SUSTAINABLE WATER MANAGEMENT

1-2007

CONCEPTS TOWARDS A ZERO-OUTFLOW MUNICIPALITY

ZERO M

ECOSANITATION

A key idea in Ecosanitation is to integrate water supply, wastewater treatment and reuse. It is about abandoning the concept of "waste" water, because there is no water to waste, and disposal is a poor and unsafe concept. From a disposal problem we shift to an asset, which has to be developed.

INTERNATIONAL GUIDELINES

Available guidelines and standards for agricultural reuse have been gathered and classified as microbiological parameters, metal concentrations in reuse water and irrigation water quality parameters.

FOR EXAMPLE: CYPRUS

From 1997 onwards, the Government of Cyprus decided, in parallel with new projects to implement water conservation measures at household level. The water resources situation in Cyprus and measures to conserve drinking water and recycle grey water is described.

RAINWATER HARVESTING

Mankind will have to deal more carefully in the future with the worldwide available and utilisable freshwater reserves. This is primarily a question of awareness and education. Rainwater catchment systems in Asia, Australia, America, Africa and Europe are compared.

AEE INTEC

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EDITORIAL

This journal, **Sustainable Water Management**, is an initiative of the project "Sustainable Concepts towards a Zero Outflow Municipality (Zer0-M). The project is part of the Euro-Mediterranean Regional Programme For Local Water Management of the European Union (MEDA Water) and the countries bordering the Mediterranean Sea.

The project aims at a new, sustainable approach to sanitation, also called Ecosantiation. In a recent paper and talk I used the word of "paradigm shift" for the Ecosan approach, compared to conventional sanitation. But the word intrigued me. Though it was familiar to me I was not totally sure of its meaning. So I looked it up. For those who read French there is quite an extensive explanation of paradigm shift on Wikipedia. The concept was actually introduced by Thomas Kuhn for leaps in scientific evolution in his book *The Structure of Scientific Revolutions*. The English Wikipedia version is shorter, but gives still a good idea.

The best summary of paradigm shift, however, was already made by A. Schopenhauer: *"All truth passes through three stages. First, it is ridiculed. Second, it is violently opposed. Third, it is accepted as being self-evident."*

This sentence struck me as the bottom line of our daily experience at AEE INTEC and in Zer0-M. There is a still shorter and sloppier wording by Einstein: *"If at first the idea is not absurd, then there is no hope for it."*

Now, we must not conclude that something new is good only because it is absurd or opposed. But on the other hand this should give us courage to carry on with the Ecosan concept even in the face of quite common ridicule or opposition. Because, as Einstein also said, *"the world we have made as a result of the level of thinking we have done thus far creates problems we cannot solve at the same level of thinking at which we created them."* We need a revolution in our handling of resources.

We hope that everyone finds interesting information for his own work and can make use of some of the matters presented. Hopefully the journal raises questions and leads to debate – there are some quite controversial subjects touched. We would be very glad to discuss these issues with you, at conferences organised within the programme – see the relative announcements in the journal and through our forum at www.zer0-m.org. We apologise for the registration, it protects the forum from spamming. You will find registration quite easy and it's open to everybody. Please raise any water issues there. The more visitors, the more the discussion will be vivid.

If you find this journal interesting or useful we'll be happy about your feedback. In the case you have suggestions for improvements or topics you would like to see covered do not hesitate to contact me, too.

Martin Regelsberger *(m.regelsberger@aee.at), February 2007*

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ZERO-M, SUSTAINABLE CONCEPTS TOWARDS A ZERO OUT-FLOW MUNICIPALITY

By MARTIN REGELSBERGER*

A key idea in Zer0-M is to integrate water supply, wastewater treatment and reuse. It is about abandoning the concept of "waste" water, because there is no water to waste, and disposal is a poor and unsafe concept. From a disposal problem we shift to an asset, which has to be developed.
Zer0-M is presently building so-called training and demonstration centres, with a great variety of different techniques to be shown and tested, and pilot plants with some of the techniques under real conditions.

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INTRODUCTION

Irrigation with raw wastewater is widespread in the Mediterranean area and, indeed, in most arid countries. No major negative effects have been reported so far due to this practice, which is actually what we should expect. 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 a sustainable, or ECOSAN, approach to wastewater, 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. In the closed system of the earth there is always somebody on the receiving end. Some have thus replaced the concept of disposal by unplanned reuse, as opposed to planned reuse. 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 seven countries. To find more information about the consortium visit the project homepage at www.zer0-m.org.

APPROACH

In practice the paradigm change of sustainable water management or Ecosan 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. 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 an Ecosan systems is: "**what uses do we need water for?**" Thus we can possibly 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 be-

Table 1:
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

cause planning, even if complex, is a lot less expensive than construction or operation over the lifetime of a plant. Table 1 summarises some of the 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 target population and 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. 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 and efficient irrigation systems.

ACHIEVEMENTS

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.

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

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

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 2 for an overview).

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.

Fig. 1:
COMMISSIONING OF MEMBRANE BIO-REACTORS AT THE TURKISH TDC, MARMARA RESEARCH INSTITUTE IN GEBBZE

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

Table 2:
WASTEWATER TREATMENT TECHNIQUES IMPLEMENTED IN THE FOUR TDCs

CW constructed wetland, HSSF is a horizontal 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

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.

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.

OUTLOOK

Zer0-M has reached a phase where results are visible. These results comprise physical realisations, which are 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 to local particularities if necessary. At the same time they are used to make future water ex-

Fig. 2:
MEETING OF WATER USERS AT THE TUNISIAN PILOT SITE CHORFECH FOR A PARTICIPATORY PLANNING SESSION

perts familiar with the concepts of sustainable water systems through research 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 this 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 "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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Fig. 3:
CONSTRUCTION OF A RAINWATER HARVESTING SYSTEM AT THE OCEANOGRAPHIC INSTITUTE IN ALEXANDRIA, EGYPT

TECHNICAL FEASIBILITY OF GREYWATER RECYCLING FOR TOILET FLUSHING IN MOROCCO

By Bouchaib El Hamouri, Maadane S. and Bey I.*

This paper presents the preliminary results obtained from a technical feasibility study regarding the recycling of GW from a sport and leisure club. Treated and UV disinfected GW was recycled for toilet flushing inside the building of the Department of Rural Engineering in the campus of the Institut Agronomique et Vétérinaire (IAV) of Rabat, Morocco.

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Greywater (GW) generated inside a sport and leisure club was collected, treated, UV disinfected and recycled for toilet flushing. The low cost treatment adopted was a gravel/sand two-step filter. Step 1 consisted of a coarse gravel, horizontal-flow filter planted with Phragmites. The second step was a vertical-flow multilayer sand filter. The hydraulic retention time was two hours. The performances of the system were satisfactory: turbidity was reduced from 28 to 2 NTU while the removal rates retained for COD and BOD5 were 75 and 80% respectively. Also, 50% of nitrogen was nitrified and 50% phosphorus were removed. The anionic surfactants' removal rate reached 90%. On the contrary, FC removal rates were unsatisfactory and did not exceed one Log Unit out of an initial concentration of $1.3x10^5$ unit/100 mL. UV disinfection was implemented and succeeded in removing three Log Units bringing the final FC counts to 10 units/100 mL. The follow up of the four toilets (two for men and two for women) flushed with recycled GW and their comparison with four others flushed with potable water and located on the first floor of the same building showed the absence of any unaesthetic aspect and smell emanation. The practice was accepted and positively evaluated by the system users.

INTRODUCTION

The generalisation of the western way of life in urban areas of developing countries experiencing water scarcity is leading to an increasing stress on water supplies. Demand management is now a dominating approach with the long term research objective being that of closed loop recycling. Following this trend, rainwater-harvesting (Nolde, 1999) and greywater (GW) recycling for site specific, non-potable urban uses such as toilet flushing are becoming more and more attractive. Large-scale projects were recently developed. In the Millennium Dome in the UK, about 7200 m^3 of run-off from hand washing basins were collected in the year 2000 and recycled to help satisfy the flushing demand of the 646 WCs and the 191 urinals, which represent 48% of the Dome daily needs (Hills and English, 1999; Hills *et al.*, 2001). In Japan, legislation was introduced to force buildings of a certain size in the metropolitan areas to implement greywater collection and recycling (Stephenson *et al.*, 2000). GW consists of waters from washbasins, showers, baths and washing machines. In developed countries, these volumes represent from 30% in households to 60% in commercial buildings (Shouler *et al.*, 1998). Some authors include water from the kitchen and dish washing machines (dark GW) some do not. GW contains small concentrations of nutrients: 5 to 22 mg/L of nitrogen and 0.2 to 3.9 mg/L of phosphorus. Its content in FC is rather low (Fittschen and Niemczynowicz 1997; Jefferson *et al.*, 2001). By comparison, black water (water from toilets) contains the greatest share of organic matter, 90% nitrogen, 80% phosphorus, 90% potassium and faecal bacteria. For these reasons, GW is easy to

Particle size (mm)	Effective size (mm)	Uniformity coefficient	Porosity (%)
0.55 (top)	0.6	1.38	28
0.95	0.8	1.08	33
1.8	1.2	1.50	35
2	1.6	1.30	37
2 to 4	2.4	1.50	40
4 to 6 (bottom)	3.5	1.40	44

Table 1
CHARACTERISATION OF THE DIFFERENT SAND TYPES USED IN MULTILAYER FILTER

treat and it is much safer to recycle for various water usages that do not need potable water quality.

For obvious reasons, treatment approaches for GW in developed countries did mainly focus on innovative high-tech systems combining biological treatment and membrane systems (Fittschen and Niemczynowicz 1997).

SET-UP OF THE GW RECYCLING SYSTEM

The Club of the Association Culturelle et Sportive de l'Agriculture (ACSA) and the campus of IAV Hassan II in Rabat are located next to each other. Waste water produced in the showers and the toilets of the fitness room of the ACSA club were segregated allowing the collection of 8 m^3/d of GW. A reservoir (reservoir 1) was dug outside the gym room to collect GW which was pumped through a 50-mm diameter pipe over a distance of 504 m to be conveyed to the waste water treatment facility located on the IAV campus.

Treated and UV disinfected GW was stored in a black, polyethylene reservoir (reservoir 2) and conveyed, using a 50-mm diameter pipe over a distance of 460 m to the building of the Department of rural Engineering (DRE). The four toilets on the ground floor of this building were connected to the GW system. Dual piping was adopted to avoid any cross connection between potable water and recycled GW. Access to potable water was allowed when GW was not available. Four other toilets, located on the first floor of the DRE building, were flushed with potable water only for a comparison.

TREATMENT UNIT

Greywater was treated in a two-step gravel/sand filtration unit. Step 1 consisted in a planted horizontal-flow gravel filter, while the second step was a vertical-flow multilayer sand filter.

FIRST STEP: PLANTED GRAVEL FILTER

The unit was constructed in reinforced concrete and had the following characteristics: length 2.25 m, width 2.0 m, depth 0.8 m, cross sectional area 1.6 m^2 and bottom slope 2%. The bed filling material was limestone aggregates with an effective diameter of 5.5 mm. The uniformity coefficient (UC; d_{60}/d_{10}) was 1.61, the porosity, 47%, and the clean Darcy's hydraulic conductivity, K was $60x10^{-3}$ m/s. The bed was planted with reeds *(Phragmites australis)* on equidistant lines separated by 0.40 m and set perpendicular to the direction of the water flow (fig. 1).

SECOND STEP: MULTILAYER SAND FILTER

The second step consisted of a vertical multilayer sand filter also made in reinforced concrete and having the same dimensions as the gravel one. Five sand layers of 0.14 m depth each were used (table1). The clean Darcy's hydraulic conductivity, K of the unit was $25x10^{-3}$ m/s

UV DISINFECTION

GW was disinfected in an apparatus purchased from Iritech Finmeccanica, Italy. GW was forced upward in a Teflon pipe placed in an aluminum box with dimensions of 0.20 m x 1.70 m x 0.20 m depths. The Teflon pipe was surrounded by four (0.90 m length) low-pressure mercury tubes of 30 Watts each emitting at 253.7 nm and placed around the tube at a distance of 0.03 m. The contact time was adjusted to be 6.35 s leading to a dose of 400 $mJcm^{-2}$.

SAMPLING AND ANALYSIS

Samples for GW characterisation were taken during the two daily peak flow periods (11:00 h and 20:30 h). In this period, GW does not stay more than 30 min in reservoir 1 and the conveying pipe together. Fresh GW was also collected right at the outlet of the segregation pipe before the contact with reservoir 1 content and the conveying network. Samples to assess recy-

Fig. 1
PLANTED GRAVEL FILTER AND MULTILAYER SAND FILTER (PLANTS SHOWN AT TWO DEVELOPMENT STAGES)

Figure 2
DUAL, NETWORK (GREYWATER RECYCLING / POTABLE WATER) FOR TOILET FLUSHING (POTABLE WATER VALVE BEING ALWAYS CLOSED)

cled GW quality were also taken from the toilet flushing reservoirs. Water analyses were performed following Standard Methods (APHA, 1985 and 2005).

RESULTS AND DISCUSSION

Table 2 shows that the values of the main pollution parameters were within the range reported by other authors. Turbidity values never exceeded 40 NTU and had an average of 30; SS solids were entirely organics representing 5% of total solids. Nitrogen and phosphorus contents were low. Almost 80% of nitrogen in the influent consisted of ammonia.

Average FC contamination was 1.3×10^5 MPN/100 mL. Conflicting FC contents were reported, with figures ranging from 10^2 to 10^5 (Lazarova et al., 2003). Such a large span might be explained by socio-cultural or technical origins. We noticed large differences depending on the point of sampling inside the collection manhole (figure 3). FC counts were lower when the samples were taken at the point # 1 (figure 3, right at the outlet of GW collection pipe coming from the showers). Those taken at point # 2 or at the entrance of the treatment unit were systematically two orders of magnitude higher.

This difference might be due to an FC subsequent growth during the residence time of GW in the collection reservoir and inside the conveying pipe. The storage of raw GW resulted in a dramatic increase in FC content. We found that FC counts were multiplied by a factor of 100 within the first 48 hours at laboratory temperature when conserved in ceramic containers similar to those of toilet flushing reservoirs.

