SUSTAINABLE WATER MANAGEMENT

1-2006

CONCEPTS TOWARDS A ZERO-OUTFLOW MUNICIPALITY

ZER0 M

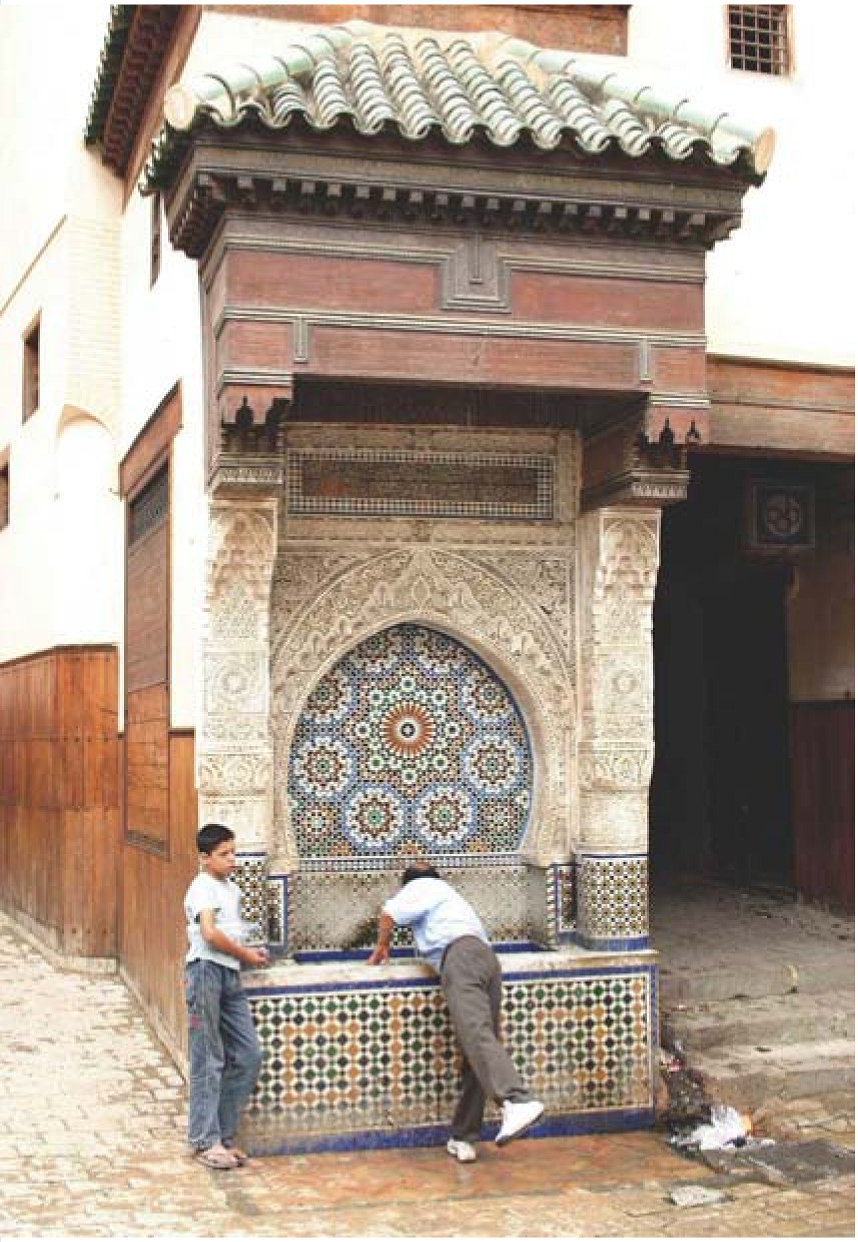


Photo: Matt Welsh

ECOLOGICAL SANITATION P. 3

Worldwide, there is a disastrous situation in the field of wastewater collection and treatment. Many surface waters are polluted with raw wastewater and untreated faeces which present a big danger for the population. Additionally, water scarcity is increasing as is soil degradation. It is a challenge to participate in the development of emerging new concepts like Ecological Sanitation.

RAINWATER CISTERN SYSTEMS P. 11

Rainwater harvesting has been practiced for more than 4,000 years. In many countries it is becoming a considerable alternative for water supply, because of the shortage and limitations of other conventional water resources.

KNOW HOW TRANSFER BETWEEN WATER SCARCE COUNTRIES P. 18

Water scarcity in dry areas is a very critical issue for sustainable development. Greywater treatment and the use for poverty reduction in rural areas is shown by means of three projects in Jordan.

AUTONOMOUS DESALINATION P. 26

The problem of water scarcity has given rise to the evaluation and development of alternative approaches to the existing water supply practices. Decentralized systems have been drawing significant attention in the last decades especially for small communities in remote areas.

AEE INTEC

This project is funded by the EUROPEAN UNION

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.

Zer0-M aims at concepts and technologies to achieve optimised close-loop usage of all water flows in small municipalities or settlements (e.g. tourism facilities)–the Zero Outflow Municipality (Zer0-M). The basis to such a sanitation is to abandon the concept of wastewater as we can not afford to waste any water, as well as the nutrients contained in it.

The discussion about how to best reclaim water is still going on. Risks associated with the practice have to be truly assessed and measures designed to prevent them. In this respect we should always keep in mind that saved drinking water is ready to be used for new purposes without any treatment, it is unpolluted and bears no risks.

Saving drinking water includes such different sanitation techniques as using water efficient appliances and systems, substituting drinking water with greywater, rainwater or reclaimed wastewater for some domestic purposes, or totally substituting the use of water, e.g. with modern and convenient dry toilets.

This second issue of the journal is discussing some possibilities, which were presented at the first Zer0-M Conference on Sustainable Water Management organised in Turkey in March 2005. It includes papers by scientists in EU and MEDA countries working in the field of sustainable water management and contributions of partner projects in the MEDA program. You find a list of the projects at the end this journal. Check out their homepages for further interesting information on sustainable water management.

If you want to discuss some of the issues presented here, do not hesitate to visit the Zer0-M forum on its homepage www.zer0-m.org. Registration there is easy and open to everybody. Your contributions will be most welcome.

If you are from one of the partner countries you may also directly contact the Zer0-M partner at home. Have a look at our homepage for upcoming events, e.g. conferences, training workshops, etc. in your country. The complete list of the consortium members is as below:

(1) AEE Institute for Sustainable Technologies (AEE INTEC), Applicant, Austria
(2) Associazione Ambiente e Lavoro Toscana – O.N.L.U.S. (ALT), Italy
(3) Tübitak-Marmara Research Center (MRC-ESERI), Turkey
(4) Water Research & Pollution Control Department, National Research Centre, Dokki, Cairo, (NRC), Egypt
(5) Institut National de Recherche Scientifique et Technique, Laboratoire Eau et Environnement (LEE), Tunesia
(6) Institut Agronomique et Vétérinaire Hassan II, Wastewater Treatment and Reuse Unit (WTRU), Morocco
(7) Institute for Geography and Regional Research, University of Vienna (IGR), Austria
(8) TU Berlin, Central Co-operation and "Fachgebiet Verfahrenstechnik I" (TUB), Germany
(9) University Hannover, Zentrale Einrichtung für Weiterbildung (weiterBILDUNG), Germany
(10) Fachvereinigung Betriebs- und Regenwassernutzung e.V. (fbr), Germany

We received a very positive echo on the first issue of this journal. We hope to be able to stand up to the expectations we have created and will be glad for any comment or recommendation from our readers.

For the Consortium: *Martin Regelsberger*

List of Funding Organisations

- European Union, Meda Water Program of EuropeAid Co-operation office
- Austrian Federal Ministry for Foreign Affairs
- Agenzia regionale per la protezione ambientale della Toscana, Italy
- Acque S.p.A. , Italy
- Tübitak-Marmara Research Center, Turkey
- National Research Center, Egypt
- Sécretariat dEtat à la Recherche Scientifique et de la Technologie, Tunisia
- Population of El Attaouia, beneficiary of pilot plant, Morocco
- Technische Universität Berlin, Germany
- Zentrale Einrichtung für Weiterbildung, Germany
- fbr association and member companies, Germany

CONTENTS

Resource Efficient Wastewater Concepts
Ecological Sanitation
By Claudia Wendland, Felix Tettenborn und Ralf Otterpohl 3

Sanitation as a Resource Management System in Urban Conditions
By Martin Oldenburg 6

Prevailing Situation of Turkish Urban Wastewater Treatment Plants
By I. Arslan-Alaton, M. Gurel, G. Iskender, S. Ovez, A. Tanik and D. Orhon 9

Use of Rainwater Cistern Systems
RWCS as an Alternative for Freshwater Augmentation
By Deniz Dolgen, Ahment Baban and M. Necdet Alpaslan 11

Use of Rapid Infiltration Technique for Aquifer Recharge with Treated Wastewater
Design of Souhil Wadi (Nabeul-Tunisia) Pilot Plant
By Hamadi KALLALI, Mitsuo YOSHIDA, Salah JELLALI, Abdennaceur HASSEN and Naceur JEDIDI 14

Greywater Treatment and Use For Poverty Reduction in Rural Areas
Exchange of Know-How Between Water Scarce Countries
By Shihab Najib Al-Beiruti 18

Anaerobic Treatment of Industrial Wastewaters
By İlda DEĞİRMENTAŞ and Nuran DEVECİ 21

Pollution Preventions in Industrial Plants: A General View
By Nihal Bektaş 24

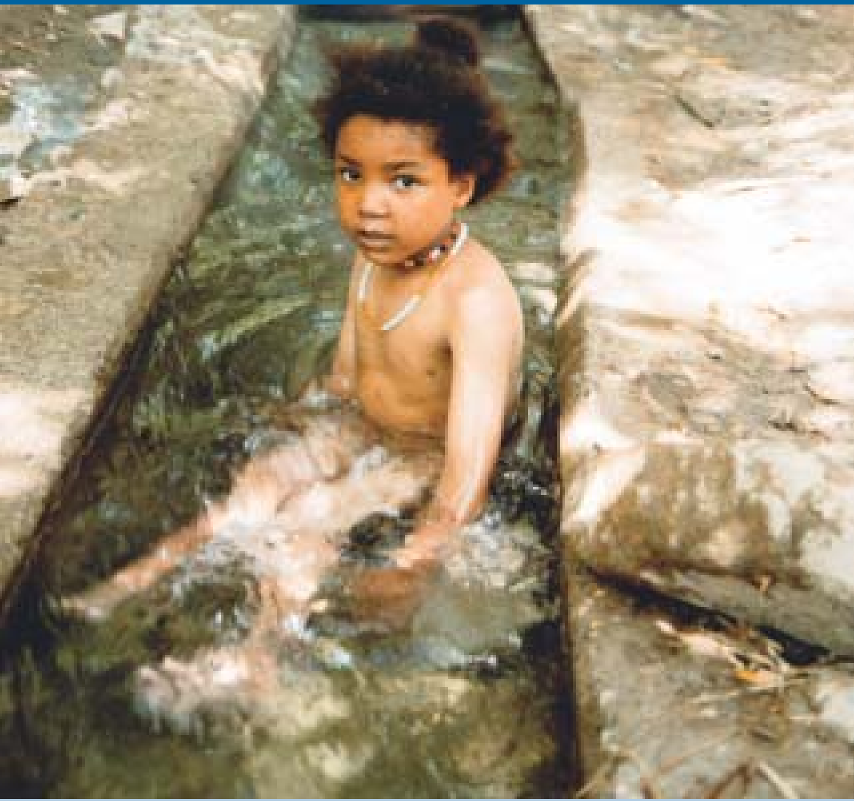
Autonomous Desalination
as an Alternative Approach to Decentralized Water Management
By Seval Sözen, Senem Teksoy, Serden Başak and Aslı Çiğğın 26

Windpowered Seawater Desalination Plant
By Ulrich Plantikow 29

MEDA Water Projects
An Overview . . . . . *Backcover*

IMPRINT

Eigentümer, Herausgeber und Verleger / Published by
AEE INTEC – Arbeitsgemeinschaft ERNEUERBARE ENERGIE – Institut für Nachhaltige Technologien / Institute for Sustainable Technologies
A-8200 Gleisdorf, Feldgasse 19, Tel.: +43 (0)3112 / 5886
Redaktion / Editors team: Elif Atasoy, Irene Bergmann, Martin Regelsberger, Barbara Regelsberger
"**Sustainable Water Management**" wird im Projekt Zer0-M vor allem für Wasserfachleute und Entscheidungsträger in den Projektländern herausgegeben. Bis zum Ende des Projekts erscheinen zwei Hefte pro Jahr.
"**Sustainable Water Management**" is issued within the Zer0-M project mainly for water experts and decision makers. Throughout the project it will come out twice a year.
Bankverbindung / Banking account:
Raiffeisenbank Gleisdorf, Kto.-Nr. 104.430, BLZ 38103, IBAN: AT09 3810 3000 0010 4430, SWIFT-BIC-CODE: RZSTAT2G103
WWW: http://www.aee-intec.at, http://www.zero-m.org
Typo, repro & design by Steinhuber Infodesign, Graz
Druck und Versand / Printed and mailed by:
Universitätsdruckerei Klampfer, 8160 Weiz
Auflage / Number of copies: 3.500



RESOURCE EFFICIENT WASTEWATER CONCEPTS

ECOLOGICAL SANITATION

By CLAUDIA WENDLAND, FELIX TETTENBORN and RALF OTTERPOHL*

Worldwide, there is a disastrous situation in the field of wastewater collection and treatment: About 2.4 billion people have no access to adequate sanitation, 2.8 billion people use simple pit latrines and in many countries the conventional wastewater treatment works are insufficient. Many surface waters are polluted with raw wastewater and untreated faeces which presents a major danger for the population. This situation contributes highly to the 5 million people who die every year due to water-borne diseases.

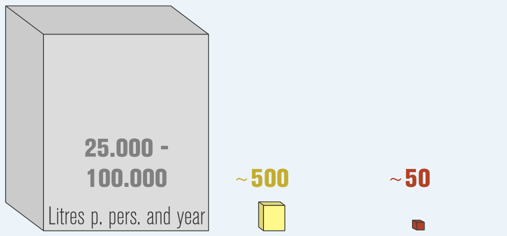
*) Prof. **Ralf Otterpohl**, **Felix Tettenborn** and **Claudia Wendland** are working at the Institute of Wastewater Management of Hamburg University of Technology with a focus on Ecological Sanitation. Claudia Wendland is project manager in the EU-project „Efficient Management of Wastewater, its Treatment and Reuse in the Mediterranean Countries“ (EMWater) which is part of the MEDA program, c.wendland@tuhh.de

Additionally water scarcity is increasing more and more as well as soil degradation. Also for the Mediterranean countries, these issues are of crucial importance and alternatives are urgently required. For rural and peri urban areas, alternative, innovative solutions have been developed, applied and are available today (Ecological Sanitation).

The principles of these Ecological Sanitation (EcoSan) concepts are source control and the hygienisation of the wastewaters followed by water and nutrient reuse in agriculture.

BASIC CONSIDERATIONS

The major objective for sanitation is minimizing hygienic risks. New systems should be better than conventional sanitation systems which have a good hygienic standard for inside the houses but in most cases not for receiving waters. Thus, a closer look at the wastewater itself can help to find the right solution.



Yearly loads kg / P · year		Greywater	Urine	Feaces (option: add biowaste)
N	~ 4 - 5	~ 3%	~ 87%	~ 10%
P	~ 0,75	~ 10%	~ 50%	~ 40%
K	~ 1,8	~ 34%	~ 54%	~ 12%
COD	~ 30	~ 41%	~ 12%	~ 47%
		Treatment ▼ Reuse / Water Cycle	Treatment ▼ Fertiliser	Biogas-Plant Composing ▼ Soil-Conditioner

Table 1: **CHARACTERISTICS OF THE MAIN COMPONENTS OF HOUSEHOLD WASTEWATER [OTTERPOHL 2001a]**

Wastewater from different sources has different distinctive characteristics. Thus, household wastewaters are described by colors: grey for little polluted water from the kitchen, washing, etc., black for toilet wastewater, which can be divided further into brown (faeces) and yellow (urine) [Otterpohl 2001]. The most important parameters are shown in table 1.

