SUSTAINABLE WATER MANAGEMENT

1-2008

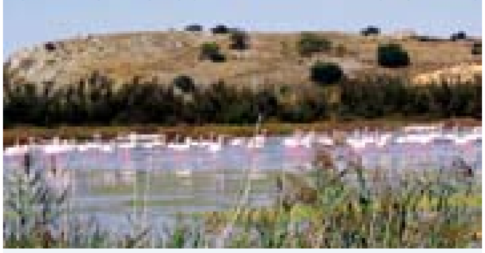
CONCEPTS TOWARDS A ZERO-OUTFLOW MUNICIPALITY

ZERO M

GUIDELINES ON WASTEWATER TREATMENT

The overall objective of the "EMWater Guide for Decision Makers in the Field of WWT and Reuse" in the MEDA countries is to provide guidance on taking decisions in wastewater management.

LOW TECHNOLOGY TREATMENT SYSTEMS

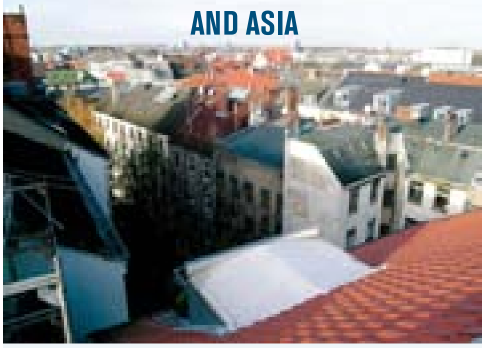


In small Mediterranean communities the daily flow of treated wastewater is accordingly low. In order to achieve a cost effective water reuse, high value applications are prefereable.

SUSTAINABLE SANITATION ALLIANCE

Helping to achieve the Millennium Development Goals by promoting sanitation systems which consider all aspects of sustainability, is the aim of the SuSanA organisation.

ECOLOGICAL WATER SYSTEMS IN EUROPE AND ASIA



The degree to which ecological water and sanitation systems contribute to the sustainable management of wastewater in cities around the world has been examined. The exemplary results for Hamburg/Germany and Seoul/ South Korea are presented.

AEE INTEC

This project is funded by the EUROPEAN UNION

EDITORIAL

Dear readers, you'll see a modification compared to the previous issues of this journal. The journal is predominantly English. In order to take into consideration the readers in countries with French as first or second language in our consortium and around the Mediterranean we have added abstracts in French. We hope this is an improvement of the journal, which eases access to its content in those countries. One article is printed in French at all (see page 9ff), with an abstract in English.

2008 is an important year for the water community. It has been declared International Year of Sanitation by the United Nations. The goal of the UN is to raise awareness and to accelerate progress towards the Millennium Development Goal (MDG) target to reduce by half the proportion of the 2.6 billion people without access to basic sanitation by 2015. Achieving this target will need a tremendous effort. And yet even providing 1.3 billion people with toilets is not enough: it will not guarantee these toilets are really used, neither that they last.

Therefore a group of organisations has joined efforts in a Sustainable Sanitation Alliance to attract attention to the fact that the solutions offered for sanitation have to be sustainable in order to really achieve the MDG target. You will find more information about the Alliance and the principles of sustainable sanitation in the first paper.

We are endeavouring to present you with concrete sustainable sanitation techniques and systems in the rest of the journal and, indeed, with all our work at Zer0-M.

Do not hesitate to visit the homepages of the Sustainable Sanitation Alliance and of Zer0-M (www.zer0-m.org), if you want to see more about this topic. You are also welcome to contact us directly.

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◀ *Fig. 1:*
FLAMINGOS IN A POND

LOW TECHNOLOGY TREATMENT SYSTEMS FOR WATER REUSE IN SMALL MUNICIPALITIES

By FRANÇOIS BRISSAUD*

Reclaimed water is a highly reliable but limited marginal water resource; e. g. the daily flow rate of a 5,000 inhabitant municipality is just sufficient to irrigate a surface of about 10 hectares. With respect to the limited reclaimed water volumes, transportation costs must be reduced as much as possible and reuse sites should be located not far from the places where wastewater is produced, treated and stored. Moreover, high added value applications should be preferred in order to make reuse cost effective.

More projects to come should be devoted to town or not-far-from-town applications. The reclaimed water applications that should be envisaged are (a) either the irrigation of high added value crops such as fruit trees and market-gardening crops, often located in the vicinity of towns and the income of which may allow the recovery of the costs of treated water supply or (b) urban uses such as the irrigation of public parks and lawns, landscape and golf courses, which often means offsetting potable water for non potable purposes and maximising the efficiency of reuse projects. These applications require that pathogenic micro-organisms be removed from reclaimed wastewater.

Taking into account the constraints of small reuse projects and the technical and economic situation of many countries of the region, the successful development of planned water reuse in small Mediterranean communities is likely to be linked to the availability of wastewater treatment techniques that allow meeting health related standards at low investment and O&M costs, requiring low O&M skills and being reliable. Thus, extensive technologies—stabilisation ponds, intermittent soil filtration and constructed wetlands—, are likely to be preferred to intensive processes. Indeed, the O&M costs of extensive facilities are very low and the O&M do not require highly qualified personnel.

RÉSUMÉ

SYSTÈMES DE TRAITEMENT DE FAIBLE TECHNOLOGIE POUR LA RÉUTILISATION DE L'EAU DANS LES PETITES COMMUNES

La planification de flux d'eaux à boucle fermée ne peut pas être réalisée sans tenir compte du potentiel de la réutilisation de l'eau. Économiquement on peut montrer que la réutilisation des petites quantités d'eau épurée produites par une petite commune tout en maintenant l'efficacité des coûts du projet demande la favorisation des applications à valeur ajoutée élevée situées au voisinage de la commune. De telles utilisations exigent de l'eau épurée sans contamination microbienne. Les technologies d'épuration extensives sont bien adaptées au contexte technique et économique des petites communes méditerranéennes pour leur exploitation et maintenance facile et peu couteuse. La capacité de ces technologies de correspondre de manière fiable aux normes liées à la santé a été prise en compte. Grâce aux efforts de la dernière décennie, la décontamination microbienne atteinte par les technologies extensives devient nettement plus prévisible. Les technologies extensives devraient jouer un rôle important dans le développement de la réutilisation et l'économie de l'eau dans le bassin méditerranéen.

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The main concerns related to extensive reclamation techniques, when planned in the framework of water reuse projects, are the microbial quality that can be achieved and the reliability of this achievement. Research conducted over the last period allows the more predictable disinfection and better design of low technology wastewater treatment systems aimed at achieving microbial disinfection for water reuse.

ADVANTAGES

Though investment costs are not much lower than those of intensive techniques, extensive systems offer the decisive advantage of very low operation and maintenance (O&M) costs. Actually, no (or a very limited) energy supply is required and as electro-mechanical equipment is reduced to a minimum, maintenance is relatively inexpensive. The power supply, which is an important part of the operation cost of conventional systems, is rapidly increasing due to the soaring cost of energy. As extensive techniques incorporate low technology equipment, the O&M do not require highly skilled personnel and are not very time-consuming. These advantages deserve the highest consideration when planning wastewater treatment in rural areas and developing countries. The work force is an important component of the construction costs of extensive systems; this may be an advantage in those countries where the local work force costs are competitive. In the rural zones of developed countries, small community budgets, poor access to equipment, supplies and repair facilities, together with the difficulty linked to the O&M of many small plants scattered over large areas often preclude the proper O&M of conventional systems and result in the recurrent violation of discharge permits [21] .

All the extensive and natural techniques allow significant to high microbial decontamination, as observed in the pond system of Mèze-France. Four to five log units removal of *Escherichia coli* can be obtained in stabilisation ponds [5, 16] more than six log units in shallow ponds [23], up to five log units in batch operated reservoirs [10] and three to four log units with infiltration percolation. One to more than three log units have been reported in vertical flow and horizontal flow constructed wetlands [13, 2]. Though decontamination performances depend on a number of factors, i.e. climatic conditions, the season of the year, the design and load and management of the plants, the potential to decontaminate wastewater is a very strong argument in favour of extensive techniques in many circumstances. Microbial decontamination is—or should be—the priority of sanitation strategies, particularly in arid regions where water reuse is on the agenda. The protection of bathing waters is of the utmost importance in tourist areas, such as the Mediterranean. In karstic areas, the disinfection of wastewater is essential for the protection of the groundwater quality. In water-scarce countries, the most rewarding water reuse applications require pathogen removal.

▶ *Fig. 2:* **OVERLOADED INFILTRATION PERCOLATION PLANT**

SLUDGE PRODUCTION

In natural systems, sludge production is limited to the settling stage. As settling is performed in Imhoff tanks, septic tanks and ponds, most of the accumulated sludge is digested, the excess being removed twice a year from Imhoff tanks, every three to five years from septic tanks and up to one year out of 15 for facultative ponds as demonstrated by **Picot et al. (2005)**. Many vertical flow constructed wetlands are fed with raw wastewater that has just been degritted; sludge accumulates on the filters rather slowly. **Molle et al. (2005)** report sludge heights of 13 and 25 cm in the primary vertical filter of a plant designed for 1,600 p. e., after nine and 15 years of operation, respectively. The SS mineralization rate was estimated to be more than 60% **[3]**. Because the dry matter content was greater than 20%, sludge deposits were easily removed without damaging the reed rhizomes. Reducing both the desludging frequency and the amount of sludge to be handled is a major advantage, not only in terms of labour saving but also because the regulations imposed on sludge disposal are so severe in several countries that costs have increased dramatically.

Extensive techniques are reliable. Treatment units are gravity fed in many plants and do not, therefore, depend on the power supply; then, the main risks of failure events are linked to the potential clogging of the infiltration systems and to the possible submersion of the plants during storm events (**Figure 2**). When pumping is necessary, pumps, often doubled and easy to replace, are the only electro-mechanical tools required to assure the proper functioning.

Systems with a high detention time, such as stabilization ponds and reservoirs can buffer load variations, thus preventing the discharge of poorly treated water into the environment.

Extensive or natural techniques are sometimes classified as “green” techniques. Ponds and vegetated constructed wetlands and infiltration systems can be designed in order to enhance the aesthetic value of the plant settings, including “natural” shapes for the treatment units, islands, plant diversity, providing wildlife habitat, etc. (**Figure 3**). However, wildlife access should be controlled in order to limit the presence of nuisance species and to prevent the detrimental impact of a waterfowl overpopulation, insects such as mosquitoes, floating macrophytes and even fish.

DISADVANTAGES

The main shortcoming of most extensive techniques is their large and often excessive footprints. They cannot, therefore, be applied in densely populated areas where land prices are often soaring.

Another disadvantage is that, in many cases, low technology systems cannot meet all the treatment objectives. If high organic matter removal is achieved in soil treatments and vertical flow constructed wetlands, COD abatement is hampered in ponds, reservoirs and other free water surface wetlands by the algal cell content in the final treatment units. Though this specificity has been taken into account in several wastewater disposal regulations, e.g. E.U. Directive 91/271 EEC **[9]**, more stringent requirements are likely to be imposed in the near future. Fortunately, this drawback can be overcome by adding rock filters or constructed wetlands to polish the effluent **[19]**.

▲ *Fig. 3:* **TERTIARY POND IN GRANVILLE / FRANCE**

Very stringent microbial criteria, i.e. ≤ 10 faecal coliforms par 100 mL, are not likely to be always met when using only low technology systems. Typically, free water surface systems can hardly supply consistent effluents of less than 100 faecal coliforms per 100 mL. Indeed, the recontamination by birds, rodents, amphibians and insects always occur in natural environments (**Figure 1**). Though in these cases the meaning of current microbial criteria in terms of public health remains unclear, natural settings usually limit the quality of the effluent. Moreover, in temperate and cold climates, the microbial decontamination in free water surface systems depends on the season, with a lower performance in winter. Seasonal variations are much less marked in soil treatments. Low loads and deep vadose zones lead to very high microbial decontamination levels.

The efficiency of free water surface extensive technologies, particularly ponds and reservoirs, is dependent on meteorological conditions. Rainfall and evaporation result in differences between inlet and outlet flow rates. Tracer tests associated with records of climate parameters are allowed to point out the key influence of temperature and wind on the hydrodynamic behaviour of ponds and the distribution of water detention times **[4]**. On the other hand, the micro-organism die-off kinetics depend on the temperature and solar radiation. Engineers are not accustomed to dealing with these contingencies; the under-estimation of climate effects and a poor understanding of hydrodynamics have contributed to the reputation of unreliability of the disinfection performances of extensive open systems.

▶ *Fig. 4:*
AERATED PONDS

EVAPORATION

Evaporation results in water losses inversely proportional to the water depth and proportional to the water residence time in free water surface bodies. The evaporation rate may reach values as high as 8.5 mm.day^{-1} and even more in arid regions. Therefore, it should be taken into account in pond design, particularly in those countries where evaporation is high and when treated water is to be reused in agriculture. Water losses can reach 20 - 30%, which results in a significant increase in salinity and tends to hamper water reuse in agriculture. Evaporation can be diminished through the reduction of the water detention time and water depth augmentation.

Potential adverse environmental impacts should not be underestimated when planning extensive wastewater treatment facilities. Odour nuisances and the proliferation of offensive insects, such as mosquitoes and midges, may ruin valuable projects. In soil treatment systems, odour nuisance may occur when the applied wastewater remains at the soil surface for a long time, i.e. more than a few hours, after the application. This situation, which usually results from overloading or poor clogging control and is detrimental for the oxygen supply to the filter and the treatment efficiency, should be prevented through the proper operation and management. In the event of underground distribution systems, odour nuisance can be due to aeration defects. Odour nuisances are likely to occur in ponds when sludge that has accumulated during the cold season starts being digested thanks to the spring temperature increase. Offensive smells also result from the temporary excess of organic load or from sludge accumulation. Several options can be taken to reduce the risk of offensive smells emitted by stabilisation pond systems **[6, 20]**. One solution is to recirculate effluents from the second or third ponds to the inlet of the primary pond. An alternative solution consists in the mechanical aeration of the primary pond (**Figure 4**). Another option is to consider the near desludging of the primary pond. Midge and mosquito proliferation can be fought against with either these ecological methods **[12]** or pesticide spreading **[8]**.

The advantages and disadvantages of low technology systems are summarized in **table 1**.

TECHNOLOGY ADVANCES

Nowadays low technology systems face several challenges among which footprint reduction, enhanced discharged water quality requirements and better performance reliability and predictability seem to be the most important.

FOOTPRINT REDUCTION

As the population is rapidly increasing in urban and sub-urban areas, land available at reasonable costs is becoming scarcer every day. Therefore in these areas, plant footprint reduction will be a major asset in the competition between low technology and conventional systems. Several technological solutions have been proposed during the last decades. Thanks to

▶ *Table 1:*
DISTINCTIVE ADVANTAGES AND DISADVANTAGES OF EXTENSIVE TECHNOLOGIES

Technique	Treatment stage	Performance (removal)	Advantages	Disadvantages
Waste stabilization ponds				
Anaerobic pond	Prim.	SS, BOD, COD	Small footprint	Odours, Frequent desludging
Facultative pond	Prim., Sec.	BOD	Desludging at 12 - 15 yr intervals	Large footprint, Risk of odours, Evaporation
Maturation pond	Sec., Tert.	COD, Nutrients, Pathogens		Large footprint, Evaporation
High rate algal pond	Sec.	BOD, Nutrients, Pathogens	Small footprint	Production of large amounts of algae
Aerated pond	Prim., Sec.	BOD	Small footprint	Power consumption
Macrophyte pond	Prim., Sec., Tert.	BOD, COD, Nutrients, Pathogens		Large footprint, Frequent harvesting
Reservoir	Tert., Quat.	COD, Nutrients, Pathogens	High perform. when batch-operated	Evaporation
Intermittent soil filtration				
Soil absorption field	Sec.	SS, Organic matter and N oxidation		Large footprint, Clogging risks
Buried sand filter	Sec.		Small footprint	Clogging risks
Infiltration percolation	Sec., Tert.	Pathogens removal	Small footprint	Clogging risks, Nitrate build up
Slow rate infiltration	Sec., Tert.			Large footprint
Subsurface Flow Constructed wetlands				
Vertical flow	Prim., Sec., Tert.	SS, COD, N oxidation, Pathogens	Small footprint	Limited sludge handling tasks
Horizontal flow	Sec., Tert.	SS, COD, N, Pathogens		Large footprint, Evapotranspiration

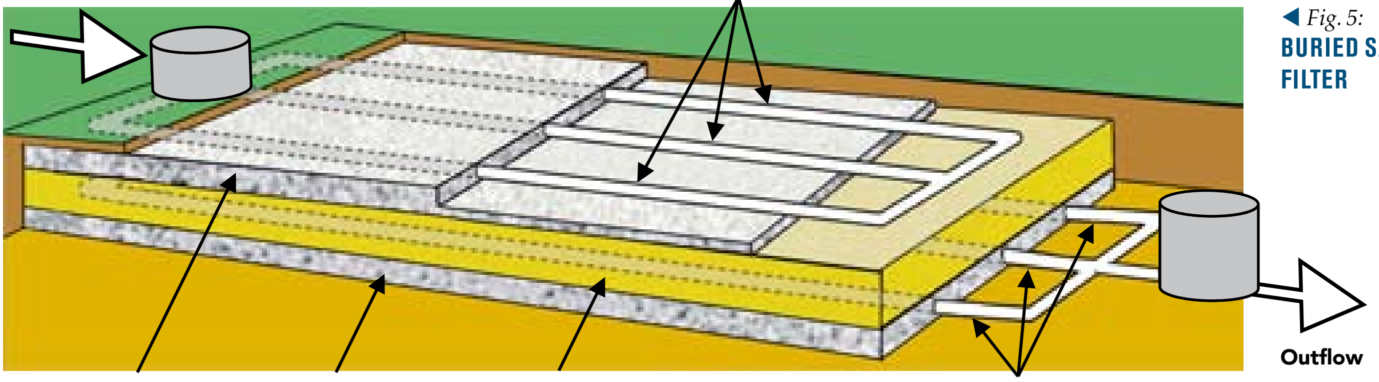

Fig. 5: **BURIED SAND FILTER**

small to moderate electric power consumption, facultative ponds can be replaced by high rate algal ponds—that can be part of Advanced Pond Systems [7]—or mechanically aerated ponds, thus considerably reducing the land surface required for pond systems. Introducing anaerobic ponds as a primary treatment stage has the same effect but does not require a power supply; however, offensive smells are frequent in the neighbourhood of anaerobic ponds. As illustrated by **Archer and Donaldson (2003)**, subdividing large ponds into smaller units may significantly improve the performance and save land surface. Another solution consisting in substituting vertical flow constructed wetlands for facultative ponds looks very promising.

The recommended hydraulic load applied on buried sand filters should not exceed 0.03 m^3m^{-2} per day for individual facilities and 0.05 $m^3m^{-2}d^{-1}$ for collective filters (**Figure 5**). This low load stems from three difficulties: (i) achieving the uniform distribution of wastewater at the surface of buried filters, (ii) the oxygen supply and (iii) clogging management in a confined and wet atmosphere. Several approaches allow increasing the hydraulic load or improving the treatment efficiency. The first one consists in providing a rather uniform spreading all over the filtrating beds; feeding the filter intermittently by pumping or using an automatic dosing batch. Inserting distribution lines at the top of buried half pipes leads to a more efficient and uniform use of the filters than the distribution through pipes inserted in gravel beds [22]. Capillary forces in polyurethane sponge-like structures or geo-textile structures also improve the water distribution via the filters. Half pipe leaching chambers and polyurethane and geo-textile structures provide for the air circulation over the filter and oxygen supply, facilitating surface clogging management and allowing the augmentation of the hydraulic load up to five to eight times.