An intriguing fact, however, was the large population of cockroaches (Dictyoptera, Blattela) living inside the collection manhole, where they freely circulate between black water and grey water segregating boxes. The existence of these insects could explain the difference in FC counts discussed above. Cross contaminations are likely to take place particularly when segregation and conveying systems are placed side by side as was the case in this study (see figure 3).

TREATMENT PERFORMANCE

The performance of the two-step gravel/sand filtration unit was quite satisfactory. The effluent turbidity was reduced from 28 to 2 NTU. Removal rates of COD and BOD_5 were 75 and 80% respectively. Half of the nitrogen was nitrified during the filtration process. The removal rate of phosphorus was almost 50% while anionic surfactants were removed at a rate of 97%. On the contrary, the gravel/sand filter performance in FC removal was low and did not exceed one log unit.

RECYCLED GW QUALITY

The effluent quality inside the flushing reservoirs was of a good quality. The difference in FC counts, before and after disinfection, was 3 Log Unit leading to a quality that complies with common, international standards for domestic recycling (table 3). Very little changes occurred in the recycled GW following disinfection except for the doubling of the electrical conductivity. This increase could be explained by the evapora-

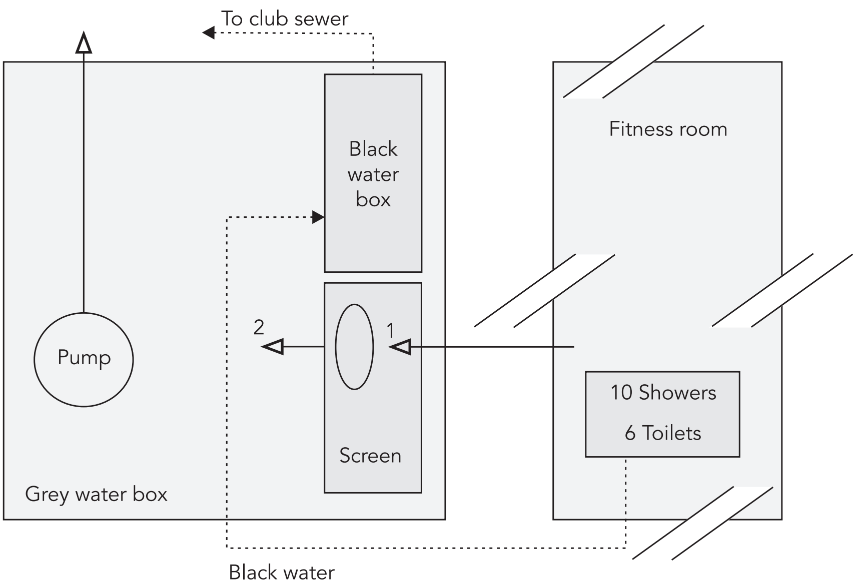

Fig. 3
LAYOUT (NOT ON SCALE) OF THE SEGREGATION NETWORK, MANHOLE WITH JUXTAPOSED GREY AND BLACK BOXES

Parameter		T	pH	CE	Turbidity	DO	COD	BOD_5	TKN	$N\text{-}NO_3^-$	Pt	$P\text{-}PO_4^{3-}$	TS	VS	SS	VSS	AS**	Faecal coliforms
	Unit	°C		mS/cm²	NTU	mg/L											µg/L	MPN/100 ml
Influent	Average	18.7	7.4	423	28	2.0	100	51	15.2	0.1	1.6	0.9	867	236	40	40	299	1.3×10^5
	SD	2.7	0.2	265	10	1.9	36	34	4.5	0.1	0.5	0.4	396	185	39	6	232	1.2×10^5
Effluent	Average	18.4	6.9	497	2	5.0	25	10	9.0	4.5	0.7	0.6	597	260	39	16	24	10^4
	SD	3.4	0.3	335	2	1.0	12	6	3.3	2.1	0.3	0.2	183	147	41	20	15	1.4×10^4
Toilet flushing reservoirs*	Average	20.2	6.9	717	2	4.6	28	3	10.6	2.8	0.9	0.7	726	301	43	ND	31	10
	SD	1.8	0.1	65	0.83	2.1	9	1	2.3	1.9	0.5	0.4	389	365	58	ND	35	14

* Effluent after UV disinfection; **Anionic surfactants as LAS; EC: electrical conductivity; DO: dissolved oxygen; TS: Total Solids; VS: Volatile Solids

Table 2
QUALITY OF GW AT THE THREE DIFFERENT STAGES (INFLUENT, EFFLUENT AND DISINFECTED)

tion that takes place in the black reservoir feeding the recycle network.

PERCEPTION OF GW RECYCLING BY THE USERS

The recycling system was checked daily and compared with the toilets on the first floor connected to potable water only. The check protocol included the following aspects: visual quality of water, smell perception, and impact on flushing equipment such as marks on the ceramic reservoirs or failure of the flushing mechanism. On all these aspects there were no differences between GW and potable water toilets. After nine months of continuous recycling, a positive perception dominates along with the astonishment that the use of recycled GW for toilet flushing can offer such comfort.

CONCLUSION

Preliminary results indicate that toilet flushing using recycled greywater collected from a sport and leisure club is technically easy to implement. Low-tech, non-energy consuming, environmental friendly systems (gravel sand filter) can provide an adequate treatment. However, residual faecal bacteria counts forced the adoption of a disinfection step in order to comply with toilet flushing quality standards. In this respect, UV disinfection was tested and found satisfactory. The recycling practice was accepted and positively evaluated by the system users.

	Total coliforms (MPN/100 mL)	Fecal coliforms (MPN/100 mL)	BOD5 (mg/L)	Turbidity (NTU)	Chlorine Residual (mg/L)	pH
Bathing water standards*	< 10,000	< 2,000				6-9
USA, NSF Federal Minimum		< 240	45	90		
USA, EPA	Non detectable		10	2	1	6-9
Australia	< 1	< 2	20	2		
UK (BSIRA)	Non detectable					
Japan	< 10	< 10	10	5		6-9
WHO*	< 200					

* suggested as appropriate for domestic water recycling, BSIRA: Building Services Information and Research Association (according to Jefferson et al., 2001)

Table 3
WATER QUALITY STANDARDS AND CRITERIA SUITABLE FOR DOMESTIC WATER RECYCLING (AFTER SMITH & DUDLEY, 1998)

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REFERENCES

- APHA, AWWA, WEF (1985 and 2005) St. methods for the examination of water and wastewater.
- Fittschen, I., Niemczynowicz, J.(1997). Experiences with dry sanitation and greywater treatment in the ecovillage toarp, SWEDEN. *Water Science and Technology*. 35(9),161-170.
- Hills.S, and English, P. (1999). Water recycling at the Millennium Dome. Presented at "water recycling and effluent reuse". 26-27th April 1999. London UK.
- Hills,S., Smith,A., Hardy,P. and Birks,R. (2001). Water recycling at the Millennium Dome. *Water Science and Technology*. **43** (10),287-294.
- Jefferson,B., Laine,A.L., Stephenson.T. and Judd, S.J. (2001). Advanced biological unit processes for domestic water recycling. *Water Science and Technology*. **43** (10),211-218.
- Lazarova,V., Hills,S. and Birks,R.(2003). Using recycled water for non-potable, urban uses: a review with particular reference to toilet flushing. *Water Science and Technology*. **3** (4),69-77.
- Nolde, E.(1999).Greywater reuse systems for toilet flushing in multi-storey building-over ten years experience in Berlin.*Urban Water*. **1**,275-284.
- Stephenson,T., Judd,S., Jefferson,B. and Brindel, K. (2000). Membrane Bioreactors for Wastewater Treatment.IWA publishing,2nd edition.
- Shouler, M., Griggs, J. and Hall, J.(1998). Water conservation. British Research Establishment (BRE) Information Paper, IP 15/98.

OVERVIEW OF INTERNATIONAL GUIDELINES AND STANDARDS FOR AGRICULTURAL REUSE

By M. GUREL, G. ISKENDER, S. OVEZ, I. ARSLAN-ALATON, A. TANIK and D. ORHON*

In this study, available guidelines and standards have been gathered and classified as microbiological parameters, metal concentrations in reuse water and irrigation water quality parameters. They are compared for various countries with the aim of giving authorities, institutions and decision-makers an overview. Upon investigating the set values, it is seen that the quality limits differ from country to country and that implementing a single standard seems to be difficult due to national and/or local circumstances. Parallel to the scientific evidence and technological advances, the continuous improvement in the revision/expansion of the existing standards and guidelines is expected.

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INTRODUCTION

Agriculture is the largest user of water comprising almost 80% of the global demand. UNEP [1] states that agriculture receives 67% of total water withdrawal. That amounts to 86% of consumption in the year 2000. In a number of arid and semi-arid countries like Israel, Jordan, and Tunisia, water reuse provides the largest share of irrigation water. Israel is the leading country in this area with over 70% of treated waste water being reused for agricultural purposes [2]. The countries practicing intensive agriculture with limited water resources tend to use treated waste water in irrigation. Examples of these countries are some Mediterranean countries (Cyprus, France, Greece, Italy, Malta, Portugal and Spain), the USA, the North African Countries (Morocco, Tunisia, Algeria), and the Middle Eastern Countries (Jordan, and Israel) [3]. On the other hand, water reuse is also growing steadily in highly populated countries with a temperate climate (Japan, Australia, Canada, North China, Belgium, England and Germany) [2].

The reuse of waste water provides financial, environmental, economic, and social benefits such as

- an increase in the available water resources,
- a more rational allocation of fresh water resources and their conservation,
- a potential reduction in pollutants to be discharged into fresh waters,
- a better use of the nutrient content in the treated waste water and
- the guarantee of a regular water supply especially in water scarce areas (i.e. farmers have access to water for restricted irrigation even in times of drought) [1, 3].

WHO [4] emphasizes the goals to ensure environmental sustainability and eliminate poverty and hunger in The Millennium Development Goals (MDGs) that encourage the use of waste water in agriculture.

Besides the benefits of waste water reuse already referred to, Helminth infections, bacterial/virus infections and protozoal infections constitute the health risks when waste water is used for irrigation [4].

HEALTH RISKS

Limited information is available for health risks arising from chemicals in waste water. The uptake of chemicals by plants is dependent on the chemicals and on soil characteristics [4]. There are also some concerns over trace contaminants that may be present in effluent known by their endocrine disrupting properties. Such substances result in the disruption of normal biological functions, including growth, development and maturation. Due to insufficient removal during primary and secondary treatment processes, despite their low concentration, these contaminants are a major health concern [5].

The greatest health risks are associated with crops that are eaten raw- for example, salad crops especially

Fig. 1
AGRICULTURE CONSUMES ALMOST 80% OF THE GLOBAL WATER DEMAND

if they are root crops (e.g. radish, onion) – or that grow close to the soil (lettuce, zucchini). Generally crops that have certain surface properties (e.g. hairy, sticky, crevices, rough, etc.) protect pathogens from exposure to radiation and make them more difficult to wash off with rain or by post-harvest washing. The amount of water each crop holds is also an important factor with exposure to pathogens.

STANDARDS AND GUIDELINES

In general, the development of standards and guidelines for waste water reuse reflects the level of development of waste water reuse in each country [3]. Some countries have established standards for minimizing any risk, whereas some others have adopted a protective approach towards anticipating negative effects. In order to reduce the impacts of reuse, many countries have adopted standards and guidelines based on especially California-USA and WHO guidelines. The standards differ between countries and even within a given country. Some countries (e.g. France, Tunisia) and regions (e.g. Andalusia, Balearic Islands, in Spain, and Sicily in Italy) have adopted a set of water quality criteria based on the WHO guidelines, whilst others (e.g. Cyprus, Italy and Israel) have elaborated regulations or guidelines close to the more strict California's Water Recycling Criteria [6]. The reuse regulations adopted by countries depend on the microbiological characteristics, treatment alternatives, the distance to residential sites, crop restriction, treated waste water application methods, the control of human exposure along with the socio-economic conditions. Most developed countries have established low risk guidelines or standards based on a high technology/high-cost approach. Many developing countries on the other hand have adopted an approach based on the WHO guidelines referring to relatively low-cost technology levels while emphasizing the health risks [7]. Countries adjust the guidelines depending on their local circumstances [8].

OVERVIEW: TREATED WASTE WATER REUSE GUIDELINES AND IRRIGATION STANDARDS

There are various standards and guidelines for waste water reuse that are under continuous improvement. The guidelines involve the establishment of appropriate health-based targets prior to defining appropriate risk-management strategies. Californian standards are technologically based requirements aimed at eliminating the presence of pathogens whereas WHO guidelines rely on the available epidemiological evidence. The WHO guideline revisions are based on new epidemiological investigations and quantitative microbiological risk assessment (QMRA) provided by Blumenthal and Peasey [9].

Different standards are set for unrestricted and restricted irrigation, and for different crop types. Coliform (feacal or total) for indicating bacteriological risks, and the number of nematode eggs, which represent parasitologic risks, are generally checked. The main differences between 1989 and 2006 WHO guidelines are new recommendations for a faecal coliform (FC) value for restricted irrigation and new nematode egg limits in certain conditions when children are exposed.

The limit values set for heavy metal concentrations are almost the same. The metal concentrations are equally important like microbiological parameters in terms of human health risks. Thus, such limits are incorporated in the standards. While the parameters like BOD, COD, dissolved oxygen etc. reflect the treatment performance of waste water, some others like boron, SAR, chloride etc. are set for crop protection. Every country has set different limit values according to their national needs and a common standard does not seem to be practicable. This situation is also seen in European Union Countries. There are no legislative regulations at the European level concerning waste water reuse so far, apart from the Urban Waste Water Treatment Directive (91/271/EEC) which advises to reuse waste water "whenever appropriate" [3].

CONCLUSIONS

In parallel to the scientific evidence (e.g. epidemiological research, exposure assessment studies) and technological advances, the standards and guidelines on waste water reuse in agriculture need to be continuously revised. Besides establishing the legislation, controls and monitoring during applications, defining institutional and supervisory responsibilities and documentation are also necessary to achieve satisfactory results in reuse applications. It is also important to note that cultural and religious prejudice directs public opinion and the acceptance of waste water reuse.