Table 1 leads to the following conclusions:

1. Most of the soluble nutrients (N, P, K) of domestic wastewater are contained in the comparably small volume flow of „yellow water“. Separately collected urine, converted for agricultural usage, is the biggest step towards nutrient reuse, highly efficient water protection, and improved wastewater treatment. More-

Fig. 1: **URINE SORTING TOILETS** (Lower left two of the German company Roediger, lower right two of the Norwegian company Gustavsberg)

over, urine contains trace metals required for plant growth. Thus, yellow water has to be taken into consideration as a fertilizer. It is related to the nutrient cycle rather than to the water cycle.

2. The increasing focus on residual organic pollutants like pharmaceuticals, which are distributed by human wastewater in the surface waters, supports the installation of source separation systems. With the separation of urine, the wide spread of these components in the natural environment can be avoided.

3. The hygienic danger of wastewater comes almost exclusively from pathogens contained in faecal matter. Faeces suspended in the huge volume flow of greywater means spreading the pathogens in a large volume of water, making it more expensive to reclaim this for reuse. Separation and low or no dilution opens the way to excellent hygienisation. – „Brown water" contributes greatly to the phosphorus load of domestic wastewater and thus can also be considered a fertilizer. The organic solids make brown water an excellent soil conditioner after suitable treatment. Therefore, brown water also belongs to the nutrient cycle which should not be mixed with the water cycle.

4. Wastewater that is not mixed with human waste (faeces and urine) – so called „grey- water" – is the biggest volume part of all. Because of its low contribution to the mass flow of the nutrients, greywater represents a splendid source for high quality reuse. Greywater contains nearly half of the organic load of domestic wastewater. Removing these pollutants before the possible reuse of greywater is far less expensive than the additional removal of nutrients, as it is realized in modern wastewater treatment plants. Bio-sandfilters and membrane technology pave the way to cost-efficient ways of producing secondary water – the on-site, local, or regional scale can be appropriate.

5. Rainwater runoff is one of the reasons for building sewerage systems. Local infiltration or trenches to surface waters for relatively unpolluted rainwater are often feasible and can be combined with usage.

Any sanitation system aims for a hygienically sound situation as efficient as possible. In EcoSan this is achieved by separating the water cycle from the nutrient cycle, and closing both loops.

TWO EXAMPLES FOR ECOLOGICAL SANITATION

Many examples worldwide, as well in industrialized as in the developing world, prove not only the feasibility, but show how beneficial these concepts are [GTZ 2003]. Two EcoSan systems are presented here, one in Germany and one in the Ukraine.

Lambertsmühle, Germany

An advantageous low-cost and low maintenance system with the potential for full resource recovery for smaller villages and single houses is based on urine sorting flush toilets (no-mix-toilets).

Yellow water is collected without dilution and is used after storage directly in agriculture. Brownwater is treated in a two-chamber separation unit (Rottebehaelter) where each chamber is used for half a year and left without further charging the other half. The compost produced can be used to improve long-term soil fertility. The filtrate from the separation unit is low in nutrients due to the previous separation of urine. Therefore, the filtrate can be treated together with the greywater (except if the high quality reuse of greywater is planned).

A pilot project of this system is in operation in an ancient water-mill museum 'Lambertsmühle' in Germany. In connection with the restoration of the building, this sanitation solution has been developed. The urine sorting toilets collect the urine undiluted (Roediger) or little diluted (Gustavsberg) (see fig. 1). The faeces are flushed with an appropriate volume of water (2 - 6 L per flush).

Greywater from the kitchen, bathroom etc. is treated in a constructed wetland and then discharged to the receiving water. A scheme of the sanitation concept regarding the water and the nutrient cycle, is shown in fig. 3.

Gozhuli, the Ukraine

An EcoSan system which is particularly reasonable in regions with no central water supply and no proper sanitation system (except pit-latrines) is the application of dry urine diverting toilets.

The principle and use of these urine diverting toilets (or variations) has been established for many years in countries like Mexico, China and Vietnam. This kind of toilet consists of a toilet room with a seat riser or slab for urine diversion. For each toilet there are two (double vault) easily accessible faeces-chambers with a sealed floor made of concrete. The vaults are designed such that one vault is in use for a minimum of 1 year, then allowed to rest for one year while the other chamber is used. Ventilation pipes are installed from the faeces-chambers to above the roof to supply the vault with oxygen and avoid odour and flies.

The urine from the toilets and the waterless urinals is collected in two urine tanks and can be applied in agriculture.

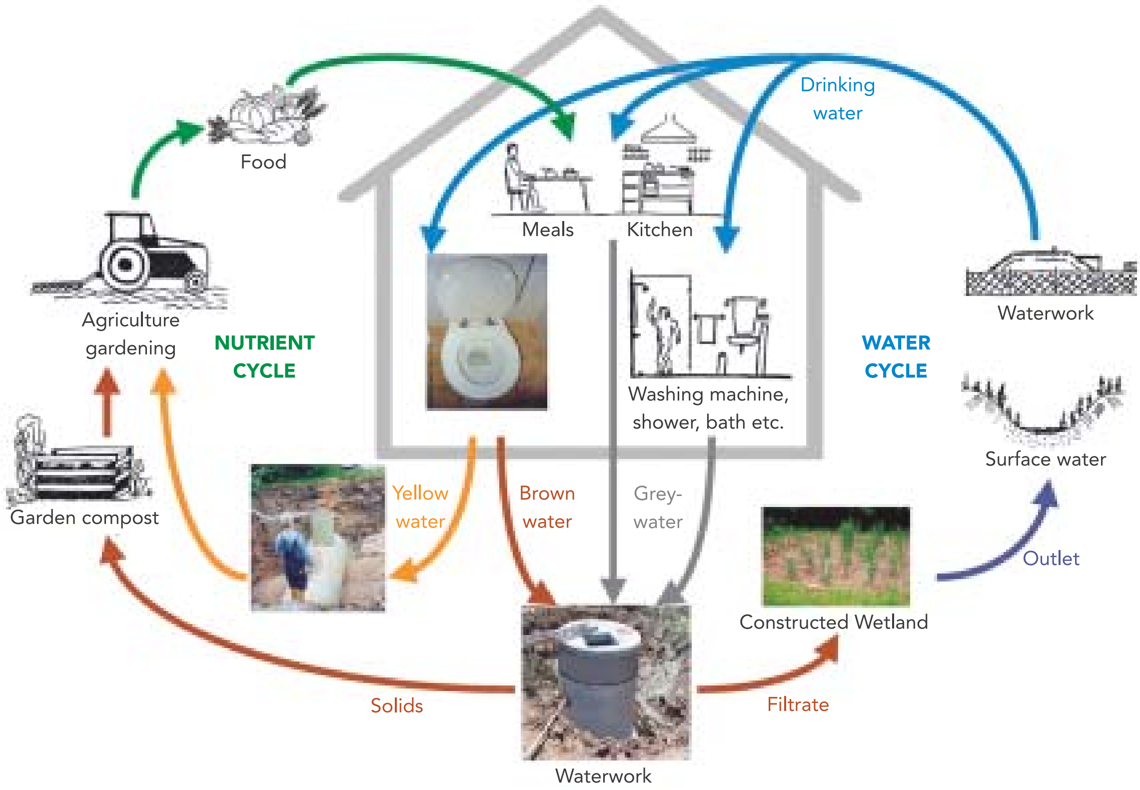


Fig. 2:
SCHEME OF ECOSAN CONCEPT LAMBERTSMÜHLE [OTTERPOHL 2001a]

In Gozhuli, in the Ukraine, it could be shown that the installation of double vault urine diverting toilets is a low cost, very fast, and easy to realise solution to protect the groundwater and to improve health conditions [Deegener et al 2005].

CONCLUSIONS

It is a challenge to participate in the development of emerging new concepts like Ecological Sanitation. Professional skills and the open-minded search for solutions are needed to further find better ways for future sanitation. An open dialogue and the exchange of experiences are essential in order to make progress. There are many possibilities that all social and economic conditions will be met. Creativity is needed to find the appropriate technology and the best way of implementing, operating, and financing it.

Since Ecological Sanitation delivers advantages like the safe reuse of excreta-derived nutrients (which are not diluted and contaminated), keeping contaminants away from water bodies, and saving money, these schemes exceed conventional sanitation systems with regard to ecological and economic sustainability.

REFERENCES

- Deegener, S., Otterpohl, R., Samwel, M., Gabizon, S. (2005), *Ecosan – a step towards sustainable rural development in Eastern Europe* Proceeding of the 3rd International Conference on Ecological Sanitation, 23 - 26 May 2005, Durban, South Africa
- GTZ (2003), *Proceeding of 2nd International Symposium on Ecological Sanitation,* ecosan – closing the loop, 7 - 11 April 2003, Lübeck, Germany
- Otterpohl R. (2001), Black, brown, yellow, grey – the new colours of sanitation, Water 21, Magazine of the International Water Association 10/2001, pp 37 - 41
- Otterpohl R. (2001a), *Design of highly efficient source control sanitation and practical experiences,* in: Decentralised Sanitation and Reuse, pp 164 - 179 (Lens P., Zeemann G. and Lettinga G., Eds) IWA Publ.

Fig. 3:
NEW TOILETS IN A SCHOOL IN GOZHULI, THE UKRAINE, INSIDE AND OUTSIDE

SANITATION AS A RESOURCE MANAGEMENT SYSTEM IN URBAN CONDITIONS

By MARTIN OLDENBURG*

The aim of sanitation as a resource management system is to use the nutrients as well as water after an appropriate treatment. The fundamental idea of these alternatives is based on the principle of separating the different flows of domestic wastewater according to their characteristics. This general idea is very well known in the field of industrial wastewater. The separation at source enhanced the appropriate treatment and is the prerequisite for the utilisation of nutrients as well as of water. Examples for these different sanitation concepts for urban conditions will be given below.

*) **Martin Oldenburg** is managing director and partner of the consultancy OtterWasser GmbH, Engelsgrube 81, 23552 Lübeck, Germany, Oldenburg@otterwasser.de

GENERAL IDEA

For most of the areas in Europe the bad hygienic conditions caused by the lack of proper sanitation facilities are solved at first by the discharge of wastewater into the water bodies. In the light of the increasing density of the population and water-borne diseases, sewer systems and wastewater plants were introduced.

For the technically developed world the solution is the connection to sewer systems during the last centuries, but no serious alternative has ever been examined. Historically, reasonable alternatives like dry toilets or vacuum toilets existed but they were widely ignored and had no chance of wide distribution.

So, the flush-based sanitation system became the standard sanitation system. It works well in wealthy countries with large water supplies. For a long time reducing the flush water volume seemed to be the single possible improvement of the water-flush systems.

But in countries with a water scarcity these sanitation systems fail after a few years. Frequent reasons for failure are too low flush volumes, which are not able to transport the solids of the wastewater, the lack of maintenance of these systems and the misuse of sewers as disposals for solid and liquid litter.

The conventional sanitation system with water for flushing and transportation represents the concept of the dilution discharging nutrients like nitrogen, phosphorus and potassium as well as harmful substances like pathogens, pharmaceutical residuals and hormones (endocrine disrupters) into the receiving waters. Despite the low concentration of these substances, the loads cannot be ignored. In particular some of these harmful substances can in the meantime be identified in groundwater as well as in the raw water of the waterworks.

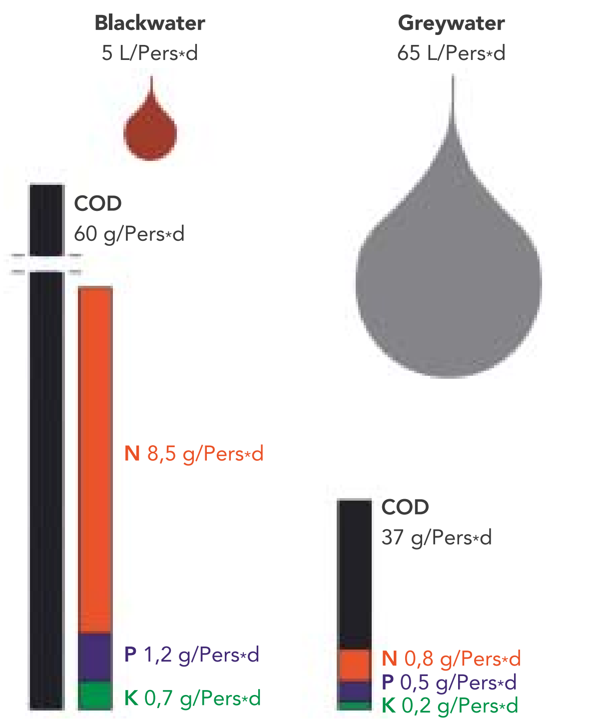
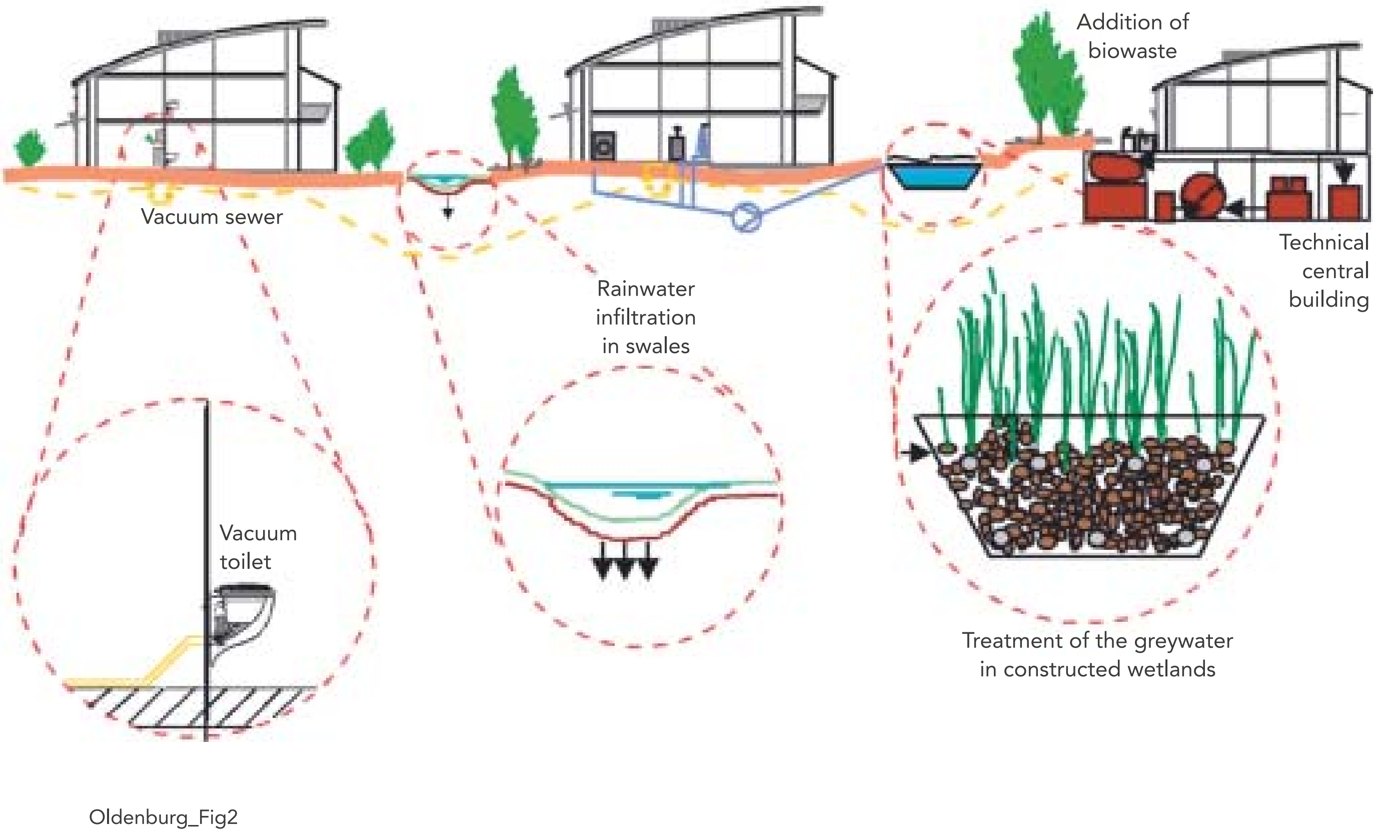


Fig. 1: **DISTRIBUTION OF VOLUMES AND CONCENTRATIONS IN BLACK AND GREY WATER**

Fig. 2: **FLOW SCHEME OF THE SANITATION SYSTEM IN LÜBECK-FLINTENBREITE**



Furthermore the conventional sanitation system works like an end-of-pipe technology mixing the different flows and their different characteristics and treating them at the end of the pipe.

