern rim of the Mediterranean Sea, especially for rural and peri-urban applications. This involves adapting the existing techniques to the new conditions, e.g. drier and hotter climate, lower income but available work force. It also means development of new techniques, particularly adapted to the climatic and socio-cultural as well as economic situation of

Table 2
Measures and corresponding techniques (non-comprehensive) to increase sustainability

Purpose	Techniques
Substitute water	Dry toilets, waterless urinals
Substitute potable water/diversify resources	Collection of rainwater and use for laundry, showering, irrigation, toilet flushing
Save water	Water saver fixtures, water efficient flushing toilets, household appliances (dishwasher, washing machine)
Separate collection, treatment and reuse	– Separate collection of different components/fractions e.g. greywater (from bathroom and sink) and blackwater (from toilet), urine – In-house greywater treatment and reuse for toilet flushing, showering, laundry, outside uses – Reuse of urine as a fertiliser – Composting of faeces and addition to soil
Low energy treatment	Ponds, constructed wetlands, SBR greywater treatment systems, sludge composting reed beds, composting
Treatment with energy recovery	Anaerobic wastewater treatment with biogas production, possibly combined with organic waste

the countries and the target population. Most of all the local traditions, a centuries if not millenary old way of dealing with water, which in most of the area have been all but erased by "modernisation", have to be checked for their applicability in modern day life and if found appropriate, should be revived, not least as a strong link to a sustainable handling of water for the local population. Examples of such techniques are rainwater harvesting, dry toilets, xerogardening or complex irrigation systems.

3. Methods

Zer0-M endeavours at different levels to develop and spread sustainable water techniques and systems. The project work has been divided into five work packages described below.

(1) There is a knowledge exchange among partners and external water experts through a project web site (www.zero-m.org), 3 conferences, the third being held from 21 to 24 March 2007 in Tunis, and a journal "Sustainable Water Management" appearing twice a year.

(2) Workshops are organised to inform an interested public about sustainable water management systems. These workshops are aimed at water experts, non-governmental organisations (NGOs) and decision makers. Each MEDA partner organises 7 workshops.

(3) The project is implementing concrete examples of the suggested techniques. The four MEDA partners have selected a site near to or on their premises for a "training and demonstration centre" (TDC) and are presently building or have implemented these TDCs. Their purpose is to comprise a maximum of different ECOSAN techniques, even though designed for small water flows of a few 100 L/day only, which are used as concrete examples during the workshops as well as for further research and adaptation of the techniques to local conditions and as starting point for possible new developments. The centres include grey and black water segregation. Several treatment trains for both fractions are implemented (see Table 3 for an overview).

Additionally there are examples of rain water harvesting, of composting toilets, water saving

Table 3
Wastewater treatment techniques implemented in the four TDCs

	Egypt	Morocco	Tunisia	Turkey
For black water		Complete wastewater		
Septic tank as first step	x			
UASB as first step		x	x	+Free flow CW + UV
MBR	x			x
Algal channel		+UV		
CW	CW HSSF + VSSF	2 parallel HSSF	VSSF + UV	HSSF + 2 VSSF CW + free flow CW + UV
Roughing filter	+VSSF CW	x		
Sludge-drying/ composting bed	x	x	x	x
Compost reactor				x
Reuse	Irrigation	Irrigation	Irrigation	Irrigation of fruit trees
For greywater				
CW	HSSF CW	HSSF + sand filter + UV		HSSF CW, free flow CW
SBR	x	x	+UV	x
MBR		x	x	x
RBC				x
Roughing filter	x			
Reuse	Irrigation, one demonstration toilet	Toilet flushing in a university building and irrigation	Toilet flushing	Irrigation, one demonstration toilet

CW: constructed wetland, HSSF is a horizontal type subsurface flow, VSSF is a vertical subsurface flow constructed wetland.
MBR: membrane bioreactor, commercial system by BUSSE GmbH, Germany.
SBR: sequencing batch reactor, commercial system by PONTOS GmbH, Germany.
RBC: rotating biological contactor.

appliances and other related items. Recycling of the treated wastewater is implemented, e.g. in Morocco the greywater is used for flushing of the toilets in the newly erected building of the Department for Rural Engineering. The TDC in Turkey is ready and working now, the ones in Tunisia and in Egypt are under preparation. In Morocco most of the techniques are already available, others (MBR, SBR, further constructed wetlands) are being added successively.