The training of the public involved in agricultural production with reuse waste water is equally important to reduce the health and environmental risks. Effective guidelines for health protection should be feasible to implement, and adaptable to local social, economic, and environmental factors.

The actual situation in some developing countries is the direct use of untreated waste water for irrigation without taking into account both the guidelines and standards, and associated risks. In order to maximize health protection along with increasing crop productivity, reuse practices should be encouraged in a controlled manner. Phases in setting waste water quality standards over a suitable period of time according to treatment capabilities are a possibility for developing countries. In this case, the initial standards may be set and as resources become available the standard could be tightened.

Fig. 2
THE REUSE OF WASTE WATER PROVIDES FINANCIAL, ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS

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REFERENCES

[1] UNEP, Water and Wastewater Reuse, An Environmentally Sound Approach for Sustainable Urban Water Management, 2005, http://www.unep.or.jp/ietc/Publications/Water_Sanitation/wastewater_reuse/index.asp

[2] USEPA, Guidelines for Water Reuse, EPA 625/R-04/108, 2004, http://www.epa.gov/ORD/NRMRL/pubs/625r04108/625r04108.htm

[3] C. Lallana, W. Krinner, T. Estrela, S. Nixon, J. Leonard, J. M. Berland, Sustainable water use in Europe, Part 2: Demand management, European Environment Agency (EEA), Environmental issue report, No: 19, Copenhagen, 2001.

[4] WHO, Guidelines for the Safe Use of Wastewater, Excreta and Grey Water, Volume 2: Wastewater use in agriculture, World Heath Organization, Geneva, Switzerland, 2006.

[5] L. D. Nghiem, J. McCutcheon, A. I. Schäfer, M. Elimelech, The role of endocrine disrupters in water recycling: risk or mania? Water Science and Technology, 50(2), 2004, 215-220.

[6] A. Bahri, F. Brissaud, Setting up microbiological water reuse guidelines for the Mediterranean, Water Science and Technology, 50(2), 2004, 39-46.

[7] http://www.usaidjordan.org/upload/keydocs/Water%20Reuse.pdf

[8] R. M. Carr, U. J. Blumenthal, D. D. Mara, Health Guidelines for the Use of Wastewater in Agriculture: Developing Realistic Guidelines, In: Wastewater Use in Irrigated Agriculture, Confronting the Livelihood and Environmental Realities, Edited by Christopher Scott, Naser I. Faruqui, and Liqa Raschid, CABI/IWMI/IDRC, 2004, 206 pp., http://www.idrc.ca/openebooks/112-4/

[9] U. J. Blumenthal, A. Peasey, Critical review of epidemiological evidence of the health effects of wastewater and excreta use in agriculture, Document prepared for WHO by London School of Hygiene and Tropical Medicine, London, 2002, http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html.

CONSTRUCTED WETLANDS FOR THE MEDITERRANEAN COUNTRIES

PROPOSAL OF A HYBRID SYSTEM'S OPTIMISED DESIGN FOR WATER REUSE AND SUSTAINABLE SANITATION

By FABIO MASI and NICOLA MARTINUZZI*

Given a particular design and configuration of the constructed wetland (CW) system, the water loss can be minimized. The most powerful combinations seems to be the coupling of horizontal (HF) and vertical (VF) submerged flow beds, called hybrid systems, the performances of which are analyzed in the present paper.

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Fig. 1
HYBRID CONSTRUCTED WETLAND FOR AN HOTEL IN FLORENCE, ITALY

One of the main problems in adopting extensive treatments for waste water purification in hot climate countries, when it's aimed also at the reuse of effluent, is the high evapotranspiration rate. This factor can play a key role in reducing the water output, a desirable effect in some cases, when zero outflow is targeted, but completely adverse when water reuse is a primary resource for the area. Comparing constructed wetlands with ponds, an increase in the evapotranspiration (EP) rate is observed and easily explained with the presence of aquatic plants. Meanwhile, a higher retention time in ponds is needed to attain the same purification goals, and constructed wetlands can assure an optimal effluent quality, for its reuse, in the shortest time comparing them to the whole extensive treatments group. The comparison of the two alternatives in terms of water loss is not of immediate perception and to obtain reliable results the knowledge of inputs such as the local meteoclimatic conditions, the EP rate, the water purification goals etc., is strongly needed. Hybrid systems, defining with this term a combination of different kinds of constructed wetlands (like horizontal subsurface flow, vertical horizontal subsurface flow, free water systems), have shown the minor request in retention time/treatment volume amongst all the constructed wetland technologies. Due to these good performances they can represent a valid technical solution to assure adequate waste water treatment with a low-tech profile and easy maintenance, hitting the final target to obtain reusable effluents without relevant losses in volume by evapotranspiration.

CWs IN THE MEDITERRANEAN AREA

Very successful experiences with Constructed Wetlands have been reported in France (Molle, 2004), Spain (Garcia, 2004), Portugal (Matos, 2002), Morocco (Mandi, 1996), Italy (Masi, 2002), Egypt (Higgins, 2001), Israel (Brenner, 2002), Slovenia (Bulc, 2003), Croatia (Shalabi, 2004), Greece (Papadopoulos, 2002) and Turkey (Yildiz, 2004). The different treatment schemes in constructed wetlands are well-known nowadays in terms of the different performances that can be obtained in the specific meteoclimatic conditions in countries like France, Spain, Italy and Greece. The few experiences available in the scientific literature for the other countries are also promising because the tendency, going north to south, seems to be the reduction of the area required to obtain the same removal rates, at least for certain parameters.

CWs are definitely an efficient waste water treatment method in the Mediterranean climate and their application for any kind of water pollution problem has to be strictly linked to the treatment scheme choice and the sizing process. The operating experiences gen-

Fig. 2
HYBRID CONSTRUCTED WETLAND FOR A WINERY ON THE TUSCANY COAST, ITALY

Kind of CW	Organic Content	Nitrogen	Ammonia	Total Solids	Pathogens
HF	73 - 99	23 - 67	18 - 76	59 - 96	94 - 99.999
VF	52 - 95	---	78 - 99	48 - 98	96 - 99.9
FWS	11 - 63	21 - 76	15 - 82	36 - 67	90 - 99.999
Hybrid Systems	86 - 99	43 - 89	85 - 96	72 - 84	98 - 99.9995
VF raw ww	82 - 99.7	66 - 98	85	95 - 99.8	---

Table 1
GENERAL PERFORMANCES OF CONSTRUCTED WETLANDS SYSTEMS IN THE MEDITERRANEAN COUNTRIES (RANGE OF REMOVAL PERCENTAGES)

erally show a high efficiency in the removal of organic content (BOD, COD), Nitrogen (Ntot, NH_4^+, NO_3^-), Suspended Solids (TSS) and Pathogens (EC, FC, TC), both in secondary and tertiary treatment plants (Table 1).

Designs are often adapted to take account of different site characteristics, treatment goals and secondary benefits such as the reuse of the treated waste water or the provision of the wildlife habitat. Surface-flow wetlands are increasingly being favored as tertiary treatment, because of their cheaper investment costs and their higher wildlife habitat values. Subsurface-flow wetlands, however, tend to be more widely applied, especially as a secondary treatment, due to their effectiveness at filtering out solids and removing BOD per unit land area. In general, the Mediterranean CWs systems seem to be obtaining better results, probably due to the more constant and warmer climatic conditions, in comparison to most of the other North European experiences.

COMPARISON OF MEDITERRANEAN EXPERIENCES

As a first example of this assumption, the constructed wetland Haran-Al-Awamied, located in Syria, can be cited: the system, running for a 7000 p.e. community, is composed of parallel HF reed beds, with a surface area equal to 0.43 $m^{2/}$pe and an HRT (hydraulic retention time) of less than one day: the organic matter removal obtained in this system is 84-85% in average, both for BOD_5 and COD (Mohamed A., 2004).

A second example is represented by the pilot system realized in Marrakech in which an HF CW with a mean HRT of four hours and a mean HLR (hydraulic loading rate) of 60 lt/m^2.d has obtained on average the 62% of removal for COD and the 97% of removal for helmint eggs. These figures show that even with a highly reduced retention time, comparing with the northern European experiences, interesting performances can still be obtained, that could be considered even more of interest in the case of sanitary emergencies and the lack of economical resources to face the situation. The high performances reached in this re-

Fig. 3
HYBRID CONSTRUCTED WETLAND FOR ENHANCED DENITRIFICATION AT THE MUNICIPAL WASTEWATER TREATMENT PLANT IN JESI, ITALY

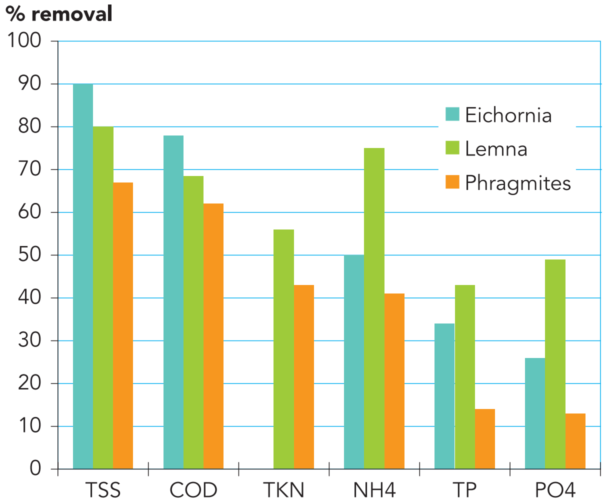


Fig. 4
PERFORMANCES IN PERCENTAGE REMOVALS BETWEEN THREE PARALLEL LINES IN MOROCCO (MANDI ET AL., 1996)

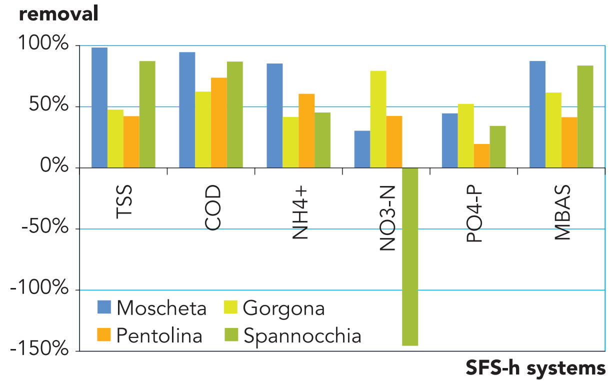


Fig. 5
PERFORMANCES IN PERCENTAGE REMOVALS FOR FOUR HF REED BEDS LOCATED IN CENTRAL ITALY (CONTE ET AL., 2001)

search (Mandi, 1996) by the floating macrophytes systems favour their usage in such climatic conditions (Fig. 3), even though the biomass management can represent a negative aspect to ensure the continued good performance of the treatment with a very low profile in maintenance. The first two lines in Fig. 4 are floating macrophytes systems (*Eichornia* and *Lemna*), while the third one is a subsurface horizontal flow reed bed (*Phragmites*).

In Fig. 5 the mean removal percentages obtained over some years of monitoring for four HF reed beds located in Central Italy are shown (Conte et al., 2001). The two cited experiences in warmer climate countries highlight an increase of more than 10% in the mean efficiency yields in comparison to the Italian systems, which seem themselves a bit more efficient in comparison to the northern countries such as the United Kingdom, Germany and Denmark.

A hybrid CW system located in Central Italy, the configuration of which could also be adapted in hot climate countries, has a "compact" configuration, with a land usage of about 2.4 m^2/pe; it constitutes an **optimized design** to reach a high disinfection level (up to 99.999% removal for the pathogens), together with the satisfactory removal of the organic content and suspended solids and a good nitrification that provides a useful nitrates concentration in the outlet for further reuse for irrigation.

The observed hybrid system HF+VF offers the advantage of obtaining performances always at the highest level for the general CW technology with a low need for surface area. The particular combination is designed to minimize all the operational problems, such as occlusion or clogging phenomena, raising the specific treatment properties of the two systems.

The hybrid CW system, realized for the treatment of waste water produced by a medium-size hotel, is suitable for the removal of pathogens and all the monitored chemical parameters since the first month of operation, and the outlet water complies with the national limits for reuse (gardening).

THE PROPOSED DESIGN: THE HYBRID CONSTRUCTED WETLAND SYSTEM HF+VF

The monitored reed bed is composed by a first stage horizontal submerged flow (HF) and a second stage vertical flow (VF) (see Fig. 6), and it treats the mixed waste water (grey+black) produced by a hotel (140 p.e.). In Table 2, the main features of the reed bed system are reported, including the measured hydraulic loading rate (HLR) and the organic loading rate (OLR) during the monitoring period. In fact, an important characteristic of this treatment plant is the tourist fluctuation, which involves the high variability of the daily flow and, consequently, of the loading rate. The waterproofing of the bed has been realized by a HDPE geo-membrane.