ENHANCED REQUIREMENTS

Regulations and guidelines on the quality of treated wastewater either discharged into the environment or reused in irrigation or for other beneficial purposes are tending to become more stringent in many countries. The treatment performance of low technology systems can be enhanced through either technological advances or the combination of natural systems.

Although they are already old concepts, baffles and rock filters should lead to the considerable enhancement of the pond system performance. Baffles can be designed on the basis of CFD modelling, which should improve their efficiency in the reduction of preferential pathways [18]. Rock filters are not that common in Europe. They have been used for years in the United States [14] and are part of current pond design in New Zealand [1]. A rock filter—the rock size being 40 - 80 mm—is a porous rock bed through which pond effluent travels, causing algae to settle on the rock surfaces. Accumulated algae are then biologically degraded by bacteria growing on the biofilm wrapping on the rocks. In addition, significant ammonia removal and microbial decontamination can be achieved.

When microbial decontamination is at stake, innovative solutions such as the shallow ponds of **Von Sperling and Mascarenhas (2005)** and the batch operation of ponds and reservoirs [11] can provide a high performance within relatively short detention times.

Combining different natural systems, namely soil treatment and free water surface systems, offer the possibility to benefit from the advantages of each component of the treatment train. Though all possibilities have not yet been investigated, combining ponds and vertical flow constructed wetlands, infiltration percolation and horizontal flow constructed wetlands, vertical and horizontal flow constructed wetlands have proven to be effective.

CONCLUSION

Extensive techniques are cost effective; their O&M is very easy; they can reliably comply with WHO unrestricted irrigation guidelines. Therefore, if such standards are to be enforced and as far as the land area they require is available at a reasonable distance from the reuse sites, extensive techniques are the appropriate option for the Mediterranean.

As many countries are now considering the equipment of small and middle-size communities, the future of natural systems looks promising, provided more care is taken of their design and operation than is often observed. The current design of extensive treatment plants—consultants often use nothing more than a rule of thumb—should be improved to provide more predictable performances and reliable disinfection. These techniques should be taken into more consideration in the educational programmes of engineers and technicians.

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REVIEW

CHRISTOPHE ÉLAIN **UN PETIT COIN POUR SOULAGER LA PLANÈTE, TOILETTES SÈCHES ET HISTOIRES D'EAU**

En 2005, plus de un milliard d'humains n'ont pas accès à l'eau potable et 2,4 milliards ne disposent pas de toilettes ou de système d'assainissement. En France, un rapport sénatorial datant de 2003 montre les dysfonctionnements et les impasses où conduisent notre gestion de l'eau et nos pratiques en matière d'assainissement. Il est donc urgent de proposer et mettre en place des alternatives. Les toilettes sèches, qui n'utilisent pas d'eau (ou très peu), en sont une et permettent notamment, grâce à la pratique du compostage, de rendre à la terre ce qui en est issu. De notre rapport aux excréments à la législation en passant par la construction de toilettes sèches, la présentation des différents modèles, le problème des organismes pathogènes, la question des odeurs mais également le traitement des eaux usées, tous les aspects sont ici abordés.

Ce livre s'adresse aussi bien aux personnes qui s'interrogent sur leurs pratiques quotidiennes qu'à celles qui, ayant déjà adopté les toilettes sèches, sont à la recherche d'informations complémentaires. Enfin, il espère montrer aux élus et aux différents intervenants en matière d'assainissement que les alternatives proposées sont sérieuses et adaptées aux campagnes et aux villes, des pays riches comme des pays pauvres.

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◀ *Fig. 1:*
TRAITEMENT COMPLÉMENTAIRE EAUX USÉES TRAITÉES PAR UNE SÉRIE DE 3 BASSIN DE MATURATION (STATION D'ÉPURATION DE KORBA, TUNISIE)

LES DÉFIS DE LA RÉUTILISATION DES EAUX USÉES

Rédigé par
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La réutilisation des eaux usées urbaines a été organisée en fonction de la qualité des eaux épurées dans les stations d'épuration urbaines avec, à la rigueur, un traitement complémentaire limité. En Tunisie, la réutilisation des eaux usées épurées a concerné essentiellement l'irrigation, avec l'aménagement de périmètres irrigués et l'arrosage de terrains de golf dans les zones touristiques.

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L'intérêt de la réutilisation des eaux usées est indéniable dans un pays où les ressources hydrauliques sont limitées comme la Tunisie. En étant convaincu de l'intérêt de la réutilisation des eaux usées

ABSTRACT

WASTEWATER REUSE CHALLENGES

Treated wastewater reuse was generally organized according to the secondary wastewater quality with limited complementary treatments. In Tunisia, Treated wastewater is primarily employed in irrigation of cultures and golf courses watering. Introducing municipal, recreational and environmental usages and reinforcing agricultural reuse infrastructure are currently defined like top priorities. Moreover, diversification of uses makes possible the increase of the wastewater reuse rate by allowing a better adaptation of wastewater supply and demand. However, promoting a new wastewater applications, and expanding actual uses come up against many obstacles of technical, economic and regulation natures. Current double limitation: quality standards and type of cultures, imposed on the agricultural reuse as well as the absence of specific regulation of other uses (recreational, municipal …) limit the development of wastewater reuse. Think wastewater reuse regulation must be made by each country on the basis of the WHO recommendations according to a pragmatic and personalized step, taking in account its economic and sanitary conditions and its natural and social specificities. It is necessary to re-examine wastewater reuse regulation to give him more flexibility without losing the importance of preservation and improvement of public health and environment.

The variability of secondary wastewater quality following from important fluctuations of the quantities and quality of the treatment plants affluent and specific malfunction of theses plants is a significant factor of socio-economic impact of wastewater reuse. The acceptance of this practice by users can be strongly compromise by inopportune falls of treated wastewater quality. The variability of secondary wastewater quality has an effect on the effectiveness of tertiary treatment processes. It is difficult to run a sand filter effectively when the concentration of suspended solids in secondary wastewater is fluctuating and present important points of load. Disinfection process performances are strongly related to the quality of water treated. For example, UV disinfection process is completely ineffective in presence of high load of suspended solids in water. Secondary wastewater quality control and tertiary processes improvement is very important for wastewater reuse development.

urbaines et industrielles, il nous faut répondre à la question suivante: Faut-il trouver des usages conformes à la qualité de l'eau disponible ou bien définir les usages et ensuite adapter la qualité de l'eau aux usages prévus? Le choix de l'une ou l'autre de ces deux possibilités a des implications économiques, écologiques et sociales. Si la première option limite les possibilités de réutilisation et implique un taux de réutilisation faible, la seconde est handicapée par la complexité des technologies à mettre en œuvre et son coût élevé. Dans l'état actuel des choses, la réutilisation des eaux usées urbaines a été organisée en fonction de la qualité des eaux épurées dans les stations urbaines avec, à la rigueur, un traitement d'affinage limité. En Tunisie, la réutilisation des eaux usées épurées a concerné essentiellement l'irrigation, avec l'aménagement de périmètres irrigués et l'arrosage de terrains de golf dans les zones touristiques. La multiplication des usages, notamment l'introduction d'usages municipaux et récréatifs, et le renforcement des infrastructures de réutilisation agricole sont actuellement définis comme des objectifs prioritaires. La diversification des usages permet en outre d'augmenter le taux de réutilisation des eaux en permettant une meilleure adaptation de l'offre à la demande.

Le développement de la réutilisation des eaux usées rencontre deux principaux obstacles: la qualité insuffisante et variable des eaux et les contraintes réglementaires. Pour améliorer le taux de réutilisation des eaux il faudra agir sur deux plan: renforcer le taux de réutilisation dans le domaine agricole, en organisant les transfert inter saisonniers, et promouvoir les usages industriels, municipaux et de loisir. Ceci ne pourra se faire que si un effort est consenti pour mieux maîtriser les procédés de traitement secondaires et tertiaires afin de produire une eau de qualité suffisante et peu variable dans le temps. Les contraintes réglementaires sont susceptibles d'être allégées si l'eau produite par les stations d'épuration est de meilleure qualité et recèle par conséquent moins de risques pour l'usager et le destinataire du produit ou du service.

RISQUES ENVIRONNEMENTAUX ET SANITAIRES DE LA RÉUTILISATION DES EAUX USÉES

Les facteurs de contamination dans les eaux usées sont de deux types: biologiques et chimiques. Les nombreux éléments chimiques présents dans les eaux usées urbaines, utilisées dans l'irrigation ou l'arrosage, constituent une menace importante pour la qualité des eaux de surface et des eaux souterraines. Les métaux lourds accumulés dans le sol sont susceptibles d'être lessivés et entraînés jusqu'aux cours d'eaux et les nappes souterraines. Les métaux lourds ne sont pas les seuls incriminés. Les apports en sels, en nitrates, en pesticides et en matières organiques sont aussi à l'origine d'impacts négatifs liés à l'usage des eaux usées dans l'irrigation. Ces matières constituent en effet les principaux précurseurs des sous produits de désinfection chimique qui seront générés lors de la potabilisation des eaux. Le meilleur moyen pour réduire les risques de contamination chimique est un contrôle efficace des rejets industriels et des produits de nettoyage employés dans les ménages. C'est souvent la présence d'organismes pathogènes qui représente le risque sanitaire majeur dans la réutilisation des eaux usées. Les bactéries, helminthes, protozoaires et virus sont les principaux agents de contamination dans les eaux usées. Un procédé d'épuration bien dimensionné et bien exploité permet de réduire a teneur en organismes pathogènes mais cette réduction reste insuffisante. Les eaux épurées recèlent une charge microbiologique résiduelle suffisamment élevée pour constituer un risque sanitaire. Dans le cas particulier de la réutilisation des eaux urbaines dans l'irrigation, on peut distinguer deux mécanismes différents de contamination: la contamination de contact et la transmission des contaminants du sol à la plante par les racines. Le choix du procédé d'irrigation permet de minimiser la contamination de contact. L'irrigation goutte à goutte et l'irrigation souterraine permettent de minimiser le contact entre la plante et l'eau usée et par conséquent les risques sanitaires. Par contre, l'irrigation par aspersion est associée à la génération d'aérosols et à l'accumulation des contaminants sur les plantes.

Les œufs d'helminthes sont caractérisés par la survie maximale et représentent donc le risque majeur de contamination lié à la réutilisation des eaux usées. Leur important temps de latence, leur longue persistance dans l'environnement, la faiblesse des doses infectieuses, l'absence d'immunité chez les hôtes et l'absence de voies d'infection concurrentes font des helminthes l'une des principales causes d'infections transmissibles par les eaux usées. La contamination par des virus entériques semble être classée la dernière en terme de probabilité de risque à cause de l'immunité acquise durant les premières années de la vie, surtout si les conditions générales d'hygiène prévalentes sont médiocres. Avec l'amélioration de l'hygiène et des conditions sanitaires dues à l'augmentation du niveau de vie, une meilleure connaissance des mécanismes de contamination virale et la mise au point de nouvelles méthodes de détection, le rôle de la réutilisation des eaux usées dans la transmission de maladies entériques virales est maintenant reconsidéré. La survie des virus dans le sol est variable entre 1 et 180 jours **Schwartzbrod (1991)**. La survie des virus dans les végétaux irrigués par des eaux usées varie généralement entre 2 et 23 jours selon le type de végétaux, la charge virale des eaux d'irrigation et de la température, **Wekerle (1986)**. Le risque de transmission de virus entériques humains par les plantes irriguées avec l'eau usée reste possible bien que les données concernant la viabilité de ces virus dans les plantes ne suscite pas encore d'inquiétudes **[8]**. Certaines parties des plantes peuvent probablement servir de réservoirs et/ou comme porteur de virus entériques humains. Selon **Smith (1982)**, Les parties protégées des plantes, telles que les racines ou l'intérieur des fruits (les grains dans les épis de maïs par exemple), réunissent les conditions favorables à la prolongation du temps de survie des virus jusqu'à une soixantaine de jours.

Fig. 2a,b,c:
TRAITEMENT COMPLÉMENTAIRE EAUX USÉES TRAITÉES PAR UNE SÉRIE DE 3 BASSIN DE MATURATION (STATION D'ÉPURATION DE KORBA, TUNISIE).
Bassin de maturation a (▲), b (◥), unite de désinfection c (▶)

La désinfection des eaux secondaires peut contribuer à minimiser les risques sanitaires liés à la réutilisation des eaux usées et permettre ainsi l'élargissement du spectre de réutilisations potentielles. Plusieurs procédés sont applicables pour réaliser cet objectif dont les principaux sont: la chloration, l'ozonation et le rayonnement ultraviolet. Mais la désinfection d'eaux usées épurée pose des problèmes spécifiques liés essentiellement à la nature de cette eau et aux objectifs de qualité visés. L'efficacité d'un procédé de désinfection, qu'il soit chimique ou physique, est fortement influencée par la qualité de l'eau traitée. L'influence de la qualité de l'eau sur la désinfection se manifeste notamment au niveau des cinétiques réactionnelles. La consommation très élevée de désinfectant qui caractérise la désinfection chimique des eaux épurées est le résultat de leur charge importante en éléments réducteurs et en matières organiques. La présence simultanée de matières organiques solubles et de matières solides en suspension, dans l'eau secondaire produite par un procédé de boues activée, peut constituer des conditions favorables à la formation de flocs protecteurs. Les microorganismes piégés à l'intérieur du floc sont difficilement accessibles au désinfectant [5].

ASPECTS RÉGLEMENTAIRES ET NORMATIFS

Deux écoles se distinguent actuellement dans l'approche de normalisation de la réutilisation des eaux usées dans l'irrigation et l'arrosage. D'une part il y a les recommandations de l'Organisation Mondiale de la Santé, qui assurent les conditions sanitaires minimales pour une réutilisation sans restriction et, d'autre part, les directives adoptées dans l'état de Californie, qui sont beaucoup plus strictes et assurent une protection sanitaire maximale. Certains pays dont la Tunisie adoptent une démarche intermédiaire en adoptant des critères de qualité peu contraignants mais imposent des restrictions quant au type de cultures autorisées. Les recommandations de l'**OMS (1989)** sont actuellement considérées comme un minimum au-dessous duquel la protection sanitaire du public n'est pas assurée [2]. Des normes extrêmement strictes réunies en 1978 sous le «Titre 22» du code administratif de l'état de Californie traduisent une approche alliant haute technologie et prudence maximale. Les recommandations du «Titre 22» sont souvent opposées dans la littérature à celles de l'OMS. Outre le fait que les directives californiennes utilisent comme critère général, pour la définition de la qualité microbiologique des eaux utilisées, la seule teneur en coliformes alors que la teneur en coliformes et en œufs de nématodes sont adoptées par l'OMS, la principale différence entre ces deux directives est la définition des traitements préalables à la réutilisation des eaux. Les experts de l'OMS admettent que la qualité microbiologique la plus stricte peut être satisfaite moyennant le passage des eaux par une série de lagunes. Les directives californiennes adoptent par contre un critère simple pour la surveillance de la qualité microbiologique mais imposent une technologie d'épuration bien plus compliquée et plus efficace. La principale divergence entre l'approche californienne et celle de l'OMS est donc que la première adopte une obligation de moyens à mettre en œuvre et que la seconde adopte une obligation de résultats à atteindre. La valorisation des eaux usées selon les critères californiens permet de lever les restrictions

Fig. 3:
DÉSINFECTION PAR RAYONNEMENT UV (STATION D'ÉPURATION DE KÉLIBIA, TUNISIE)
▲ Vue général du système
◥ Réacteur de désinfection par UV

quant aux usages de ce type d'eau. Il devient ainsi possible d'utiliser ces eaux pour irriguer des cultures maraîchères dont le produit est consommé cru. **Asano et Levine (1996)** ont rendu compte de deux études épidémiologiques réalisées en Californie durant les années 70 et 80 qui démontrent scientifiquement que les cultures vivrières, irriguées avec des eaux usées urbaines valorisées selon la méthode californienne, peuvent être consommées crues sans effets néfastes pour la santé. Le traitement des eaux usées nécessaire pour atteindre les critères californiens élimine les éléments nutritifs ce qui enlève en partie la qualité fertilisante de ce type d'eau. **Bouwer et al (1999)** regrettent cependant que les critères adoptés n'incluent pas les sous produits de la désinfection chimique et leurs précurseurs. Les sous produits de réaction, comme les trihalométhanes ou les acides haloacétiques, peuvent être formés lors de la désinfection des eaux potables et se retrouver dans l'eau usée à l'entrée des stations d'épuration. Ils sont aussi susceptibles d'être formés lors de la désinfection des eaux usées au niveau du traitement tertiaire.

Une nouvelle tendance est actuellement en train de voir le jour qui stipule que la démarche d'établissement de normes de réutilisation doit être mieux adaptée aux conditions économiques, au niveau de maîtrise technologique et aux conditions générales d'hygiène dans chaque pays. Imposer des normes qualitatives strictes, dans des pays dont les conditions sanitaires, socio-économiques et de maîtrise technologique sont faibles pourrait avoir un effet inverse conduisant à l'emploi d'eaux usées brutes pour des usages non contrôlés. D'autre part, certains experts estime que l'impact sanitaire de l'emploi d'eaux usées dans les pays où l'hygiène est médiocre n'entraîne pas une augmentation sensible des affections entériques par exemple. D'autres sources de contamination comme la nourriture ou l'insalubrité de l'habitat sont plus importantes. Par contre, dans des pays plus développés, l'impact sanitaire et socio-économique de l'utilisation pour l'irrigation d'une eau de qualité médiocre est beaucoup plus important. En optant pour une démarche adaptée à leurs conditions spécifiques, certains pays ont établit des critères qualitatifs moins stricts pour la réutilisation des eaux usées. Dans ces pays où il n'y avait pas de contraintes à la réutilisation, l'établissement de normes, même peu strictes, constitue une amélioration sensible. Le Mexique par exemple a adopté des normes de réutilisation moins strictes que celles de l'OMS mais suffisante pour l'amélioration des conditions sanitaires locale et pouvant être atteintes avec les moyens de traitement disponibles (< 5 œufs de nématode par litre, < 2000 cfu / 100 ml en moyenne journalière). L'étude de la réglementation tunisienne actuelle, Norme NT 106.03 de 1989, montre que la réutilisation des eaux usées a été définie en fonction de la qualité de l'eau produite par les stations d'épuration urbaines. Cette approche limite considérablement les possibilités de la réutilisation des eaux. Circonscrire le domaine de la réutilisation des eaux au seul usage agricole pose le problème de gestion de ces eaux avec une production uniforme et une demande saisonnière. D'autre part, restreindre le type de cultures aux seules cultures fourragères, industrielles et arboricoles diminue sensiblement l'intérêt de la réutilisation des eaux. Une reconsidération du cadre réglementaire de la réutilisation des eaux usées est indispensable. Elle ne doit pas forcément allez dans le sens de l'allègement des contraintes de la réutilisation des eaux usées mais doit chercher à permettre le développement des possibilités de réutilisation dans le respect des impératifs de protection de l'environnement et de l'hygiène. Cette démarche ne pourra voire le jour que si un certain nombre de conditions sont satisfaite:

- évaluer objectivement les retombées économiques de la réutilisation des eaux en la comparant aux autres ressources (évoluer vers la pratique du vrai coût de l'eau)
- mettre en place un mécanisme de contrôle strict de la qualité des eaux usées épurées.