Phosphorus as a main fertilizing substance is only available in limited conditions. Estimations of the available phosphorus resources have been calculated on a time scale of 120 to 150 years depending on the increase in the use of fertilizers. So the end of phosphorus as a natural resource becomes obvious.

Fig. 1 shows the very different characteristics of domestic wastewater flows with reference to their volumes and loads per capita and year.

In this figure the volume and loads of nutrients for the blackwater (faeces diluted with flushing water from a vacuum toilet system) and the greywater is investigated for a housing estate in Northern Germany. The project will be described in detail below.

The distribution of volumes and concentrations is typical for these flows and can be described as follows:

- The volume of humane excreta (faeces and urine) is very low compared with the greywater from the kitchen or bathroom.
- The predominant source of nitrogen is the blackwater. It is known, that more than 80% of the nitrogen is found in urine
- The main fraction of phosphorus and potassium is found in the human excreta fraction
- The greywater is very slightly polluted with nutrients. The phosphorus load in the greywater is caused by dish-washer detergents which contain up to 30% of phosphorus
- The separate collection of the nutrient rich fractions (like blackwater as well as separated into urine (yellowwater) and faeces (brownwater) and its appropriate treatment allows nutrient recovery and utilization e.g. as a fertilizer.

The installation of new sanitation equipment like toilets and urinals is mandatory for resource management systems. An overview of these facilities is given in [1].

VACUUM BIOGAS SYSTEMS

In Lübeck-Flintenbreite, Germany, a decentralised sanitation concept has been realised in an urban area.

On a total estate area of 5.4 ha terraced houses, double houses and flat units are planned. In addition a community building for flats and the installation of all technical infrastructure facilities is erected.

As by now, 106 inhabitants are connected to the plant with a maximum capacity of 350 persons.

Greywater and blackwater (wastewater originating from toilets) are collected and treated separately. Inside the houses vacuum-toilets are installed and connected to a vacuum sewer system. By using these vacuum-toilets (see fig. 3) the volume of the flush-water can be reduced down to 0,7 L per flush. The low dilution of the blackwater enables anaerobic treatment, and the nutrients in the treated blackwater can be used as a fertilizer.

From the view of the user the use of the vacuum toilet is similar to conventional flush-toilets, only the

Fig. 3:
VACUUM TOILET

noise when sucking away the blackwater is different to gravity flush systems.

After mixing the collected blackwater with grinded bio-waste the material is thermally hygienised and fermented anaerobically in a biogas plant. The biogas will be used in a central heat and power unit for energy and heat production for the settlement.

Despite the common treatment of urine and faeces with its high nitrogen concentrations of more than 1 g/L ammonia, the treatment in the biogas plant works without any inhibitions or other negative impacts.

Greywater is drained by gravity and treated in a vertical flow constructed wetland. The main parts of the system have been in operation since the beginning of 2000.

The average water consumption for the last five years is about 68 L/(PE*d), whereof approximately 62 L/(PE*d) is greywater. Greywater is very poor in nitrogen as extensive measurement campaigns have proven (see fig. 1).

The technical system is operated by an operation company which is responsible for all of the technical installations on the housing estate; this means the operation and maintenance of the technical installation in and outside of the houses and of the external green areas.

Because of the low energy standard of the houses, the water saving installations and the vacuum-toilets operated by a separate company, the operation costs are 20 - 30% less compared to conventional houses.

URINE SEPARATING SYSTEMS

Starting with the Scandinavian countries, urine separating toilets are in use in different projects. Meanwhile different types of separation toilets are known and the experience with these types of toilets is increasing. In addition to these toilets, waterless urinals are available to a growing market. Especially in buildings with public toilets (schools, motorway service areas etc.) with a high user frequency, the installation of these sanitation facilities using no water can save a lot of money. Both facilities are a prerequisite for urine separation with the intention of concentrating the nutrients from the source and their following use.

Several large-scale projects with urine separation are in the planning state or under construction. For a part of the new settlement "Solar City" (88 flats and a school) in Linz, Austria, a urine separating wastewater system was realized. The school building is equipped with urine separating, squatting toilets as well as waterless urinals and the flats only with the urine separation toilets. Up to now, the acceptance of the new type of toilets is good and the inhabitants have not remarked on any differences to the conventional system. The urine is colleted in urine storage tanks in the housing areas which are emptied regularly. Brownwater (faeces with flushwater) and the greywater are transported in one system and treated in constructed wetlands with a filter unit as a pre-treatment stage for the separation of solids. The solids, mainly from the brownwater, are treated by a vermi-composting stage in aerobic conditions. Urine and the product of the vermi-composting shall be investigated for a possible use later on.

In Berlin the Centre of Competence for Water (Kompetenzzentrum Wasser Berlin) together with its partners Berliner Wasserbetriebe and Veolia Water has started a demonstration project on new sanitation concepts, which is funded by the EU-Life program [2]. In order to define the experiments for testing new, sustainable sanitation concepts a pre-study has been performed. This study included a cost comparison between two new sanitation concepts with gravity and vacuum separation toilets and the conventional system. It could be demonstrated that the new sanitation concepts may have cost advantages depending on the situation. This was a further motivation to start a Demonstration project near Berlin testing the innovative toilet systems under realistic conditions. The operation of the sanitation concept was started in an office building in October 2003 und was extended to an apartment house in 2005. Different type of separation toilets (gravity and vacuum systems) are tested as well as different possibilities for the treatment of the flows. The project was extended by a Life Cost assessment and investigations concerning the use of the products on farmlands.

REFERENCES

[1] Wach, F.G., Sanitary facilities, Sustainable Water Management 1-2005, 36 - 39

[2] KompetenzZentrum Wasser, http://kompetenz-wasser.de/dt/projekte/proj_scst.htm

PREVAILING SITUATION OF TURKISH URBAN WASTEWATER TREATMENT PLANTS

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

According to recent official records, there are a total number of 129 urban wastewater treatment plants (UWWTPs) in Turkey serving a grand total of 30.374.000 capita in 81 provinces, among which 28 plants are located in the 12 Greater Metropolitan cities [1]. Although at first sight one may conclude that only approximately 45% of the country's overall population is "sewered" and officially receives wastewater treatment services, this number should be considered with care for a developing country facing economic constraints and imbalances.

*) **Idil Arslan-Alaton** is an Assoc. Prof., arslanid@itu.edu.tr; **Melike Gurel** is an Assist. Prof., mgurel@ins.itu.edu.tr; **Gulen Iskender** is an Assoc. Prof., geremektar@ins.itu.edu.tr; **Suleyman Ovez** is an Instructor, sovez@ins.itu.edu.tr; **Aysegul Tanik** is a Prof., tanika@itu.edu.tr; **Derin Orhon** is a Prof. – All the authors are from the Istanbul Technical University, Department of Environmental Engineering, Maslak, Istanbul, 34469, Turkey.

This study is part of the MEDAWARE project that refers to the outcome of a detailed survey of the current situation of Turkish UWWTPs and reflects a unique and comprehensive example of sustainable wastewater management in a typical developing country.

MAIN OBJECTIVES

The main objectives of the project are to identify the prevailing situation of water resources, urban wastewater treatment and management in Turkey, to develop tools and a database for the promotion of sustainable urban wastewater treatment, to improve the already existing national policy, and to establish guidelines to be utilized by the responsible authorities on the most efficient solutions regarding the operation of the wastewater treatment systems.

EXPECTED RESULTS

The expected results will be the establishment of a reliable database representing the prevailing situation in the country regarding water resources and wastewater treatment practices, a transfer of knowledge within the entire country by means of the establishment of a network, the heightening of public awareness and an increase in the education level with regard to the problems likely to be encountered, the strengthening of the active involvement of all the persons affected and involved in water planning and wastewater management. The main purpose of this study is the identification of the existing situation regarding water resources and wastewater management applications in the country which will act as the first and the most important milestone for sustainable management strategies.

Fig. 1 shows the provinces of the country with respect to the number of UWWTPs. As can be seen from the figure, 43 provinces have urban wastewater treatment plants. There are a total number of 129 UWWTPs in operation in the country according to the recent official records. A total number of 28 plants in cities are those that are located in 12 of the Greater Metropolitan cities. For example, Istanbul Greater Metropolitan City, being the most crowded city of the country, has 13 urban UWWTPs, followed by 14 plants in Antalya along the south-western coast, and six treatment plants in the highly industrialized province of Kocaeli near Istanbul.

The data collected suggests that most of the people to benefit from UWWTPs are those residing in the Greater Metropolitan cities. However, the Greater Metropolitan Municipalities have still not managed to construct and operate a sufficient number of UWWTPs. For example, the total population that benefits from UWWTPs represent approximately 45% of the country's overall population. The ratio of the municipal population to the total population of the country was stated as approximately 80% in year 1997 [2]. The number of municipalities having wastewater treatment fa-

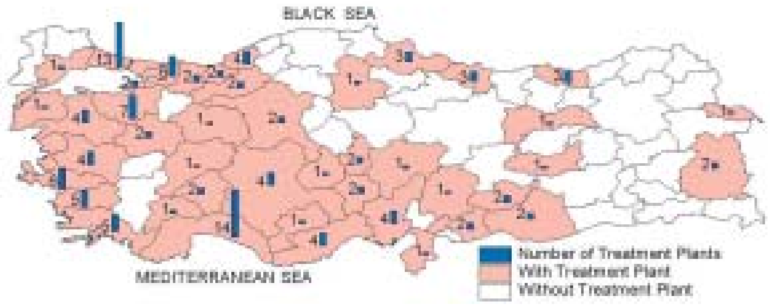


Fig. 1: **PROVINCES OF TURKEY AND DISTRIBUTION OF THE COUNTRY'S UWWTPS**

cilities was recorded as 115 in 1995 [3] and 119 in 1998 [4], with the expectation that this figure would increase up to a number of 129 in the year 2000. Owing to the financial constraints and the economic crises faced in the period between 2001 and 2002, the number of plants foreseen was realized by the end of December 2003 [1]. Another reason for the delay in constructing UWWTPs is the lack of coordination between the institutions involved which highly affects the distribution of infrastructure investments. Besides, the lack of sufficient technical personnel in municipalities leads to problems with the operation, the accomplishment of repairs and maintenance and renewal work. The share of the investment costs of UWWTPs in the general budget that is gradually decreasing has increased the external credit demands of the municipalities. The financing and equipment provided from abroad are more expensive than in the domestic market and this raises the costs of projects [5].

Fig. 2: **TRICKLING FILTER WITH ROTATING SPRINKLER**

DISPOSAL METHODS

Among the total number of 129 treatment plants, 46 of them are physical treatment plants, 74 consist of biological treatment units and nine feature advanced treatment. The distribution of existing plants according to treatment technologies applied are 36% physical, 57% biological and 7% advanced. Most of the advanced treatment practices take place in coastal Greater Metropolitan Municipalities like Istanbul, Izmir, and Antalya that discharge their effluent into the sea. A breakdown of the effluent receiving bodies, the total effluent flow for each category and the respective percentages are summarized in table 1. According to the table, treated municipal effluent is mainly discharged into flowing receiving water bodies like rivers, creeks, and the coastal and deep sea environment. Those discharged into rivers and creeks are partly directly and/or indirectly used for irrigation purposes.

Effluent Disposal Method	Number of Plants	% of sum of plants	Total Effluent Flow (m^3year^{-1})	% of Total Effluent Flow
Land (Agricultural Area)	17	13	131 319 517	6
Dams, Lakes	10	8	68 622 832	3
Coastal, Marine	49	38	1 150 746 062	55
Streams, Rivers, Creeks	53	41	732 780 646	35
TOTAL	**129**	**100**	**2 083 469 057**	**100**

Table 1: **EFFLUENT DISCHARGE METHODS AND PRACTICES IN TURKEY**

DATA SURVEY

During the data inventory stage of the study, it was a time-consuming task to collect all the data available. Besides, some of the data had to be estimated based on literature surveys and personal contacts with the related governmental personnel. Part of the data necessitated confirmation and is considered to be less reliable. A systematic database still needs to be established to record the data properly and to make this something that can be easily accomplished even by the public. New developments should be immediately included in the databank and all the obtainable information must be updated. Regarding the findings of the survey, it can be seen that there is an imbalance in the distribution of the population in the country, making the water and wastewater issues a difficult task. Most of the population is settled around the coasts of the country and the highly industrialized regions. Among the many reasons for this fact, the most important ones may be referred to as climatic conditions, geographical structure, the existence of transportation networks, the fertility of the land, and political aspects. Sustainable wastewater management can be promoted unless the existing situation is well defined. It also necessitates the investigation of the national monitoring and control acts since without an idea of the national water and wastewater policies it is very hard to establish a healthy and satisfactory management strategy.

This work is a part of the project titled "Development of Tools and Guidelines for the Promotion of the Sustainable Urban Wastewater Treatment and Reuse in the Agricultural Production in the Mediterranean Countries (Project Acronym: MEDAWARE)" which is financially supported by the European Commission, Euro-Mediterranean Partnership, Euro-Mediterranean Regional Program for Local Water Management.

REFERENCES

[1] Municipalities (2003). Personal communication with each of the municipalities with UWWTP(s).
[2] SIS (2000). General report on demography. Turkish Republic State Institute of Statistics, Istanbul.
[3] SIS (1995). Environmental statistics, river basins statistics. Turkish Republic State Institute of Statistics, Istanbul.
[4] SIS (1998). Environmental statistics, river basins statistics. Turkish Republic State Institute of Statistics, Istanbul.
[5] SPO (2001). 8th Five year development plan (2001-2005). Chapter Eight, Turkish Prime Ministry, The State Planning Organization (SPO), Ankara.

◀ AN ANCIENT CISTERN IN TURKEY

USE OF RAINWATER CISTERN SYSTEMS

RWCS AS AN ALTERNATIVE FOR FRESHWATER AUGMENTATION

By DENIZ DOLGEN, AHMENT BABAN and M.NECDET ALPASLAN*

Rainwater harvesting has been practiced for more than 4,000 years, and in most countries, it is becoming a considerable alternative for water supply, because of the shortage and limitations of other conventional water resources. It offers an ideal solution in areas where there is significant rainfall but an absence of any kind of conventional, centralized water supply system, and also in areas where there is a lack of good quality in the fresh surface water or groundwater [3].

*) Dr. **Deniz Dolgen** and Dr. **M. Necdet Alpaslan** are the staff members of the Environmental Engineering Department of the Dokuz Eylul University, Izmir, Turkey, deniz.dolgen@deu.edu.tr, necdet.alpaslan@deu.edu.tr. Dr. **Ahmet Baban** is researcher at TUBITAK-MRC, Gebze, ahmet.baban@mam.gov.tr

Historically, interest in the technology was restricted in terms of a wide application to rural areas; however, more recently, even urban environments equipped with piped water supply systems have started to adopt rain water cistern systems (RWCS) for the multi-sourcing of water.