Considering the general performances of the whole treatment system, looking at the inlet and the VF bed outlet related figures, it can be noticed that the outlet

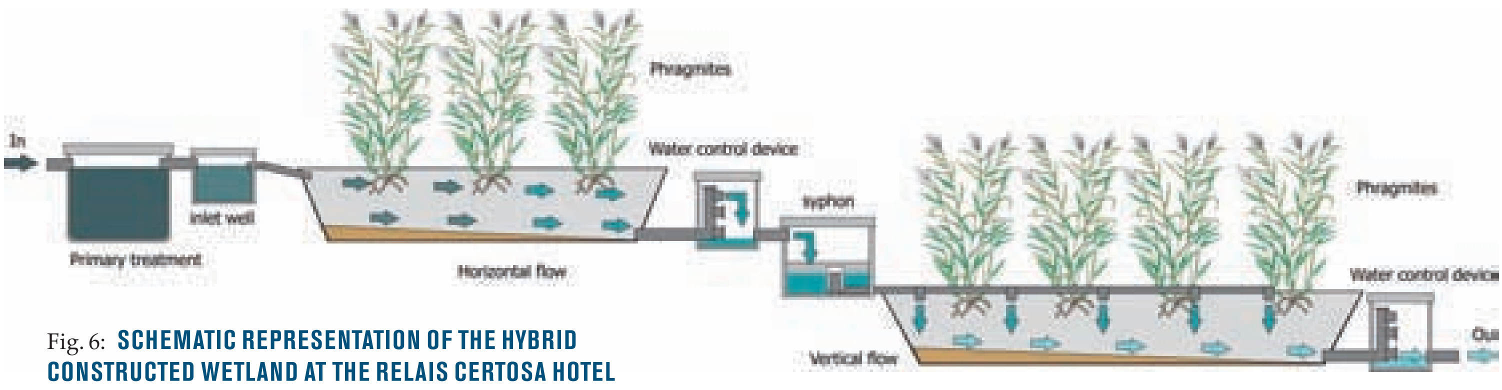


Fig. 6: **SCHEMATIC REPRESENTATION OF THE HYBRID CONSTRUCTED WETLAND AT THE RELAIS CERTOSA HOTEL**

Parameter	Value
Load (p. e.)	140
Inflow ($m^3\ d^{-1}$)	17 - 33
Surface Area HF (m^2)	160
Surface area VF (m^2)	180
HF depth (m)	0.7
HF Gravel size (mm)	5 - 10
VF filling media (sand+gravel)	Top 10 cm ∅ 6-12mm Middle 60 cm sand ∅ 0/4 Bottom 20 cm ∅ 30-40 mm
VF depth (m)	0.9
HRT – HF (theoretical) (d)	3
HLR ($m^3\ m^{-2}\ d^{-1}$)	HF: mean 0.17 min 0.11 max 0.23 VF: mean 0.15 min 0.10 max 0.21
OLR (g COD $m^{-2}\ d^{-1}$)	HF: mean 23.5 min 6.8 max 38.1 VF: mean 2.0 min 0.9 max 5.7
Primary treatment	Imhoff - Total volume 70 m^3
Operating since	January 2003

Table 2
MAIN FEATURES OF THE RELAIS CERTOSA HOTEL WASTE WATER TREATMENT FACILITY

Fig. 7
HYBRID CONSTRUCTED WETLAND

concentrations have always satisfied the national limits for discharging in surface water for facilities under 2000 p.e. (Table 3 Annex 5 DL 152/99 - Italian Law).

The mean overall removal rates performed by the RBTS during the monitored period were respectively 84% for TSS, 94% for COD and BOD_5, 86% for NH_4^+, 60% for Total Nitrogen, 94% for Total Phosphorus.

The main part of the COD removal takes place in the 1st stage, thus reducing the risk of clogging in the 2nd stage VF bed. This low organic matter content, together with the high removal of solids (TSS), permits a quite high HLR (hydraulic loading rate) in the VF bed, at least 3 to 4 times higher than the usual values applied when a VF bed is adopted as a unique stage, without a 1st stage. The roles assigned to the 2nd stage are this way only the nitrification and strong refining of the disinfection. Thus the system discharges quite a high amount of nitrates, that could be reduced introducing a recirculation to the primary treatment and the consequent good action of the anoxic HF bed.

The average removals of the four analyzed hygienic indicators were in the range of 99.93 - 99.99%, showing the very high efficiency of the hybrid system at removing the pathogens. During the passage through the HF Reed Bed, the bacteria were reduced 2.9 - 3.2 log units, whereas the reduction in the second stage VF bed was 0.7 - 1.2 log units. The treated wastewater fulfills the Italian regulation limits for reuse as regards the pathogens indicator *E. Coli* (80 percentile equal to 50 cfu/100ml and maximum admitted value equal to 200 cfu/100ml).

Parameters	R. lim.*	influent RBTS			effluent RBTS		
		mean	range	n*	mean	range	n*
Temperature [°C]	-	-	10.2 - 27.2	17	-	8.5 - 28.4	17
pH [-]	5,5 - 9,5	-	7.1 - 7.8	17	-	6.9 - 7.4	17
Total suspended solids [mg/l]	≤ 80	26	11 - 47	17	4	2 - 14	17
Electrical conductivity [µS/cm]	-	1115	706 - 1427	17	1015	653 - 1534	17
Alkalinity [mmol/l]	-	7.0	4.0 - 10.0	17	6.2	4.4 - 8.1	17
COD [mg/l]	≤ 160	115	14 - 218	17	7	5 - 14	17
BOD_5 [mg/l]	≤ 40	41	9 - 82	17	2	1 - 6	17
TKN [mg/l]	-	53.0	17.0 - 86.0	17	21.00	7.0 # 47.0	17
NH_4 -N [mg/l]	- (≤ 15)	15.0	0.1 - 62.0	17	2.2	0.03 - 9.5	17
NO_3 - N [mg/l]	- (≤ 20)	2.00	0.20 - 14.00	17	15.1	0.3 - 43.5	17
NO_2 - N [mg/l]	≤ 0,6	-	- - -	-	0.09	0.010 - 0.310	17
P_{tot} [mg/l]	≤ 10	5.1	0.6 - 8.9	17	0.3	0.02 - 0.6	17
Faecal coliformes [CFU/100 ml]	-	4.2E+06	4.1E+04 - 3.0E+07	17	1.3E+03	1.0E+00 - 1.9E+04	17
E. coli [CFU/100 ml]	≤ 5000	3.4E+06	4.0E+04 - 3.0E+07	17	1.8E+02	1.0E+00 - 1.0E+03	17
Total coliformes [CFU/100 ml]	-	8.0E+06	7.7E+04 - 3.0E+07	17	3.8E+03	3.0E+01 - 2.9E+04	17

Table 3
INFLUENT/ EFFLUENT CONCENTRATIONS OF THE COMBINED HORIZONTAL+ VERTICAL-FLOW CW AT "RELAIS CERTOSA HOTEL" IN ITALY

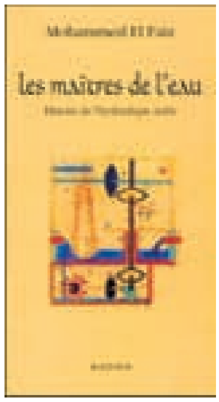
* n = number of samples, R. lim. means Regulation limits

REFERENCES

- Brenner, A. and Messalem, R., "Wastewater Treatment and Reuse in Israel: Policy and Applications", in Proc. of *"Small wastewater technologies and management for the mediterranean area"*, Seville, Spain, 2002.
- Bulc T., Zupancic M., Vrhovsek D., "CW experiences in Slovenia: development and application", in Proceedings of the conference "Constructed wetlands: applications and future possibilities, 90-105, Volterra, Italy, 2003.
- Conte G., Martinuzzi N., Giovannelli L., Pucci B., Masi F. "Constructed wetlands for wastewater treatment in central Italy", Water Science & Technology, vol. 44, n. 11-12 , 339-343, 2001.
- Garcia J., Morato J., Bayona J.M., Aguirre P., "Performance of Horizontal Sub-surface Flow CW with different depth", Proceedings, *9th International Conference on Wetland Systems for Water Pollution Control*, Avignon, France, 26-30 of September 2004, 269-278, 2004.
- Higgins John M., El-Qousey D., Abul-Azm A. G., and Abdelghaffar M., "Lake Manzala Engineered Wetland, Egypt" in Proceedings of the *2001 Wetlands Engineering & River Restoration Conference*, August 27-31, Reno, Nevada, 2001.
- Mandi L., "The use of aquatic macrophytes in the treatment of wastewater under arid climate: Marrakech experiment" in Proceedings of *5th International Conference on Wetland Systems for Water Pollution Control,* Vienna, Austria, September 1996.
- Masi F., "A survey of constructed wetlands in Italy as low-cost wastewater technologies", in Proc. of *"Small wastewater technologies and management for the mediterranean area"*, Seville, Spain, 95-112, 2002.
- Matos J., Santos S., Dias S., "Small wastewater systems in Portugal: challenges, strategies and trends for the future" in Proceedings of *"Small wastewater technologies and management for the mediterranean area"* Seville, Spain, 2002.
- Mohamed A., "Constructed wetland Haran-Al-Awamied, Syria". Data sheets for ecosan projects. Web source: http://www2.gtz.de/ecosan/download/ecosan-pds-015-Syria-HaranAlAwamied.pdf, 2004.
- Molle P., Lienard A., Boutin C., Merlin G., Iwema A., "How to treat raw sewage with CW: an overview of the French Systems", Proc. of *9th International Conference on Wetland Systems for Water Pollution Control*, Avignon, France, 26-30 of September 2004, 21-30, 2004.
- Papadopoulos A., "The Nagref experimental station in the Thessaloniki Greece", in Proceedings of *"Small wastewater technologies and management for the mediterranean area"*, Seville, Spain, 2002.
- Shalabi M., "CW in Croatian Adriatic Area" in Proc. of *9th International Conference on Wetland Systems for Water Pollution Control*, Avignon, France, 26-30 of September 2004, 307-314, 2004.
- Yildiz C., Korkusuz A. E., Arikan Y., Demirer G.N., "CW for municipal wastewater treatment: a study from Turkey", in Proc. of *9th International Conference on Wetland Systems for Water Pollution Control*, Avignon, France, 26-30 of September 2004, 193-202, 2004.

UN OUVRAGE SUR «LES MAÎTRES DE L'EAU – HISTOIRE DE L'HYDRAULIQUE ARABE»

THE WATER MASTERS – A HISTORY OF HYDRAULICS IN THE ARAB WORLD (IN FRENCH)



Sorti en novembre 2005, l'ouvrage de Mohammed El Faïz est une synthèse des cultures de l'eau de la civilisation arabe, principalement dans le monde méditerranéen.

Fruit de patientes recherches dans les archives de nombreux pays, l'ouvrage affirme la position de l'hydraulique arabe dans le développement des sciences de l'eau et rappelle les nombreuses inventions des hydrauliciens arabes.

Puisant ses informations aux sources premières (rapports, traités techniques, protocoles de chantiers, etc. …) jusqu'ici inaccessibles, l'auteur offre un large panorama des techniques et savoir-faire de l'Ecole arabe de l'eau, de leurs évolutions et de leurs expansions géographiques autour de la Méditerranée.

Cette somme de plus de 300 pages comble un vide qui a trop longtemps persisté. Elle ne peut que passionner notamment les scientifiques et ingénieurs de tous pays et tout particulièrement ceux qui interviennent de près ou de loin dans le cadre du Programme MEDA EAU.

Mohammed El Faïz, enseignant chercheur à l'Université Ayyad de Marrakech (Maroc), est l'auteur de nombreuses publications sur l'eau, l'agronomie et les jardins dans la civilisation arabe.

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RAINWATER HARVESTING FOR DOMESTIC USE IN TUNISIA

By AHMED GHRABI*

The mobilization of water resources in Tunisia has deeply characterised the hydraulic way of thinking during the last two millennia; the many still intact or crumbling water harvesting works built in the country testify to this. The cistern is the hydraulic structure most widespread in Tunesia since antiquity. The technique applied of constructing the cisterns (structures of various forms based on various techniques of rainwater harvesting) was greatly improved during centuries of successive civilizations [1].

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Fig. 1
RAINWATER HARVESTING IN THE COURTYARD OF GREAT MOSQUE KAIROUAN, SINCE CENTURY IX

Cisterns were and remain until now the only resource of potable water for several families in Southern Tunisia. In some parts of the country, where potable water is supplied by public networks, rainwater harvested in cisterns could be supplemental for certain domestic uses (as drinking water, in kitchens, for cleaning clothes, washing machine, etc). This alternative has to be developed in order to save water and the rehabilitation of this rainwater harvesting system is inescapable and perfectly compatible with the concept of the local and sustainable management of water.

In this paper, we will present the Tunisian experience and know-how in the field of rainwater mobilization and its use in the various domestic activities. This document was compiled based on paper reviews, on site observations, and the surveys and questionnaires carried out in several regions in Tunisia.

EVOLUTION AND HISTORY OF CISTERNS: ROMAN TIME

To have an adequate water supply, the Romans used very ingenious techniques, building vast and monumental cisterns in all of the countries they conquered. Generally, most historians agree on the fact that the Romans exploited more rain water than ground water to meet their needs. Indeed, the many Roman vestiges strewn on the Tunisian territory, show the control which the Romans had. The Roman cities Turbo (Tébourba), Cilma (Jelma), Suffetula (Sbeitla), Cillium (Kasserine) and Tignica (Aïn Touna) were also supplied by rainwater harvested in cisterns.

ARABO-MOSLEM PERIOD

In the VIth century, a second age of water appeared in Tunisia, following its conquest by the Arabs. Arab civilization was inspired by the Roman cisterns, and the most important installations consisted of 200 large cisterns, with an average capacity of about 1000 m^3 distributed in the low and high steppes. The most prestigious of these installations is undoubtedly the basins of 'Aghlabides' in Kairouan that were built between 859 and 863 by the Emir Abu Ibrahim Ahmed Ibn Mohamed, the sixth prince of the Aghlabide dynasty. This installation comprises three basins; the first one is for decantation, the second for storage and the last for drawing up and the supply of water to the Kairouan city. The mosque is also fed by the underground rainwater cistern managed in the courtyard (see photo at the beginning of this article).

Fig. 2
UNDERGROUND PRIVATE CISTERN

Fig. 3
HARVESTING OF RAINWATER ON THE ROOF OF THE HOUSE

XX^TH CENTURY (CURRENT SITUATION)

Different in their dimensions, their typology and technical nature, the cisterns currently mark out the whole of the territory with a major abundance in the areas with a chronic water shortage such as: the Sahel region, the Kerkena archipelago, the Jerba island, Sfax and the area of the South-West. The cistern depth varies from 3 to 5 m and the house roof form their impluvium. The public and private cisterns census carried out in the Sahel area in 1970 revealed the presence of 650 cisterns in the Sousse Department, 200 in Monastir and 5830 in Mahdia. In 1986, 31 new public cisterns were recorded in Sousse, 19 in Monastir, and 81 in Mahdia. In addition to the 70 cisterns built by open benevolence and the 40 others integrated in public buildings (primary schools, dispensaries, mosques, etc).