UNE MEILLEURE MAÎTRISE DE LA QUALITÉ DES EAUX ÉPURÉES

Le développement de la réutilisation des eaux nécessite l'entreprise d'un certain nombre d'actions visant la production d'une eau épurée de meilleure qualité. La stabilité de la qualité des eaux est aussi un

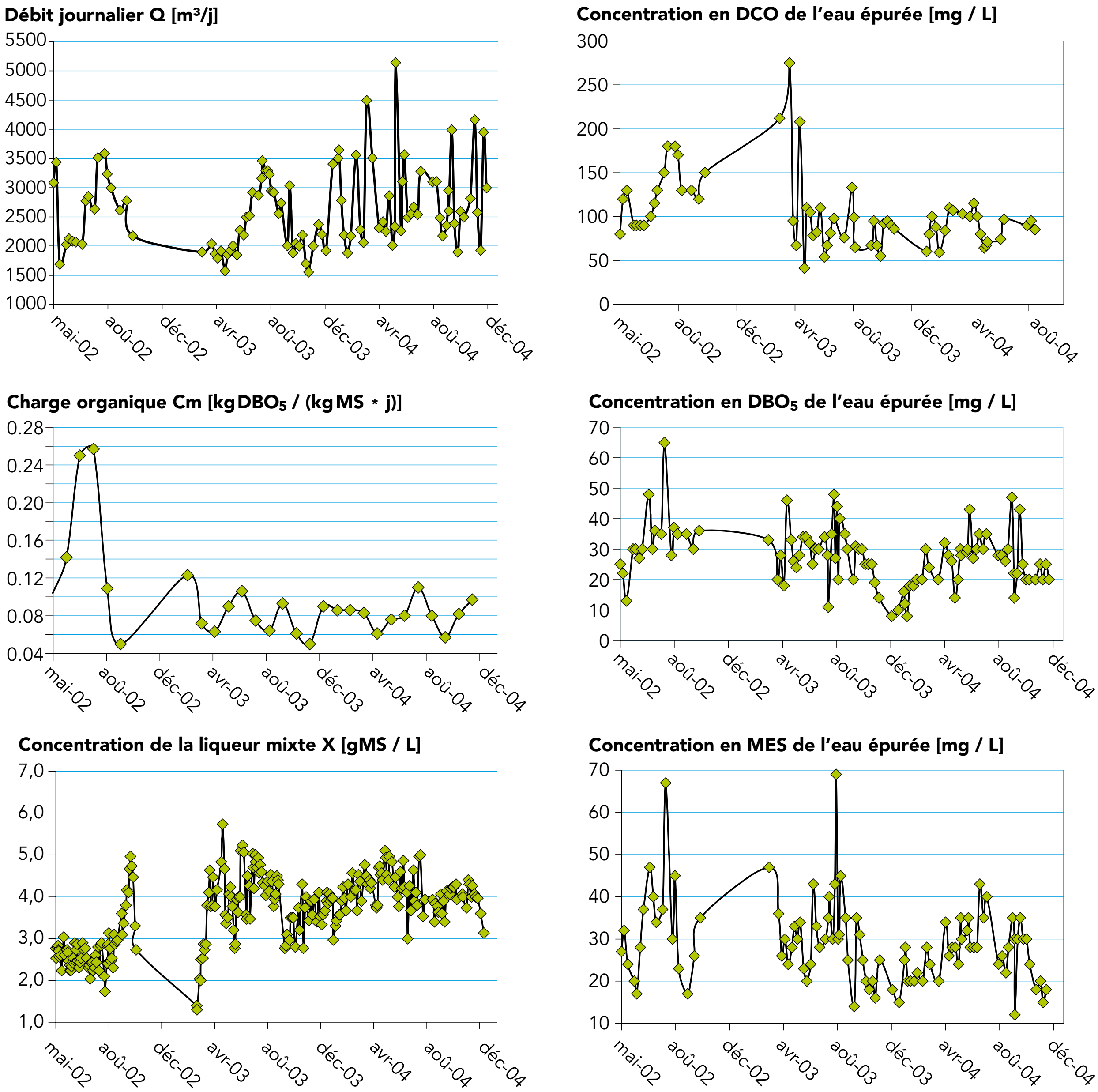

Fig. 4: **CONDITIONS DE FONCTIONNEMENT ET PERFORMANCES D'UNE STATION D'ÉPURATION PAR BOUES ACTIVÉES**

facteur essentiel. Les procédés de traitement complémentaire, prévu pour améliorer la qualité de l'eau par l'abattement de leur charge en micro-organismes notamment, ne sont efficaces que si la qualité des eaux secondaires est convenable et stable dans le temps.

Le bilan de fonctionnement de stations d'épuration par boues activées, même en bon état et bien exploitées, montre que le rendement de ces installations est plus ou moins aléatoire. La qualité de l'eau épurée est très variable dans le temps sans qu'on puisse toujours l'expliquer par la variabilité temporelle quantitatives et qualitatives des eaux usées reçues par ces stations. Il n'est souvent pas possible de dégager une corrélation entre les conditions de fonctionnement des installations et leurs performances épuratoires (**figure 4**). Nous pouvons relever des cas où les charges de fonctionnement sont élevées et le rendement épuratoire est maximal. Au contraire, des charges de fonctionnement minimales peuvent conduire à des rendements faibles. Ce décalage, qui n'est pas systématique, peut avoir plusieurs explications dont les principales concernent la méthodologie de contrôle et de suivie des installations. Les échantillonnages moyennés conduisent à la perte partielle de l'information lorsqu'on constate que les conditions de fonctionnement sont constamment variables. D'un autre coté, en dehors de la mesure du débit et de la concentration en oxygène dissous dans le bassin, effectuées in situ, la détermination des autres paramètres de qualité nécessite souvent plusieurs heures, voir plusieurs jours pour la teneur en DBO_5. La conduite d'une installation biologique en se basant sur de telles mesures pose un véritable problème. Le temps nécessaire à la caractérisation des conditions de fonctionnement de l'installation et à la prise de décision sont largement supérieurs à la fréquence de la variation des paramètres de fonctionnement tels que la charge massique et volumique ou la qualité des eaux usées brutes. Les opérateurs sont ainsi contraints à faire appel uniquement à leur expérience et à leur intuition pour la conduite des installations d'épuration. Cette méthode de gestion conduit souvent à la production d'une eau épurée de qualité variable bien qu'en terme de moyennes annuelles, elle reste conforme aux normes. Les techniques simples de contrôle, basées sur la mesure des flux ou la programmation temporelle, sont insuffisantes lorsqu'on vise une gestion optimale des installations surtout face à la complexité croissante des procédés. Les stations d'épuration actuelles sont appelées à traiter aussi bien la pollution carbonée (DBO) que la nitrification—dénitrification de l'azote et parfois la déphosphatation. Étant donné que l'élimination de ces différentes composantes est en grande partie séquentielle et exige des conditions opératoires spécifiques, l'exploitant doit gérer des séquences d'anaérobiose, d'anoxie et d'oxydation aérobie. La mise en place d'un système plus évolué de contrôle et de commande pose cependant des problèmes d'ordres techniques et économiques. Le coût de ces systèmes est élevé. Leur mise en place et leur exploitation sont complexes. Un effort d'optimisation de l'exploitation des installations pourrait néanmoins se révéler profitable. La mise en place de moyens de contrôle en ligne efficients et d'un système de commande évolué ainsi que l'utilisation d'un modèle de simulation avancé auront pour effet d'utiliser au mieux la capacité des équipements disponibles, d'améliorer la qualité des eaux épurées et d'optimiser le coût énergétique de l'épuration. La mise à la disposition de l'exploitant de la station d'un logiciel de simulation, même simplifié, lui permettra de réagir plus rapidement et efficacement aux variations des conditions de fonctionnement de la station et d'apporter les corrections nécessaires au bon fonctionnement du système. Le maintien de charges de fonctionnement convenables du bassin d'aération par exemple nécessite le réglage du taux de recyclage des boues en fonction de la charge hydraulique et biologique arrivant à la station. La simulation des conditions de fonctionnement et du rendement de la station pour un taux de recyclage donné constituera alors pour l'exploitant une aide appréciable à la décision.

UNE MEILLEURE MAÎTRISE DE LA DÉSINFECTION DES EAUX SECONDAIRES

La désinfection d'eaux usées épurée pose des problèmes spécifiques liés essentiellement à la nature de l'eau traitée et aux objectifs de qualité visés. L'efficacité d'un procédé de désinfection, qu'il soit chimique ou physique, est fortement influencée par la qualité de l'eau traitée. L'influence de la qualité de l'eau sur la désinfection se manifeste notamment au niveau des cinétiques réactionnelles. La consommation très élevée de désinfectant qui caractérise la désinfection chimique des eaux épurées est le résultat de leur charge importante en éléments réducteurs et en matières organiques. La présence simultanée de matières organiques solubles et de matières solides en suspension, dans l'eau secondaire produite par un procédé de boues activée, peut constituer des conditions favorables à la formation de flocs protecteurs. Les micro-organismes piégés à l'intérieur du floc sont difficilement accessibles au désinfectant **[5]**. Les études épidémiologiques montrent que l'approche actuelle de la désinfection comporte de sérieuses déficiences **[12]**. Le chlore, actuellement le plus utilisé, semble relativement inefficace sous sa forme combinée pour l'élimination des virus pathogènes **[11]**. Aux Etats Unis par exemple, les données épidémiologiques montrent une progression spectaculaire des affections entériques d'origine virale transmise par les eaux de baignades et les fruits de mer **[4]**, (**Cubitt, 1991** cités dans **[12]**). Cette progression est due, au moins partiellement, à l'inefficacité du procédé de chloration pratiqué dans l'inactivation de nombreux agents viraux incluant le virus de l'hépatite A et le virus Norwalk (**Keswick et al, 1985** cité dans **[12]**). **Tyrrell et al (1995)** ont conduit une étude expérimentale pour comparer l'efficacité de l'ozone et du chlore dans la désinfection d'eaux usées épurées. Ils constatent que l'ozone peut être considéré comme un excellent agent virucide, contrairement au chlore combiné. Comparé au chlore, l'ozone est apparemment moins efficace dans l'élimination de bactéries végétatives. D'autre part, son action est limitée dans le temps à cause de sa forte réactivité tandis que le chlore continu d'agir pendant longtemps, si on veille au maintien d'une concentration résiduelle suffisante dans l'eau. L'action du rayonnement UV sur les micro-organismes est très rapide mais il faut noter que le temps de contact entre l'eau à désinfecter et ce rayonnement est généralement très bref, quelle que soit la conception du réacteur. D'autre part, les expériences de désinfection d'eaux usées secondaires ont montré qu'il n'est pas possible de descendre en dessous d'un certain seuil d'abattement du nombre de micro-organismes. L'hétérogénéité de l'eau et la non uniformité du rayonnement dans le réacteur peuvent conduire à une «hygiénisation» incomplète. Il faut noter que ceci n'est pas l'apanage du procédé de désinfection par l'UV mais concerne aussi les autres procédés de désinfection lorsque les réacteurs mis en œuvre présentent des vices de conception. Contrairement à la désinfection chimique, où la mesure du résiduel de produit dans l'eau est en fait une évaluation de la qualité de l'eau traitée, l'inconvénient principal dans la conduite d'un système de désinfection par UV réside dans l'impossibilité de mesurer directement la dose de rayonnement reçue par chaque élément fluide.

CONCLUSION

Les défis qu'il faudra relever pour donner un nouvel essor à la réutilisation des eaux usées, par l'élargissement du spectre de réutilisations notamment, sont multiples. Ils concernent en particulier la recherche de moyens plus efficaces de gestion des procédés de traitement afin d'augmenter leur fiabilité. La variabilité de la qualité des eaux secondaires est en effet un des obstacles au développement de la réutilisation des eaux usées. La faible maîtrise des procédés secondaires a aussi un impact sur l'efficacité et la fiabilité des procédés de traitement complémentaires. D'autre part, le niveau de maîtrise des procédés de désinfection reste insuffisant. Un effort pour une meilleure caractérisation de ces procédés et le développement de meilleurs outils pour leur conception et leur gestion reste à faire. La médiocrité de la qualité des eaux, de façon continue ou périodique, incite peu le législateur à assouplir la réglementation de la réutilisation ce qui pose un frein au développement de cette pratique.

Sur le plan stratégique, l'approche de la réutilisation des eaux usées ne pet pas être globale dans des territoires aussi hétérogènes que ceux des pays méditerranéens. Une approche plus locale, considérant les potentialités et les contraintes de chaque région, est plus judicieuse. La réutilisation peut être un facteur important de développement socio-économique dans certaines régions et présenter relativement peut d'intérêts dans d'autres.

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ANNOUNCEMENT

MEDA Water

SECOND MEDA WATER REGIONAL EVENTS ON LOCAL WATER MANAGEMENT

28, 29 & 30 APRIL 2008

MANSOUR EDDAHBI HOTEL - PALAIS DES CONGRÈS CONFERENCE CENTRE / MARRAKECH - MOROCCO

This Regional Event is organized by the Regional Monitoring and Support Unit within the framework of the MEDA Water Programme "Euro-Mediterranean Regional Programme for Local Water Management" funded by the European Commission and in coherence with the Declaration of the Euro-Mediterranean Ministerial Conference on Local Water Management (Turin, 1999) and managed by the European Commission Delegation in Jordan.

This 2nd Event will be composed by the:

- **Second MEDA Water Partners Workshop (28 and 29 April 2008)**
- **Second MEDA Water Event (30 April 2008)**

THESE EVENTS AIM TO ...

- Present the MEDA Water Projects results and technical outputs; the MEDA Water Projects involved are: ADIRA, EMPOWER, EMWATER, EMWIS, IRWA, ISIIMM, MEDAWARE, MEDROPLAN, MEDWA and ZERO-M
- Give the opportunity to organizations of the MEDA countries not participating in the MEDA Water Projects but falling within the scope of the workshops to enrich the debate by presenting their experiences
- Optimize the impact of the MEDA Water Projects results by exchanging experiences and know-how gained towards the National Authorities representatives, research, education and training institutions, stakeholders, civil society and local and regional experts
- Discuss the MEDA Water Projects results and the need and possibilities for the continuation of similar initiatives in the future, in coherence with EU Water Initiative (Horizon 2020 and ENPI)
- Give the opportunity for the local and regional practitioners working in the field of local water management to participate actively

The Preliminary Programme and other documents related to the "Second MEDA Water Regional Event" are available on the MEDA Water Programme website: http://www.medawater-rmsu.org

◀ *Fig. 1:*
RAINWATER HARVESTING FROM ROOF TOP OF GREEN HOUSES IN JENIN

RAINWATER HARVESTING IN PALESTINIAN TERRITORIES

PRACTICES, PERSPECTIVES AND OBSTACLES

By ABDELLATIF MOHAMMED*

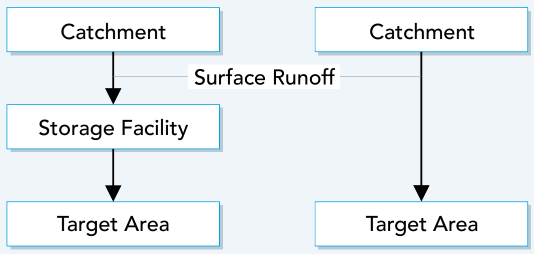
Rainwater harvesting in the Palestinian Territories is deeply rooted in the Palestinian traditions. Many of the early villages and towns that were built in Palestine centuries B.C. included facilities for rainwater harvesting.

Rainwater harvesting is a very ancient technique that is practiced in a great number of countries all over the world. From the inception of very early human civilization, rainwater harvesting was practiced at scales varying from small hand-dug cisterns, which are used for individual or a very few households to very big dams[1], which were behind the development and growth of important civilizations.

A rainwater harvesting system can be divided into three main components:

1. **Catchment:** This is the part of the land that contributes by its share of rainwater or part of it in favour of the targeted area. The catchment area can be very small (a few kilometers), or big to very big totaling hundreds of square kilometers. It can be agricultural land, marginal, rocky or just the roof-top of a small house.
2. **Storage facility:** This is the place where harvested rainwater is stored till it is used. This can be in underground reservoirs, cisterns, or surface open reservoirs, dams, etc. It can be the soil where harvested rainwater is stored as soil moisture.
3. **Target area:** This is the place where harvested water will be used. This can vary from a single household to a big city in case this is used for domestic purposes. Or it can be a small farm or wide planes in case it is used for agricultural use.

The harvested water can be used for domestic, agricultural and industrial purposes and can be the major source of water when ground water aquifers are not found or they are either polluted or very deep.



RAINWATER HARVESTING IN PALESTINIAN TERRITORIES

This is deeply rooted in the Palestinian traditions. Many of the early villages and towns that were built in Palestine centuries before Christ included facilities for rainwater harvesting. Any visitor to these tourist sites can see these facilities and can even use some of these

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1 The dam of Maa'reb in Yemen thousands of years B.C. The damage of this dam was behind the waves of migrations of tribes from Yemen to the North Arabic Peninsula.

which were maintained for tens of centuries. Though most of these were constructed for domestic purposes, some served both domestic and agricultural use.

Rainwater harvesting for domestic use continues to be practiced in the Palestinian territories and according to 2006 statistics provided by the PCBS (earlier reference), rainwater harvesting represents the main source of domestic water consumed by 8% of the Palestinian population. For agricultural use, rainwater harvesting is gaining in importance.

MODES OF RAINWATER FACILITIES

Rainwater harvesting in Palestinian territories which are practiced either at household or farm level can be distinguished into two main types:

- Terraces System (see figure 2): This is one of the known methods of rainwater harvesting in the mountainous areas along the slopes at farm level. This technique is one of the most efficient rainwater harvesting techniques in the mountainous area and harvested water in this case is stored as soil moisture. In addition to rainwater harvesting, terracing plays a very important role in soil protection.
- Roof Top Systems (see figure 1): This can be any permeable surface like the roof tops of houses, green houses or any similar surfaces. The rainwater from these roof tops can be stored in various storage facilities which can be underground cisterns, cement pools or metallic reservoirs. Roof top systems are characterized by a very high percentage of runoff that can reach up to 95% of the height of precipitation. Underground cisterns were among the first storage facilities for both domestic and agricultural purposes.. Recently, the construction of cement pools and metallic reservoirs has become common practice for harvesting rainwater which will be used for agricultural purposes.

SIZES OF RAINWATER STORAGE FACILITIES

The size of the rainwater storage facilities depends on the use of these facilities. The size of the cisterns whether used for domestic or rain-fed agriculture varies between 50 to 100 m^3 and in rare cases the size of these cisterns may reach 150 m^3.

To make this economically feasible, we have to establish a balance between the size of these facilities and the volume of water needed at a specific time. For the high lands and semi-coastal parts of the West Bank, the average height of precipitation varies between 446.7 mm/year in Jenin to 680.03 mm in Nablus [2]. For a family for whom this rainwater constitutes the main source of fresh water, we can find the optimum volume of the cistern by finding the balance between the actual rainfall and the families' consumption of water.

The average surface of households' roof tops is about 150 m^3. The great majority of rain is received between October and May (7 months). The height of precipitation per month varies between 63.8 and 97.15 mm per month. The potential volume of harvested water should vary between 9.57 and 14.57 m^3. However, the rainfall is not evenly distributed throughout the rainy season. If we want the cistern's volume to be enough to accommodate the maximum volume of possible rainfall in the month, then, perhaps it would be better to base the calculation of the optimum volume in reference to the maximum rainfall per year in these districts. The maximum registered rainfall in Jenin was 653.6 and 942.7 mm in Nablus. This makes the monthly average rainfall per household in Jenin equal to 14m^3/month and that of Nablus equal to 20.2 m^3/month.

If the mean consumption is equal to 80 l/capita*day, then the monthly consumption of a family of seven persons is equal to 16.8 m^3/month. And if these families have a 100% dependence on rainwater then the volume of cisterns in these districts should exceed these values.