RAINWATER CISTERN SYSTEMS

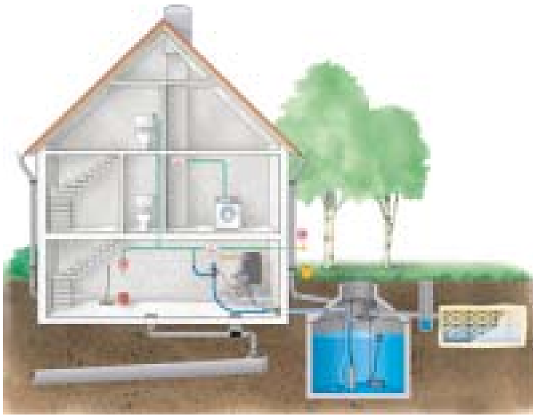
A typical rain water cistern system (RWCS) consists of three basic elements: a collection (catchment) area, a conveyance system, and storage facilities (see fig. 1). The collection area in most cases is the roof of a house/or a building, and a field. The effective roof area and the material used in constructing the roof influence the efficiency of collection and the water quality. Any roofing material is acceptable for collecting water for non-potable uses. Water to be used for drinking should not be collected from roofs covered with asphalt shingles, and lead flashing should not be used in these systems.

A conveyance system usually consists of gutters or pipes that deliver rainwater falling on the rooftop to cisterns or other storage vessels. Both drainpipes and roof surfaces should be constructed of chemically inert materials such as wood, plastic, aluminum, or fiberglass, in order to avoid adverse effects on the quality of the water. Sand, gravel or charcoal filters are sometimes used to filter water before it enters the cistern but they require frequent maintenance to prevent contamination.

The water ultimately is stored in a storage tank or cistern, which should also be constructed of an inert material, e.g. reinforced concrete, fiberglass, stainless steel, etc. Storage tanks may be constructed as part of the building, or may be built as a separate unit located some distance away from the building [2]. These may be constructed surface or above-ground tanks (most common for roof collection) and sub-surface or underground tanks (common for ground catchment systems, see fig. 2). Cisterns are usually designed with circular, rectangular and square plans with depths not more than 2 to 3 m. They must be equipped with outlet-works and over flows for large tanks. Appropriate access to the cistern must be provided.

The storage or cistern capacity is a crucial component of a RWCS. Low storage capacities limit the amount of harvested rainwater, so that the system may not be able to provide enough water in a low rainfall period. Increased storage capacities increase construction and operating costs and may make the technology economically unfeasible, unless it is subsidized by the government. Thus, the role of governments in this field can be expanded, including offering funds to users in order to encourage them to utilize cisterns and to introduce standards and specifications (codes) for the construction, operation and maintenance of this technology, in order to prevent any nonconformity that might endanger public health.

Fig. 1:
PRINCIPLE COMPONENTS OF A RWCS



Source: GEP

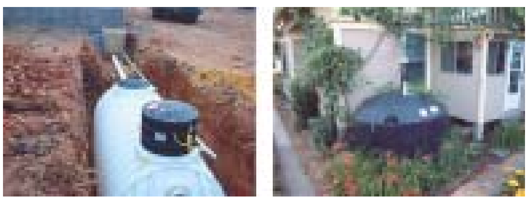
DETERMINATION OF CISTERN CAPACITY

When it comes to determining the cistern capacity, there is no exact formula to plug into. Once factors such as the water consumption, rainfall characteristics, runoff collection area, and the availability of other sources of water are determined, then the capacity can be figured out. There are rules of thumb approaches in capacity determination and also some guidelines and statistical methods. The statistical approach proposed and referred to in paper [1] is formulated by the frequency analysis of annual precipitation data. In this case, cumulative frequencies of annual rainfall are computed to estimate the probability distribution of precipitation. Furthermore, both the inputs (precipitation that is collected from a certain area) and the output (water demand) are considered as total values so that the cistern volume is determined by equating the inputs and the outputs. Such an approach is valid only when periods of rainfall do not coincide with periods of water use. Some designers suggest that cisterns should be designed at maximum sizes (maximization approach) considering that small increases in dimensions lead to significant increases in capacity. This approach may be valid for small-scale privately-owned dwellings, however, if a system of cisterns is to be planned with a broader scope of application, such a sizing procedure may lead to inefficient investments. Under these conditions, the design procedure, as proposed in this paper, may prove to be much more effective within a longer time perspective. However, all of the factors need to be traded-off with the cost.

OVERALL CHARACTERISTICS OF RWCS

A SWOT analysis is applied in order to delineate the overall characteristics of RWCS. The main conclusions are grouped in two parts as a) **S**trengths and **W**eaknesses and b) **O**pportunities and **T**hreats (see table 1).

Fig. 2:
UNDERGROUND AND ABOVE-GROUND CISTERNS



Strengths

- RWCS provides a source of water.
- It provides an essential reserve in times of emergency and/or breakdown of public water supply systems.
- The technology is flexible.
- The physical and chemical properties of rainwater may be superior to those of groundwater or surface waters that may have been subjected to pollution.
- The running costs are low.
- Construction, operation, and maintenance are not labor-intensive.
- It is owner operated and managed.
- It is a sustainable water source that is renewed every year naturally.

Weaknesses

- Seasonal variation of rainfall.
- Low storage capacities may limit rainwater harvesting.
- It may not be able to provide water in a low rainfall period.
- Cisterns and storage tanks can be unsafe for small children.
- Possible contamination of water.
- The technology is only effective if rainfall rates are relatively high.
- Trapping of mosquitoes, pests, etc.
- The water may not be fresh after prolonged storage periods.

Opportunities

- Development of new materials to lower the costs.
- Natural conditions favor RWCS in small residential communities, isolated highlands and mountain foothills.
- Implementation of pilot projects.
- Increasing need for a supplemental water source for urban communities.
- Growing water supply deficits.
- Lack of sufficient quantity of water resources.

Threats

- The tendency of governments towards the implementation of conventional water supply systems.
- Lack of standards and specifications (codes) for the construction, operation and maintenance of the technology.
- Risk of reduction of revenues from public utilities.
- Lack of proper knowledge of RWCS.
- Contamination of rain water from air pollution.

Table 1:
SWOT ANALYSIS ON RWCS

According to the SWOT analysis results, the application of an appropriate rainwater harvesting technology can make possible the utilization of rainwater as a valuable and, in many cases, needed water resource. However, the success of rainfall harvesting depends on the rainfall characteristics (seasonal variation, frequency intensity, etc); therefore, cisterns may be interpreted as an unreliable water supply instrument, particularly for periods of dry weather or prolonged droughts.

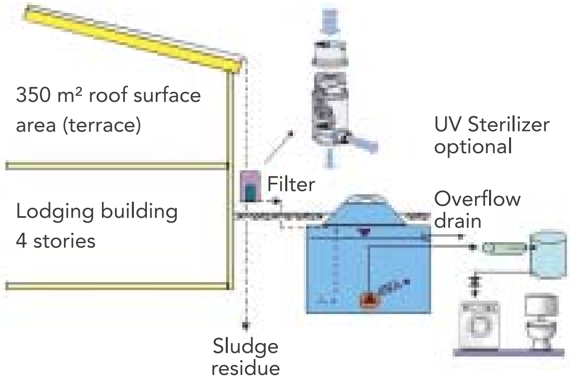


Fig. 3: **SCHEMATIC REPRESENTATION OF THE RWCS OF THE TUBITAK-MRC**

RWCS PROJECT AT TUBITAK-MRC

Within the training and demonstration activities in the context of the Zer0-M project, rainwater harvesting is practiced. For that purpose a building with four floors will be used in the MRC premises where, approximately 20 people are residing. The intended use of the collected rainwater, i.e. toilet flushing/drinking water is subject to the results of water quality analysis. The annual rainfall is taken from the Gebze Meteorology Station as 835 mm. Then, the volume of the rainwater reservoir, i.e. cistern is determined as 15 m^3 taking the roof area as 350 m^2 and the roof factor as 0.9. This figure represents a rough approximation of 50% - 70% of the water needed for toilet flushing purposes, depending on the climatic conditions.

To conclude, the use of rainwater is very effective in lessening the demand on the public water supply system. The rainwater collected can augment other water sources when they become scarce. If the long forgotten cistern applications can be put back into widespread use, then future investigations of RWCS will lead to better designs and operational features with reduced unit costs.

REFERENCES

[1] Alpaslan, N., Harmancioglu, N.B. and Singh, V.P. (1992) Cisterns as a water supply alternative for sparse establishments. *Hydrology Journal of Indian Association of Hydrology*, 15 (1-2), 1-13.

[2] French, R. (1988) Cisterns for water conservation and flood control. *Journal of Water Resources Planning and Management, ASCE*, 114 (5), 565-577.

[3] Waller, D.H. (1989) Rain water an alternative source in developing and developed countries. *Water International, IWRA*, 14 (1), 27-36.

USE OF RAPID INFILTRATION TECHNIQUE FOR AQUIFER RECHARGE WITH TREATED WASTEWATER

DESIGN OF SOUHIL WADI (NABEUL-TUNISIA) PILOT PLANT

By HAMADI KALLALI, MITSUO YOSHIDA, SALAH JELLALI, ABDENNACEUR HASSEN and NACEUR JEDIDI*

The intensive tourist activities, the overexploitation of coastal aquifers and the demographic increase, are numerous factors which induce pronounced saline intrusion in coastal aquifers. An integrated water management including wastewater reuse became a necessity to assure sustainable development. The main challenge is to reach the zero discharge of the wastewater treated in order to provide the farmers with sufficient water and avoid coastal water pollution. In Tunisia, the artificial recharge of groundwater with treated wastewater is gaining wide acceptance as a simple and low cost technique to replenish over-drafted aquifers.

*) **Hamadi Kallali** is Chief Engineer of Rural Engineering, waters and Forests and Assistant researcher at Wastewater Treatment and Recycling Laboratory (LTREU) of Tunisian National Institute for Scientific and Technical Research (INRST), Hammam-Lif, Tunisia,
Kallali.Hamadi@inrst.rnrt.tn
Salah JELLALI, Abdennaceur HASSEN and **Naceur JEDIDI** are researchers at Laboratoire Traitement & Recyclage des Eaux Usées, Institut National de Recherche Scientifique et Technique B.P.95, Hammam-Lif, TUNISIA.
Mitsuo YOSHIDA is researcher at the Institute for International Cooperation, JICA, JAPAN.

GEOLOGIC DESCRIPTION OF BOREHOLE CORES

The site of the borehole is located at a pilot plant for treated wastewater infiltration for aquifer recharge, at the western bank of the Souhil Wadi, the north-western part of Nabeul City, Tunisia. The exact position is identified by a Global Positioning System (GPS) as latitude N36°27'22", longitude E10°42'02". A 30-m-deep borehole (∅ 10 cm) was inserted at the site using a rotary drilling machine. Approximately 94% of drilled borehole cores have been retrieved. The results of the borehole core observation are illustrated as a geologic columnar section in fig. 1. According to the observation, the subsurface strata can be divided into two geologic units; the upper unconsolidated sand-gravel layers ("Upper Unit") and the lower consolidated silt-clay beds ("Lower Unit"). The Upper Unit is composed of unconsolidated coarse sediments such as sand, coarse sand, and gravel layers, where six upward-fining sequences are observed. The Upper Unit is most probably correlated with Late Quaternary. The Lower Unit is constituted by well-consolidated silt to clay sediments that yield fossil mollusca. Probably they are Tertiary marine strata [1]. The discrepancy of lithologic facies and estimated age suggests that the Upper Unit shows a non-conformity with the Lower Unit. The water table was measured around 10 m in depth, within the lower part of the Upper Unit. Unconsolidated sand and gravel layers in the Upper Unit are the porous media for groundwater circulation, and consolidated silt and clay beds in the Lower Unit play the role of a hydrogeological basement.

PERMEABILITY

In order to measure the permeability of the subsurface sediments, we collected eight non-disturbed samples (labelled from P1 to P8) from the borehole cores.

MEASUREMENT METHODS

We employed two different methods for the indoor permeability test; the Constant Level (CL) and the Variable Level (VL) methods.

Sample	Method	Temp.	t_1	Q_1
		°C		cm^3
P1	CL	27	20"41	8
P2	CL	27	20"59	12
P3	VL	26	9'11"83	-
P4	VL	26	7'20"75	-
P5	VL	26	3'2"51	-
P6	CL	26	20"86	4
P7	VL	26	6h56'59"	-
P8	VL	26	7h10'41"	-

Table 1: **RESULTS OF PERMEABILITY MEASUREMENTS**

RESULTS AND DISCUSSION

The results of the indoor permeability test are summarized in table 1. The permeability in saturated state varies from 10^{-4} to 10^{-5} m/sec for sand and gravel in the Upper Unit with less than 10^{-9} m/sec for silt and clay in the Lower Unit.

The results are in concordance of further investigations in the region, indeed, Rekaya, 1986 estimated that the vadose zone varies from the river bed to the basin site from 10 to 13 m, the aquifer thickness 2 to 3 m and the aquifer permeability estimation based on granulometry 10^{-4} to 10^{-5} m/sec [2].

CONCEPTION AND DESIGN OF THE INFILTRATION FACILITY: DETERMINATION OF THE ANNUAL LOAD

Determining the design annual hydraulic loading rate is one of the most critical aspects of rapid infiltraion (RI) system design. The hydraulic loading rate is based directly on the field and laboratory test results for infiltration and permeability. If the site investigation reveals a specific layer that will restrict flow, the design is based on the permeability of that layer regardless of its thickness [3]. In our case the lowest value for the vadose zone and the aquifer reservoir permeabilities, is 5.4×10^{-5} m/sec (according to CL method). This value (19.4 cm/h) defines the amount of clean water that can move through a unit cross-section in the soil, at unit gradient and under saturated conditions. Thus, the clean water rate, Lcw is given by:

$$Lcw = (19.4\ \text{cm/h})(24\ \text{h/d})(365\ \text{d/yr})(1\ \text{m}^2) / (100\ \text{cm/m}) = 1699.4\ \text{m}^3/\text{yr}$$

The loading can also be expressed in terms of the depth of water on a unit area because of the dimensions involved, so:

$$Lcw = (1699.4\ \text{m}^3/\text{yr}) / 1\ \text{m}^2 = 1699.4\ \text{m/yr}$$

However, most of the commonly used test procedures require the adjustments (safety factors) considering that wastewater will be used for infiltration. This factor is estimated by [3] upon full scale systems which are successfully operated. For Laboratory permeability measurements, this factor is 4 to 10% of restricting soil layer permeability. Thus, annual wastewater loading, Lww, is between :

$$Lww = (0.04)(\text{clean water rate, Lcw}) = (0.04)(1699.4) = 68\ \text{m/yr}$$

and

$$Lww = (0.1)(\text{clean water rate, Lcw}) = (0.1)(1699.4) = 170\ \text{m/yr}$$

The determination of the annual loading rate is in effect a definition of the capacity of the site to transmit wastewater if applied at some undefined, but regular

	t_2	Q_2	t_3	Q_3	$K_{15°C}$
		cm^3		cm^3	m/sec
	20"38	8	20"39	8	1.2×10^{-4}
	20"63	12	20"66	12	1.8×10^{-4}
	9'12"15	-	9'12"71	-	7.5×10^{-5}
	7'18"50	-	7'28"57	-	6.9×10^{-5}
	3'1"39	-	3'2"03	-	5.6×10^{-5}
	20"65	3.5	20"45	3.5	5.4×10^{-5}
	-	-	-	-	1.4×10^{-9}
	-	-	-	-	2.5×10^{-9}