The private cisterns are of two types:

- Fosquiya: this is similar to the public cisterns but with less storage capacity and natural impluvium. This system is generally constructed in rural areas.
- Mejel (or Mejen): this is bottle-shaped or in a vase or prism in the Sahel. Its capacity is mostly low (20 to 40 m^3) and seldom reaches 80 m^3. It is connected either to a natural or more or less arranged impluvium, or integrated in the dwelling using the roof or an arranged surface as impluvium (see Fig. 3). In isolated rural locations, the rain water harvested in these cisterns is used chiefly for human drinking and animals, watering and sometimes to irrigate vegetable fields and small orchards. In this later case, the impluvium is arranged near the house and could be natural or of concrete.

The extraction of water from the cistern could be manually via a seal or automatically using a pump. It

Fig. 4
AS TRADITIONAL FILTER HARD DRY THORNY PLANTS WORK FOR PROTECTION OF CISTERN AGAINST RODENT AND WASTE

Fig. 5: **TRADITIONAL FILTER FOR HARVESTING RAINWATER INSERTED IN THE PIPE**

Fig. 6
RURAL RAIN WATER CISTERN, MATMATA

Fig. 7
RURAL RAIN-WATER CISTERN FOR DRINKING WATER IN MATMATA IN THE SOUTH OF TUNISIA

is recommended to use a traditional filter inserted in the pipe connecting the impluvium to the cistern to prevent the introduction of waste and polluted first flow (see Fig. 5, 8 and 9).

THE QUALITY OF WATER

The water quality in the cisterns varies regarding the use. The well kept cisterns for domestic use (including for drinking) deliver a very good quality (physicochemical and bacteriological) of water. The cisterns located in insulated rural areas, which are generally reserved for animal watering, are of medium quality. The collected water is unsuitable for human consumption, except for certain cisterns which are well maintained. Table 1 gives an idea of the quality of the water stored in the private sector, resulting from a study undertaken by the INRST [2] on several private cisterns in the Sahel region and the South-West of Tunisia.

ENCOURAGEMENT OF THE STATE

The decree N°90-822 of May 12, 1990 [3] stipulates aid by the Tunisian Government in the form of subsidies, loans, or complementary allowances for water resource mobilization, including rainwater harvesting.

For the construction of private agricultural cisterns, the subsidy reaches 25% of the amount invested, 65% will be granted in the form of loans and the remaining 10% is covered by self-financing. In the case of the creation of water points as cisterns, the maximum amount of expenditure is fixed at 100 DT (about 70 Euro) per m^3 of harvested water (Decree 95-793 of 2nd May 1995 regulating the encouragement of the Tunisian Government to the profile of the small farmers and fishermen [4]).

CONCLUSION

Cisterns were always present in the minds of Tunisians. They are spread across all the territory with a

Fig. 8: **TRADITIONAL FILTER FOR HARVESTING RAINWATER, POSITION FOR FEEDING THE CISTERN**

Fig. 9: **TRADITIONAL FILTER FOR HARVESTING RAINWATER, POSITION FOR ELIMINATION OF THE FIRST FLOW**

Fig. 10
THE KITCHEN IS CONNECTED TO RAINWATER (LEFT FAUCET) AND PUBLIC MAINS (RIGHT FAUCET)

high concentration in areas with chronic water shortage (the Sahel and mostly the South-East). The use of water of harvested water in cisterns to meet domestic needs varies from the North to the South. In the south and because of the poor quality of the public water supplied (high salinity above 1.5 g/l), the cisterns are used mainly for drinking and cooking. However, in the other areas, this stored water is used in cleaning and to wash clothes. In isolated rural areas, the water from cisterns is the only source of water to fulfil human needs and water animals.

ACKNOWLEDGEMENTS

The author would like to thank M. Anane for the help with the English text.

Fig. 11
WASHING MACHINE CONNECTED TO A RAINWATER CISTERN IN A PRIVATE HOUSE

REFERENCES

[1] Ennabli N. (1993). Les aménagements hydrauliques et hydro agricoles en Tunisie, 255p.
[2] Ghrabi (1999). Réhabilitation d'un système traditionnel de collecte des eaux pluviales.
Les citernes privées. Rapport final d'un projet de recherche, PNM94 - INRST.
[3] JORT (1990). Décret N° 90-822 du 12/05/90; JORT N°36. pp: 684-687.
[4] JORT (1995). Décret N° 95-793 du 2/05/95; JORT N°38. pp: 1091-1101.
[5] NT09.14. Tunisian Norms of drinking water.

Parameters	Unit	Concentration (interval of variation)	Limit admissible Concentration NT09.14 [5]
Turbidity	NTU	0.8 - 4.5	5
pH	-	6.8 - 7.5	6.5 – 8.5
Total Hardness	°F	7.9 - 65.9	100
Salt (dried)	mg/l	136 - 286	
Ca^{2+}	mg/l	22.5 - 170	300
Mg^{2+}	mg/l	2.6 - 52	150
Na^{+}	mg/l	6 - 15	
K^{+}	mg/l	2 - 14	
CO_3^{-}	mg/l	0	
HCO_3	mg/l	53 - 99	
Cl^{-}	mg/l	16- 36.5	600
SO_4^{2-}	mg/l	16 - 191	600
NO_3^{-}	mg/l	0 - 6	50
NO_2^{-}	mg/l	0	
Fe	mg/l	0 - 0.18	0.5 - 1
Mn	mg/l	0 - 0.004	5
Cu	mg/l	0 - 0.009	1
Al	mg/l	0 - 0.072	
Si	mg/l	0.88 - 12	
Zn	mg/l	0.008 - 0.022	5
F	mg/l	0.12 - 0.87	2
As	µg/l	< 0.1 - 10.75	
Hg	µg/l	0.199 - 0.733	1
Ag	µg/l	0.009 - 10	200
Total Coliform	MPN /100ml	0 - 9	0
Fecal Coliform	MPN /100ml	0	0
Fecal Streptococcus	MPN /100ml	0	0

Table 1
WATER QUALITY IN THE CISTERN (RAINWATER), 10 SAMPLES

ASSESSMENT OF JORDANIAN GREY WATER TREATMENT AND DISPOSAL NEEDS

By ABU GHUNMI, L., ZEEMAN, G., LIER, J. V., and FAYYAD, M.*

Jordan is one of the ten poorest countries in the world when considering water resources. Nineteen percent of its land area receives an annual precipitation of less than 100 mm. With a population growth rate of 3.8%, the water demand exceeds the supply by one fourth. Grey water forms 70% of the Jordanian domestic waste water consumption. Reclaimed domestic waste water forms 6 % of the annual Jordanian water budget.

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Waste water reuse comes along with the public acceptance, environmental issues and investment costs. These basic requirements should be fulfilled. This paper assesses water treatment and identifies disposal needs based on the grey water characteristics.

GREY WATER IN JORDAN

This study aims to assess the treatment and disposable needs for grey water in Jordan. The assessment was based on the quantity and quality characteristics of grey waters generated at different sources in Jordan. Quality characteristics were measured in terms of the physical, chemical and biological constituents of grey water. The results showed that the daily generation of grey waters in rural and urban residential places and commercial buildings per capita are respectively 16, 59 and 64 L.

The quality characteristics in terms of BOD, TSS, TP, and TN varied from weak to strong waste waters. Grey waters in Jordan need to be treated, to different levels, in order to reduce organic, solids and pathogens and the phosphorous content to a level that complies with the disposal needs. Grey water from domestic places consumes less than 21 m^3 water per month mainly in the rural area, community on site treatment and direct reuse may be the feasible options. On the contrary, with places consuming more than 21 m^3 monthly, i.e. urban and commercial buildings, on site treatments and indoor and outdoor reuse options may be the feasible options.

SOURCE OF DATA

A student flat on a Jordanian university campus was selected to measure and characterize grey water that is generated in rented domestic buildings. Moreover, data from local reports was used for comparison, see table 1.

ANALYSIS

To determine the quality characteristics at the student flat, initially an Auto sampler (during December) was programmed to collect 200 ml samples every 15 minutes (four samples per bottles). Daily composite samples were prepared by mixing the content of the 24 Auto sampler bottles in one container then the composite sample was taken to be measured. Temperature (thermometer), pH, EC (electrodes) alkalinity and hardness (titration) were measured for each composite sample and samples were analyzed for COD, BOD, TS and TSS. Methods of analysis were applied according to [3].

RESULTS AND DISCUSSION

[5] distinguished external and internal waste water reuse options. For external reuse, the water is sourced directly from sewage treatment works and used for crop irrigation & wetland development, preservation and aquifer recharge. For internal reuse, the water is retained within a local process loop such as domestic

Table 1
GREY WATER QUALITIES MEASURED IN TERMS OF THE PHYSICAL, CHEMICAL AND BIOLOGICAL CONSTITUENTS, GENERATED IN A JORDANIAN URBAN, RURAL AND STUDENT FLAT

Parameters	Units	Urban Area[1]	Student Flat	Rural Area[2]	Standards	
					(4)	(5)
Water consumption	L/cap d	51-115 (84)	57-93 (77)	39-50		
Grey water	L/cap d	39-80 (59)	64-74 (66)	16		
pH		7.51-8.08 (7.81)	7.41-7.80 (7.62)	5.2	6-9	6-9
EC	dS/cm	0.75-4.45 (1.91)	0.95-1.2 (1.071)			4.0**
Alkalinity ($CaCO_3$)	mg/l	195-274 (225)	450-560 (518)	140		
HCO_3	mg/l		305-348 (332)			400**
Settable solids	ml/l		1-5 (2.5)			
TS	mg/l	736-1477 (1061)	727-987 (848)			
TSS	mg/l	54-419 (168)	42-205 (125)	264	50	50
COD	mg/l		483-631 (560)	1460	100	100
BOD_5	mg/l		110-273 (136)	764	15	30
T-N	mg/l	5.5-14.3 (9.2)	2-11 (7)	25	30	45
NH_4	mg/l		2-6 (5)	1	5	15
T-P	mg/l	0.4-22 (9.0)	8-26 (18)	13.8		15
TC	MPN/100	205-1597 (852)				
E.Coli.	MPN/100	673-742 (689)			< 2.2	100

1; [4]: 2; [1]: 3; [6]: 4; Jordanian standards for ground water recharging (might be considered for toilet flushing and the irrigation of edible crops): 5; Jordanian standards for parking & lawn irrigation inside cities; ( ) typical values.

or industrial reuse. Internal reuse water can be further classified as outdoor and indoor reuse options. The Jordanian public has practiced the reuse of grey water for a long time. Grey water is reused within a local process loop, on site, for irrigating lawns, edible crops, and olive and fruit trees. A public survey revealed acceptance of the reuse of grey water for toilet flushing, home laundry and car washing [4].

In the absence of grey water reuse standards, the Jordanian standards for the reuse of reclaimed domestic waste water are considered in this study (see table 1). The standards include measurements related to the environmental risks; soil, plants and water courses and other measurements are related to the health risks.

The quantity and quality characteristics of grey water generated in Jordan in rural, urban areas and commercial buildings are given in table 1. The daily generation of grey waters in rural and urban residential places and commercial buildings per capita are respectively 16, 59 and 64 L. Figures 1A&B show grey water in Jordan can be classified in terms of total solids (TSS) as weak to strong waste water, in biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) as weak to medium, for Total Phosphorous (T-P) weak to strong and Total Nitrogen (T-N) as weak. Grey water in Jordan needs to be treated to reduce the BOD, TSS, T-P and pathogens to different levels to comply with different reuse standards. Furthermore, the practical experience of [2], which revealed that solids and organic compounds in grey water cause problems like the clogging of the irrigation system and prevent cistern closing and water leakages and increase the health risk.

The extent of water bill reduction as a result of the treatment and reuse of grey water is used to decide on a house-on-site or community-on-site approach. Water bill savings vary with the potential reclaimed wa-

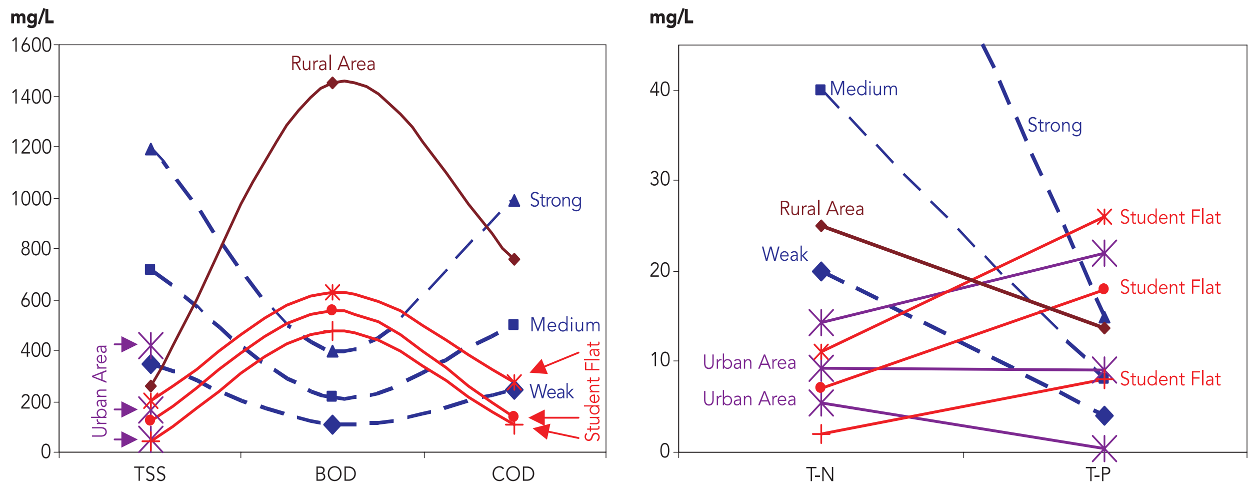

Fig. 1 A, B
CLASSIFY GREY WATER IN JORDAN BASED ON ITS CONSTITUENTS OF TSS, BOD,COD,T-N AND T-P (AFTER [6] CLASSIFICATION OF DOMESTIC WASTE WATER