The same can be applied to the sizes of roof top systems used for agricultural purposes. The size of the cement or metallic reservoirs used for rainfall collection from the roof tops of green houses will depend mainly on the rainfall height in this location as well as on the number of green houses that will provide the storage facility with water. The intensity of storms is also of vital importance in determining the size of these facilities. The most common size for these ranges is between 150

RÉSUMÉ

RÉCUPÉRATION D'EAU DE PLUIE DANS LES TERRITOIRES PALESTINIENS PRATIQUES, PERSPECTIVES ET OBSTACLES

La récupération d'eau de pluie dans les Territoires palestiniens est profondément enracinée dans les anciennes traditions palestiniennes. Un grand nombre des premiers villages et villes construits des siècles avant notre ère disposaient d'installations de récupération d'eau de pluie. La récupération d'eau de pluie constitue la source principale d'eau potable pour environ 8,1% des familles en Cisjordanie. Elle est pratiquée dans les territoires palestiniens aussi bien pour l'usage domestique que pour l'usage agricole. Il s'agit de systèmes de récupération d'eau de pluie à micro-échelle, la taille de ces installations variant entre des douzaines de mètres cubes et plusieurs centaines de m³.

Cette pratique importante et les installations produites à cette fin contribuent à une amélioration de la gestion des ressources en eau (approvisionnement et demande) pour les ménages et fermes. Elle permet de réduire la pénurie d'eau pour environ 8,1% des familles palestiniennes en Cisjordanie*. Elle aide également les fermiers à réduire leurs dépenses d'eau et leur permet d'utiliser de l'eau saumâtre pour diversifier leur récolte. En plus, elle rend le travail agricole plus rentable et les fermiers moins dépendants des fluctuations du marché.

La récupération d'eau de pluie peut représenter une des activités principales pour assurer les ressources en eau nécessaires pour les Palestiniens et construit un lien entre la demande et l'approvisionnement. A cet effet, les Palestiniens devraient avoir la possibilité de développer des installations à moyenne et grande échelle dans les oueds situés sur les côtes de l'Est et de l'Ouest de la région montagneuse de la Cisjordanie. Le manque de contrôle de la Palestine des ressources en eau dans les territoires palestiniens et la pénurie de ressources financières représentent des obstacles pour ce type de développement.

* Bureau de statistiques centrale palestinien (PCBS), 2006 Brochure des indicateurs trimestriels, deuxième trimestre

▲ *Fig. 2:*
TERRACING MODE FOR RAINWATER HARVESTING

and 450 m^3. More detailed work is needed to optimize this size.

MODES OF HARVESTING IN AGRICULTURE

Both modes of rainwater harvesting in the Palestinian Territories are used for agricultural purposes. In most cases terracing and cistern construction are used in rain-fed agriculture while in irrigated agriculture the roof top system is the one used.

- Terraces System: The importance of this system of rainwater harvesting comes from its role in the program of land development in the Palestinian territories. Due to these practices Palestinians are able to develop the mountainous marginal areas into arable land. By practicing this technique, Palestinians were able to safeguard the mountain soil and have converted hundreds of thousands of marginal sloppy land into arable fertile land cultivated by great varieties of fruit trees: olives, figs, grapes, almonds and apples.

- Roof Top Systems: As mentioned above, these systems are used for both domestic and agricultural purposes. Their importance in agriculture can be summarized in the following:
  - Enable Palestinians to increase the irrigated area: Although agriculture consumes 65 - 70% of the available water resources, the irrigated agriculture does not represent more than 5% of the agricultural land. The competition for water resources between the various uses will increase which will subsequently decrease the water available for agriculture. Installing rainwater harvesting facilities beside the green houses to collect rainfall from the roof-tops of green houses will render these independent of external water resources for almost 60% of the season. This will eventually enable farmers to increase the irrigated area by an equal percentage.
  - Enable farmers to improve the management of irrigation water at farm level. Farmers, who wait their turn for water for a long period that may extend to a week in some cases, will use the water when available in a non-rational way, leading to a waste of water and fertilizers.
  - The harvested rainwater will enable farmers to diversify their cultivated crops. The ground water, which represents the major source of irrigation water suffers from increased salinity and limits farmers to cultivate very few number of crops which can tolerate a high water salinity. The mixing of harvested rainwater with water from the ground water wells will decrease the salinity of the irrigation water and give farmers the chance to cultivate less tolerant crops and ensure the diversification of cultivated crops. This is of great importance for farmers because it renders them less vulnerable to price fluctuations and makes their agricultural work more profitable.
  - Provide farmers with the fresh water necessary for dissolving pesticides and insecticides. In areas such as the Jordan valley and great parts of Gaza, the salinity of irrigation water is an obstacle with regard to the use of certain pesticides and insecticides and harvested rainwater can be the solution.
  - Ensure the success of planted fruit trees seedlings, which are planted in the newly reclaimed land. In this case the roof top system is coupled with terracing in the projects of land reclamation that depends mainly on terracing.

LARGE SCALE RAINWATER HARVESTING FACILITIES

Developing large scale rainwater facilities is highly recommended and is economically feasible in the Palestinian territories. The height of the rainfall in the central high land of the West Bank has supported the development of important wadies that ensure an important runoff on yearly bases. These wadies are found on both the western and eastern slopes of the high land. Although, these are very suitable for the development of medium scale dams, all of the runoff is either lost in the dead sea/Jordan river or captured in medium scale dams in Israel. Not even one single dam was constructed in the West Bank.

DEVELOPMENT OF LARGE SCALE RAINWATER HARVESTING FACILITIES

The development and construction of large scale rainwater harvesting facilities, dams and inter hills, is of vital importance and it would ensure additional tens of millions of fresh water for agricultural purposes. There are many obstacles in the way of the development of this option. Among these the following are the most important:

- The absence of Palestinian's control over the water resources. According to the Oslo agreement, the discussion of the Palestinian authorities regarding the water resources has been postponed to the negotiations of

Location	Year									Average
	1997	1998	1999	2000	2001	2002	2003	2004	2005	
Jenin	653.6	388.0	237.4	477.6	311.8	..	649.3	424.8	431.1	**446.7**
Meithaloun	741.2	559.3	273.3	673.3	451.4	..	788.2	521.3	519.2	**565.9**
Tulkarm	918.4	531.3	290.0	784.4	557.9	..	770.2	547.3	585.8	**613.93**
Nablus	828.3	556.7	343.2	835.3	505.0	..	942.7	638.5	790.5	**680.03**
Jericho	224.6	90.1	48.7	152.8	148.4	..	194.0	128.5	117.0	
Jerusalem	596.7	302.2	..	..	364.8	..	654.2	..	..	**475**
Hebron	586.8	328.2	243.4	681.8	520.1	..	538.7	570.8	475.9	**493.34**
Gaza	353.8	241.1	196.5	563.3	436.7	..	524.8	408.3	260.5	

Table 1: **ANNUAL RAINFALL QUANTITY IN THE PALESTINIAN TERRITORIES BY YEAR AND STATION LOCATON, 1997 - 2005 [mm]**

the final settlement between Israel and the Palestinians. In the present time, all of the Palestinian efforts to construct such dams have been hindered and prohibited by the Israelis,

- Technical difficulties: During the last 40 years of the Israeli occupation of the Palestinian territories, the Palestinians were deprived from developing their skills and know-how in this field, even the very basic information that is needed for the development of such structures: runoff gages on the wadies and possible information on these wadies is missing.

- A lack of financial resources: Since the establishment of the national authority in line with the Oslo agreements, the Palestinians have for most of the time been obliged to live in emergency situations in which all of the financial resources were focused to fulfill the humanitarian needs and very little resources were left for development purposes. The share of the agricultural sector in the Short Term Development Plan [3] was less than 1% of the budget.

REFERENCES

[1] PCBS, 2006 Brochure of the Quarterly Indicators, second quarter

[2] Annual Rainfall Quantity in The Palestinian Territory by Year and Station Location, 1997-2005, PCBC, 2006.

[3] Short Term Development Plan, 2004, Ministry of Planning, Palestinian National Authority.

◀ *Fig. 1:*
OLIVE TREE IN THE EXPERIMENTAL FARM IN SFAX / TUNISIA

FERTILIZER VALUE OF TREATED WASTEWATER FOR CHEMLALI OLIVE TREES

By SAIDA BEDBABIS[1], BÉCHIR BEN ROUINA[2] and MAKKI BOUKHRIS[1*]

In the face of the increasing water scarcity, the reuse of treated wastewater in agriculture seems to be one sustainable solution. Recycled water contributes to the improvement of olive tree fertility. The effect of treated wastewater on the nutritional elements in olive leaves was investigated over a two year period (2003 - 2005).

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In arid and semi-arid areas, countries face an increasing water scarcity. The problem of water shortage will intensify due to population growth and increased demand from the agricultural sector. The reuse of treated wastewater (TWW) can play an important role in satisfying the growing demand for water and contribute to the preservation of existing water resources. Irrigation with TWW provides environmental and socio-economic benefits, mainly due to an increase in the available water resources, nutrient recovery as a fertilizer **[10]**, the reduction in effluent disposal in receiving water bodies, improvements in crop production during the dry season **[18, 9]**; tree production **[5]** and reducing the use of chemical fertilizers in agriculture **[8]**. However, TWW may contain heavy metals which are known as soil and plant contaminants **[21]**. The reuse of TWW in Tunisia can satisfy the increasing water requirements and constitutes a tool to preserve water resources and means to protect the aquatic envi-

RÉSUMÉ

VALEUR FERTILISANTE DES EAUX USÉES TRAITÉES POUR LES OLIVIERS CHEMLALI

Compte tenu de la pénurie d'eau de plus en plus importante, la réutilisation des eaux usées traitées dans le domaine agricole semble être une solution durable. L'eau recyclée contribue à une amélioration de la fertilité des oliviers. L'effet des eaux usées traitées sur les éléments nutritifs dans les feuilles d'olivier a été étudié pendant une période de deux ans (2003 - 2005). L'irrigation d'une oliveraie avec des eaux usées traitées a montré l'enrichissement des oliviers avec les substances nutritives principales (K et P) sans accumulation excessive des éléments toxiques dans les feuilles d'olivier. Les résultats ont montré qu'un taux d'application annuel de 5000 m^3ha^{-1} d'eaux usées traitées dans une terre sableuse et argileuse peut être considéré comme un engrais phosphoreux complémentaire (50 kg P ha^{-1} an^{-1}). Le même taux peut toutefois agir comme un engrais potassique (83.3 kg K ha^{-1} an^{-1}) pour la variété Chemlali. Malgré les concentrations de sodium plus élevées dans les eaux usées traitées, les feuilles d'olivier n'ont pas accumulé les ions de sodium, l'accumulation de sodium dans les feuilles ayant été diminuée par le potassium. Ces résultats démontrent la capacité d'autorégulation des oliviers. Ce mécanisme permet une absorption de sodium sélective. Après deux ans, aucune accumulation de ions toxiques tels que Zn^{2+}, Mn^{2+}, Pb^{2+} et Cd^{2+} n'a été observée dans les oliveraies irriguées avec des eaux usées. Néanmoins, une irrigation continue à long terme peut éventuellement entraîner une accumulation de métaux et métaux lourds et provoquer une toxicité des feuilles.

▲ *Fig. 2:*
MARKS OF TREATED WASTEWATER ON THE SOIL

ronment. In our country, irrigation with TWW had a favourable effect on the growth and production of olive trees [5] and crops, and led to a significant increase in mineral element contents in plant tissues [15]. The mineral element contents were well correlated with different phonological stages of olive trees [2]. Besides the benefits listed, the reuse of TWW can have controversial impacts, especially because of the associated potential heavy metals risk for plant growth and agriculture [21].

A considerable amount of research is available on the impact of TWW on heavy metal contents on crops, such as rice and sorghum [13, 21] and on major nutrient contents in rice, sorghum, berseem [14, 21], while a minimal amount of research has been done on trees. Nonetheless, the knowledge of the impact of TWW on olive nutrient contents and yields has been studied to a slight degree in Tunisia and in Mediterranean countries.

The aims of this study were to: (i) assess the effects of irrigation with TWW on mineral nutrient and heavy metal contents in olive leaves and (ii) to evaluate the fertilisation value of TWW and its importance on shoot growth and plant productivity.

MATERIALS AND METHODS

EXPERIMENTAL OLIVE PLANTATIONS

Twenty-year old trees of the "Chemlali" olive cultivar growing at the El Hajeb Experimental Farm in Sfax (34° 43 N, 10° 41 E), Tunisia, were used in this experiment. The soil type is sandy with 83.1% of sand, 9.8% of clay and 5.8% of silt. The plot contained ten randomized olive trees planted with a spacing of 24 x 24 m and irrigated by a continuous drip system at an annual rate of 5000 m^3 ha^{-1} with TWW. Olive trees bore lots of fruit in the year 2003 (year On) and not much fruit the next year (year Off).

CHEMICAL CHARACTERISTICS OF WATER

The characteristics of TWW were reported in Table 1. The pH of the TWW was 7.5 which ranged within the pH 6 - 9 values appropriate for irrigation reuse [13]. The EC value was 6.3 mS cm^{-1} indicating a moderate level of salinity [16].

The concentration of all of the nutrient elements and heavy metals from the TWW were all below the Tunisian standards [12]. The TWW had a chloride sodium feature.

▲ *Fig. 3:*
MEASUREMENT OF SOIL COMPACTION WITH A PENETRO METER

LEAF SAMPLING AND MINERAL ANALYSES

Four current season shoots per experimental tree were collected in paper bags and stored in a portable cooler at quarterly intervals during two years. Shoots were taken randomly around the tree at heights of 1.5 to 2.0 m above the ground. Twenty to thirty leaves per tree were dried at 60°C for 48 h in the oven and ground with a grinder of the type RETSECH ZM 100 for nutrient analyses. Approximately 1g of plant tissues was weighed, placed in a crucible and mineralised over-

Element	Unit	Treated Wastewater	Tunisian norm
pH		7.46	6.5 - 8.5
EC	mS cm^{-1}	6.30	7
Salinity	g L^{-1}	4.66	
P total	mg L^{-1}	10.3	
K^+	mg L^{-1}	38	
Na^+	mg L^{-1}	470	
Cl^-	g L^{-1}	1.985	2
Ca^{2+}	mg L^{-1}	95.8	
Mg^{2+}	mg L^{-1}	83.8	
Pb^{2+}	mg L^{-1}	< 0.041	1
Cd^{2+}	mg L^{-1}	< 0.004	0.01
Zn^{2+}	mg L^{-1}	0.42	5
Mn^{2+}	mg L^{-1}	0.5	5
SS	mg L^{-1}	59	
trightCOD	mg L^{-1}	73	90
BOD	mg L^{-1}	22	30

◀ *Table 1:*
CHARACTERIZATION OF IRRIGATION WATER (MEAN VALUES)

▲ *Fig. 4:*
THE TRIAL PLOT

night at 450°C in a muffle furnace. The ash samples were dissolved in a 10 ml 1N HNO_3 and diluted to 100 ml with distilled water after filtration. The sample extracts were analysed for P, K, Na, Cl, Mg, Ca and trace elements. K and Na concentrations were measured using a JENWAY flame photometer. Cl was determined using the volumetric method. P was determined using the Olsen method with a JENWAY 6405 UV/Vis spectrophotometer. Ca, Mg and heavy metals were determined using a PERKIN ELMER A Analyst 300 atomic absorption spectrophotometer.

STATISTICAL ANALYSES

Statistical analyses were made to study the effect of TWW on mineral nutrient and heavy metal contents in olive leaves. Data was analysed using the Superanova statistical software SPSS.10. The means were separated by Fisher's protected least significance difference (LSD) test at p 0.05.

▼ *Fig. 5:*
THE SOIL PROFILE OF TRIAL PLOT

RESULTS AND DISCUSSION

MAJOR MINERAL NUTRIENTS IN OLIVE LEAVES

Leaf P and Ca concentrations were significantly ($p < 0.05$) higher in the year 2003 (0.11% of P and 2.5 % of Ca) when compared to the next year (0.10% of P and 2.08% of Ca). While leaf K (1%) and Mg (0.40%) concentrations were similar in both years (**Table 2**), a statistical analysis showed no significant differences between the years ($p > 0.05$). Significant seasonal variations of major mineral element concentrations were reported in leaves during the experimental period associated to the biological cycle of olive trees ($p < 0.05$). Our results are in agreement with these reported by several authors **[11, 2, 20]**. Except for Ca, leaf P, K and Mg concentrations in TWW irrigated trees were higher than those reported by **Braham and Mehri (1997)** and by **Fernandez-Escobar et al. (1999)** for unfertilized olive trees.

Higher leaf P, K and Mg concentrations in olive trees compared to those reported by several authors in non fertilized orchards is likely due to the fertilization value of TWW.

SALTS IN OLIVE LEAVES

Leaf Na and Cl concentrations were significantly higher in the year 2004 than compared to the previous year (**Table 2**). Results revealed that irrigation with TWW can induce an increase of salts in olive leaves after two years. The Na levels were lesser than those reported by **Hartman et al. (1962)** and by **Bouat et al. (1961)** in fresh water irrigated olive trees. Leaf Na concentrations in TWW irrigated olive trees were relatively similar to those reported by **Lavee and Blanks (2001)** in fresh water irrigated Barnea olive, while the Cl concentrations in Chemlali were less than the values ranging between 0.06% and 0.32% for the species reported by the same authors. Irrigation with TWW cannot show excessive values of Na and Cl for Chemlali variety.

METALS AND HEAVY METALS IN OLIVE LEAVES

Mean contents of Zn in the dry matter of olive trees irrigated with TWW were 17 mg kg^{-1}. A statistical analysis showed no significant differences between the years. The results revealed that irrigation with TWW cannot make an increase of Zn in olive leaves after two years. The Zn levels were less than the maximum reported by several authors in irrigated olive trees **[3, 17, 9]** and than those considered normal levels for non-irrigated olive trees and agricultural crops **[7]**. Indeed, the water quality had no negative effect on leaf Zn concentrations. Lower leaf Zn concentrations can be explained by a minor Zn transfer from the soil to the leaves and by salt soil accumulations. Indeed, a high accumulation of Zn was reported in irrigated soils (28 - 30 mg kg^{-1}).

Leaf Mn concentrations ranged between 25.1 and 62.6 mg kg^{-1} (**Table 2**). Significant differences were shown between both years and between seasons ($p < 0.05$). The optimal level of Mn reported in our

Biennial cycle phase		% DM						ppm	
		P	K	Ca	Mg	Na	Cl	Zn	Mn
2003	Winter	0.11	0.92	2.9	0.53	0.02	0.03	14.5	43.5
	Spring	0.10	0.93	2.39	0.47	0.03	0.04	21	36.2
	Summer	0.10	1.33	2.82	0.39	0.04	0.05	19.4	46.5
	Autumn	0.13	0.93	1.93	0.43	0.04	0.03	18.9	62.6
2004	Winter	0.14	1.07	1.81	0.49	0.05	0.04	14.7	54.1
	Spring	0.11	0.93	2.28	0.35	0.04	0.07	18.8	46.7
	Summer	0.07	1.16	2.46	0.33	0.05	0.03	16.1	25.1
	Autumn	0.09	1.13	1.80	0.37	0.03	0.07	14.3	31.3
	ANOVA								
	Seasons	***	***	***	Ns	**	***	**	Ns
	years	Ns	***	Ns	Ns	**	*	Ns	**

Table 2: **CHEMICAL COMPOSITION OF OLIVE LEAVES**

study was higher than the maximum reported by **Fernandez-Escobar et al. (1999)** in the non-irrigated Picual variety. The leaf Mn concentrations in the Chemlali cultivar were higher than those reported by **Ulger et al. (2004)** in the fresh water irrigated Memecik variety and by **Troncoso et al. (2005)** in olive trees, while these remained lower than those reported by **Lavee and Blanks (2001)** in the Barnea cultivar. Results revealed that TWW had no effect on Mn concentrations.