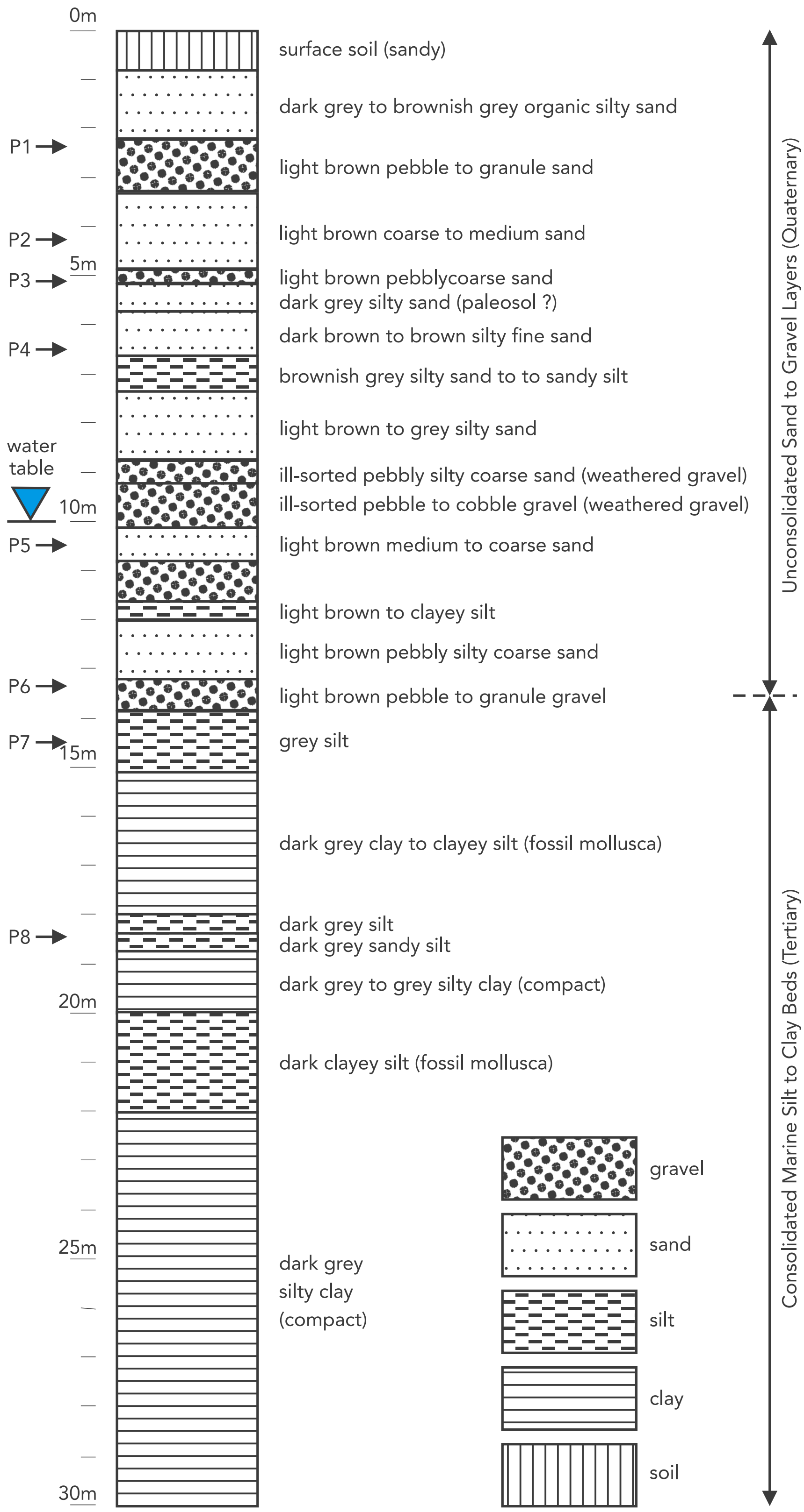


Fig. 1:
GEOLOGIC COLUMNAR SECTION OF THE SITE AND SAMPLED HORIZONS FOR PERMEABILITY TESTS

Fig. 2: **DOSING PERIOD**

schedule throughout the year. But in the case of the Wadi Souhil system, operation is limited to the winter because there is no demand for the irrigation area. For that, we have to reduce the annual loading proportionally to account for the non-operating period. System operation is planned for the winter period (November-March), so six months per year and the annual wastewater loading becomes between:

Lww = (6/12)(68 m/yr) = 34 m/yr

and Lww = (6/12)(170 m/yr) = 85 m/yr

DETERMINATION OF THE WET/DRY CYCLES AND APPLICATION RATE

In order to maximize the infiltration in winter, a cycle of three days of dosing (see fig. 2) for 10 days of resting (fig. 3) are recommended by [3]. We have 14 cycles in six months and a wastewater load by cycle of 1.7 m/cycle. The daily load, calculated on the basis of three days of dosing, is determined as follows:

L_D = 1.7 m/cycle/3days = 0.57 m/j= 57 cm/j

Fig. 3: **RESTING PERIOD**

DETERMINATION OF LAND REQUIREMENT

Land required for daily flow rate infiltration:

A = C Q (365 days/year) / Lww
A = Land area, ha
C = conversion factor = 10^{-4} ha/m^2
Q = mean flow rate, m^3/d
Lww = annual loading rate m/a

In this case
A= C Q (181 d / 6 months) / Lww

The flow rate is 260 m^3/d

A=10^{-4}.260.(181)/24 = 0,1961 ha = 1961 m^2

MINIMUM NUMBER OF BASINS REQUIRED

On the basis of the expertise acquired after the operation of a large number of RI facilities in the USA, the USEPA recommends a minimum number of basins according to the wet/dry cycle. In our case, the number corresponding to 3:10 is 5.

DEVELOPMENT OF A METHOD OF CALCULATION

At equilibrium, we have

$$\frac{N_d}{D} = \frac{N_r}{R} \text{ and } N = N_d - N_r$$

With N: Total number of basins, N_d: Number of dosed basins for a given day, N_r: Number of resting basins for a given day, D: Number of dosing days and R: number of resting days. Thus N could be written as follows:

$$N = \left(1+\frac{D}{R}\right) \cdot N_r$$

Where N_r is determined by the denominator of the irreducible D/R quotient. In our case, the wet/dry cycle is 3:10, the number of resting basins for a given day will be 10 because 3:10 is irreducible and the total number of basins N = (1 + 3/10) × 10 = 13 basins. The comparison of results between the two methods is given by fig. 4.

We notice that:

- USEPA recommendations meet the calculated number mostly for one or two days dosing.
- The USEPA recommends only three basins when the real number needed is very high
- When the quotient is not reducible, the number increases tremendously and in order to reduce significantly the required basins number, we have to choose a number of resting days n times of the number of dosing days (e.g. 9:16 gives 25 while 8:16 gives 3).

BASIN AREA CALCULATION

As A is the land area required to absorb the daily flow rate and N_d the number of dosed basins, the basin area required is: $S_B = A/N_d$. For our case, S_B = 1961/3 = 654 m^2. But if we want squared basins, we will take 26 × 26 = 676 m^2.

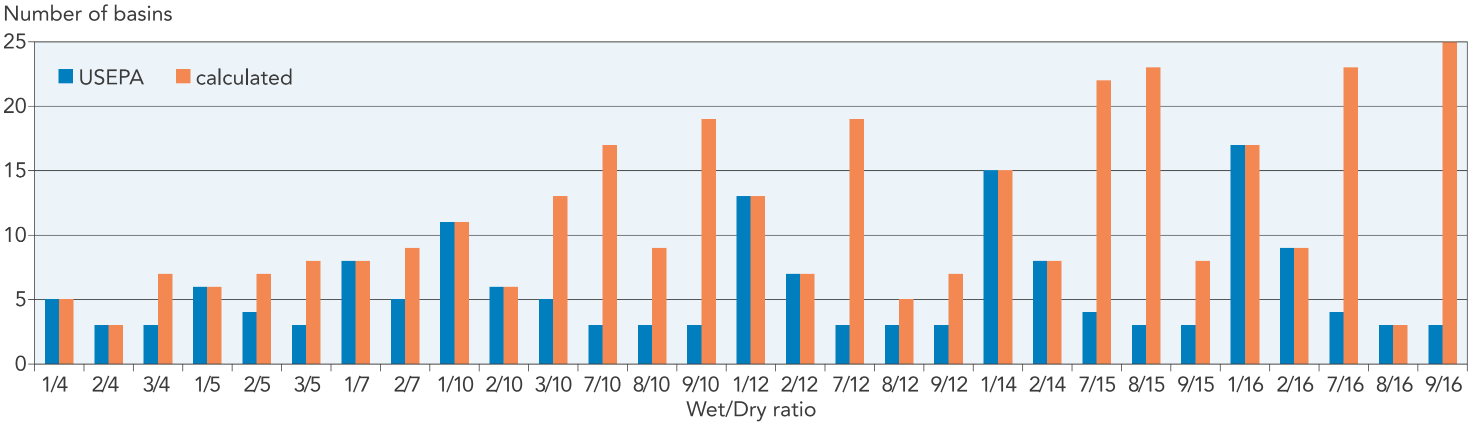


Fig. 4: **COMPARISON BETWEEN RECOMMENDED AND CALCULATED NUMBERS OF BASINS**

TOTAL LAND AREA REQUIREMENT

The infiltration area required is given by: $S_T = N.S_B$. For our case, $S_T = 13 \times 676 = 8788\ m^2$. Additional land may be needed for buffer zones, access roads, storage or flow equalization (when provided), and future expansion. Buffer zones can be used to screen RI sites from public view. Pre-application treatment facilities, access roads, and storage or flow equalization may be included in the buffer area. Access roads must be provided so that equipment and labour can reach the infiltration basins. Maintenance equipment must be able to enter each basin (for scarification or surface maintenance).

CONCLUSION

With the implementation of the rapid infiltration technique in the region of Cap Bon (Tunisia), we are moving towards closed loop wastewater management with direct irrigation with treated wastewater in the period of plant needs (summer time) and wastewater storing in the aquifer in the winter period.

ACKNOWLEDGEMENTS

This work is one of the outcomes of the project contracted by INRST and Tunisian Ministry of Research and Competences development (2002 - 2006) and INRST-JICA technical cooperation programme 2000 - 2002.

REFERENCES

[1] Bensalem, H. and Taamallah, N. (1995). Notice Explicative de la Carte Géologique de la Tunisie à 1/ 500.000^{e}, Nabeul-Hammamet Feuille No.30 & 37. Direction du Service Géologique, Office National des Mines, Ministère de l'Industrie, République Tunisienne, 32p.

[2] Rekaya, M. (1986). Expérimentation pilote de recharge artificielle à partir des eaux usées traitées. Cas de la nappe de l'Oued Souhil (Nabeul). Séminaire maghrébin sur la réutilisation des eaux usées après traitement en agriculture. Tunis, 24th-26th April 1986.

[3] US Environmental Protection Agency (1981). Process design Manual for Land Treatment of Municipal Wastewater. EPA 625/1-81-013.

GREYWATER TREATMENT AND USE FOR POVERTY REDUCTION IN RURAL AREAS

EXCHANGE OF KNOW-HOW BETWEEN WATER SCARCE COUNTRIES

By SHIHAB NAJIB AL-BEIRUTI*

Water scarcity in dry areas is a very critical issue for sustainable development. Efficient integrated water resources management (IWRM) methods require the implementation of all the possible alternatives for water supply and demand management methods.

*) **Shihab Najib Al-Beiruti** is researcher at Head of Services and Programs Section, The Inter-Islamic Network on Water Resources Development and Management (INWRDAM), Amman, Jordan, shihabinw@nic.net.jo

Water supply in Jordan is limited and the lack of new water resources and the competition between the different water uses like domestic, industrial and agricultural, is expected to increase in the near future. Applied research conducted by the Inter-Islamic Network on Water Resources Development and Management (INWRDAM) over the last five years on decentralized wastewater treatment and use focused on a holistic approach for the development of "state of the art" modular on-site low-cost greywater treatment and use units at the household level and implementing capacity building of the local peri-urban communities to enable them to practice sustainable Urban Agriculture (UA) by saving fresh water and safe guarding the environment. The outcome to date of this research has resulted in the optimization of the modular low-cost units for greywater treatment, the use of techniques for drip irrigation and the selection of crops for home gardens.

These findings were the results of three projects. One entitled "Post Project Evaluation of Permaculture Techniques" and a second one entitled "Greywater Treatment and Reuse in Home Gardens". Both projects were conducted in the town of Ein Al-Baida, Tafila Governorate, in the South of Jordan and were funded by research grants from the International Development Research Centre, Ottawa, Canada (IDRC). A third project entitled "Community Involvement in Reuse of Greywater to Improve Agriculture Output" was financed by the Jordanian Ministry of Planning and International Cooperation of Jordan (MOPIC) and involved benefiting more than 800 households in 90 peri-urban sites throughout Jordan with greywater treatment units and drip irrigation systems. INWRDAM also succeeded in setting up similar greywater activities in other Islamic countries such as Lebanon where the adoption of greywater in a cluster of six towns in Lebanon is being implemented. The results of this research were well accepted by the local community and by the government of Jordan. More projects addressing greywater use are now being implemented in Jordan, Palestine and Lebanon with the emphasis on conserving fresh water, the improvement of sanitation and generating extra income for the poor in peri-urban areas and constituted sustainable urban agriculture practices. A recent evaluation of INWRDAM' greywater projects by an external evaluator have indicated that: "INWRDAM has contributed to raising the profile of greywater use both in Jordan and in other parts of the world".

The main aim of this paper is to concentrate on the methods and results of INWRDAM' greywater treatment and to use this experience in order to make it easily affordable to more countries in order to contribute to the reduction of poverty in rural areas.

GREYWATER USE

A functional and sustainable wastewater management scheme begins at the household level and is largely dependant on the "software" or the human component. Only when the perception of need and perhaps the anticipation of a wastewater use system has been internalized at the neighbourhood/user level, will planning and implementation be successfully executed.

Greywater use represents the largest potential source of water saving in domestic uses. The use of domestic greywater for landscape irrigation makes a significant contribution towards the reduction of potable water use. In Arizona, for example, it is documented that an average household can generate about 135,000 to 180,000 liters of greywater per year [1]. This illustrates the immense potential amounts of water that can be used, especially in arid regions like the Middle East and North Africa. Domestic greywater use offers an attractive option in arid and semi arid regions due to severe water scarcity, rainfall fluctuations, and the rise in water pollution. To ensure sustainable water management, it is crucial to move towards the goal of efficient and appropriate water use. Greywater use contributes to promoting the preservation of high-quality fresh water as well as reducing pollutants in the environment. Meeting different needs with the appropriate quality of water may prove to be economically beneficial and at the same time reduce the need for new water supplies at a higher marginal cost.

DESCRIPTION OF TECHNOLOGY

On-site greywater treatment methods developed by INWRDAM [2] were designed with the objective to achieve low costs, an ease of construction, low operation and maintenance costs and to yield greywater of a quality suitable at least for restricted irrigation.

THE 4-BARREL SYSTEM

This system is an improvement on the two barrel kit. Two tanks each with 220 liter capacity and filled with gravel media that act as anaerobic filters are inserted between the pre-treatment tank and final storage tanks. The four barrels are lined up next to the other and interconnected with 50 mm PVC pipes.

Once solids and floating material settle in the first barrel, the relatively clear water from the first barrel enters into the bottom of the second barrel. Next the water from the top of the second barrel enters into the bottom of the third barrel. This water passes through the gravel lumps (2-3 cm size graded gravel) and from the top of the third barrel it is taken into the fourth. Anaerobic treatment is accomplished in the two middle barrels. Anaerobic bacteria get established on the stone surface so that when the greywater passes through the stones, the bacteria works on breaking down components of the organic material found in the greywater. The last barrel acts as a storage tank for treated greywater. As soon as this barrel is filled, a floating device switches on a small water pump which then delivers the water through the drip irrigation network. For an average family home, 20-30 trees (olives, fruit etc) that are planted in the domestic garden can be irrigated.

Fig. 1:
INSTALLED 4-BARREL GREYWATER TREATMENT SYSTEM

With the resident time of one to two days in the 4-barrel treatment kit the influent greywater undergoes a treatment level equivalent to between primary and secondary treatment and meets the World Health Organization's guidelines for restricted irrigation. Fig. 1 shows an installed 4-barrel system.

THE CONFINED TRENCH SYSTEM

Two plastic barrels and a dug trench filled with gravel media constitute the confined trench system. The first barrel acts as a grease, oil and solids separator and thus acts as a pre-treatment or primary treatment chamber, where the solid matter from the influent greywater settles and the floating components, such as grease and soap foam floats and can be removed regularly. A trench is dug close to the first barrel with dimensions of approximately three meter long, one meter wide and one meter deep and is lined with an impermeable polyethylene sheet with a thick-

Fig. 2:
INSTALLED CONFINED TRENCH GREYWATER TREATMENT SYSTEM

ness of 400 - 500 µm. The trench is then filled with 2 - 3 cm size graded gravel. Pre-treated wastewater from the first barrel enters the bottom part of the trench from one side and follows slowly to the other end. The sides of the side trench are plastered with a mud layer so that the liner sheet is not punctured by sharp stones. A 120 liter capacity plastic barrel is perforated and burred in the gravel at the exit of the trench so that treated wastewater follows throughout the trench and upwards to fill this barrel. As soon as this barrel is filled, a floating device switches on a small water pump which then delivers the water through the drip irrigation network.