All four partners have monitored the grey and black water of their TDC. Grab samples were taken once a month and analysed following Standard Methods [1,2] in each partner's laboratory. The characteristics of the different greywaters are discussed below.

To work on a larger scale and under real field conditions, pilot plants are under design and will be realised in Egypt, Morocco and Tunisia. These are a wastewater treatment system for a farm compound, a water and wastewater system for a hotel and dolphin research centre and a water and wastewater system for a village of 300 inhabitants in the three countries respectively.

The TDC in Turkey is large enough to serve as a pilot plant itself.

(4) A decision support system (DSS) for water technicians is developed that shall guide them through the process of planning sustainable water systems, assist in the development and comparison of different variants, and visualise the results. Finally technically unskilled decision makers or community members should be able to take an informed decision about the best system to implement.

The tool is first a computer version, which presently runs as a web-based application. For technicians without sufficiently powerful access to the internet a certainly simplified paper version will be prepared. The computer tool shall be available for testing and discussion in the project homepage. With the continuous development of the internet it can be expected that the access to the computerised DSS will extend to all possible users in the near future.

(5) In order to raise the awareness for the potential of sustainable water solutions to solve the water scarcity and environmental pollution problem in rural areas of MEDA countries two video shorts and info material about relevant water topics are prepared, to be integrated into one DVD.

4. Results

First results are available from greywater measurements shown in Table 4. For the TDCs

Table 4
Characteristics of greywater at the four TDCs, average values of grab samples; Analyses carried out according to Standard Methods [1,2]

Parameter	Unit	Egypt[a]	Morocco[b]	Tunisia[c]	Turkey[d]
Number of samples		3		11	4
pH	–	8.1	7.4	7.6	7.4
Conductivity	mS/cm		628		507
TSS	mg/L	90	200	35	65
Oil & grease	mg/L	149			1.2
BOD_5	mgO_2/L	335	90	95	135
COD	mgO_2/L	590	180	100*	280
N_{tot}	mg/L	26.4	14.0	10.2	11.6
NH_4	mg/L	8.0		8.6	
$N\text{-}NH_4^+$	mg/L	6.2	12.0	6.7	
Nitrate	mg/L	0.4	n.d.	1.7	
Nitrite	mg/L	n.d.		0.4	
$P\text{-}PO_4^{3-}$	mg/L	0.6	0.8	1.7	
P_{tot}	mg/L		2.0		5.3
Faecal coliforms	CFU/100 mL		2E + 06	2E + 05	318
Detergent	mg/L				>0.004
Anionic surfactants	mg/L		55		

*23 samples.
[a]Egypt: from apartments of an apartment building across the street of the NRC in Dokki, Cairo, including kitchen wastewater.
[b]Morocco: showers of a sports club next to IAV Hassan 2.
[c]Tunisia: bathrooms of a student hostel for approximately 200 girls.
[d]Turkey: bathroom greywater of 17 mostly single households in a staff apartment building on the premises of the MRC.

greywater systems have been implemented in all four countries. The collected greywater has been monitored since the implementation of the segregation schemes which gives a first valuable impression of the characteristics of greywater in these countries.

Values for the four different greywater examples are given in Table 3. The four greywaters are quite different. It is however premature to explain the differences with their country of origin. Especially greywater differs highly according to its source in the household.

It was tried to situate the greywater found in Zer0-M in comparison to other greywater from previous investigations and the literature. It is rather difficult to compare greywater values from the literature. One of the most comprehensive collections of data was presented by Eriksson et al. [3]. This collection of quite a large number of data makes two problems obvious: greywater is not defined, its characteristics are very much depending on the source and on the behaviour of the water consumers, and the data are not easily comparable because the sets of parameters do not match. For BOD only, if there is a value available at all, it is given as BOD, BOD_5 or BOD_7.