Leaf lead and cadmium concentrations were below the analytical detection limit of 0.004 mg kg^{-1}. These very low concentrations are as expected both lead and cadmium in the TWW at non-detect limits (< 0.004 mg/Liter). This is consistent with the results of **Rattan et al. (2005)** who found cadmium and lead contents in tissues of all the crops below the analytical detection limits (Rice, Maize, Wheat …). Irrigation with TWW did not provoke an accumulation of lead and cadmium in olive leaves.

CONCLUSION

The irrigation of olive plantations with TWW showed the enrichment of olive trees with major nutrients (K and P) without the excessive accumulation of any toxic element in olive leaves. Thus, the efficient use of TWW can effectively increase water resources for irrigation and may prove to be a boon for agricultural production. Results showed that an annual application rate of 5000 m^3 of TWW in sandy soil can be considered as a complementary phosphorus fertilizer (50 Kg P ha^{-1} $year^{-1}$). While the same rate can operate as a potassium fertilizer (83.3 Kg K ha^{-1} $year^{-1}$) for the Chemlali variety. Despite the higher Na concentrations in irrigation water, the leaves of olive trees did not accumulate sodium ions, with the leaf Na accumulation being depressed by potassium. These results demonstrate the capacity for self-regulation of olive trees. This mechanism permits selective sodium absorption. After two years, the accumulation of toxic ions like Zn^{2+}, Mn^{2+}, Pb^{2+} and Cd^{2+} was not observed in TWW irrigated olive plantations, however, continuous irrigation over the long term could potentially result in the accumulation of metals and heavy metals and cause leaf toxicity. The apparent advantage of irrigation with TWW is that although irrigation with this water resulted in the elevated concentration of metal in soil, the same would not be proportionately transferred to olive leaves. More studies describing the benefits and limitations of TWW on crops and trees would be valuable. However, there is a lack of information on the possible accumulation of metals and heavy metals in fruit and olive oil in Tunisia. Metals and heavy metals accumulation (Zn, Mn, Pb and Cd) in fruits and olive oil must also be determined to avoid toxic ions accumulation in human beings and the possibility of heavy metal toxicities.

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sustainable sanitation alliance

Towards more sustainable sanitation solutions

Version 1.2 (January 2008)

Introduction

The urgency for action in the sanitation sector is obvious, considering the 2.6 billion people worldwide who remain without access to any kind of improved sanitation, and the 2.2 million annual deaths (mostly children under the age of 5) caused mainly by sanitation-related diseases and poor hygienic conditions.

The United Nations, during the Millennium Summit in New York in 2000 and the World Summit on Sustainable Development in Johannesburg (WSSD) in 2002, developed a series of Millennium Development Goals (MDGs) aiming to achieve poverty eradication and sustainable development. The specific target set for the provision of water supply and sanitation services is to halve the proportion of people without access to safe drinking water and basic sanitation by 2015.

As the Joint Monitoring Programme of WHO/UNICEF and the UNDP Human Development Report (2006) have shown, the progress towards meeting the MDG sanitation target is however much too slow, with an enormous gap existing between the intended coverage and today's reality especially in Sub-Sahara Africa and parts of Asia.

The reasons for this are numerous. A major issue is the fact that sanitation rarely receives the required attention and priority by politicians and civil society alike despite its key importance for a society. Political will has been largely lacking when it comes to placing sanitation high on the international development agenda. This has pushed sanitation into the shadows of water supply projects for example, and limited innovation in the sector.

Motivated by the UN's decision to declare 2008 as International Year of Sanitation (IYS), a core group of organisations active in the field of sanitation took the initiative to form a task force to support the IYS. In January 2007, a first meeting resulted in a large number of commitments by the participants from various organisations, and in drawing up a first draft of a "joint road map for the promotion of sustainable sanitation in IYS 2008". During a second meeting which took place mid April, the goal and the objectives of this global competence network were clarified and the joint road map was reviewed.

In order to have a joint label for the planned activities, and to be able to align with other potential initiatives, the group formed the "Sustainable Sanitation Alliance (SuSanA)".

What is sustainable sanitation?

The main objective of a sanitation system is to protect and promote human health by providing a clean environment and breaking the cycle of disease. In order to be sustainable a sanitation system has to be not only economically viable, socially acceptable, and technically and institutionally appropriate, it should also protect the environment and the natural resources. When improving an existing and/or designing a new sanitation system, sustainability criteria related to the following aspects should be considered:

(1) **Health and hygiene:** includes the risk of exposure to pathogens and hazardous substances that could affect public health at all points of the sanitation system from the toilet via the collection and treatment system to the point of reuse or disposal and downstream populations. This topic also covers aspects such as hygiene, nutrition and improvement of livelihood achieved by the application of a certain sanitation system, as well as downstream effects.

(2) **Environment and natural resources:** involves the required energy, water and other natural resources for construction, operation and maintenance of the system, as well as the potential emissions to the environment resulting from use. It also includes the degree of recycling and reuse practiced and the effects of these (e.g. reusing wastewater; returning nutrients and organic material to agriculture), and the protecting of other non-renewable resources, for example through the production of renewable energies (e.g. biogas).

(3) **Technology and operation:** incorporates the functionality and the ease with which the entire system including the collection, transport, treatment and reuse and/or final disposal can be constructed, operated and monitored by the local community and/or the technical teams of the local utilities. Furthermore, the robustness of the system, its vulnerability towards power cuts, water shortages, floods, etc. and the flexibility and adaptability of its technical elements to the existing infrastructure and to demographic and socio-economic developments are important aspects to be evaluated.

(4) **Financial and economic issues:** relate to the capacity of households and communities to pay for sanitation, including the construction, operation, maintenance and necessary reinvestments in the system. Besides the evaluation of these direct costs also direct benefits e.g. from recycled products (soil conditioner, fertiliser, energy and reclaimed water) and external costs and benefits have to be taken into account. Such external costs are e.g. environmental pollution and health hazards, while benefits include increased agricultural productivity and subsistence economy, employment creation, improved health and reduced environmental risks.

(5) **Socio-cultural and institutional aspects:** the criteria in this category evaluate the socio-cultural acceptance and appropriateness of the system, convenience, system perceptions, gender issues and impacts on human dignity, the contribution to food security, compliance with the legal framework and stable and efficient institutional settings.

Most sanitation systems have been designed with these aspects in mind, but in practice they are failing far too often because some of the criteria are not met. In fact, there is probably no system which is absolutely sustainable. The concept of sustainability is more of a direction rather than a stage to reach. Nevertheless, it is crucial, that sanitation systems are evaluated carefully with regard to all dimensions of sustainability. Since there is no one-for-all sanitation solution which fulfils the sustainability criteria in different circumstances

to the same extent, this system evaluation will depend on the local framework and has to take into consideration existing environmental, technical, socio-cultural and economic conditions. Taking into consideration the entire range of sustainability criteria, it is important to observe some basic principles when planning and implementing a sanitation system. These were already developed some years ago by a group of experts and were endorsed by the members of the Water Supply and Sanitation Collaborative Council as the “Bellagio Principles for Sustainable Sanitation” during its 5th Global Forum in November 2000:

(1) Human dignity, quality of life and environmental security at household level should be at the centre of any sanitation approach.

(2) In line with good governance principles, decision making should involve participation of all stakeholders, especially the consumers and providers of services.

(3) Waste should be considered a resource, and its management should be holistic and form part of integrated water resources, nutrient flow and waste management processes.

(4) The domain in which environmental sanitation problems are resolved should be kept to the minimum practicable size (household, neighborhood, community, town, district, catchments, city).

Goal and objectives of the “Sustainable Sanitation Alliance” (SuSanA)

The overall goal of the SuSanA is to contribute to the achievement of the MDGs by promoting sanitation systems which are taking into consideration all aspects of sustainability. The MDGs and the UN’s “International Year of Sanitation 2008”

are highly appreciated by the “Sustainable Sanitation Alliance” as they help push sanitation high up in the political agenda. The main focus of the work of the ”Sustainable Sanitation Alliance” will be to promote the implementation of sustainable sanitation systems in large scale water and sanitation programmes, in line with the strategies proposed e.g. by WHO, UNDP-PEP, UNSGAB and UNESCO.

General objectives of the SuSanA are therefore:

- to raise awareness around the globe of what sustainable sanitation approaches are and to promote them massively;
- to highlight how important sustainable sanitation systems are as a precondition to achieve a whole series of MDGs (e.g. to reduce child mortality, to promote gender equity and empower women, to ensure environmental sustainability, to improve livelihood, and to reduce poverty);
- to show how sustainable sanitation projects should be planned with participation of all stakeholders at an early stage, should respond to the initiative and preferences of the users, and that these has to go hand in hand with hygiene promotion and capacity building activities for sustainable water and wastewater management.

Specific objectives of the SuSanA are:

- to collect and compile information, which will assist decision makers (including the civil society) to assess different sanitation systems and technologies with regard to the full range of sustainability criteria so that informed decisions can be taken;
- to demonstrate how sanitation systems, which produce soil conditioner, fertiliser, biogas, energy, and irrigation water, can contribute to reaching the MDGs beyond sanitation, and consequently present a change of paradigm from purely disposal oriented to more reuse oriented sanitation;
- to collect and present examples of “smart practice” in sanitation for the “International Year of Sanitation 2008” and beyond;
- to identify and describe the mechanisms to up-scale implementation of more sustainable sanitation systems including appropriate financing instruments for pro-poor sanitation provision;
- to develop global and regional visions of how sustainable approaches can contribute to reach the sanitation MDG and to promote them in the IYS 2008 and beyond.

How to achieve the objectives?

A joint roadmap

In order to achieve these objectives, a joint road map of sustainable sanitation related activities for the IYS was developed in the meetings of January and April 2007 by participants from more than 30 multi and bilateral organisations, NGOs and research institutions. The roadmap consists mainly of a series of thematic working groups that will jointly elaborate a range of publications on sustainable sanitation issues, will organise or contribute to international events and will contribute to develop new funding instruments as well as sustainable sanitation capacity building and program initiatives.

The “Sustainable Sanitation Alliance” invites others to ioin in

SuSanA is not a new organisation, but rather a loose network of organisations working along the same lines, and open to others who want to join and be active in the promotion of sustainable sanitation systems. The Sustainable Sanitation Alliance invites other international, regional and local organisations to join the network, contribute ideas, and to become active members in the thematic working groups. Feedback for the advancement of the joint road map is certainly appreciated, as it is work in progress that will be continuously updated, and will include all joint activities leading towards an increased implementation of sustainable sanitation systems.

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NEAR-NATURAL WASTEWATER TREATMENT IN JORDAN

USING COMBINED VERTICAL AND HORIZONTAL FLOW CONSTRUCTED WETLANDS

By ZAFER IBRIK* and MARKUS LECHNER**

Constructed wetlands are a ground-breaking and inexpensive treatment approach that has the potential to treat organic and inorganic compounds in wastewater from a range of sources. Constructed wetlands can be considered treatment systems that use natural processes to stabilize, sequester, accumulate, degrade, metabolize, and/or mineralize contaminants.

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◀ *Fig. 1:*
REINFORCE OF RECEIVING AND ASBR TANK

It is a very suitable treatment alternative as it is a comparatively cheap technology and a near-natural system, and in addition does not require external energy to operate the plant. Wetland systems are designed to take advantage of processes (physical, chemical and biological) that take place in the natural wetlands to remove contaminants from the wastewater. Constructed wetlands also have significantly lower total lifetime costs and often lower capital costs than conventional treatment systems. Compared to conventional systems, natural systems can be operated using less electricity and less labor [1].

The design and construction of this pilot plant in Jordan is funded by the MEDWA project under the EU-MEDA "Regional Program for Local Water Management".

MATERIALS AND METHODS

The design goal for the wetland system is to calculate the required area for the basin. In addition to operation and performance parameters including the hydraulic retention time (HRT), the pollutant loading

RÉSUMÉ

TRAITEMENT NATUREL DES EAUX USÉES EN JORDANIE

UTILISATION DES FILTRES PLANTÉS COMBINÉS, À ÉCOULEMENT VERTICAL ET HORIZONTAL

Le traitement naturel est largement étudié et appliqué comme solution pour les petites communes où il n'y a pas de réseau d'assainissement ou d'installation de traitement.

Un filtre planté (à écoulement souterrain vertical et horizontal) a été conçu comme système de traitement secondaire. Pour le système de traitement anaérobie, un réacteur biologique séquentiel a été développé pour diminuer les chrématistiques affluentes élevées (8000 mg/l DCO, 2000 mg/l DBO).

Le filtre planté lui-même est divisé en
1) un écoulement souterrain vertical (VCW) et
2) un écoulement souterrain horizontal (HCW).
Les caractéristiques des eaux usées attendues à l'entrée dans le filtre planté étaient de 54 m^3d, DBO 300 mg/l avec 110 mg/l d'NH_4. Le taux d'efficacité de traitement exigé par les normes de Jordanie pour les filtres plantés est de 85%, des conditions d'exploitation permettant un traitement optimal ont été sélectionnées afin de pouvoir réutiliser l'eau traitée pour l'irrigation.

▲ *Fig. 2:*
EXCAVATION OF EARTH

rate BOD_5 [g/(m²·d], comparable to any other treatment process.

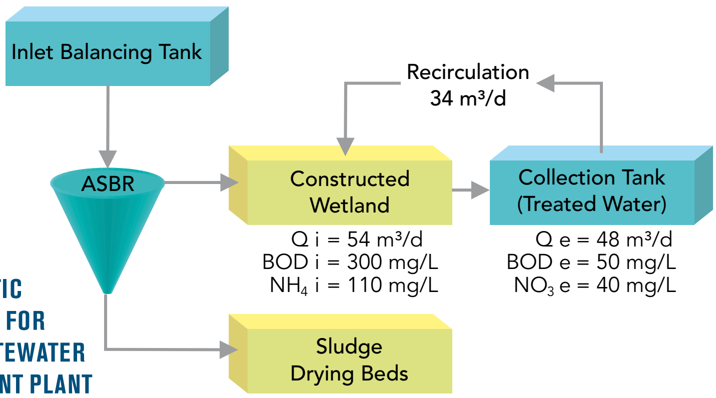
The (Ghor al Safi) area was selected to construct this plant; it's located in the south of Jordan and lies in the Jordan rift valley.This location is characterized by extreme weather conditions, particularly during the long hot summer days. The average temperature in the summer is 42°C [2] during the day, which supports the biological treatment process.

Wastewater samples were collected from septic tanks which will be the source of wastewater, to determine the quality in terms of COD, BOD_5, and Nitrogen (NH_4, NO_3). The average concentration was found: 8,000 mg COD/L, 2,000 mg BOD_5/L, 300 mg NH_4

For these high loads, an anaerobic pre-treatment system (ASBR) is foreseen to reduce the load for the constructed wetland system in an inexpensive and efficient way. The expected ASBR effluent concentration for the above parameters was used to design the wetlands as follows (Influent characteristics for constructed wetland):

Daily flow Q = 54 m³/d
BOD i = 300 mg/L (i … inlet)
NH_4 i = 110 mg/L

The schematic diagram below shows the treatment process.



▶ *Fig. 3:*
SCHEMATIC DIAGRAM FOR THE WASTEWATER TREATMENT PLANT

The constructed wetland area was divided into three basins and each basin has a vertical and horizontal basin. The Kadlec and Knight Model [3, 5] was used to design the effective area of the horizontal flow system, as follows

$$A_s = Q / K \ln (C_i - C^*) / (C_e - C^*)$$

Where

K = first order areal rate constant (m/d)
Q = input discharge to wetland m³/d
A_s = Surface area of the wetland m²
C_i = Inlet Concentration mg/L
C_e = Outlet Concentration mg/L
C^* = Irreducible Background Concentration mg/L

DESIGN ASSUMPTION

Vertical Constructed Wetland (VCW): The design assumption for determining the required area for the vertical basin that 2.5 m²/PE was used [3], and the target area inhabitant is 267 inhabitants, assuming 80 L/d and 60 g BOD_5/d for each inhabitant. The bed slope is 0.005, while the depth is 1.05 m [4].

Horizontal Constructed Wetland (HCW): The design assumption for the horizontal basin based on the above model, and the design assumption are summarized in Table 1.

Parameter	Value
K, first order areal rate constant [m/d] [6]	0.13
C* Irreducible Background Concentration [mg/L] [6]	0.3
Hydraulic gradient [%]	0.03
Depth [m]	0.85

▲ *Table 1:*
DESIGN ASSUMPTION PARAMETERS FOR HORIZONTAL CONSTRUCTED WETLANDS

The hydraulic conductivity of the wetland filter media is a very important factor that influences the treatment efficiency. Suitable hydraulic conductivity guarantees that the substrate provides a surface for the growth of a Biofilm. This supports the removal of fine particles by sedimentation or filtration. In addition it provides suitable support for the development of an extensive root and rhizome system for emergent plants.

To determine the appropriate filter media for the main layer, two criteria must be approved as follows [3]:

1. Hydraulic Conductivity, Ks range 10^{-3} - 10^{-4} m/s
2. $U = d60/d10 \leq 4$

It's important to chose a plant that has extremely rapid growth and a deep root zone, like reed and ornamental plant in a density of one plant for 2 m² (1 plant/2 m²) [7].

RESULTS AND DISCUSSION

Based on the previous assumptions the effective area of the vertical basin was calculated as 225 m² and

90 m² for the horizontal basin. The reason for separating the constructed wetland system into a vertical and horizontal fraction was the ability of the horizontal flow part to act as an anoxic stage for denitrification. An efficiency of app. 50% with regard to Nitrate reduction is assumed. Further Nitrate elimination will be achieved by recycling effluent to the anaerobic pre-treatment step. The hydraulic retention time for HCW was 4.8 d which is enough to maintain the denitrification process in basin **[4]**. **Figure 6** shows the cross section for the wetland.

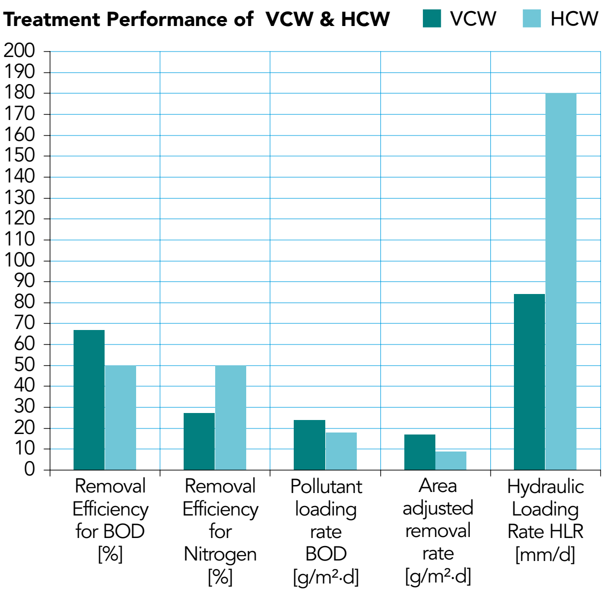
Soil tests were conducted to determine the suitable soil type for the basin in means of hydraulic conductivity k_s which was 0.004 m/s and thus in an acceptable range. The slope of the basin is a very important issue in the construction process, 3% slope for the horizontal basin is important in order to assure the contact time for water in an anaerobic basin.