The residence time of greywater in the trench is two to three days in anaerobic conditions. The confined trench unit can serve more than one nearby family sharing the same garden plot and it also can deliver more water quantity between pumping cycles. Fig. 2 shows an installed confined trench system.

RESULTS AND DISCUSSION

The project resulted in many direct and indirect benefits to the community and the environment. Women in the community benefited most from this project through training workshops, dialogue and learning by doing and acquired new skills to build a productive garden and management skills. The monthly domestic water consumption decreased by about 30% to all greywater users and the income of the poor increased on average by US$ 50 to US$ 150 per month and many beneficiaries had no longer to pay a large portion of their monthly income to regularly empty their septic tanks. Many families started to copy and imitate the practice of their neighbours with respect to greywater use.

The following recommendations can be made regarding the appropriateness of greywater use technologies:

- The scheme or technology should be a felt priority in public or environmental health, and either centralized or de-centralized technologies should be considered;
- The technology should be low-cost and require low energy input and mechanization, which reduces the risk of malfunction;
- The technology should be simple to operate, be local labor intensive, maintained by the community, not relying on expensive chemical inputs such as chlorine or ozone to meet quality guidelines;
- The treatment should be capable of being incrementally upgraded as the user demand or quality standards and treatment guidelines increase.

REFERENCES

[1] http://www.watercasa.org/pub/graywater-guidelines.html

[2] Bino, J. Murad and Al-Beiruti, S. Greywater Treatment And Reuse Project, Tafila, Jordan (2000 - 2003). Conducted by the Inter-Islamic Network on Water Resources Development and Management with financial support from the International Development Research Centre (IDRC).

Fig. 3: **CONFINED TRENCH SYSTEM**

Foto: Christian Platzer

ANAEROBIC TREATMENT OF INDUSTRIAL WASTEWATERS

By İLDA DEĞİRMENTAŞ and NURAN DEVECİ

In this study, the anaerobic treatment of high-strength antibiotic production wastewater was attempted. Anaerobic treatability was investigated using synthetic solutions and original wastewater of which the initial chemical oxygen demand (COD) was determined. The initial COD of solutions was increased from 3000 to 43000 mg O_2/L in an anaerobic bioreactor. The bioreactor pH was maintained at 6.5 - 7.5. The temperature was kept constant at 37 ± 1°C.

Raw materials and original wastewater containing penicillin antibiotics were obtained from the Fako Pharmaceutical Factory (Fako) in Istanbul, Turkey. The anaerobic sludge used for the treatment was obtained from Pakmaya Baker's Yeast Producing Factory (Pakmaya) in Izmit, Turkey and Fako. According to the results of experimental data, the maximum biodegradation efficiency of the anaerobic treatment obtained in approximately 60 days was 97 %.

INTRODUCTION

Anaerobic digestion is a multistage biochemical process that can stabilize many different types of organic material [1, 2]. It has been proven that anaerobic wastewater treatment is a suitable technology for the treatment of concentrated wastewater. Research into the treatment of antibiotic production wastewaters has not been reported in the literature. So our research will clarify these points.

MATERIALS AND METHODS

Raw materials and original antibiotic wastewater were obtained from the Fako Medicine Producing Factory at Istanbul, Turkey. The characteristics of the high-strength process effluents from the Fako antibiotic production factory (Fako) are presented in table 1.

Parameter	Range
COD (mg O_2/L)	10000 - 43000
pH	7.75 - 10.62
TS (mg/L)	16800 - 23800
VTS (mg/L)	6210 - 8240
SS (mg/L)	120 - 580
VSS (mg/L)	100 - 560

Table 1: **CHARACTERISTICS OF HIGH-STRENGTH PROCESS EFFLUENTS FROM THE FAKO MEDICINE PRODUCING FACTORY, ISTANBUL-TURKEY**

Wastewater was stored at 4°C to avoid biodegradation and treated as soon as possible. Anaerobic sludge was obtained from Pakmaya Baker's Yeast Producing Factory (Pakmaya) at Izmit, Turkey and Fako.

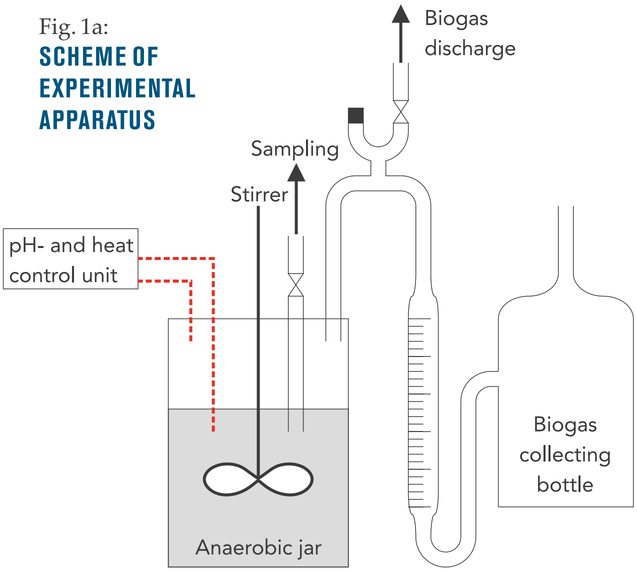
Anaerobic treatability was investigated using synthetic solutions and original wastewater, of which the initial chemical oxygen demand (COD) was determined at the beginning of the experiments. The anaerobic biodegradation was investigated in a laboratory-scale bioreactor (see fig. 1a and 1b) of two liters in volume.

The stirred reactor was suitable for nutrient addition, pH and temperature control. The bioreactor contents (antibiotic wastewater) were maintained at pH 6.5 - 7.5. The temperature was kept constant at 37 ±1°C, and a mixing speed of 150 rpm.

In the experimental studies, the wastewater samples were prepared by diluting the original wastewater and preparing synthetic solutions to obtain vari-

*) Dr. İlda Değırmentaş is researcher in the Chemical Engineering Department of Istanbul Technical University, Istanbul, Turkey, ildad@ttnet.net.tr

Fig. 1a:
SCHEME OF EXPERIMENTAL APPARATUS



ous COD values between 3000 and 43000 mg O_2/L. During the experiments, COD, volatile fatty acids (VFA), total solids (TS), suspended solids (SS), dissolved solids (DS), volatile total solids (VTS), and volatile suspended solids (VSS) were determined according to standard methods [3]. pH control was carried out in the samples taken at start-up, shut-down and periodically during the treatment.

RESULTS AND DISCUSSION

In this study, anaerobic treatability was investigated for the antibiotic production wastewater (of COD values ranging between 3000 - 43000 mg O_2/L). The maximum biodegradation efficiency of the anaerobic treatment obtained in approximately 60 days was 97%. In all the anaerobic degradations, except for the blank experiment with distilled water, there was an inert COD. This inert COD had values of 725 - 3250 mg O_2/L. One of the reasons for the low efficiency in the treatment of low-strength antibiotic production wastewater (COD = 3000 - 10000 mg O_2/L) was this inert COD. However, this inert COD did not affect the efficiency of the anaerobic treatment of the high-strength antibiotic production wastewater because of its relatively small magnitude.

Fig. 1b:
EXPERIMENTAL APPARATUS

Regarding the results of this study using the first-order kinetic equation (1) and second-order kinetic equation (2) the rate constants of the anaerobic biodegradation reactions k_1, k_2 and k_3 were determined (see table 4). Because of the conformity of the anaerobic degradation of medium strength (COD = 10000 – 20000 mg O_2/L) antibiotic production wastewater to the first-order kinetic, reaction rate constants k_1, k_2 and k_3 (given in italics) were calculated according to the latter equation presented in the literature [4]. And also the anaerobic treatment kinetics of high strength (COD >25000 mg O_2/L) antibiotic production wastewater fits the second-order biodegradation model, reaction rate constants were calculated according to the second-order kinetic equation [5].

The calculated rate constants according to the medium strength (COD = 10000 - 20000 mg O_2/L) antibiotic production wastewater are given in table 2. The calculated rate constants according to the equation (2) are given in table 3.

COD (mg O_2/L)	10000	-	20000
$k_1 \cdot 10^3$ (L/mg·h)	4.271	-	19.920
$k_2 \cdot 10^3$ (L/mg·h)	1.373	-	3.119
$k_3 \cdot 10^1$ (L/mg·h)	6.550	-	25.190

Table 2: **FIRST-ORDER RATE CONSTANTS k_1, k_2 and k_3***

*) The rate constants k_1, k_2, and k_3 were calculated for the given COD interval.

COD (mg O_2/L)	31500	-	43000
$k_1 \cdot 10^7$ (L/mg·h)	0.4459	-	0.9207
$k_2 \cdot 10^4$ (L/mg·h)	0.0342	-	0.0397
$k_3 \cdot 10^{-2}$ (L/mg·h)	605.800	-	719.800

Table 3: **SECOND-ORDER RATE CONSTANTS k_1, k_2 and k_3***

*) The rate constants k_1, k_2, and k_3 were calculated for the given COD interval.

CONCLUSION

According to the model equation that follows second-order kinetics, the rate constants, k_1, k_2 and k_3, of the anaerobic biodegradation reactions were determined. As a result of this study, k_1, the rate constant for the hydrolysis step, was found to be smaller than the k_2 and k_3 values. For this reason, it can be concluded that hydrolysis is the rate-limiting step in the anaerobic treatment reactions of antibiotic production wastewater.

According to the results of this study, the anaerobic biodegradation of medium strength (10000 ≤ COD ≤ 20000 mg O_2/L) antibiotic production wastewater fits the first-order kinetics, and the anaerobic biodegradation of the high strength (COD > 25000 mg O_2/L) wastewater fits the second-order kinetics.

REFERENCES

[1] Pavlostathis, S.G. and Giraldo, G.E., (1991). Kinetics of anaerobic treatment, Water Science and Technology, 24 (8), 59-35.

[2] Gray, N. F., (1989), *Biology of Wastewater Treatment*, Oxford Science Publications, London.

[3] APHA, AWWA, WPCF (1989), *Standard Methods For The Examination Of Water And Wastewater*, American Public Health Assoc., Washington.

[4] Deveci, N. and Çiftçi, G., (2001). A mathematical model for the anaerobic treatment of Baker's yeast effluents, Waste Management, 21, 99-103.

[5] Değırmentaş, I., Deveci, N., (2004). Anaerobic treatment of antibiotic production wastewater and kinetic evaluations, Journal of Biochemistry, 136, 177-182.

The first-order kinetic equation:

$$S_T = S_{A0} \cdot e^{-k_1 t} + k_1 S_{A0}\left(\frac{e^{-k_2 t} - e^{-k_1 t}}{k_1 - k_2}\right) + k_1 k_2 S_{A0}\left(\frac{(k_2 - k_3)\cdot e^{-k_1 t} - (k_1 - k_3)\cdot e^{-k_2 t} + (k_1 - k_2)\cdot e^{-k_3 t}}{(k_1 - k_2)(k_2 - k_3)(k_1 - k_2)}\right) \quad (1)$$

The second-order kinetic equation:

$$S_T = \left(\frac{S_{A0}}{1 + k_1 S_{A0} t}\right) + \Big(\frac{k_1 S_{A0}}{2k_2 + 2tk_1 k_2 S_{A0}} + \frac{1}{2k_2(1 + tk_1 S_{A0})}\Big\{-\sqrt{k_1}\sqrt{k1 + 4k_2}\, S_{A0} +$$

$$\frac{2\sqrt{k_1 + 4k_2}\, S_{A0}}{1 + \left(\frac{(1 + tk_1 S_{A0})^{-\sqrt{k_1 + 4k_2}/\sqrt{k_1}}(k_1 S_{A0} + \sqrt{k_1}\sqrt{k_1 + 4k_2}\, S_{A0})}{-k_1 S_{A0} + \sqrt{k_1}\sqrt{k_1 + 4k_2}\, S_{A0}}\right)}\Big\}\Big) +$$

$$\frac{k_1 S_{A0}}{2k_3 + 2tk_1 k_3 S_{A0}} + \frac{\sqrt{k_1(k_1^{\,2} + 4k_1 k_2 + 4k_2 k_3)S_{A0}^{\,2}}}{2\sqrt{k_1 + 4k_2}\, k_3(1 + tk_1 S_{A0})} +$$

$$\left(\frac{\Big(\big(k_1^{\,2} + 4k_1 k_2 + 2k_2 k_3\big)S_{A0} + \sqrt{k_1 + 4k_2}\sqrt{k_1(k_1^{\,2} + 4k_1 k_2 + 4k_2 k_3)S_{A0}^{\,2}}\Big)(-1 + (k_1 + 4k_2)^2 k_3^{\,2}(1 + tk_1 S_{A0}))}{2(k_1 + 4k_2)k_3(1 + tk_1 S_{A0})}\right) \quad (2)$$

Table 4: **FIRST ORDER AND SECOND ORDER KINETIC EQUATIONS**

Source: www.emwater.org Meda Projekt: EMWater

POLLUTION PREVENTION IN INDUSTRIAL PLANTS: A GENERAL VIEW*

By NIHAL BEKTAŞ**

Pollution prevention means eliminating or reducing at source the use, generation or release of toxic chemicals, hazardous materials or solid waste. This can be done through increased efficiency in the use of raw materials, energy, water or other resources, or through the protection of natural resources by conservation [1].

*) This work was previously presented at the 1st ZER0-M Conference on Sustainable Water Management 15 - 16 March 2005 Istanbul, Turkey.

**) Nihal Bektaş is an Assistant Prof. in Environmental Engineering Department, Gebze Institute of Technology, Gebze, TURKEY, nihal@gyte.edu.tr

Source reduction can also be defined as any practice that:

- Reduces the amount of any hazardous substance, pollutant or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment or disposal.
- Reduces the hazards to public health and the environment associated with the release of such substances, pollutants or contaminants.

Waste prevention assessments aim at the systematic identification, evaluation and implementation of waste prevention opportunities. Furthermore, an assessment should initiate an on-going waste prevention programme catalysing the corporate effort involved in achieving environmental improvements in its operations. To achieve success, the assessment procedure should be tailored to company characteristics, especially in small and medium-sized enterprises [1, 2]. This paper describes what the pollution prevention techniques and benefits are and how to use them in industrial plants.

METHODS

POLLUTION PREVENTION TECHNIQUES

In the waste management hierarchy, source reduction and recycling are considered the most viable pollution prevention techniques, preceding treatment and disposal [1, 2, 3, 4]. A detailed flow diagram is given in fig. 1.

Of the two approaches, source reduction is usually preferable to recycling from an environmental perspective [1, 2, 3]. Source reduction and recycling are comprised of a number of practises and approaches which are shown in fig. 2.

As can be seen from fig. 2, pollution prevention can be accomplished through a variety of different techniques which involve changes in human behaviour, materials, equipment, technology or some combinations of these factors.

A systematic approach that can be used during the procedure to find a recommended pollution prevention strategy, could be outlined as follows [1, 2, 3]:

1. Define the problem: review plants, operation and personnel
2. Develop unit flow diagrams: Collect emissions and waste inventory and identify causes
3. Develop pollution prevention strategies: Investigate process chemistry, design and maintenance changes
4. Estimate costs

DEFINING THE PROBLEM AND GETTING STARTED

The first step in establishing a pollution prevention programme is the obtainment of management commitment. The data collected during the actual evolution is then used to develop options to reduce the types and amounts of waste generated.

Once a policy statement has been written, approved and distributed, the process of incorporating a pollution prevention programme into daily company activities begins [5]. The steps involved include designing a pollution prevention coordinator, developing a pollution prevention team, increasing employee awareness and involvement, establishing a recognition program, training employees, goal setting and developing a written pollution prevention plan. To effectively implement this plan, it is necessary to develop a complete understanding of the various unit processes and points in these processes where waste is being generated. The information assembled in the process characterization and flow diagrams will be used to help identify pollution prevention opportunities. Once wastestreams have been identified and prioritized, the assessment of specific pollution prevention opportunities can begin. Once one of these projects has been found technically feasible the economic analysis of this project should be examined. Once approval is received and implementation has begun, the team members should closely monitor all pollution prevention activities to make sure that any problems are resolved immediately. This programme should also be continuously evaluated and updated to improve overall effectiveness.