Fig. 1 locates the results for BOD_5 and total nitrogen in a wider context. The selected cases presented here are from an own previous investigation at Fischerhof in Austria, a restaurant and sanatorium for mentally challenged people, Israel [4], Queensland in Australia [5], Western Australia [6] and Sarawak [7]. The two ellipses show two cases where values were given in ranges, from a minimum to a maximum for both parameters. These values could not be drawn as dots. The values stem from BO90, a tenant-owned development in the central part of Copenhagen, Denmark, with greywater from bathrooms (washbasins, showers and bathtubs) [8], and another study about greywater from different sources, the values shown here being from bathroom greywater [9].

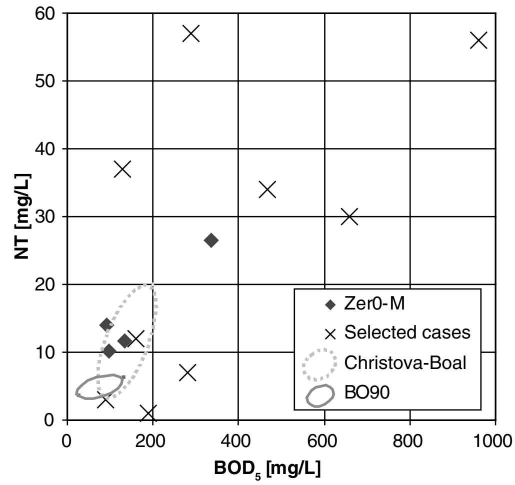

Fig. 1. Characteristics of different greywaters shown as BOD_5 vs. total nitrogen. Selected cases are Fischerhof in Austria, typical German values, values from Israel, Queensland, Western Australia, Kuching in Sarawak.

The same comparison has been made for phosphorus. The BOD_5, nitrogen and phosphorus values in the greywater samples collected in the context of the Zer0-M project are rather at the lower side of the literature range. Three of them are quite similar, whereas the values for the Egyptian greywater are somewhat higher, probably due to its content of highly loaded greywater from family kitchens sinks.

5. Conclusions

The Zer0-M project has reached a phase where results are visible. These results comprise physical realisations, which can and will be shown to an interested public in the respective countries. They will also help in assessing the suitability of the technical solutions provided and in adapting them if necessary to local particularities. At the same time they are used to make future water experts familiar with the concepts of sustainable water systems through research work and theses prepared under the supervision of the project partners.

The results also include first data about particular wastewater fractions, i.e. greywater and blackwater, of the partner countries. These come to complement the existing databases and should be useful in dimensioning such systems. The TDCs and pilot plants will continue to provide data through the remaining period of the project and beyond.

The project approach has been successfully disseminated through a journal, various workshops and two conferences. Further workshops and a third conference, on March 21st to 24th 2007 in Tunis, will add to this dissemination effort. The dissemination will be complemented and enhanced through pilot plants, where the suggested concepts are tested under real "field" conditions.

Since October 2005 the MEDA Water program has a co-ordination office, the Regional Monitoring and Support Unit (RMSU) based in Marseilles and Amman. This unit allows joint efforts to present the contributions of the program as a whole for a sustainable management of water resources. It can be expected that thus the visibility of the project work as part of a whole program with a reach over all the Mediterranean region will be further increased and the sanitation techniques and water systems promoted by Zer0-M are seen in a more comprehensive framework.

The direct involvement of the project partners in the national water policy design, development of technical solutions for the nationally identified problems and the education of future generations of water experts is a guarantee for the achieved results to gradually become part of the standard practice in water management of those countries.

With all optimism, however, it is clear that five years of even intensive work is a short period to redirect such a wide region as the MEDA countries in their attitude towards sanitation techniques, even for a whole program of the European Union. It is true that there is a high pressure on this region to continuously increase the efficiency of their water systems and to reduce pollution through wastewater. Nevertheless it will take a longer period to introduce modern and sustainable sanitation techniques, especially given the sensitivity of this part of human live, which personally involves everybody and can only be optimised with the concurrence and active contribution of all people together. Next phases of the current program should consolidate and further the present effort. Based on several thousands of years of experience in sustainable management of the ever scarce resource, however, there is justified hope that the Mediterranean region can have a decisive role in bringing about a paradigm change in our behaviour towards water.

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