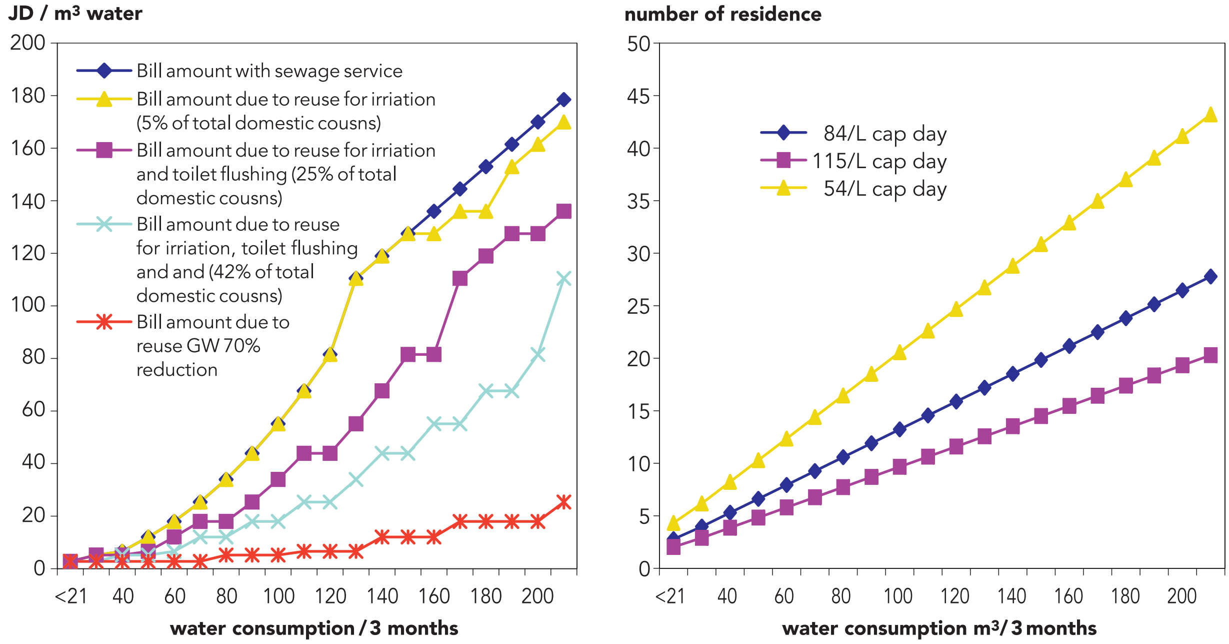

Fig. 2 A, B
WATER PRICES AS A FUNCTION OF THE WATER CONSUMPTION AND RESIDENCE NUMBER

ter market. Figure 2 A presents the calculated water price given an increasing water consumption for different reuse options. The water price in Jordan increases as the consumption increases. Generally grey water from domestic places consumes less than 21 m^3 of water. House-on-site-treatment and internal reuse might be a feasible option. For places consuming more than 21 m^3, such as combined family houses and recreational places, community-on-site treatment and indoor or outdoor reuse, might be the feasible option. Affordable investment costs with acceptable payback times can be estimated from figure 2 A&B, based on these estimated values a grey water treatment system can be selected. Domestic buildings with a large number of residences are the most feasible places to treat and reuse grey water.

CONCLUSIONS

The quantity and quality characteristics of grey water generated at different residential places in Jordan in rural, urban areas and commercial buildings, can be classified as weak to strong waste water which needs to be treated to reduce the BOD, TSS and pathogens to different levels to comply with different reuse standards.

On-site grey water treatment and reuse for irrigation is the feasible option for rural areas. On-site and community on site are feasible options for the treatment of grey water for urban areas, dormitories, resorts and hotels. Both direct and indirect reuses options are feasible. Quantity and quality characteristics, in addition to the economic considerations, make commercial buildings such as hotels, dormitories and resorts the most suitable places to separate, treat and reuse grey water.

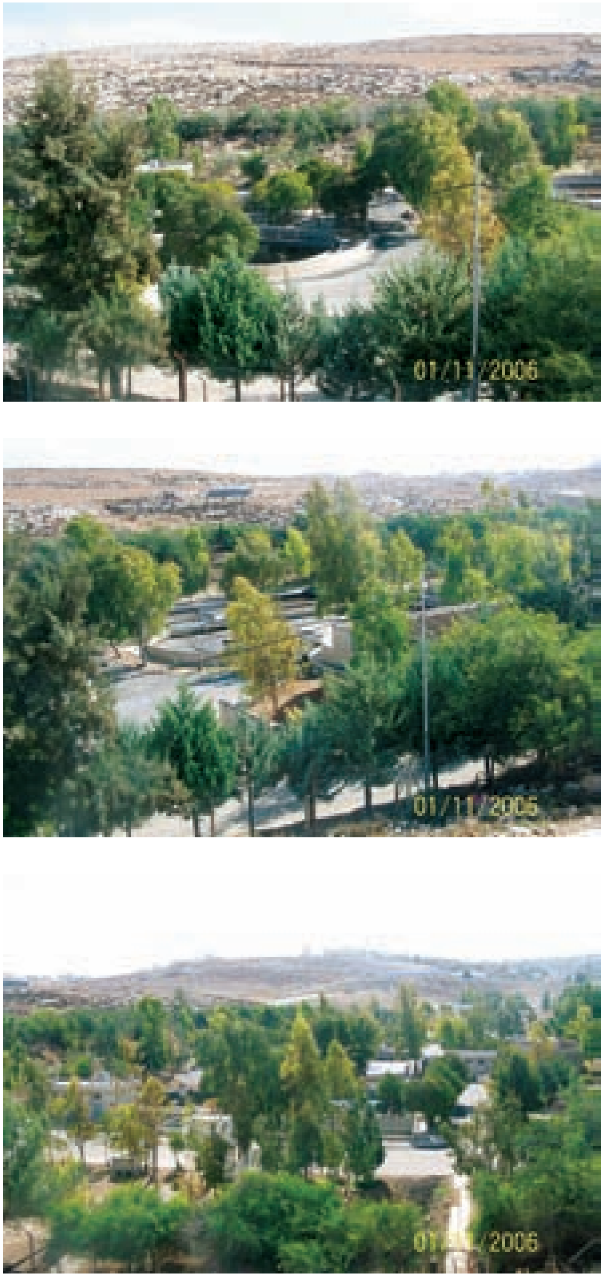

Fig. 3
GREY WATERS IN JORDAN NEED TO BE TREATED TO REDUCE ORGANIC, SOLIDS, PATHOGENS AND THE PHOSPHOROUS CONTENT TO A LEVEL THAT COMPLIES WITH THE DISPOSAL NEEDS

Fig. 4
GREY WATER IS RE-USED IN JORDAN IN A LOCAL PROCESS LOOP FOR IRRIGATING LAWNS, EDIBLE CROPS AND OLIVE AND FRUIT TREES

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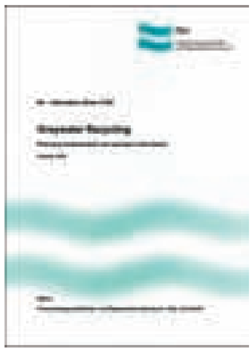
REFERENCES

[1] Al-Jayyousi, O. (2003). Grey water reuse: towards sustainable water management. *Desalinization.* 156, 181-192.
[2] Christova-Boal, D., Eden, R. E., McFarlane, S. (1995). An investigation into grey water reuse for urban residential properties. *Desalinization.* 106, 391-397.
[3] Eaton, A. D., Clesceri, L. S., and Greenberg, A. E., (1995). Standards methods for the examination of water and waste water. American Public Health Association.
[4] Jamrah, A., Al-Omari, A., Al-Qasem L., and Abdel Ghani, N., (2006). Assessment availability and characteristics of grey water in Amman. International water resources association. 31 (2), 210-220.
[5] Jefferson, B., Laine, A., Parsons, S., Stephenson, T. and Judd, S. (2001). Advanced biological unit processes for domestic water recycling. *Wat. Sci. and Tech.* 43 (10), 211-218.
[6] Metcalf and Eddy (2003). Waste water engineering treatment and disposal and reuse. McGraw-Hill, Inc.
[7] Royal Scientific Society of Jordan (1998) Poverty and Unemployment in Jordan.

FBR-INFORMATION SHEET "GREYWATER RECYCLING" IS COMPLETED



The fbr-Information Sheet H 201 "Greywater recycling, planning fundamentals and operation information" has been published by the German Association for Rainwater Harvesting and Water Recycling (fbr) as the first and only regulatory guide to be published so far on this topic. The fbr-Information Sheet H 201 documents the up-to-date standard of knowledge in this field and defines requirements for design, implementation, operation and maintenance that have been proved and tested in the practice. The fbr-Information Sheet H201 is recommended for manufacturers, consultants and interested individuals and gives first information on the operation of greywater recycling plants. A complete version of the Information Sheet H 201 can be found under:

http://www.fbr.de/aktuell/information.htm.

For more information visit fbr-homepage:

www.fbr.de

Fig. 1:
GREY WATER TREATMENT PLANT AT A SCHOOL

RECYCLING OF GREY WATER IN CYPRUS

By CHRYSOSTOMOS. A. KAMBANELLAS*

From 1997 onwards, the Government decided, in parallel with new projects to implement water conservation measures at household level (on site waste water treatment and recycling). Over 50 % of the domestic water demand could be met by water of a lower grade quality, such as processed water. Saving water from the existing domestic water supply systems has exactly the same results as water supplied from new water supply schemes.

As a practical measure, to save drinking water, a scheme was put into practice, to subsidize the recycling of "grey water" for irrigation and/or for operating WC's in households or buildings. With this practical measure there is a conservation of drinking water from 35% - 40% of the per capita water consumption. The recycling of grey water started on an experimental basis in 1997 and continued right through 1998, by the Water Development Department. The advantage of recycling grey water, in comparison with recycling treated sewage effluents, is that this is done in the building/household itself. Hence, this water is used again, either for the irrigation of the garden or for the flushing of the toilets of the same building/household. In this way, true savings in drinking water are accomplished, in residential areas.

LIMITED FRESH WATER

Comparing the earth and its life support system to a spaceship is a vivid way of illustrating the finite nature of our ecosystem and there is no escape from the necessity to recycle waste materials. Water is one of man's most valuable commodities. Without it there can be no life. Over 97% of the world's water is sea-water and because of its salinity, it is unsuitable for agricultural, industrial and life-sustaining needs. About 2.5% of the world's water is fresh with much of it locked in icecaps and unavailable for our use. Only the estimated 0.1% or less of the world's water supports the world's population and this is unequally distributed around the world.

In arid or semi-arid regions of the world the need for a satisfactory water supply poses a constant problem because of the low or uneven distribution of precipitation and high evapotranspiration. Water conservation and water reuse are becoming increasingly important, particularly in the South and Eastern Mediterranean Regions. The reuse of water is one of the means which would help to meet present and future demands. It has the additional benefits of conserving valuable drinking water resources.

ABOUT CYPRUS

Cyprus is situated in the North-Eastern part of the Mediterranean Sea. It is one of the ten countries that have just joined the European Union (in May 2004), as part of the EU expansion. Cyprus is one of the 27 countries which are members of the Euro-Mediterranean Information System on the know-how in the water sector. (EMWIS http://www.emwis.org Cyprus NFP http://www.emwis-cy.org)

Cyprus is the third largest island in the Mediterranean Sea with an area of 9250 km^2. 40 % of the area of Cyprus, is under Turkish occupation. The population

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in the government controlled area of Cyprus is about 700000. Every year the island is visited by more than 2.5 million tourists.

THE WATER RESOURCES SITUATION

The development of water resources on the Island of Cyprus is one of the major concerns and objectives of the Water Development Department. Water resources in Cyprus are very limited and expensive to develop. Water is required both for domestic and agricultural purposes which constitute the main uses. Industrial and other uses are limited. Out of the total water demand now used, 70% is for irrigation and the remaining 30% for domestic, industrial and tourist uses.

Until 1974, only ground water was used to supply urban areas with potable water. Coupled with the much greater demands placed on ground water by irrigation needs, this resulted in the over-exploitation of ground water. The depletion of aquifers and the intrusion of the sea into several coastal aquifers were problems that had to be tackled by turning to the development of surface water sources.

Thus from 1960 to 1996, dam storage was increased 50-fold from just 6 to 300 MCM, and the proportion of surface water used until 1996, for the urban water supply sector has increased from nil to 60%.

A Reverse Osmosis sea-water desalination plant came on stream at the beginning of April 1997. Today the proportion of the domestic water supply is 27% ground water, 28% surface water and the remaining 45% is desalinated water.

Today almost all towns and villages in Cyprus are served by piped house-to-house water supply systems, covering almost 100% of the population. The supply to each consumer is metered and charged on the basis of a rising block tariff designed to discourage waste. Different tariffs apply to domestic and industrial consumers.

MANAGEMENT OF THE IRRIGATION SCHEMES

The planning, design and construction of large and medium size projects are carried out by the Water Development Department. Small size schemes are constructed by individual farmers. The irrigation networks are of modern type, consisting of pressurized conveyance and distribution systems with the metered delivery of water to the farm outlets. Modern on-farm irrigation systems are used, and these include in order of preference: drip irrigation, mini-sprinklers, and low capacity sprinklers.

MANAGEMENT OF DRINKING AND INDUSTRIAL WATER

The executive responsibility of the Water Development Department includes the production, treatment and conveyance of potable water, up to the inlets to the service reservoirs of towns and villages. Water is sold in bulk to the water distribution authorities of each town or village. A unified, flat, bulk water tariff is charged which covers the full cost of water.

Water distribution authorities are the Water Boards or Water Committees in the case of villages. Some of these authorities also manage their own sources.

Regarding the water quality, the Water Development Department continuously monitors water quality at its sources, water treatment works and points of delivery. The Ministry of Health, acting through its Department of Public Health and the State General Laboratory, also exercises control which extends from the sources to the consumers' premises.

WATER CONSERVATION

Each project built for the solution of the water problem of Cyprus from 1960 up to 1996 is bigger than the previous one. At the same time the water problem is not getting better but it is growing larger each year. From 1997 onwards, the Government has decided, in parallel with new projects, on the implementation of water conservation measures at household level.