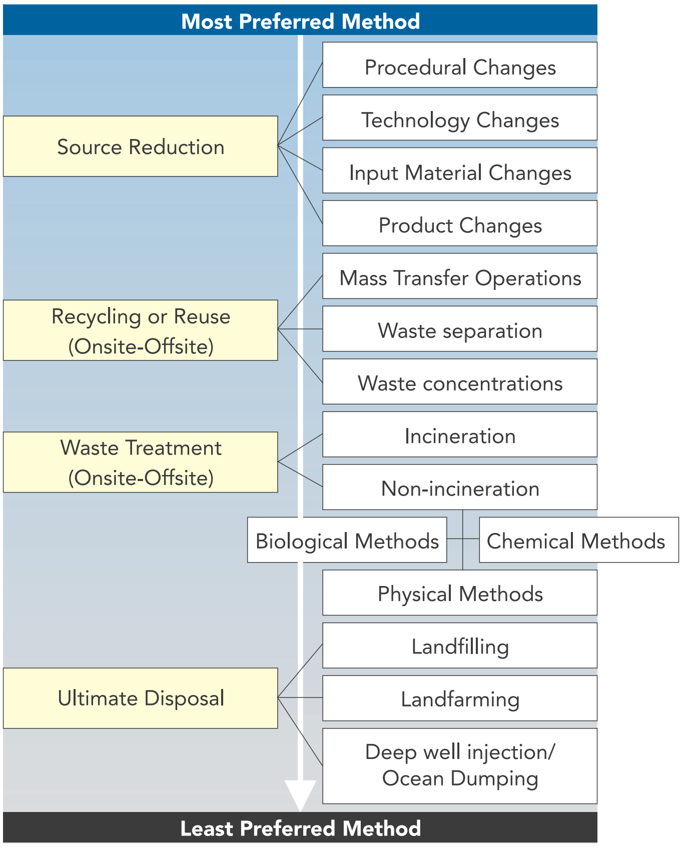


Fig. 1:
THE WASTE MANAGEMENT HIERARCHY

BENEFITS OF POLLUTION PREVENTION

Waste is lost raw material, lost products, lost resources and lost profit. Generating significant amounts of waste is not sustainable for todays society. Waste minimization often makes good economic and business sense. Source reduction and recycling, reuse, and reclaiming technologies have helped many companies reduce [1]:

- The quantity and toxicity of hazardous and solid waste generation;
- Raw material and product losses;
- Raw material purchase costs;
- Waste management recordkeeping and the paperwork burden;
- Waste management costs;
- Workplace accidents and worker exposure;
- Compliance violations;
- Environmental liability.

At the same time, waste minimization can improve:

- Production efficiency;
- Profits;
- Good community relations;
- Employee participation morale;
- Product quality;
- Overall environmental performance.

CONCLUSIONS

The basic elements of pollution prevention have been outlined. Many techniques and technologies exist to treat and recover waste once it has been generated. However, a pollution prevention programme should not rely on technology alone. Management commitment, a careful waste minimization programme and continuing emphasis on the reduction at source are prerequisites for success. Constant improvements must be made and new methods of reducing waste sought.

REFERENCES

[1] http://www.epa.gov

[2] Liu, D.H.F. (1999) Pollution Prevention in Chemical Manufacturing, CRC Press Boca Raton, Florida, section 3.2.

[3] Theodore, L., Duponts, R.R. and Reynolds, J. (1994) Pollution Prevention: problems and solutions, Gordon ND Breach Science Publisher, 1-35p.

[4] Kiely, G. (1998) Environmental Engineering, McGraw-Hill New York, 801-826p

[5] Freeman, H.M. (1995) Industrial Pollution Prevention Handbook, McGraw-Hill New York, 1-119p.

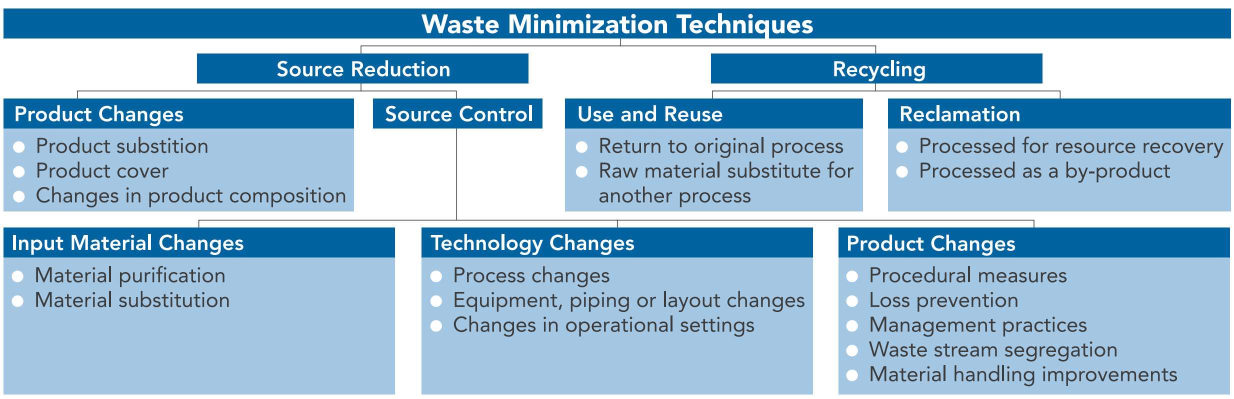


Fig. 2:
WASTE MINIMIZATION TECHNIQUES

◀ BRACKISH WATER WELL / SMALL PICTURE: DESALINATION PLANT

AUTONOMOUS DESALINATION

AS AN ALTERNATIVE APPROACH TO DECENTRALIZED WATER MANAGEMENT

By SEVAL SÖZEN, SENEM TEKSOY, SERDEN BAŞAK and ASLİ ÇİĞGIN*

1.3 billion of the worlds population does not have access to freshwater which is expected to double in 25 years time. The water demand has increased 60% in the last 25 years. The problem of water scarcity has given rise to the evaluation and development of alternative approaches to the existing water supply practices. Decentralized systems have been drawing significant attention in the last decades especially for small communities in remote areas facing fresh water shortages [1, 2].

*) **Seval Sözen** is professor at Istanbul Technical University, Environmental Engineering Department, Istanbul, Turkey. Her studies concentrate on environmental biotechnology (activated sludge modeling, biological nutrient removal etc.), industrial pollution control, waste management, integrated water management and water quality modeling. She has directed and supervised a significant number of researches and projects in the field of wastewater management, industrial pollution control, kinetics of biological processes and integrated water management. She has published more than 60 scientific papers; sozens@itu.edu.tr

The concept of autonomous desalination systems (ADS) relying on renewable energy sources (RES) (solar, wind and geothermal, etc.) has recently been introduced in the European Union Co-funded project namely, ADIRA (Autonomous Desalination system concepts for seawater and brackish water In Rural Areas with renewable-energies-potentials, technologies, field experience, socio-technical and socio-economic impacts). The project focuses on the implementation of small-scale ADS depending on existing technologies which have fresh water output in the range of 100 L/day to 10 m^3/day. The countries involved are Morocco, Egypt, Jordan, Cyprus and Turkey [3].

In the case of Turkey, according to the studies reviewing the country's water resources and RE potential, the most feasible option to implement the ADS concept was pointed out to be the adoption of this concept in the Aegean and Mediterranean coast lines. These regions with heavy tourist activities face freshwater shortages in the high season as a result of the substantial increase in the water demand and an uneven distribution of the stored water across the region. The abundance of RES, especially solar and in some cases wind energy, in these regions allows the use of sea and brackish water as water resources through an energy sustainable alternative where conditions are also favourable in terms of the social and economical sustainability of ADS due to the interest and involvement of local entrepreneurs in the tourist sector and the government organizations. Therefore the small-scale ADS units will provide a sustainable water supply alternative to compensate for the water-deficient summer seasons.

STATE OF THE ART IN TURKEY: WATER POTENTIAL

Turkey has a total land area of 779 452 km^2 (78 million ha), of which 765 152 km^2 is surface water. The total technically and economically usable surface and ground water potential of Turkey is only around 110 km^3, with 95 km^3 (86%) coming from rivers within Turkish borders, 3 km^3 (3%) from external rivers originating outside the country borders and 12 km^3 (11%) from groundwater resources [4]. The amount of actual water consumption through the exploitation of surface waters is 26.4 billion m^3 as of the groundwater is 7.6 billion m^3. The development of water consumption in Turkey is given in table 1 [5].

The consumption trends in the year 2000 revealed that 75% of the water withdrawn was used for irrigation, 15% for domestic use and 10 % for industrial use.

The water resource management in Turkey is based on a basin approach where the responsible agency, the General Directorate of State Hydraulic Works (SHW), categorizes the country into 26 main hydrological bas-

Table 1:
DEVELOPMENT OF WATER CONSUMPTION IN TURKEY [6]

YEAR	TOTAL WATER WITHDRAWAL		SECTORS		
			Irriagation	Domestic	Industrial
	million m^3	%	million m^3	million m^3	million m^3
1990	30 600	28	22 016	5 141	3 443
1992	31 600	29	22 939	5 195	3 466
1995	33 500	30	24 700	5 300	3 500
2000	42 000	38	31 500	6 400	4 100
2002	38 900	36	29 200	5 700	4 000

ins according to their respective drainage areas. Basin-wide master plans have been realized mostly based on a demand-oriented approach. Turkey's water potential on the basis of basin classification is depicted in figure 1. It is evident that there is an uneven distribution of water resources among the basins.

The basins in the Mediterranean (Antalya, Batı Akdeniz, Burdur Göller) and Aegean (Kuzey Ege, K. Menderes) regions are observed to have relatively less stored water.

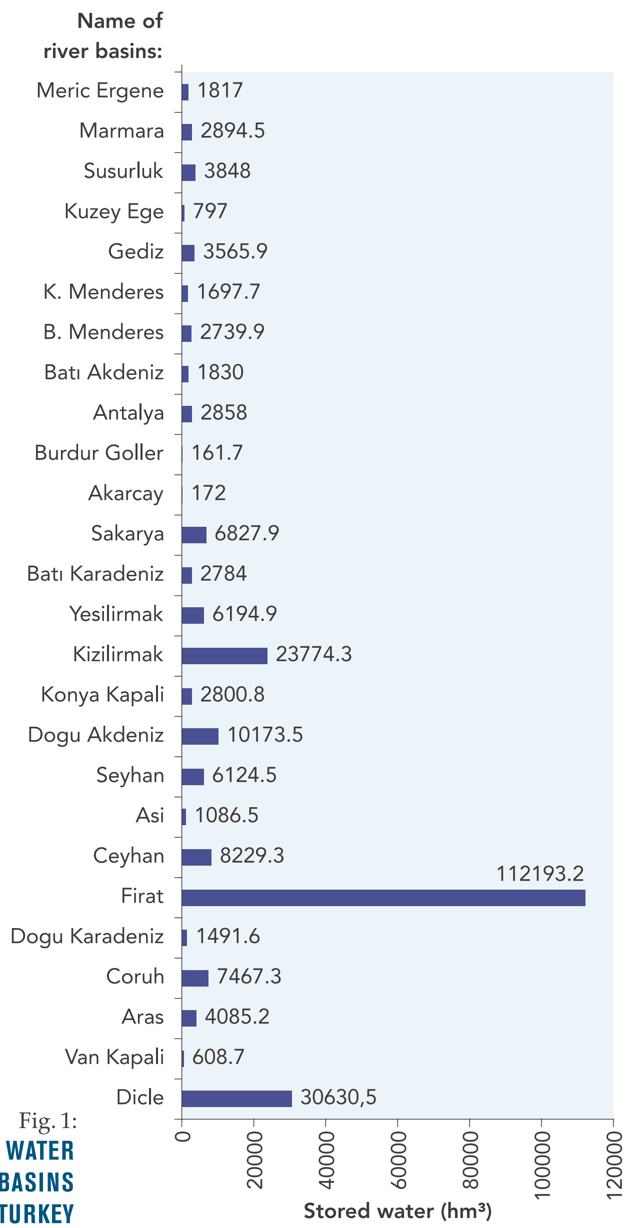


Fig. 1:
STORED WATER IN THE BASINS OF TURKEY

RENEWABLE ENERGY SOURCES (RES)

Turkey is unique among other European countries having substantial reserves of RES. The share of RE production of the total primary energy supply (TPES) was approximately 14.4%, i.e. 10.10 million tons of oil equivalents (Mtoe) in 1999, as the second-largest domestic energy source after coal. The main RES in Turkey are hydro, biomass, wind, biogas, geothermal and solar. Turkey is considered to have significant wind energy potential up to 20,000 MW of which around 8,000 MW is estimated as the usable wind energy potential [7]. The most favorable locations for wind power generation; with annual average wind speeds around 2.5 m/s and annual wind power densities of 2.4 W/m^2 are the Marmara Sea region, the Mediterranean and Aegean Sea coasts, and inland Anatolia. The total installed capacity has reached 18.9 MW and 72 new projects totaling about 2,000 MW are under evaluation by the Ministry of Energy and Natural Resources (MENR) [8]. Total production for the year 2001 is 152 GWh.

Solar energy also could provide a significant amount of power for Turkey, which is calculated as 35 Mtoe per year [7]. Preliminary studies indicate that the country has an average of 2,640 hours of sunshine annually, and an average solar intensity of 3.6 kWh/m^2day, with higher peaks at some locations like the South-Eastern Anatolia and the Mediterranean at 3.97 kWh/m^2.day and 3.86 kWh/m^2.day, respectively [9].

IDENTIFICATION OF SUITABLE REGIONS

The most suitable regions for the implementation of the ADS concept in Turkey were determined according to the preliminary water and renewable energy potentials. Regions which have populations not as dense, not highly industrialized and where high RE potentials, especially solar, and a lower amount of stored water may be pointed out as the Mediterranean coast and the west Mediterranean region.

These regions are also known for their high tourist attractions with their natural and historical assets. As a result of heavy tourist activities, they are exposed to wide fluctuations in water demand which causes severe water stress. The water demand may go up to three times the usual demand in high seasons especially in coastal areas. This intolerable water demand also leads to the unsustainable use of the existing water resources as a result of short-term solution approaches. Therefore these regions may be evaluated as feasible target areas for ADS implementation since they prove to have the satisfactory RE potential and sources of sea and brackish water as alternative water resources, which may be subjected to desalination to produce potable water.

RENEWABLE ENERGY-DRIVEN DESALINATION SYSTEMS

The desalination systems driven by RES are scarce, only representing 0.02% of the total desalination capacity. However, there are many reasons that indicate that the use of RES is feasible for the desalination of sea or brackish water. These have been identified in reviews conducted by Garcia Rodriguez (2002) [11] as seasonal changes, energy availability, self-sufficiency, technology, environmental impact, economics, and lastly the operation and maintenance. RES are more durable and resistant to deterioration and hence their operation and maintenance are normally easier than conventional energy ones, making them a good choice for remote areas. Their costs also have been falling significantly during the last decades. Table 2 summarizes the major desalination technologies coupled with RES.

Renewable Energy Source	Feed Water	Desalination Technology	Costs (€/m³)
Solar energy			
Solar thermal	SW	MED, MSF	3.5
Photovoltaics	SW/BW	RO	6.5
	BW	ED	
Wind energy	SW/BW	RO	3
	SW	MVC	
Geothermal	SW	MED	

SW: Sea water, BW: Brackish water, MED: Multi Effect Distillation, MSF: Multi Stage Flash, RO: Reverse Osmosis, ED: Electrodialysis, MVC: Mechanical Vapor Compression

Table 2: **RES COUPLED WITH DESALINATION TECHNOLOGIES [12, 13]**

CONCLUSIONS

There is a growing awareness that water resources development as well as all other types of development efforts must be sustainable for the rational management of water resources. The evaluation of techniques to provide water from alternative resources is of critical importance for sustainability because of the predictable impacts of the expanding population, increasing pollution and the heightened severity of extreme water-related events such as droughts and floods.