To describe the treatment performance of VCW and HCW, **figure 4** shows the main expected performance parameters. BOD removal will mostly take place in the VCW since it is designed for full Nitrification. This criteria guarantees sufficiently low organic loading rates to allow the growth of autotrophic bacteria for the oxidation of Ammonia to Nitrite and Nitrate. The VCW basin on the contrary is designed for Nitrogen removal by providing anoxic conditions in the submerged part of the filter media. Nitrate which is produced in the VCW will be reduced in the HCW basin. Further Nitrate reduction to assure that the effluent quality obeys Jordanian standards is possible by recirculation of the effluent from the HCW to the first anaerobic pre-treatment step.

CONCLUSIONS AND RECOMMENDATIONS

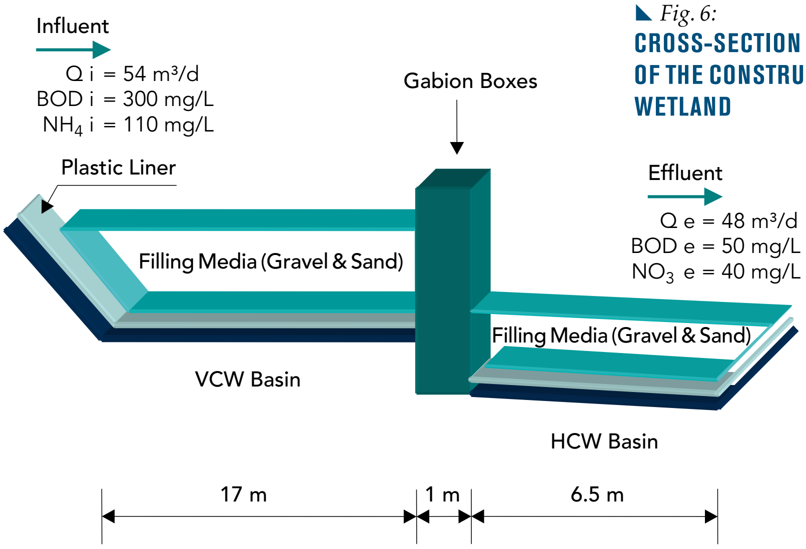
Constructed wetlands are an appropriate solution for wastewater treatment, with an efficiency of the process which can reach 85% for COD. Design is based on

▼ *Fig. 4:*
TREATMENT PERFORMANCES FOR VCW &HCW



▲ *Fig. 5:*
FORMWORK

empirical models for both vertical and horizontal flow systems. In addition to the correct implementation of the described design process, the selection of appropriate media for the filter is crucial. Current design models assume the availability of appropriate media in the local market, basing design methods on available material would still further decrease the cost of construction. The absence of the need for electrical power is an attractive feature of this system. Also the operation cost for this system is much less than a conventional treatment system (e.g. the extended aeration system). Additionally also the investment cost of treatment for 1 m³ in this system is with app. 1,000 EURO lower compared to the extended aeration which costs around 2,000 EURO. The quality of treated water is suitable to be used as reclaimed water according to Jordanian Standards, which is 50 mg/L for BOD_5 and 40 mg/L for NO_3. An important step after constructing the wetland will be to monitor the plant's performance including sampling for the effluent, to monitor the plant growth, the water level in the media, etc.. A comprehensive monitoring plan will be introduced to ensure maximum treatment efficiency, and to eliminate any risks.



◣ *Fig. 6:*
CROSS-SECTION OF THE CONSTRUCTED WETLAND

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◀*Fig. 1:*
VILLAGE HARBOUR AT THE MEDITERRANEAN COAST IN NORTH LEBANON

DEVELOPMENT OF A GUIDE ON WASTE-WATER TREATMENT

AND REUSE WITHIN THE EMWATER PROJECT

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In many MEDA countries, wastewater is not always adequately treated, leading to the deterioration of existing freshwater resources and the Mediterranean Sea. The Mediterranean region is already one of the areas in the world most affected by water shortage, and moreover the demand for water is expanding due to the population growth, rising standards of living, urbanization, increasing economic activities and expanding areas of irrigated agriculture. Therefore, improved water demand management and the development of new water resources are desperately needed. Here, the reuse of treated wastewater can be a valuable alternative to freshwater resources, especially in water-scarce countries.

Since the fresh water shortage in the Mediterranean Countries is a fact, the EMWater Project "Efficient Management of Wastewater, its Treatment and Reuse in the Mediterranean Countries" aims to increase the security and safety of the water supply. The specific project objectives are:

- Strengthening local capacities and regional co-operation through the creation of co-operative networks of professionals in the field of integrated water resource management;
- Enhancing public awareness of the currently insufficient wastewater treatment, for the need for im-

RÉSUMÉ

DÉVELOPPEMENT D'UN GUIDE POUR LE TRAITEMENT DES EAUX USÉES ET DE LEUR RÉUTILISATION DANS LE PROJET EMWATER

Le document est destiné à présenter le développement du «Guide EMWater pour les décideurs dans le domine du traitement des eaux usées et de leur réutilisation» dans les pays MEDA. L'objectif général du guide EMWater est de fournir des instructions pour la prise de décision en ce qui concerne la gestion des eaux usées. Les groupes cibles du guide EMWater sont les fonctionnaires et décideurs surtout au niveau municipal, y compris les personnes sans connaissances en ingénierie et les ONG et conseillers-experts actifs dans le domaine des eaux usées. L'objectif spécifique du guide EMWater est de prendre en compte toutes les conditions cadre et solutions alternatives pour effectuer une présélection des technologies appropriées au traitement des eaux usées et leur réutilisation et d'assister les décideurs avec un manuel facile à comprendre et précis. Le guide ne peut pas, cependant, remplacer une analyse profonde des conditions spécifiques et la consultation d'experts lors de la réalisation d'un tel projet.

▲ *Fig. 2:*
VIEW ON THE CITY OF TRIPOLI, NORTH LEBANON

proved hygienically safe disposal, and the potentials of wastewater reuse.

- Promoting the transfer of appropriate wastewater treatment technologies, such as low-cost technologies for rural areas;

EMWater contributes to these goals through the following activities:

- Training programmes for technicians, engineers and employees of authorities and non-government organizations (local, regional and web-based);
- Public awareness campaigns;
- The applied research and demonstration of innovative solutions through the design, construction and operation of pilot plants applying low-cost techniques, as well as through
- The development of a guide for decision-makers in the field of wastewater treatment and reuse.

Experts from the field, decision-makers, interested citizens, and civil organisations are involved in all stages of the project implementation.

EMWater is one of the projects funded by the MEDA Water Programme of the European Community; it is implemented by nine partners: InWEnt Capacity Building International (Germany), Birzeit University (West Bank/Palestine), Al Al-Bayt University (Jordan), Yildiz Technical University (Turkey), University of Balamand (Lebanon), Lebanese American University (Lebanon), TUHH—Hamburg University of Technology (Germany), ENEA—Italian National Agency for New Technologies, Energy and the Environment (Italy), and the independent, non-profit research institute Adelphi Research (Germany).

The main target countries of the EMWater project are Jordan, Lebanon, Palestine and Turkey. Fresh water availability varies significantly between these four countries: Jordan and Palestine are already seriously affected by a water scarcity. Lebanon and Turkey, on the other hand, are today still classified as water-rich countries but are likely to face a water scarcity within the next decades. In Turkey, the water availability varies strongly from region to region.

In the MEDA region, the largest consumer of water is by far irrigated agriculture with around 70% of water usage. And the demand for irrigation water is growing constantly. Wastewater can be a valuable alternative to fresh water resources, if managed and treated properly and especially agricultural irrigation has the major potential for wastewater reuse applications. In Jordan, for example, the desperate need for water has necessitated the reuse of treated wastewater in agriculture for many years. In Lebanon, Palestine and Turkey on the other hand, there is very limited wastewater reuse application to date. Proper wastewater management is required to allow for its reuse, but today, even if the standard of wastewater management differs in the four countries, in most cases it can be described as insufficient in general.

Reasons for failing to promote proper wastewater management and reuse in the region have mainly socio-cultural and technical origins. In addition, the lack of laws and regulations or the lack of their enforcement contributes to the rejection of reuse. EMWater, therefore, aims to create public awareness for innovative solutions for wastewater treatment and reuse and supports the installation of new technologies. It encourages reuse-oriented wastewater management in its four target countries Jordan, Palestine, Lebanon and Turkey. One element of this strategy is the development of a guide for decision-makers in the field of wastewater treatment and reuse. This paper is aimed to present the development and the main characteristics of the EMWater guide.

METHODS AND MEANS USED FOR THE DEVELOPMENT OF THE GUIDE

Methods and means used for the guide development were the know-how and experience of the EMWater project partners, literature and internet research, a background paper on water reuse guidelines by Adelphi Research as well as a questionnaire survey on the guide's contents. 50 questionnaires have been filled in by the MEDA partner countries. The respondents included staff at municipalities, authorities, ministries, universities, utilities, user groups, etc. The general outline of the guide has been developed according to the results of this questionnaire survey. After preparing the first draft version of the guide, a multistage review process by all project partners, experts in the field and from the region and by local stakeholders was initiated. Especially the MEDA partners of the project team were involved in collecting local feed-back on the guide structure and content. The response was not as widespread/extensive as hoped for, but sufficiently qualified and substantial comments were received, and the final version of the guide has been available since mid March 2007. It was published at the end of 2007 and distributed in the region.

OBJECTIVES AND CONTENTS OF THE EMWATER GUIDE

The EMWater guide shall support decision-making in wastewater management and the planning of related projects. The main target group of the guide are officials at the municipal level, i.e. people who do not necessarily have a background in engineering or natural sciences. Therefore, the guide does not aim to present detailed information on e.g. the technological or biological aspects of wastewater management. Rather, they intend to present the main criteria for decision-making in a concise way—easy to understand and in a short form, using figures and tables as much as possible. For detailed information the reader is referred to the existing literature. The guide also provides lists of references and other sources of information for planning and implementing wastewater projects. It could, therefore, also be useful for other stakeholders such as NGOs or consultants active in the field, or authorities at the national level.

It is important to point out that the guide cannot replace in-depth analyses of the existing framework conditions, feasibility studies and other surveys. For implementing wastewater projects the involvement of experts from different disciplines remains crucial. To give the reader a short overview of what to expect and also to clarify the limitations of the guide, a fact sheet is included in the beginning of the guide (see below). It summarises objectives, target groups, structure, etc.

PART I "WASTEWATER COLLECTION AND TREATMENT"

The guide consists of two parts, one on wastewater collection and treatment and a second on water reuse.

Part I "Wastewater Collection and Treatment" focuses on small communities, and small centralised and small decentralised systems for rural areas. Wastewater treatment systems for small communities are of high concern in every country. They represent the majority of the existing systems and have to deal with specific conditions such as high fluctuations of hydraulic and organic loads (on a daily, weekly and monthly basis) and the need for easy management and operation.

The following criteria are considered most important for the long-term sustainability of wastewater collection and treatment concepts in suburban and rural areas of the MEDA countries:

- Affordable; especially low operation costs
- Operable; operation must be easily possible with locally available staff and support
- Reliable; producing a safe effluent for water reuse
- Environmentally sound; e.g. little sludge production and low energy consumption
- Suitable in a Mediterranean climate (average wastewater temperature e.g. in Istanbul 23°C in July and 15°C in January)

▲ *Fig. 3:* **HAMMANA WASTEWATER TREATMENT PLANT IN MOUNT LEBANON**

The main objective of Part 1 is to provide an overview of different collection and treatment systems and to support the selection process of the most feasible wastewater treatment systems. Therefore the strengths and the weaknesses of each alternative are highlighted with a special focus on low-cost and easy-to-manage treatment techniques. Also non technical criteria such as social participation and acceptance are included in order to provide sustainable sanitation.

In the first part, the advantages and disadvantages of centralised and decentralised wastewater treatment systems are discussed as the decision "decentralised or centralised" is the first choice that planers and decision-makers have to make. Information is given on how to find an appropriate solution.

In the following, different wastewater treatment technology options are described, including on-site systems as well as small treatment systems serving urban centres and peri-urban areas. Aspects and parameters affecting the selection of the appropriate treatment sys-

▼ *Fig. 4:* **SMALL WWTP AT THE AL AL-BAYT UNIVERSITY CAMPUS, AL MAFRAQ, JORDAN**

tem are highlighted. The presented technologies include various extensive systems, such as constructed wetlands, waste stabilisation ponds (natural lagoons), and aerated lagoons, as well as intensive treatment systems, such as Imhoff tanks, biofilm systems, activated sludge systems, hybrid technology, and anaerobic systems (UASB reactors). Furthermore, tertiary treatments are shortly explained and the topic of sludge production and management is presented. Part 1 concludes by explaining the process of selecting an appropriate small wastewater treatment system.

PART II "WATER REUSE"

The Part II focuses on small communities, the reuse of municipal wastewater, and reuse for irrigation in agriculture. The reuse of treated wastewater can be a valuable alternative to freshwater resources, especially in water-scarce countries. Today, technically proven wastewater treatment and purification processes exist to produce water of almost any desired quality. Treated wastewater can be reused for many different applications. Most common is the reuse in agricultural irrigation. Industrial reuse and groundwater recharge are also largely applied, and the reuse in aquacultures and for landscape irrigation is becoming more and more common.

TYPICAL REUSE APPLICATIONS

- Most common: reuse in **agricultural irrigation**.
- **Industrial reuse** and **groundwater recharge** also largely applied.
- Reuse in **aquacultures** and for **landscape irrigation** more and more common.

In the beginning of Part II of the EMWater Guide, an overview of the common reuse applications is given, including quality requirements, benefits, risks and potential constraints.

Benefits of water reuse	Risks and potential constraints
● Reduces the demand on conventional water resources, ● Reduces the volume of wastewater discharged into the environment, ● Recycles beneficial constituents of the wastewater (e.g. nutrients in agriculture). ● Can reduce WWT costs, as e.g. nitrogen does not need to be removed when reused for irrigation.	● Health aspects need to be considered. ● Economic feasibility needs to be checked. ● Practices must be culturally and religiously accepted. ● The available wastewater quality can limit the possible reuse applications.

The next chapter supports the reader in selecting a feasible reuse application. The process of selecting appropriate reuse application starts from a very general identification of the reclaimed water supply and demand. Step by step, through further analyses of framework conditions and requirements, the range of potential reuse applications will be reduced. The process leads from a very broad assessment of potential supply and demand for wastewater to a more detailed evaluation of related benefits and risks, and also to an assessment of the costs. It includes the following steps:

1. Inventory of potential sources and demand for wastewater
2. Identify legal requirements and responsible institutions
3. Detailed analysis of reuse alternatives
4. Economic evaluation
5. Financial feasibility check

Also included in Part II of the EMWater guide is information on ways to prevent health risks caused by pathogens and parasites when using reclaimed water for irrigation, and on the importance of awareness raising, education, and capacity building. Water reuse is one of the main options considered as a new source of water in water-scarce regions. However, water reuse can also entail risks, and therefore the adequate information and training of the potential users and the proper handling and management of the treated wastewater is most important!

A challenge in developing the guide was the lack of sufficient and adequately detailed case studies to draw general conclusions on the costs and viability etc. of reuse projects. Points for discussion remain in the question whether it is reasonable to make general recommendations for MEDA countries with very different framework conditions and where the existing guidelines (Jordanian, WHO 1989, WHO 2006, etc.) are most appropriate as a general model for the MEDA region.

EMWATER'S WASTEWATER TREATMENT AND REUSE RECOMMENDATIONS

Based on research, studies and project work, the EMWater project team has developed the following basic recommendations regarding the implementation of wastewater treatment and reuse systems:

- Local water management should take a long-term perspective giving preference to the protection of scarce water resources and develop sustainable wastewater treatment and reuse projects accordingly.
- Decentralised wastewater treatment systems should always be given preferential consideration, since sewerage networks' costs account for up to 80% of total wastewater treatment costs.
- Operation and maintenance costs, including energy costs, should be calculated with care when selecting a wastewater treatment technology.
- Setting up a schedule of treated wastewater/reclaimed water charges may serve to recover the costs of operating and maintaining the wastewater treatment system.
- Consider an appropriate technology for wastewater treatment. High technology does not always represent the best option. Make sure to have the financial and human capacities necessary to properly operate and maintain the facilities.

FACT SHEET OF THE EMWATER GUIDE

TITLE

EMWater Guide — Improving wastewater treatment and reuse practices in the Mediterranean countries — A practical guide for decision-makers

OBJECTIVE

The overall objective of the EMWater Guide is to provide easy-to-understand guidance on taking decisions in wastewater management.

Specific aims of the EMWater Guide

- Enabling decision-makers to pre-select appropriate technologies for wastewater treatment and reuse, while
- Considering all relevant framework conditions and alternative solutions
- Taking an integrated and sustainable approach to water and wastewater management and planning

The reader is referred to existing literature and research results for detailed information.

The EMWater Guide will NOT replace in-depth analyses of specific conditions and the consultation of experts, once the decision to start a wastewater project has been taken.

TARGET GROUPS

- Officials and decision-makers mainly at municipal level, including those without an engineering background
- NGOs and consultants active in the field of wastewater management

STRUCTURE

Introduction

Part I: Guide for Wastewater Collection & Treatment

Part II: Guide for Water Reuse

Annex

FOCUS

Part I focuses on:

- Small communities
- Small centralised systems and
- Small decentralised systems

Part II focuses on:

- Small communities
- Reuse of treated municipal wastewater
- Water reuse for irrigation in agriculture

METHODS AND RESOURCES

- Know-how and experience of EMWater project partners
- Literature and internet research
- Background paper on water reuse guidelines by Adelphi Research
- Questionnaire survey on guide contents:
  - 50 questionnaires filled in the MEDA partner countries
  - Respondents included staff at municipalities, authorities, ministries, universities, utilities, user groups, etc.

CONTENT

Introduction

- EMWater recommendations on wastewater treatment and reuse
- Short review for each EMWater partner country of the current situation and existing policies and legislation on wastewater treatment and reuse
- Glossary and acronyms

Part I: Wastewater Collection & Treatment

- Wastewater collection (centralised versus decentralised options)
- Overview of wastewater treatment technology options
- On-site systems
- Small treatment systems (extensive systems, intensive systems)
- Tertiary treatments
- Sludge production and management
- Selection of appropriate small wastewater treatment systems
- Local water management and integrated water resources planning

Part II: Water reuse

- General benefits, risks and constraints
- Different options available for water reuse (advantages and disadvantages; quality requirements)
  - Agriculture; aquacultures
  - Groundwater recharge
  - Industrial recycling and reuse
- Selecting appropriate reuse applications
- Guidance on how to prevent a health risk
- The importance of awareness raising, education and capacity building

Annex

- Information on existing legal frameworks (standards and regulations in the MEDA region and elsewhere: WHO (1989 and 2006), US EPA, Mexico, Tunisia, Jordan, Turkey, and Palestine)
- Link list: Regional and international experience on water reuse & sources of awareness raising material
- List of selected organisations involved in wastewater treatment and reuse in the MEDA region, other sources of information & relevant links

- Consider the options of source separation: domestic versus industrial wastewater, rainwater runoff versus grey water versus black water.
- Water reuse has major benefits, since it means protected freshwater resources, lower costs for wastewater treatment and fertilisers, and possibly an increase in agricultural production.
- Effluent quality objectives: Nutrient (nitrogen, phosphorus) removal is not always necessary, when the treated wastewater is meant for reuse in agriculture or aquaculture. However, pathogens and suspended solids removal as well as the biodegradation of organic matter are a prerequisite for the reuse of water in agriculture.
- Ensure that groundwater aquifers are not contaminated through the seepage of reclaimed water. This includes taking into account seasonal fluctuations in nutrient requirements of crop plants.
- Market assessments are needed as to whether the usage of reclaimed water and the farm-goods produced are accepted and economically feasible.
- Additional expenditure for transfer, storage, distribution and drainage need to be considered when planning a water reuse project.
- Microbiological water quality standards are only one way to prevent health risks. Other measures such as crop restriction and human exposure control should also be taken into account.
- Regulations for water reuse should not be too strict in order to promote sustainable reuse practices.
- Any legal standards to regulate water reuse need to be adapted to local conditions: They should be affordable, achievable and enforceable.
- Awareness raising is a major issue in water reuse projects. Campaigns for farmers and consumers should be included already at the project planning stage.
- Water reuse can be demonstrated and promoted by subsidising pilot projects that can be visited by local farmers, decision-makers and the interested public.