CONSERVATION OF DRINKING WATER

Potable water used in households and industry is normally taken directly from the drinking water system and discharged into a central sewage system or into an on site wastewater system. Water, suitable for potable use, is therefore taken from the supply system and used for other purposes, before discharge into the waste water system.

It is quite obvious that water of this quality is not needed for many domestic and industrial applications. To meet these non-potable water demands with an appropriate quality of water, two solutions are currently available:

a) The installation of a separate processed water system,
b) The decentralized recycling of at least a suitable part of the discharge water for reuse as processed water.

Only about half of the average annual supply of domestic water in Cyprus needs to be of drinking water quality. Over 50% of the demand for water could be met by water of a lower grade quality, such as processed water. Processed water is usually defined as water which meets the requirements – in terms of dissolved components and other essential parameters – for various systems such as instruments, machinery, or living organisms.

The conservation of drinking water has been initiated as a practical means of assisting water demand management where, for instance, capital expenditure on water resource development (new dams, main conveyors, water treatment, etc) might be reduced or deferred. "Water saved is exactly the same as water supplied" and "One person's reduction in water use makes water available for someone else to use".

As a practical measure, to save drinking water, a scheme has been put into practice during the last few years, by the Government of Cyprus, to subsidize the recycling of "grey water" to water the garden and/or for the operation of the WC's in the individual house-

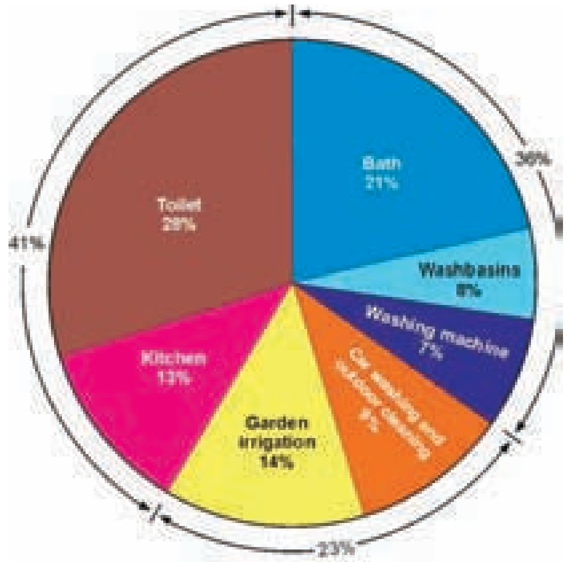

Fig. 2
AVERAGE CONSUMPTION OF WATER IN A HOUSEHOLD IN CYPRUS

holds or buildings. With this practical measure there is at the moment a saving of 2.5 MCM per year of drinking water.

RECYCLING OF GREY WATER

In Cyprus slightly polluted or Grey Water from baths, showers, hand or wash-basins and washing machines is kept separate from heavily polluted or Black Water from WC's and kitchens. As a result it is relatively easy to intercept each type of waste water at household level for subsequent treatment and reuse. This reuse is novel in Cyprus.

The recycling of grey water started on an experimental basis [1] in 1997 and continued right through 1998, by the Water Development Department, with the support of the Ministry of Agriculture, Natural Resources and Environment and the Planning Bureau.

The advantage of recycling grey water, in comparison with the recycling of treated sewage effluents from the central sewage systems, is that this is done in the building/household itself from which the grey water comes. Hence, this water is used again, either for the irrigation of the garden or for the flushing of the toilets of the same building/household. In this way, a true saving in drinking water is accomplished in residential areas where there is a shortage of water.

In countries like Australia (the driest Continent on our planet), efforts are being made to recycle grey water in residential areas. However, these efforts are limited due to the fact that the drainage system of the buildings is common for grey and black water. The idea for the installation of a network for the distribution to towns of recycled water from sewage treatment plants has been abandoned because of the high capital cost and the danger of polluting drinking water from the network for the distribution of recycled water [2], [3].

INSTALLATION AND OPERATION OF GREY WATER TREATMENT PLANTS

In the region of Nicosia, the following seven grey water treatment plants were installed. One at a Hotel, one at a Stadium and the remaining five in five different households. They were installed in mid 1997 and the quantity of water that had been recycled until the end of December 1998 was 220 cubic meters. This water was reused, without any problems, for the watering of the gardens of the hotel and the households, the watering of the lawn at the stadium and the flushing of the toilets of the households. Following chemical analyses performed by the Government General Chemical Laboratory and the Water Development Department, it was verified that the quality of the recycled water is suitable for irrigation as well as toilet flushing. The settling of material from treatment is minimal and it is discharged to the septic tank of the building or to the central sewage system.

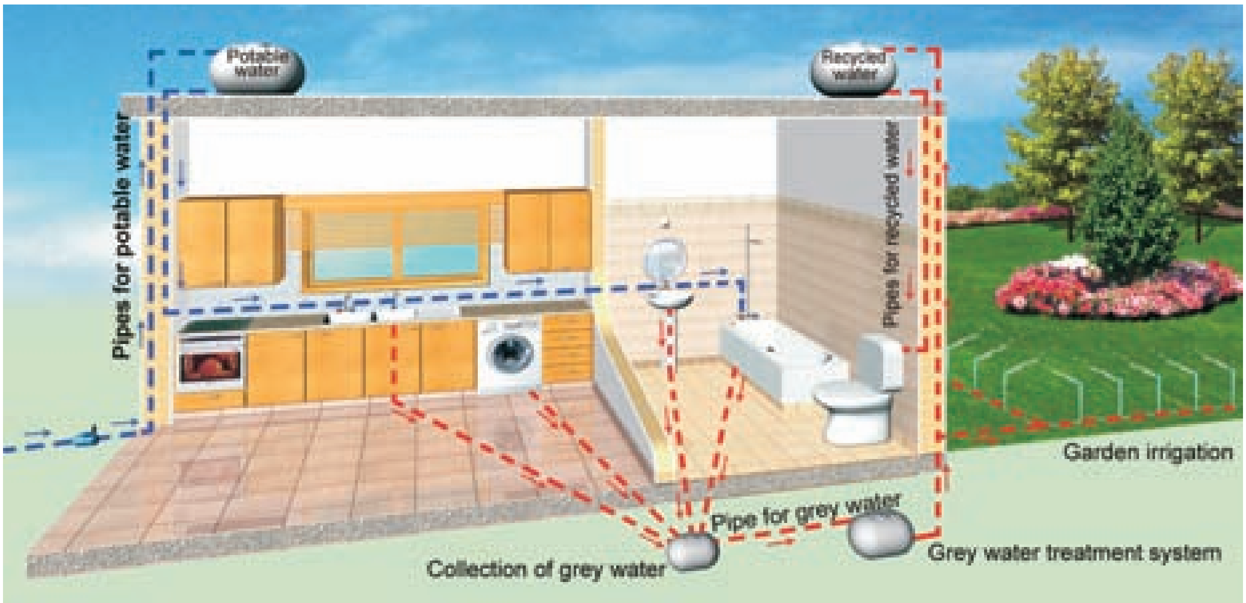

Fig. 3
RECYCLING OF GREY WATER AT HOUSEHOLD LEVEL

At first, the grey water treatment plant was not automatic. Today, this equipment functions automatically, and the recycled water, after being treated, is stored in a tank for reuse without the intervention of man.

During the experimental work, measurements were taken to calculate the percentage of reuse in relation to the per capita drinking water consumption. For the Hotel, the mean per capita drinking water consumption by guests of the pool that used the showers reached the amount of 40 litres per day. This water was used for the irrigation of the gardens. For the stadium, the water that was recycled was that of the showers used by the football players, which amounted to 71% of the drinking water measured by the central water meter of the stadium. This water is reused for the watering of the lawn. For the five households, the mean per capita drinking water consumption amounted to 122 litres per day, from which the grey water is 36 litres per day or 33%. This water is reused for the flushing of the toilets and for the irrigation of the gardens in the same households the grey water comes from, see figure 3.

After five years (1985 - 1991) of research and two years (1997 - 1998) of experimental work on a pilot scale, the Government of Cyprus decided to subsidize, as from the beginning of 1999, the installation of a Grey Water Treatment Plant (GWTP). The cost of such a treatment plant, fully automatic, for a household with a production of one cubic meter per day is € 1400 and the Government of Cyprus, through the Water Development Department gives € 350 as a subsidy. As from 2003, this subsidy was doubled reaching € 700 and from 2006 was increased to € 1050 and now covers more than half the cost of the GWTP. This decision was taken, because drinking water saved is approximately four times cheaper than the same amount of drinking water supplied to the same town, from new projects.

With this scheme there is a conservation of drinking water from 35% to 40% of the per capita water consumption. This means that the conservation of drinking water from every three people covers the needs of the fourth person.

Fig. 4
GREY WATER TREATMENT PLANT AT AN ARMY CAMP

Fig. 5
GREY WATER TREATMENT PLANT AT A FOOTBALL FIELD

Fig. 6
GREY WATER TREATMENT PLANT AT A HOUSEHOLD

CONCLUSIONS

- The water resources of the Island of Cyprus are limited, and they are almost fully developed.
- Water conservation and reuse remain a top priority in Cyprus. By the use of lower grade water such as recycled water for non-potable needs, at household level, there is a conservation of about 35% of the per capita drinking water consumption.
- The operation and maintenance of the grey water treatment plant is simple and does not present any particular problems.
- The quality of the recycled water is suitable for irrigation purposes and for toilet flushing.
- With the recycling of Grey Water, there are substantial savings in drinking water in residential areas (for every three people the amount of water saved can satisfy fully the needs of the fourth person).
- The cost for installing and operating the grey water treatment plant is quite low compared to other methods of treating waste water, such as biological treatment.
- With the recycling of grey water, the problem of overflow of the septic tanks/absorption pits due to low absorption of the soil is alleviated.

REFERENCES

[1] KAMBANELLAS, C.A. (1998) "Recycling of Grey Water in Cyprus", Water Development Department, Nicosia, Cyprus.

[2] USTRALIAN WATER RESOURCES COUNCIL (1993): "Guidelines for the Provision of Water Efficient Appliances and Plumbing."

[3] SYDNEY WATER BOARD (1994): "Demand Management in the Water Board".

Foto source: König

Fig. 1
STAIRS FOR THE RAIN WATER FROM THE ROOF TO THE CISTERN, CAS CONCOS, MALLORCA

RAINWATER HARVESTING - A GLOBAL ISSUE MATURES

By KLAUS W. KÖNIG and DIETMAR SPERFELD*

The English term "Rainwater Harvesting" has been widely accepted internationally. Interestingly enough, the emphasis has not been on the utilisation of rainwater but on its harvesting. Harvesting has to do with "yield" and implies a "gift of nature". It goes without saying, however, that the harvest should also be utilised and every yield is preceded by its own activities.

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Mankind will have to deal more carefully in the future with the world-wide available and utilisable freshwater reserves. This is primarily a question of awareness and education. In Taiwan, Korea and Australia, programmes to promote rainwater utilisation have been launched in schools in order to familiarise future generations with this topic.

WATER DISTRIBUTION WORLD-WIDE:

(Source: Water in Crisis, World Water Council, Marseille 2002)

- 0.025% of the amounts of water available world-wide is utilisable
- 1.4 billion people have no access to clean drinking water
- 2.3 billion people lack adequate sanitation
- 7 million people die every year from water-borne diseases
- The daily domestic water consumption per capita is
  - 350 litres in North America
  - 200 litres on average in Europe
  - 130 litres in Germany
  - 20 - 30 Litres in Sub-Saharan Africa
- Over 260 river basins are shared by two or more countries mostly without adequate legal or institutional arrangements

In the future, service water and rainwater utilisation can back up the water supply in some countries. Resolution methods can be differentiated into two groups depending on the country or region [7]:

Group 1 contains predominantly developed nations with an existing infrastructure:

- Drinking water substitution in the building services engineering
- Load relief of the existing combined/gravity sewer systems
- Load relief of the existing waste water treatment plants
- Water retention as a preventive measure against urban floods
- Water for agriculture
- Water for trade and industry
- Back up of the local drinking water supply

Group 2 contains predominantly developing or newly industrialising countries (NICs) with little developed water infrastructure:

- Back up of the regional water supply/basic sanitation
- Water for agriculture
- Water retention as a preventive measure against urban floods

Countries belong to group 1 from Europe, North America, East Asia and Australia which may use service water and rainwater as a supplement to the already existing systems. In countries which belong to the second group, rainwater utilisation can be used cost effectively for the basic supply mainly in rural areas.

These themes are represented world-wide by the International Rainwater Catchment Systems Association IRCSA which was founded in 1991. The aim of this organisation is the promotion of rainwater utilisation on a technical, scientific, planning and educational basis. The IRCSA is represented by eight directors and 41 national representatives distributed in all of the continents.

ASIA

PACIFIC ISLANDS: HEAVEN'S WATER HARVESTED FROM TREES

Asia has a special tradition and culture when it comes to rainwater. On Jeju-Island south of Korea and on Miyake, a volcano island in the Pacific about 200 km south of Tokyo, rainwater is harvested from trees. For this purpose, many strings with interwoven ends hang down from trees. Water trickles over this meshwork into a gutter which is directed into a cistern or a jar.

The indigenous people of Miyake use the tap water of the newly installed centralised drinking water supply system only to conserve their cistern reserves. With the hygienically clean municipal tap water which smells strongly of chlorine, they only flush their WC, irrigate their garden or use it for the washing machine.

JAPAN: DISASTER PROVISIONS

Japan is one of the developed countries in Asia who fostered an intensive international exchange in the field of rainwater utilisation from the very beginning. The activities of the administration of Sumida-City are internationally well known and have been recognised since the first rainwater utilisation conference in Japan in 1994. At the World Congress "Global Cities 21" in 2000 in Dessau, it received a distinction for its activities.

In the Rainwater Museum of Sumida, national and international projects are presented and products exhibited which come partly from Germany. In the past few years, the number of urban buildings in Tokyo utilising rainwater has increased considerably from three plants in 1970 to about 1000 in 2003. The city advises and supports residents and firms in the planning and installation of rainwater plants. Newly constructed public facilities must collect and use rainwater. Other Japanese cities are following in their steps.