Although the major systematic aspect of water-related activities in Turkey is central planning, in order to guide planning at the national level and facilitate rational decision-making, special emphasis should be given to develop a decentralized strategy, based on the specific water stresses faced by particular regions. According to the results of this study, desalination with RES offers a sustainable solution to the water deficiency problems of the tourist regions faced during the high seasons along the Mediterranean coast. The abundance of RES, especially solar and in some cases wind energy, in these regions makes it possible to evaluate the sea and brackish water as water resources through an energy sustainable alternative. These regions are also favourable in terms of the social and economical sustainability of the ADS due to the interest and involvement of the local entrepreneurs in the tourist sector and the government organizations. Therefore the small-scale ADS units will provide a sustainable water supply alternative to compensate for the water-deficient summer seasons.

ACKNOWLEDGEMENTS

This project ADIRA with the partners Egyptian Energy and Water Association, Foundation Marrakech 21, The Middle East Desalination Research Center, Agriculture University of Athens, National Center for Scientific Research DEMOKRITOS, Technological Institute of the Canary Islands, Jordan University of Science and Technology, Istanbul Technical University and Fraunhofer ISE and the subcontractors WIP Munich and is supported by the European Commission under contract number ME8/AIDCO/2001/0515/59610.

This document has been produced with the financial assistance of the European Community. The views expressed herein are those of the Istanbul Technical University and can therefore in no way be taken to reflect the official opinion of the European Commission.

REFERENCES

[1] Kujinga, K. (2002) Decentralizing water management: An analysis of stakeholder participation in the management of water in Odzi sub-catchment area, save catchment, Phys Chem Earth, Parts A/B/C, 27: 897-905.
[2] Lemos, M.C. and Oliveira, J. L. F. (2004) Can water reform survive politics?, World Dev. 32, 2121-2137.
[3] Seibert, U., Vogt, G., Brennig, C., Gebhard, R., Holz, F. (2004) Autonomous desalination system concepts for seawater and brackish water in rural areas with renewable energies – potentials, technologies, field experience, socio-technical and socio-economic impacts – ADIRA, Desalination, 168, 29-37.
[4] General Directorate of State Hydraulic Works (1999) Mapped Statistics Bulletin, Ministry of Energy and Natural Resources, Ankara.
[5] General Directorate of State Hydraulic Works (2002), Annual Report, Ankara.
[6] EC Euro-Mediterranean Partnership, Development of Tools and Guidelines for the Promotion of the Sustainable Urban Wastewater Treatment and Reuse in the Agricultural Production in the Mediterranean Countries-MEDAWARE, Subtask1- Report, Turkey, 2003.
[7] Hanağasıoğlu M. (1999) Wind energy In Turkey, Renew Energ. 16, 822–7.
[8] Kaya, D. (2004) Renewable energy policies in Turkey, Renew Sust Energ Rev. 10 (2), 152–163.
[9] TÜSİAD (1999) An Overview Of Turkeys Energy Strategy On The Eve Of The 21st Century, part 5: Renewable Energy Potentials, Utilization and Development Opportunities.
[10] Kaygusuz K, Sarı A. (2003) Renewable energy potential and utilization in Turkey, Energ Convers Manage, 44, 459–78.
[11] Garcia-Rodriguez, L. (2002) Seawater desalination driven by renewable energies: a review, Desalination, 143, 103-1 13.
[12] Desalination Guide Using Renewable Energies (1998). THERMIE Programme, CRES, Greece, ISBN 960-90557-5-3
[13] Voivontas, D., Misirlis, K., Manoli, E., Arampatzis, G., Assimacopoulos, D., Zervos A. (2001) A tool for the design of desalination plants powered by renewable energies, Desalination, 133, 175-198.

WINDPOWERED SEA-WATER DESALINATION PLANT

By ULRICH PLANTIKOW*

The steadily rising world population in connection with changing climatic conditions not only leads to problems with nutrition but above all with problems regarding the potable water supply. This can be observed in the Middle East region dramatically. Between 1940 and 2000, the world population more than doubled. Simultaneously water consumption per capita doubled over the same period. Following this development, total water consumption has more than quadrupled, making potable water an increasingly scarce commodity in many parts of the world also in colder latitudes despite ample total reserves.

*) Dr. **Ulrich Plantikow** is manager of the WME Gesellschaft für windkraftgetriebene Meerwasserentsalzungs mbH, Dranske/Rügen, Germany, WME-GmbH@t-online.de, www.wmea.de

Of the various processes available today, vapour compression has emerged to become the most sophisticated process for capacities of up to 2,000 m^3/day. This simple but effective method ensures maximum reliability with an almost maintenance-free operation. Both the reliability and economic efficiency of such plants have been demonstrated in numerous installations worldwide.

ECOLOGIC AND ECONOMIC SOLUTION

The growing interest in decentralized systems has also prompted efforts to design new plants that operate off the public electric grid and do not, necessarily, require any infrastructure for the supply of fossil sources of energy and also chemicals. Especially remote areas need to run their own desalination plants because water transports are expensive. As a result of the poor infrastructure in these areas, a desalination plant that is dependent on the existence of an electric grid is in many cases no solution to the water problem. The use of wind energy allows the grid-independent operation of a new desalination system and aside its considerable ecologic advantages, it is a very economic solution.

The stand-alone wind-powered mechanical vapour compression (MVC) seawater desalination system would be of special interest to the tourist industry as it is ideally suited for remote areas and islands in particular. Large numbers of tourists lead to a substantial increase in the water consumption per capita, mostly in areas in which water is already scarce.

CONDITIONS FOR OPERATION

The variable nature of wind power is not a problem, because water can be stored inexpensively even for long periods of time without deterioration. With a plant that is dimensioned according to the local wind conditions, water becomes available at any time.

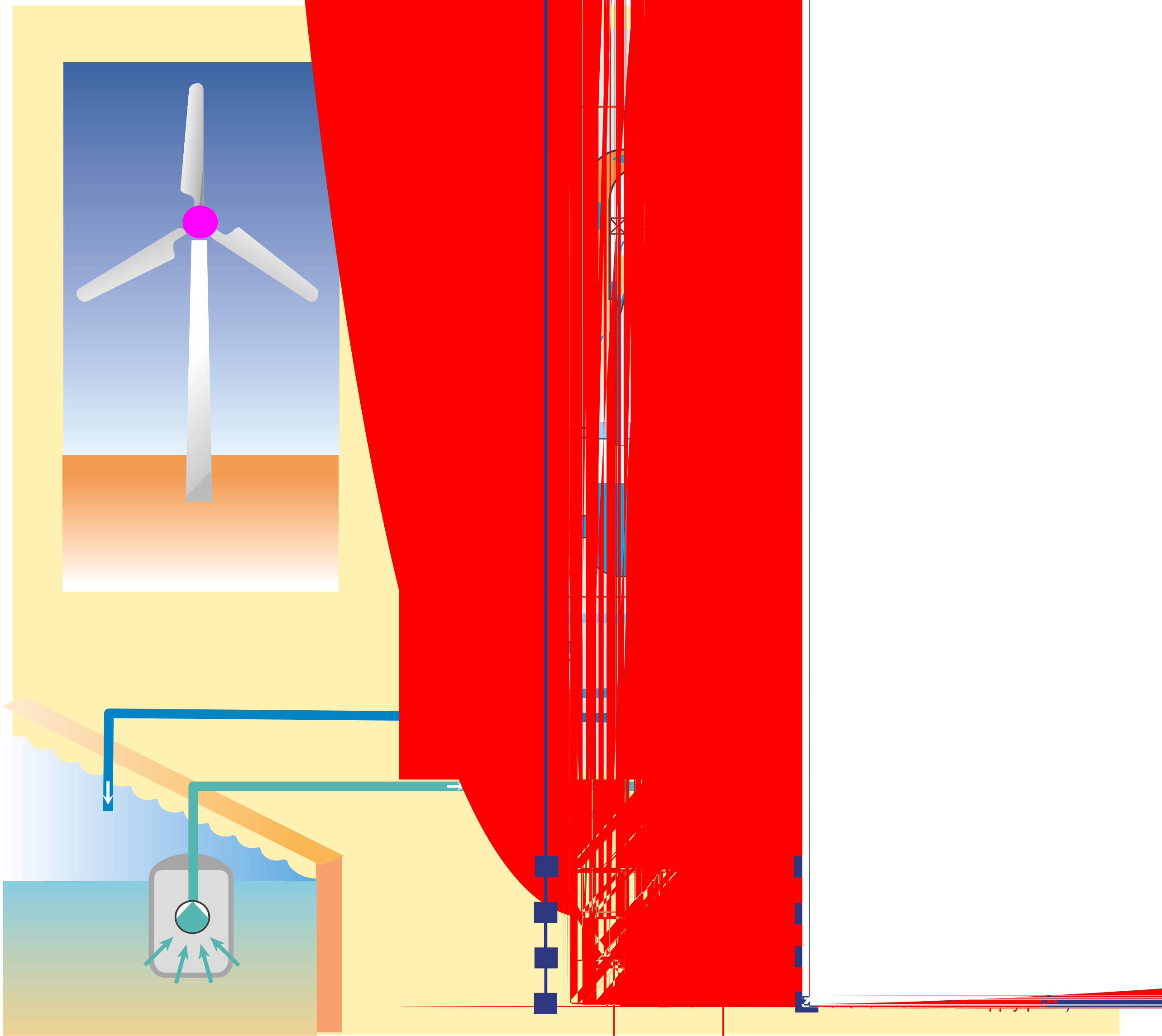
For the operation of a windpowered desalination plant it is most important to have a plant that has to be insensitive to repeated start up and shut down cycles caused by what are sometimes rapidly changing wind conditions.

MVC plants are widely used all around the world and have proven to be efficient and economic for many applications. Both, the wind turbine and high pressure blower of the MVC-plant, are fluid flow machines with similar characteristics. There is therefore a natural affinity of both machines. By varying the compressor speed and the evaporation temperature, the power consumption can also be adapted to rapid changes in wind conditions.

The combination of a wind turbine and a MVC [1] plant is therefore able to utilize wind energy to a very high degree at all times and conditions.

The plant described in the following is therefore a MVC-plant with a vertical tube evaporator-condensor-unit (see fig. 1).

Fig. 1:
PRINCIPAL SCHEME



DESCRIPTION OF THE DESALINATION PLANT

The filtered seawater is pumped into an intermediate tank of about 4 m^3, and from here into the desalination plant (fig. 2).

For preheating incoming seawater flows in two parallel lines through plate heat exchangers. In these exchangers heat is transferred from the outgoing distillate and brine to the incoming seawater.

INSIDE VIEW

The pressure in the following degasifyer is reduced to almost the level of the evaporation pressure of the preheated seawater using a vacuum pump. The gaseous components (air and CO_2) dissolved in the seawater escape and are removed.

The more water evaporates, the higher the salt concentration in the remaining seawater. Usually the salt concentration should not become higher than 7 - 9%, therefore concentrated seawater [2] is led back continuously into the sea and fresh seawater is supplied.

RESULTS

The characteristic of the desalination plant is shown in fig. 3. The higher the evaporation temperature and/or the energy input, the larger the amount of desalted water. The quality of the produced water is high, it is distilled water with an electrical conductivity of less than 5 µS/cm, that means it is also useful for unlimited irrigation, industrial processes and the production of table water [3].

The wind-powered salt water desalination plants operating according to the process of mechanical vapour compression offer an environmental and economic solution in order to cover the daily demand for potable water of up to 4000 people. Today these plants produce between 4 - 20 m³ distillate per hour.

The method is characterised among other things by an excellent water quality, minimal maintenance, proven technology, high economy and no use of chemicals. The process is pollution free and environmental friendly.

REFERENCES

[1] U. Plantikow (1999) „Wind-powered MVC Seawater Desalination - Operational Results“, *Desalination 122*, p. 291.

[2] R. Huß, U. Plantikow (2002) „New Materials in the Wind Powered Seawater Desalination Plant“, *4th European Stainless Steel Science and Market Congress*, June 2002, Paris.

[3] U. Plantikow, R. Huß (2003) „Production of potable water by a wind-driven seawater desalination plant - experience with the operation“, *WWEC 2003*, Cape Town, South Africa, 23.11.2003 - 26.11.2003, World wind energy conference and renewable energy exhibition.

Picture source:
Fotos and schemes have been provided by Dr. Ulrich Plantikow and LEEN design.

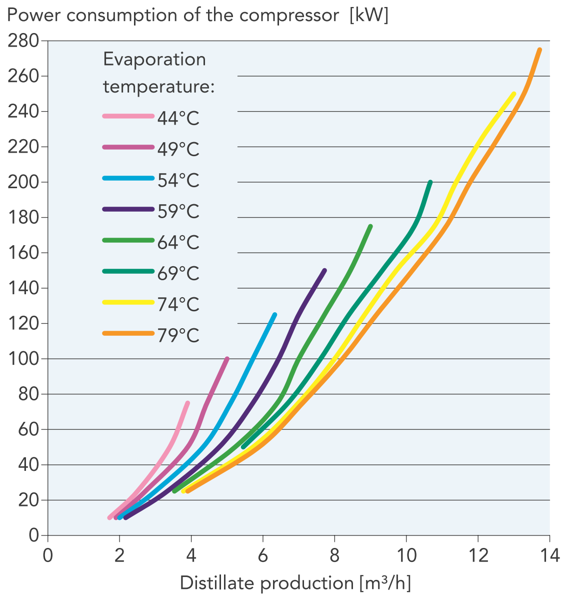


Fig. 3:
CHARACTERISTIC OF THE DESALINATION PLANT

Fig. 4:
OUTSIDE VIEW OF THE WIND DRIVEN DESALINATION PLANT

MEDA WATER PROJECTS

www.emwis.org/meda/projects.htm

PROJECT TITLE / ACRONYM	Countries involved	COORDINATION	INFORMATION
Autonomous desalination system concepts for sea water and brackish water in rural areas with renewable energies – Potentials, Technologies, Field Experience, Socio-technical and Socio-economic impacts / **ADIRA**	DE, EG, ES, GR, JO, MA, TR	Agricultural University of Athens, Dept. of Natural Resources and Agricultural Engineering (GR)	www.adira.info
Development of tools and guidelines for the promotion of the sustainable urban wastewater treatment and reuse in the agricultural production in the Mediterranean countries / **MEDAWARE**	CY, GR, JO, LB, MA, PS, SP, TR	National Technical University Athens, School of chemical Engineering. Unit of Environmental Sciences (GR)	147.102.83.100/ projects/ meda/meda.htm
Efficient Management of Wastewater, its Treatment and Re-Use in the Mediterranean Countries / **EMWATER**	DE, IT, JO, LB, PS, TR	InWent - Carl Duisberg Gesellschaft (DE)	www.emwater.org
Euro-Med Participatory Water Resources Scenarios / **EMPOWERS**	EG, JO, NL, PS, UK	CARE International (UK)	www.empowers.info
Improvement of irrigation water management in Lebanon and Jordan / **IRWA**	ES, IT, JO, LB	Istituto per la Cooperazione Universitaria (IT)	www.irwaproject.com
Institutional and social innovations in irrigation mediterranean management / **ISIIMM**	EG, ES, FR, IT, LB, MA	Agropolis (FR)	www.isiimm.agropolis.fr
Mediterranean Drought Preparedness and Mitigation Planning / **MEDROPLAN**	CY, ES, GR, IT, MA, TN	Mediterranean Agronomic Institute of Zaragoza (ES)	www.iamz.ciheam.org/ medroplan
Stakeholder Participatory Sustainable Water Management at Farm Level **MEDWA**	AT, ES, JO, PS	HWA – Hilfswerk Austria (AT)	www.hilfswerk-austria.at
Sustainable concepts towards a zero outflow municipality / **ZerO-M**	AT, EG, GE, GR, IT, MA, TN, TR	Institute for sustainable technologies (AT)	www.zero-m.org