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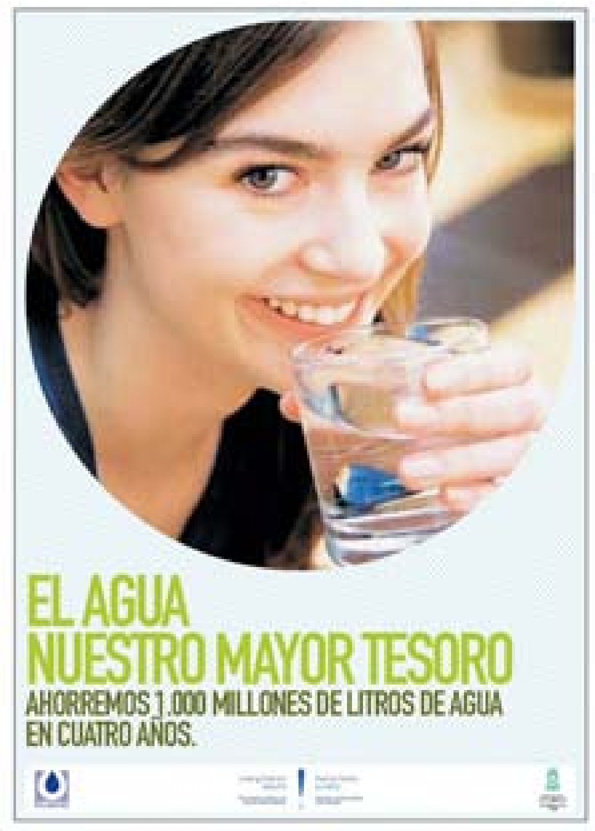

Fig. 1:
POSTER IN THE CITY OF VITORIA-GASTEIZ

10 YEARS OF WORK PROMOTING THE EFFICIENT USE OF WATER IN CITIES: RESULTS ASSESSMENT

By LAURENT SAINCTAVIT, VÍCTOR VIÑUALES EDO, MARISA FERNÁNDEZ SOLER, ANA LAPEÑA LAIGLESIA and CLARA PRESA ABOS*

Having worked for 10 years in the field of water efficiency use in cities, the Fundación Ecología y Desarrollo has gained a broad experience and knowledge in this field.

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The training processes mentioned below are not exhaustive, there are many more rich and diverse conclusions which have been drawn up from the many courses of action that are being developed in more and more cities on the planet. Some ideas have been highlighted which we find to be more interesting and relevant for the stimulation of changes in Spanish cities.

The different training processes are designed according to the following points:

- Changes in technology campaigns: the objective is to draw up a map showing the places where the different initiatives have been put into action over the past few years. Showing if they were carried out as part of a wider campaign, how many elements were put into action, if they were subsidised or not and what effects were felt by the local population or in the companies concerned...
- The legislation concerning this matter that has appeared over the past few years; for example, bye-laws, the autonomous regions regulations, the new technical buildings code, etc. The objective is to analyse what has happened in these past 10 years where a specific rule has been developed and if they were developed as part of a wider campaign and if the results are available...
- Comprehensive Water Saving Plans *(Planes Integrales de Ahorro de Agua, PIAA)* or Demand Management Plans *(Planes de Gestión de la Demanda)*. There are not many comprehensive initiatives, however, in recent years plans have started to be put into action. We would like to gather where and what results are being obtained. In spite of being a comprehensive and complete action plan, we have found this the hardest one. Is this trend changing at all?
- Implementing ways to get the public involved. Has the process to involve the public in this matter been put into effect or has it just been a one-off?

CAMPAIGNS TO OBTAIN SUBSIDIES

Replacement of obsolete technologies for more modern and efficient ones has always had a certain imitation component to it. Scepticism felt about the advantages of making a change is easier to overcome if others have already made the change. This is achieved by having society's most active minority groups voluntarily use environmentally-friendly and good practices. In doing so, it allows us to create a network of people who can spread the word about environmental change and the new technologies to use water efficiently.

Water saving programmes intend to support this dynamic and innovative minority in different ways:

- Awarding recognition and prestige through competitions or an official statement of "good practices".
- Technical consultant support by having a water auditor for the users who want to use water efficiently.

- Financial subsidies to end users for particular practices.

The latter process is designed to improve the efficiency of the domestic hydraulic fixtures and fittings. This will tackle a wide range of processes, from controlling leaks and installation defects, replacing traditional models of taps, showers and toilets, even replacing washing machines and dishwashers. These types of programmes first appeared in California at the beginning of the eighties as part of water saving plans. They soon became successful due to the noticeable effects and low cost which lead to them spreading throughout the country. As well as the huge programmes in Los Angeles and New York, other programmes of substantial size were undertaken in Boston, San Francisco Bay, the Texas metropolitan triangle of Houston, Dallas and San Antonio as well as other large metropolitan areas. With all of this several million water-saving devices had been distributed throughout the country by the beginning of the nineties. In most cases, such as shower heads or spray taps, they were given free of charge or in the case of low flush toilets, washing machines and dishwashers they were highly subsidised.

LAUNCHED CAMPAIGNS

Although to a less extent, this type of campaign has also been developed in the urban sector in Spain over the past few years. For example in 2002 the Catalonian campaign, *"Catalunya estalvia aigua"* run by Ecologistes en Acció, the Agència Catalana de l'Aigua and the Generalitat de Catalunya Regional Government, financially supported the installation of water saving devices in the municipalities of Torredembarra, Santa Perpètua de Mogoda and the areas of Nou Barris and Sarrià-Sant Gervasi in Barcelona. Several projects which were successfully developed in Aragon, for example the distribution of 1,800 low-flow tap aerators at a subsidised price as part of the "Zaragoza, the Water-Saving City" *(Zaragoza, ciudad ahorradora de agua)* pro-

RÉSUMÉ

10 ANS DE TRAVAIL POUR FAVORISER UN USAGE PLUS EFFICACE DE L´EAU EN ESPAGNE UN PREMIER BILAN

Rédigé par LAURENT SAINCTAVIT, VICTOR VIÑUALES EDO, MARISA FERNANDEZ SOLER, ANA LAPEÑA LAIGLESIA et CLARA PRESA ABOS*

Cette communication prétend dresser un bilan des avancées et des résultats obtenus par les expériences menées en Espagne pour favoriser un usage plus efficace de l´eau au cours des 10 dernières années.

L´expérience accumulée par la Fundación Ecología y Desarrollo dans le domaine de l´usage efficace de l´eau en usage urbain nous a permis développer une ample connaissance dans ce domaine. 10 années de travail qui nous permettent établir un premier bilan des changements et de l´évolution qui se sont produits en Espagne. Les programmes réalisés par notre organisation ainsi que par d´autres entités ont eu différentes répercutions et résultats. Pourquoi se sont généralisées ces dernières années les campagnes d´instalation de produits économes comme les filtres pour les robinets par exemple ou pourquoi les règlements municipaux visant à favoriser un usage plus efficace de l´eau se sont-ils multipliés? Quelles ont-été les clés du succés ou de l´échec de ces iniciatives?

MÉTHODOLOGIE

Les expériences qui seront étudiées au cours de cette comunication ne prétendent pas épuiser toute la richesse et díversité de conclusions qui peuvent être extraitent de ces actions qui se sont déroulées dans un nombre de plus en plus important de villes. Nous insisterons principalement sur les idées les plus pertinentes et intéresantes afin de stimuler le changement en Espagne.

RÉSULTATS ET DISCUSSION

Les différentes expériences analisées se structureront en fonction des chapitres suivants:

- **Les campagnes de changement technologiques**: l´objectif est d´établir une carte des diverses iniciatives qui ont été mises en marche au cours de ces dernières années, préciser si elles ont été réalisées dans le cadre d´une campagne plus générale, établir le nombre d´élèments installés, préciser si ces élèments ont été subvencionnés, et l´impact qu´elles ont eu dans la population ou les entreprises.
- **Les textes normatifs** relatifs au sujet qui se sont développées ces dernières années, comme par exemple les règlements municipaux (ordenanzas municipales de ahorro de agua), les textes réglementaires des Communautés Autonomes, le nouveau «Code Technique de l´Edification» … L´objectif est d´analyser ce qui s´est produit lors de la dernière décennie, où se sont implantés ces normes, préciser si on dispose de résultats de leur application …
- **Plans Intégraux d´Economie d´Eau ou Plan de Gestion de la Demande:** Il existe peu d´expériences intégrales, mais ces dernières années leur nombre s´est accru. Nous souhaitons faire le point des résultats obtenus. Bien que ce soit la mesure la plus complète, c´est aussi celle qui a eu le plus de difficulté pour s´implanter: cette tendance est-elle en train de s´inverser?
- **Participation publique**: La participation publique s´est-elle développée dans ce domaine ou bien n´a-t-elle encore qu´un caractère marginal?

CONCLUSIONS

Les exemples étudiés appartiennent à différentes lignes d´action et ont eu des résultats quantitatifs différents. La récente multiplication de leur nombre, bien que due probablement en grande partie à la dernière sècheresse que l´Espagne vient de connaître, nous permet d´être optimiste et pourrait consolider l´établissement définitif d´une Nouvelle Culture de l´Eau dans notre pays.

Enfin, nous souhaitons préciser que depuis notre organisation, nous pensons que ces expériences ne peuvent atteindre leur pleine potentialité que lorqu´elles se réalisent de forme complementaire et coïncide dans le temps et dans une même ville ou territoire. Cette simultaneïté doit permettre la création d´un nouveau climat civique.

ject in the city of Zaragoza in December 2005. In 2005 the project "Campo de Borja Region: Water Responsible" *(Comarca Campo de Borja: Responsable con el agua)* 3,000 devices (2 low-flow tap aerators and a flow reducer for the shower) were distributed to homes in the Campo de Borja region in the province of Zaragoza. These initiatives, which are promoted by non-governmental organisations and public administration bodies, were adopted last year, 2006, by the private sector. Ariel launched a campaign "Every Drop Counts" *(Cada gota cuenta)* in which they issued 40,000 low-flow tap aerators and guides with advice on how to save water free of charge to those who joined their campaign, according to the organisers.

Regarding the campaigns to subsidise household electrical appliances, in Spain they have been adopted on some occasions, although they were generally part of an energy efficiency programme and not specially a water saving plan. The objective of these campaigns is to update obsolete or heavy energy consumer electrical appliances, the campaigns are to be based on the Action Plan 2005 - 2007 of the Strategy of Energy Saving and Efficiency in Spain *(Estrategia de Ahorro y Eficiencia Energética en España)*. A large part of the regions' campaigns were valid up to the end of 2006, as for example in the autonomous regions of Andalusia, Cantabria (described further on), Castilla La Mancha, Basque Country, Galicia, Murcia, Navarre and Valencia. The plans to update electrical appliances offer discounts on the prices of the appliances which have the EU Energy label A (A+ or A++) and which are bought at authorised outlets. The financial help is between € 70 and € 185 depending on the type of appliance and the autonomous region.

The first trial of this type of campaign within Spain was the initiative drawn up by the Regional Government of the Balearic Islands, Programme to provide subsidies for the purchase of efficient household electrical appliances, 2004 *(Programa de ayudas para la compra de aparatos electrodomésticos eficientes)*. Individual financial help of € 80 was given for each grade A appliance. This programme of help was part of a wider Energy Efficiency Plan from the Balearic Islands autonomous region, whose first edition 2000 - 2004 continued through to the second edition 2006 - 2015.

OUTSTANDING PROJECT

In addition, the Regional Government of Cantabria recently developed an outstanding project. This was part of their plan to save water, which was also supported by the Strategy for Energy Saving and Efficiency, and it involved subsidising grade A+ washing machines and grade A dishwashers. As a result, 22,741 electrical appliances were subsidised and roughly 19,260 homes benefited from the initiative. As well as saving water, the campaign also showed there was a substantial energy reduction in the Cantabrian homes.

To conclude, the campaigns of subsidising hydra equipment and domestic hydraulic fixtures and fittings show a great effectiveness in their low cost and outstanding public response. All of this has transformed the campaigns, especially at an international level, into an obligation towards water saving plans. In Spain the projects have been more irregular although also successful and probably they will become even more frequent, not only as a way to be more efficient but also in terms of the social repercussions and public environmental awareness.

Nevertheless, the international trials have also shown us that all the ways of financial help to increase the efficiency of domestic water use must be accompanied by:

- Firstly, a set of complementary efficiency and awareness programmes, within a comprehensive water saving plan which affects different sectors of the population.
- Secondly, that the campaigns must be backed up by legislation establishing the minimal conditions for sanitary-hydra and power source equipment that new constructions, housing and other buildings must fulfil.

LEGISLATION AND BYE-LAWS FOR THE EFFICIENT USE OF WATER

Regulations on saving and the efficient use of water are one of the ways of assuring that future urban development is aimed at saving water. In Spain we can see more and more examples of bye-laws that regulate the efficient consumption of water in cities. The first regulation with this objective that was passed in Spain, was that of the Alcobendas city council in 2001. The city councils in Camargo, Getafe, San Cristóbal de Segovia, San Cugat del Vallés, Castro Urdiales all followed suit. Most recently the Regional Government of the Principality of Asturias Water Consortium (proposed regulations for the towns belonging to the Principality of Asturias Water Supply and Sanitation Consortium) has also approved a similar regulation.

In general these bye-laws demand that all new constructions of apartment blocks or individual housing units and industrial buildings in the municipal district must have individual water counters for each house or property, as well as when there is a central hot water system.

Consumer individual measuring, that is to say, the use of counters in each house or property that consumes water, must follow fundamentally two objectives: the first is that each person pays for what he uses,

▼ *Fig. 2:* **ADVERTISEMENTS IN THE CITY OF VITORIA-GASTEIZ**

and the second is that the user is more aware of the need to use water rationally. Trials which were carried out in various cities show that by installing an individual way to measure water could lead to a reduction of up to 40% in consumption, depending on other factors which could be the price, type of rates, the weather, saving campaigns, etc.

INSTALLATION OF EFFICIENT FIXTURES

Furthermore, what is common to all these bye-laws is the obligation to install efficient fixtures in newly-built housing, such as tap aerators or low-flow controllers and mechanisms to reduce the water flow from the taps or showers, and to limit the flush on the toilet to a maximum of six or seven litres depending on the municipality and dual flush or intermittent flush system. Sinks and basin taps in public areas should also have timers or similar mechanisms to limit the flow to one litre of water.

Installing water saving systems should be considered before granting building permission to new construction projects or to those buildings which pre-date the regulations and that need building permission.

In these municipalities the design of new public or private green areas should include effective systems to save water and at the very least programmed watering, short range sprinklers in grass areas, spray watering systems in areas with bushes and trees and damp detectors on the floor. In addition, when the surface area is more than 1 hectare (0.5 hectares in the case of the principality of Asturias) the design of the new plantations will have no more than 15% of grass area, 40% of low maintenance bushes and 45% of low watering needs trees, with the watering system adapted to each type of foliage.

The most recent bye-laws also regulate that the carwash machines have devices to recycle used water or that the swimming pools cannot be emptied between 31st May and 31st October and that with correct maintenance they need not be emptied.

OTHER WAYS TO SAVE WATER

Likewise, the most recent local laws also incorporate other ways to save water such as reusing water from both public and private swimming pools which have panels of more than a variable m² quantity (40 m² in Sant Cugat del Vallès or 80 m² in the Principality of Asturias). Water from showers and baths of residential buildings which have more than eight homes in Sant Cugat del Vallès and 24 in the case of The Principality of Asturias will also be reused. Furthermore, when buying a property the seller and/or the owner will be responsible for informing the buyers about the existence, the working and maintenance of the installed saving systems.

In the majority of cases city councils promise to: draw up a plan to install water saving devices in municipal buildings; incorporate methods to encourage saving water in its Environmental Education programmes, promote public awareness; continue to or create municipal programmes aimed at saving hydraulic resources in the watering of parks and public gardens, and promote other water saving programmes.

From all these examples we must highlight Madrid's bye-laws to manage and use water efficiently which was approved on 31st May 2006. Not only did it incorporate all the above-mentioned rules of the previous regulations, but it also added innovative measures to achieve better management and a more efficient use of water. Amongst these measures our attention was drawn to the aims to control water erosion and contamination in building sites and areas of road works, stricter measures concerning the watering of parks, gardens and green areas (such as limiting the maximum flow of the watering system, limiting the time to water or specific ways to efficiently water golf courses), creating a municipal register of public and private swimming pools, specific measures for fountains, ponds and ornamental water features, measures concerning dumping liquids in the municipal sanitary network and finally, amongst others, what alternative resources are available.

As well as this type of municipal legislation, we cannot ignore the Council of Ministers' approval in mid-March 2006 of the Technical Buildings Code *(Código Técnico de Edificación, CTE)*. Unfortunately in the CTE there were not many measures to promote the saving and the efficient use of water. The Code's most innovative measures on saving water, taking into account that they function at a national level, are that each subscriber or water consuming property has a hot and cold water counter and that any building used by the public must have water saving devices installed on the taps.

In February 2006, the Generalitat de Catalunya passed a decree that went further than that of the CTE. The decree had stricter eco-efficiency parameters, such as, the need for a sanitary network to separate roof drainage from waste water and the installation of saving devices on taps and in cisterns in all newly built houses and to reconvert old buildings, regardless of whether these are public or private.

OTHER RULES AND REGULATIONS

As well as these specified water saving bye-laws, there are also other rules and regulations, such as tax regulations which can help to save water by offering financial incentives on prices, these are in fact becoming more commonplace here in Spain.

Another example to look at is the Tax Regulation No. 24.25 introduced by Zaragoza's city council which regulates the public water rates for drinking water supply and waste water services. Customers who consumed at least 10% less in relation to the consumption of the previous two years, a year being from the first reading to the fourth consecutive reading, received a 10% reduction in the water rates.

Madrid's public water company, which manages the whole water cycle within the Community of Madrid, Canal de Isabel II, also promoted efficient water usage through their water rates. The company not only has a gradual rate system but also gives rebates for saving water. Domestic household users, users with a similar household use, companies and those with a similar use to a company who manage to reduce their consumption during a year in comparison to the previous year, receive a rebate of 10% of the amount they had saved of the variable rate. Furthermore, it is a seasonal initiative in order to give incentives to save water in the periods when there are water shortages or when more water is consumed.

Last year the ACA, Agència Catalana de l'Aigua (Catalonian Water Authority) approved a modification to the water rates to penalise excessive consumption within households and with the idea to promote efficient water use and to reduce water usage by the high consumption users. From January 2005 there are three ranges of rates which are based on a household with only three inhabitants, the adjustment to the basic water rates per inhabitant came into effect on 1st April 2005. Households can benefit from a reduced rate while they consume less than 30 m^3 each yearly quarter, this is 3 m^3 per person per month, which amounts to 100 litres per person per day, as well as 1 m^3 per month for the property. If they exceed this amount they have to pay the double up to 54 m^3 and if they exceed this volume the rate will be five times more expensive than the base rate. Families of more than three people can ask to have a wider range of rates.

As we have seen legislation is one more way to promote water saving. It is therefore necessary to carry out campaigns to communicate to the different sectors in society to make people aware of them and to help overcome the natural resistance to changes.