Besides rainwater utilisation in the building services engineering, a focal point in Japan is disaster provisions in earthquake events [6]. Topics like "Treatment to drinking water" and "Water storage for firefighting" are thus strongly promoted. Some fbr member firms are already represented in Japan with their products.

Fig. 2
ROJISON IS A RAIN WATER TANK WHICH IS ACCESSIBLE FOR THE PUBLIC IN THE MATTER OF A DISASTER

Foto source: König

SOUTH KOREA: FLOODS AND DROUGHT

South Korea is rated by the UNO as a country with a water shortage. Measures which conserve drinking water resources are especially important. Flood protection in this country also enjoys the same priority. Strong precipitations within very short time periods always result in heavy floods. Public institutions and universities are developing suitable measures. In addition, rainwater utilisation in buildings plays an important role as part of the rainwater retention measures.

Currently a government programme is being developed which will accommodate future construction projects for the installation of retention reservoirs. Due to the uneven distribution of rainfall with long dry periods, water recycling measures such as greywater recycling, are becoming part of a sustainable water management [4]. The current low water price and flat rates which do not follow the polluter-pays-principle, are still a hindrance for an effective implementation.

CHINA: ENVIRONMENTAL EDUCATION AND OLYMPIC GAMES

Prevailing water scarcity dominates in the high density area of Beijng as well as in other parts of North and West China. Groundwater recharge, efficient drinking water supply and the economical use of water are very important issues in these regions. During the past 10 years, the groundwater table sank 10 meters and in some areas even 20 meters. Currently, priority is given to decentralised rainwater management systems and the multiple use of non-faecal waste waters from residential areas. Exemplary results have already been presented within the scope of an EU project in Beijng [10] [11].

Precisely Peking needs at the present time compensatory measures since in connection with the construction works for the Olympic Games 2008, new sports and residential areas with the corresponding infrastructure are emerging at a very high speed.

INDIA: LOW COST

Traditionally, rainwater has been the basic provision of the population in India before the colonial power England supplied the country with centralised drinking water supply systems. In the meantime, local community initiatives revert to the well established decentralised concepts. The Centre for Science and Environment (CSE), an independent organisation, which supports and promotes rainwater utilisation in India through several measures, offers courses continuously in the different regions of India. The adapted technology for community self-responsibility, which means on implementation and operation instructions, is documented in the Book "Making Water Everybody's Business" [12]. The CSE received the internationally renowned Stockholm Water Prize 2005 for its commitment.

Rainwater distribution varies from 100 mm in the north-west deserts to 15,000 mm in the mountains of the north-east. Rainwater harvesting has supported agriculture in India for a long time. In addition to that, there is a demand for novel methods for decentralised water supply systems in urban areas. Large investments in residential construction programmes for the coming years in Mumbai (Bombay) are an answer to the continuing migration into the cities. Due to the strong population growth, urbanisation as well as increasing commercial activities, India has been ranked by the Food and Agriculture Organisation of the United Nations (FAO) as one of six countries with a significant future water shortage. Today, comprehensive government programmes are promoting a water-saving building services engineering.

AUSTRALIA: COMMITMENT TO RAINWATER UTILISATION

In Australia, a considerable expansion in the service water and rainwater utilisation is anticipated for the next years. In Sydney, private households consume about 70% of the total drinking water requirement. The government of New South Wales began action by enacting ordinances and propagating massive water-saving campaigns in order to reduce the water consumption. One part of these measures is the Building Sustainability Index, BASIX, a programme which incorporates rainwater utilisation among other issues. Since October 1, 2005 all new buildings have to be constructed according to the BASIX-Standard. This implies that rainwater utilisation plants are becoming a must.

Rainwater has been used for a long time as a drinking water resource in Southern Australia. Likewise, it is common to use rainwater in "hot water systems" (building services systems for water heating) for personal hygiene. Long-term, scientific investigations on the impact of rainwater used as drinking water have been available in Australia since 2001. The risk of intestinal diseases has been rated as very low [5].

Water suppliers and public health authorities in Australia promote water-saving measures such as rainwater and greywater utilisation on a wide basis. This will considerably enhance the development of service water and rainwater technology. A special case was the application of rainwater technology in WCs in the Olympic Village in Sydney in 2000, in which the athletes lodged [6]. A spectacle in itself was the action of the Australian Airlines Quantas who filled bottles with rainwater from Tasmania and distributed them as a delicacy among its passengers.

AMERICA

BRAZIL: ONE MILLION CISTERNS

Problems are featured on the one hand by the dry north-east and on the other hand by megacities like Sao Paulo on the coastline, which is repeatedly afflicted with typhoons with a high precipitation [15]. Due to climate changes, the clouds rain down over the big cities, so that the drinking water reservoirs in the highlands remain empty. Governmental agencies have reacted and imposed the construction of rainwater reservoirs for roof surfaces above 500 m^2. Due to the threatening water shortage also as a result of the high water consumption in the cities, rainwater utilisation is becoming more popular.

In the North of the country, the government launched a one-million cistern programme. With this, a basic water supply should be established for a wide population group.

THE CARIBBEAN: TAX REDUCTION FOR CISTERN CONSTRUCTION

On Haiti, where only a small part of the population have access to the public drinking water supply, the whole water requirement is traditionally covered by rainwater cisterns. Freshwater reserves are not available on the island. In the capital Port-au-Prince where most of the population live, water from tank lorries can also be bought to fill the cistern. However, the costs for this water exceed the contingency of the family budget. Also in Bermuda, Antigua and Anguilla it is self-evident to use rainwater from cisterns for drinking purposes.

On Barbados, there is an obligation in new buildings to set up appropriate cisterns dependent on the

Fig. 3
IN THE DOMINICAN REPUBLIC RAIN WATER SUBSTITUTES DRINKING WATER AND IS DIRECTLY LED TO THE KITCHEN WITHOUT THE HELP OF A PUMP

Foto source: Götsch

Foto source: König

Fig. 4
TREATMENT OF WOODEN ROOFS IN CANADA WITH FIRE RESISTANT MATERIAL RESTRICTS THE USE OF RAIN WATER

area of the building. The costs can be set off against tax liability [6].

NORTH AMERICA: CRITICAL ROOF MATERIAL

An increasing interest in rainwater utilisation can also be identified in the USA and Canada. Storage technology is so far available, however, other remaining components do not conform with the German standards and are still in the initial stages of development [3]. A lack of environmental awareness and across-the-board billing methods during consumption measurement in buildings are the causes for about three to four-fold higher water consumption than in Germany. Other reasons are partly the lower construction standards in the house services and sanitary engineering.

The high requirements of the currently much demanded LEED-Certificate for buildings may find a remedy in the long term. Special commitment to rainwater management is known from the US States of Maine, California, Oregon and Washington. Rainwater utilisation for irrigation is popular in Texas. The American Rainwater Catchment Systems association ARCSA is based there as well as a commercial filling station for rainwater for use as drinking water. The bottle labels have been humorously designated with "fresh squeezed cloud juice". The source of origin is the Dripping Springs.

In Canada, the wood shingle roofs which are being treated with fire resistant materials in compliance with guidelines from the insurance companies, influence the quality of the draining rainwater. The same influence from fungicides can be seen in asphalt shingle roofs [3]. Under the aspect of environmental protection and the improvement of the water quality for rainwater utilisation, a rethinking is urgently required. In the coastal regions of the Atlantic and the Pacific, rainwater is often utilised as a drinking water substitute although these roof materials are widely spread.

AFRICA: HELP FOR SELF-HELP

Rainwater utilisation is an option for a decentralised water supply or a supplement to the existing water infrastructure. A product transfer, for example from Germany, is actually only in cities of the northern coastal regions with a water infrastructure partly available, possible. This is presently being investigated within the scope of the Zer0-M EU project for Egypt, Tunisia and Morocco [7] with fbr participation.

In the Harambee culture in Kenya, women are responsible for the community infrastructure. They construct cisterns above the ground made from local concrete with the help of church organisations from Germany [6] and with governmental aid from New Zealand [9].

EUROPE

Due to the extensive market development and about 80,000 plants produced yearly, Germany is as before the leading country in Europe playing a significant role in the development of service and rainwater utilisation. Developments in the field are also found in Austria, Switzerland, Belgium and Denmark. The popularity of rainwater utilisation depends on the water price. The higher the price, the better the amortisation of the plant. Denmark (1.84 Euro/m^3) and Germany (1.73 Euro/m^3) have the highest costs and according to the National Consulting Group NUS, are world leaders.

Further markets are developing slowly in France, Great Britain (foundation of the Rainwater Harvesting Association UKRHA, 2004), Eastern Europe and Northern Italy.

GERMANY: WORLD-WIDE IMPULSE

Through the International Rainwater Conference 2001 in Mannheim, the fbr contacts have considerably widened. Over 400 participants from 68 countries met for the first time in Germany in order to amply discuss the role of rainwater utilisation in settlements and urban developments.

From press releases it can be seen that Germany, like other developed countries, can hardly maintain the widely-spread conventional system of combined/gravity sewers in the long run. In a current state-wide study, the German Association for Water, Wastewater and Solid Wastes (DWA) estimated the costs for the rehabilitation of the sewer system at about 50 to 55 billion Euros [2]. The Frauenhofer Institute ISI in Karlsruhe forecast that in a few decades, the drinking water quality cannot be guaranteed anymore with the conventional structures of the water supply systems. Assistance can be brought about by shifting the drinking water "production" to the consumer. Raw water which then flows in public supply networks will consist largely of rainwater similar to the pilot project in Knittlingen [13].

It is quite clear that rainwater harvesting and water utilisation have gained internationally in significance.

Germany is leading in this field and defines the trend for technical standards, public relations, advanced training and system dissemination. fbr firm members are increasingly exporting their products with a great deal of success. In order to accommodate this fact, the fbr takes over the European office of the International Rainwater Catchment Systems Association, IRCSA, in 2006.

REFERENCES

[1] Verband deutscher Mineralbrunnen e.V., Bonn, April 2005

[2] DWA, Pressemeldung. St. Augustin, 2005

[3] KÖNIG, KLAUS W.: Regenwasserbewirtschaftung in Nordamerika. In: fbr-wasserspiegel 4/05, S. 6-7. fbr, Darmstadt, 2005

[4] SCHÜTZE, THORSTEN: Dezentrale Wassersysteme im Wohnungsbau internationaler Städte am Beispiel Hamburg in Deutschland und Seoul in Süd-Korea, Dissertation. Hamburg, 2005

[5] HEYWORTH, JANE: A Dairy Study of Gastroenteritis and Tank Rainwater Consumption in Young Children in South Australia. In: 10 th International Rainwater Catchment Systems Conference, Mannheim. Proceedings of the Conference, S.141 ff. fbr, Darmstadt, 2001

[6] KÖNIG, KLAUS W.: Das Handbuch der Regenwassertechnik. Wilo-Brain, Dortmund, 2001

[7] SPERFELD, DIETMAR: Entwicklung der Regenwassernutzung, Impulse für die Wasserwirtschaft. In: fbr-Schriftenreihe Band 10, S. 7-20. fbr, Darmstadt, 2005

[8] KÖNIG, KLAUS W.: Regenwassernutzung im Reich der Mitte, wwt 6/2005. Verlag Huss Medien, Berlin, 2005

[9] GOULD, JOHN et al.: Case Study Kenya, Rainwater Catchment Systems for domestic supply, ITP London, 1999

[10] GEIGER, WOLFGANG et al.: Regenwasserbewirtschaftung in semi-ariden Stadtgebieten. In: fbr-wasserspiegel 2/03, S. 3-4. fbr, Darmstadt, 2003

[11] WILHELM, CHRISTIAN: Nachhaltige Stadtentwässerung in Peking. In: fbr-wasserspiegel 2/03, S. 8-11. fbr, Darmstadt, 2003

[12] AGARWAL, ANIL et al.: Making Water Everybody's Business. CSE, New Delhi, 2001

[13] HIESSL, HARALD: Zukünftige Herausforderungen für den Umgang mit Wasser in Siedlungen. In: fbr-Schriftenreihe Band 10, S. 129-136. fbr, Darmstadt, 2005

[14] KÖNIG, KLAUS W: Französische Regionalkonferenz HQE am 2.7.2003 in Paris. In: fbr-wasserspiegel 4/03, S. 18. fbr, Darmstadt, 2003

[15] SCHUMANN, ANJA: Regenwassernutzung in Brasilien, ein Abenteuer. In: fbr-wasserspiegel 3/00, S. 8-9. fbr, Darmstadt, 2000

Foto source: Nolde

Fig. 5
COMBI SYSTEM FOR RAIN WATER AND WELL WATER USE IN A RESIDENTIAL BUILDING IN TUNIS, TUNISIA

TUNIS: 21 to 24 March 2007

At the occacion of the WORLD WATER DAY 2007

MEDA WATER International Conference

on Sustainable Water Management

www.zer0-m.org/medawaterconf/organise.htm

The Conference is organized by Zer0-M and will be held in Tunis. The official language of the conference is English. The presentations will be held in English or French, simultaneous translation will be provided. The conference will focus on water saving, alternative water resources like rainwater harvesting and wastewater reuse after treatment, wastewater treatment technologies suited especially for decentralised sanitation in peri-urban and in rural contexts or tourism facilities located in remote areas.

THE MAIN TOPICS OF THE CONFERENCE ARE

- Water systems (water saving, suitable quality versus usage, greywater/blackwater segregation, wastewater treatment, reuse and recycling) for small rural communities, remote tourist facilities, and peri-urban areas
- Household-centred water management
- Rainwater harvesting for domestic use
- Industrial water management and cleaner production (segregation, pre-treatment of industrial wastewater and reuse)
- Integration of wastewater reuse in the overall water resources management
- Best technologies/systems for sustainable treatment of urban wastewater in the Mediterranean area
- Risk assessment (human health/environment)
- Approaches for the assessment and valuation of safe wastewater agricultural reuse/Relevant policies and socioeconomic instruments
- Guidelines and quality standards for reclaimed water
- Case studies
- Demand management

MAIN ORGANISING PARTNER: **Centre de Recherches et des Technologies des Eaux (CERTE), Tunisia**

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- Minister of Research, Technologies and Development of Competences
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