COMPREHENSIVE WATER SAVING PLANS

The Comprehensive Water Saving Plans (PIAA) or Demand Management Plans are practices in the strategic planning of water management. They have been fundamentally developed from the viewpoint of demand, not focusing on the offer. The PIAA's objective is to assure a correct water supply both in the medium and long term with the following conditions:

- Minimise natural water resources extraction.
- Satisfy the diverse needs of providing a water supply.
- Adjust the water quality to each particular need.
- Have higher guarantees of supply by increasing distribution and usage efficiency and not by increasing the amount of water.
- Distribute costs fairly amongst customers.
- Maintain the economic and financial stability of water suppliers.

With these objectives in mind, the processes found within the PIAA framework concentrate on optimising the water's final usage. This is achieved through very diverse action plans and is structured around the Operative Programmes which to some extent affect the different aspects of the water cycle. These programmes contain ways or processes to be carried out over several years. They must be carried out according to the feasibility criteria, which means that the programmed measures must be perfectly acceptable from an environmental point of view, social or economical (Estevan, 2000).

After the first trials in the eighties and beginning of the nineties by Goleta-California, Massachusetts Water Resources Authority in the U.S.A., we had to wait until 1996 for the first PIAA to be drawn up in Spain. However it was never developed.

VITORIA-GASTEIZ

Even after these slow beginnings the trials are nowadays increasing in Spain. From 2004 the water company for the city of Vitoria-Gasteiz is carrying out a plan which has these characteristics (see **Figure 2**).

The Vitoria-Gasteiz[1] PIAA has a time scale of four years and its main objectives are to foster water saving amongst its different distributors and its consumption in urban areas. This objective is expected to be reached through a series of operational programmes that affect all sectors and can be summarised as:

- Stop the domestic household demand's growth.
- Reduce the institutional sector's present consumption
- Establish the industrial-business sector's present consumption
- Maintain the volume of water available below 25 m^3 annually
- Maintain the distribution network's performance at the same level of the last three years (82 - 85%) and
- Analyse and assess the possibilities of substituting drinking water for water that has been regenerated in industrial processes, for cleaning the streets and watering garden areas.

In 2005 the citizens of Vitoria showed that they had embraced the need to save water as they consumed three litres less per person per day than in 2004. The average daily water consumption per inhabitant is 286 litres, this includes the service industry, industry and institutions. This figure is even better than statistics from the period 1989 - 1990 when there were restrictions due to water shortages and a total of 307 litres of water per person was consumed. In 2005 the citizens in all used 16,000 m^3 less water than in the previous year, in spite of 2,009 new customers, which brings it to a total of 95,000 customers in Vitoria-Gasteiz and in spite of a very hot and dry month of August which increased the consumption.

1 The Comprehensive Water Saving Plan of Vitoria-Gastiez was granted to the Joint Venture of Bakeaz, Xabide and Fundación Ecología y Desarrollo

▲ *Fig. 3:*
PROGRAM IN ZARAGOZA

MADRID

In 2005 the Regional Government in Madrid approved the Municipal Water Demand Management Plan in the city of Madrid, forecasted to run in 2011. Using this Municipal Water Demand Management Plan, Madrid hopes to promote a sustainable management in water usage and a better efficiency in its municipality.

For its development they have laid out two areas in which to take action:

- Municipality. The programmes focused on the city have a wide target population and there is a need to reach agreements to collaborate and coordinate with institutions that are experienced in water management. It also stresses the importance of providing information and the raising of public awareness.
- City council. The programmes designed for the Local Administration have a lot of possibilities to apply saving, efficiency and management measures in a much more direct and tangible way.

The programmes that are going to be developed from the present plan are a process of strategic planning in water management. They deal with attending to the existing water needs with fewer resources but also increasing the efficiency of the water usage. They also hope to develop the idea using water of a lower quality instead of drinking water in areas which do not have the sanitary or quality demands needed for human consumption. In this way they will manage to lower the city's water demand.

SOME OF THE LEGISLATIVE NORMS TO HELP PROOTE INVOLVEMENT AND ACCESS TO INFORMATION

European framework

- Water Framework Guidelines (art.14) that establish the obligation to promote public participation in all relevant parts in applying the guidelines and specifically in the development, checking and updating of water basins plans.
- Directive 90/313/EEC about the freedom of access to environmental information.
- The Aarhus Convention about access to information, public participation in decision making and judicial access in environment issues.

State framework

- Reform text of the Water Law (Royal Legislative Decree 1/2001), art. 15, describes the right for all natural persons and legal entities to have access to information concerning the matter of water.
- Law 38/1995, 12th September, about access to environmental information.

CANTABRIA

In the beginning of March 2006 the Comprehensive Water Saving Plan in Cantabria was launched, making Cantabria the first autonomous region to develop a PIAA in Spain.

The urban sector in Cantabria presently consumes a total of 80 million cubic metres of water per year, which means 399 litres per inhabitant per day, a much higher figure than that registered in the other autonomous regions. Using this Plan, the Cantabria Regional Government and the Environment Council foresee reducing consumption by 20%, hoping to decrease to 72 million cubic metres by 2010. The reduction in demand, which one assumes means a loss of quality of life, will be achieved by the rational use of the water resources and the improvement of the infrastructures.

PUBLIC INVOLVEMENT PROCESSES

The big unresolved challenge is the involvement of the public as a tool to motivate the efficient use of water in Spanish cities. In spite of the numerous regional and Spanish legislations (see box 1) which are set up to stimulate participation and the access to information, Spanish citizens still hardly take part in the policies which have been developed to promote a more rational use of water.

Among the reasons that explain the need to promote public involvement to encourage efficient water usage, we can highlight the following: 1. There are innovators, we have to launch initiatives to locate them. 2. The importance of using familiar methods, professional and/or business and/or institutional and/or already existing social networks. 3. There is a need to accompany and facilitate in the long term leading from the moment of being aware to acting on it. 4. The positioning of the organisations used as a reference, for example, at the forefront or in the rearguard, can influence the citizens' attitude to changes. 5. There still remains in people a psychological excuse, that when confronted with environmental problems, they blame public authorities and demand that they take action, while at the same time they do not take any share of the responsibility; 6. The weight of inertia is enormous. Until the moment when responsible environmental behaviour is established and is reproduced in society there is a period in which current reality (technology, processes, norms, issues, etc.) resists and it is necessary to be persistent to overcome it.

WATER FORUM

The Water Forum in the Balearic Islands is an example of participation that has been carried out in Spain. The forum was set up by the Balearic Islands Environment Council in 2001 and was organised and run by the Fundación Ecología y Desarrollo. The purpose of the forum was to coordinate the participation of the local population in drawing up an analysis of the current situation of water management in the Balearic Islands and the forming of a consensus based on water policies in the islands. Menorca and the Pitiusas Islands (Ibiza and Formentera) held participative workshops using the Logical Framework approach. In 2003 the forum came to a close with another participative workshop in Majorca, this time using the EASW (European Awareness Scenario Workshop) approach. The results of the latter were embodied in the Conclusions of the Balearic Islands Water Forum, which put together the debated points of consensus in the participating workshops during the forum. Concepts to promote efficient water usage were included in these Conclusions; some are as follows:

a. Improve the efficiency in the usage points: improve and modernise watering systems, recycle and use of closed circuits in industrial processes, water saving devices installed in the plumbing, etc.
b. Transform gardens' green areas to low water consumption areas, including redesigning watering systems on golf courses when they do not use recycled water.
c. Use recycled water, with priority being given to where there is already a consumption of water by splitting the distribution system when necessary; also installing a dual plumbing system in new buildings so as to facilitate the use of this water; as well as adjusting public investment in order to provide the infrastructure and management tools to optimise its re-usage.

Independent of the results of this type of initiative, it is essential that the participants understand how this process will continue and that the citizens and social organisations who have taken part are not left disappointed.

OFFICE OF HYDROLOGIC PARTICIPATION

Another example that has been put into action recently is that of the Office of Hydrologic Participation. This is an initiative by the Cantabria Regional Government's Environment Council working with the Ministry of the Environment on water resources in Cantabria. The Office's main objective is to channel the process of information, consultancy and public involvement connected to implementing the Water Framework Guidelines in Cantabria. It also tries to achieve the biggest consensus possible with the social establishments on the contents of the future Hydrographic Border Plans. The office hoped to carry out a plan of *"from top to bottom"*, a transparent and dynamic action plan. In September 2006 they presented the plan, therefore it is still too early to have the results' assessment concerning the promotion of citizen involvement in water management. However, the essential part of this initiative is that it established a permanent organism to facilitate the public involvement in water management.

CONCLUSION

The studied examples belong to very different action plans and have diverse quantitative results. The recent increase of these plans, although greatly due to the latest drought period that Spain is suffering, is very hopeful and at last it can strengthen the basis of a New Water Culture.

Finally, we would like to highlight that from our point of view these lines of action will reach their real potential when they are carried out as a complementary measure and simultaneously in the same city or area. This will allow the creation of a new civil awareness.

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◀ *Fig. 1:*
DRINKING WATER AND ENERGY DAM WITH WATER SHORTAGE IN TABAEKSAN KOREA

ECOLOGICAL WATER AND SANITATION SYSTEMS IN RE-MODELLED URBAN HOUSING ESTATES IN EUROPE AND ASIA

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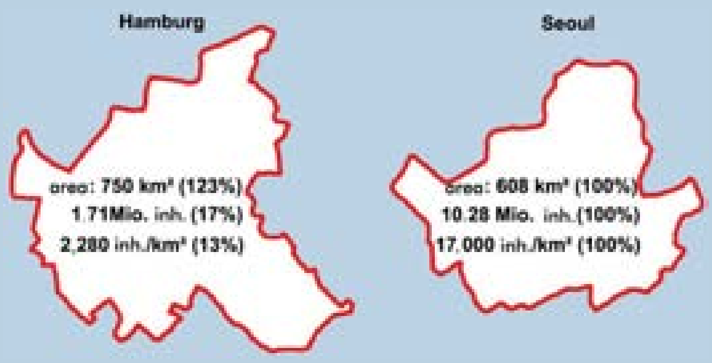
The main disadvantages of conventional central systems for waste water treatment are that sewage streams with different characteristics and noxiousnesses are mixed and nutrients are eliminated. Leakages in the sewage system, overflows of mixed sewers and treatment lead to the contamination of ground- and surface waters with pollutants. They incur high costs and the lockup of capital for long periods of time—even decades—and they are not safe against catastrophes. Furthermore, adapting to changing demographic structures, user behaviour, changing precipitation patterns as well as new technologies for sanitation involves high constructive and financial effort. As opposed to that alternative decentralized systems for sewage treatment and ecological sanitation (ecosan) provide manifold advantages and the possibilities of changes for the positive, e.g. the separation of waste water streams with different characteristics (see **Figure 3**), which allow for an efficient treatment and the high-quality utilization of nutrients **[2]**. The protection of ground- and surface water is achieved by the avoidance of waste water, the decentralized treatment of different substances and waste water streams respectively. The freshwater demand can be reduced by the reuse of recycled waste water in the form of service water. By saving mainly on canalization, the construction of alternative water systems only incurs capital lockup for relatively short periods (< 30 years). The systems are adaptable to changing demographic structures, changing precipitation patterns as well as new sustainable technologies for sanitation, and are insusceptible to catastrophes and malfunctions. Furthermore they have the advantage of short pipeline lengths, minimized water losses and close water cycles **[3]**.

The potentials for the integration of alternative decentralized systems for sewage treatment and ecological sanitation in existing buildings for domestic use in the cities Hamburg/Germany and Seoul/ Korea were investigated and a sophisticated evaluation according to social, economic and ecological criteria was conducted in the framework of the described research. The results are compared with the characteristics and effects of the existing central systems for drinking water supply and sewage treatment in cities; the differences as well as the potential are shown. To allow the transferability of the results of investigations, the housing estates have a high inhabitant density which is above average. In Hamburg it is 13.7 m² per inhabitant and 72,774 inhabitants per km², in Seoul it is 15.67 m² per inhabitant and 63,797 inhabitants per km². Compared with the average density of the city areas, the density in



◀ *Fig. 2:*
THE CITIES HAMBURG (LEFT) AND SEOUL (RIGHT). THE SHAPE OF BOTH CITIES IS ILLUSTRATED IN THE SAME SCALE [3]

Seoul is 3.2 times higher and in Hamburg it is 32 times higher (see also **Figure 2**). The floor area ratio (FAR) of the housing in Hamburg is 3.6 (only 10% of all buildings in Hamburg have a FAR which is above 1.2). **[3]**

MATERIALS AND METHODS

The method of this research is the qualitative and as far as possible quantitative analysis of approved ecological water management and sanitation systems on the bases of recent research results and of investigations by the author. Their applicability as well as the user acceptance in existing urban housing estates has been examined in Germany and the Republic of Korea.

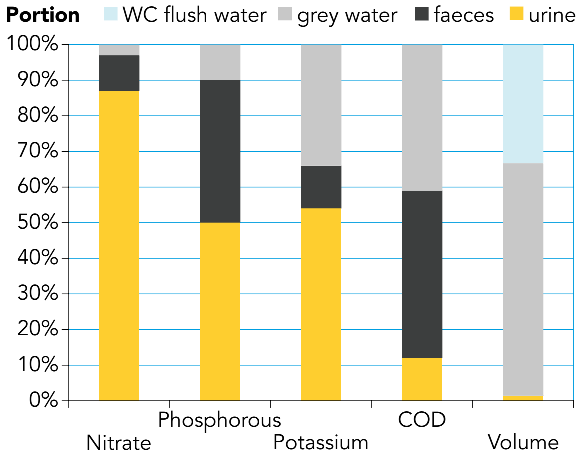
RESULTS AND DISCUSSION

The investigated alternative measures for the treatment of sewage can be assigned to two types: "decentralized rainwater conditioning" and "decentralized waste water conditioning", which include also the supply with service water. The results for the application of different measures in the investigated housing estates are described below. Decentralized rainwater conditioning is the starting basis for the realization of decentralized water systems. It can be used for the sustainable development as well as for the redevelopment of rural and urban human settlements **[4]**:

Measures for rainwater utilization may not be counted as a credit for the calculation of measures for the retention of rainwater and flood control. The service water demand in Hamburg and Seoul is covered with max. 25 - 26% due to the natural and structural basic conditions (climate, high population density and small rainwater catchment area). The amount is equivalent to 9 % of the total water demand of water saving households. Rainwater catchments from greened roofs reduce the degree of efficiency. The related construction work for this purpose does not limit the utilization of real estate and buildings in the investigated housing estates.

Measures for the extensive greening of roofs contribute substantially to the retention of rainwater and may be counted as a credit for the calculation of infiltration systems. Together with intensive greening measures of roofs and buildings, they contribute to an increase of the evaporation ratio thus approximating the micro climate to natural conditions. By irrigating with reclaimed waste water, positive interactions can be achieved (e. g. decomposition of remaining nutrients, like phosphorous).

Measures for the infiltration of rainwater and reclaimed waste water with shallow pits and infiltration ditches out of plastic allow the complete retention of precipitation events up to dimensioning precipitation events with a rainwater contribution frequency of 0.01/a. The related construction work for this purpose does not limit use of real estate and buildings in the investigated housing estates and is cheaper than rainwater utilization systems.



◀ *Fig. 3:*
DISPOSITION OF NUTRIENTS AND PERCENTAGES OF SPECIFIC MATERIAL FLOWS IN RELATION TO THE TOTAL VOLUME OF DOMESTIC WASTE WATER. THE PERCENTAGE IS CALCULATED WITH THE AVERAGE WATER CONSUMPTION OF A HOUSEHOLD IN HAMBURG/GERMANY, 117 L PER RESIDENT AND DAY AND NUTRIENTS PER RESIDENT AND DAY [1, 3]

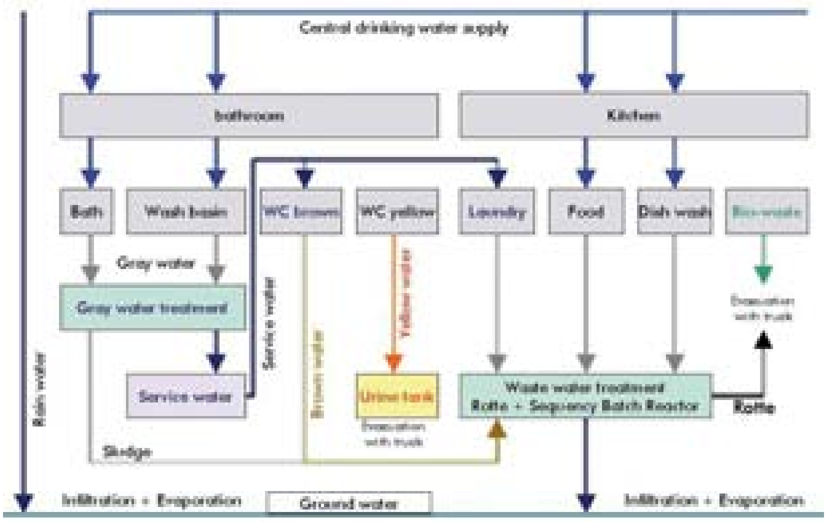
DECENTRALIZED WASTE WATER CONDITIONING

Measures for the recycling of grey water (with Sequency Batch Reactors or Membrane Activation Systems) from bathrooms and the utilization of service water can cover the service water demand in the investigated housing estates in Hamburg and Seoul by 100% (~ 37 and 26% of the total water demand). In Hamburg,

RÉSUMÉ

RÉSEAU DE DISTRIBUTION D'EAU ET D'ASSAINISSEMENT ÉCOLOGIQUE DANS DES LOTISSEMENTS URBAINS REMODELÉS EN EUROPE ET ASIE

Le degré auquel l'introduction d'un réseau de distribution d'eau et d'assainissement écologique peut contribuer à une gestion des eaux usées durable et à la sécurité des ressources en eau potable dans de nombreuses villes du monde a été examiné dans la présente recherche. Parallèlement à la faisabilité architecturale, urbanistique et technique dans le contexte des travaux de rénovation de bâtiments, le cadre culturel, financier et institutionel a été pris en compte. Les résultats d'études menées à Hambourg/Allemagne et Séoul/Corée du Sud sont exemplaires pour les régions métropolitaines européennes et asiatiques et sont évalués au moyen de critères de durabilité (écologiques, environnementaux et sociaux). Ce travail fournit un support de planification et de décision interdisciplinaire lors de la réalisation de réseaux urbains de distribution d'eau et d'assainissement écologiques. Les réseaux de distribution d'eau alternatifs sont identifiés comme une combinaison de mesures individuelles de traitement décentralisé des eaux usées et d'alimentation en eau. Outre l'utilisation des réseaux d'assainissement écologiques, ils comprennent également la transformation des eaux usées en eau de service. La consommation d'eau moyenne dans les ménages privés peut être réduite avec des coûts d'investissement et des coûts d'exploitation minimaux et sans perte de confort par l'installation de limiteurs de débit, d'appareils ménagers et de toilettes économiques en eau. Pour déterminer la transférabilité des constatations faites dans les zones d'essai et pour comparer le réseau central d'alimentation en eau potable existant et le traitement des eaux usées à Hambourg et Séoul, trois systèmes adaptés aux lotissements dans les deux villes ont été étudiés. Les études démontrent que des réseaux de distribution d'eau alternatifs et des lotissements sans effluent sont possibles dans de nombreuses villes internationales et seront acceptés par les utilisateurs.



▲ *Fig. 4:*
FLOW-CHART WITH ILLUSTRATION OF THE MATERIAL FLOWS OF THE DESCRIBED DECENTRALIZED WATER SYSTEM 3 [3]

the measures are linked to additional required space (0.06 m²/resident), while in Seoul no additional space is required.

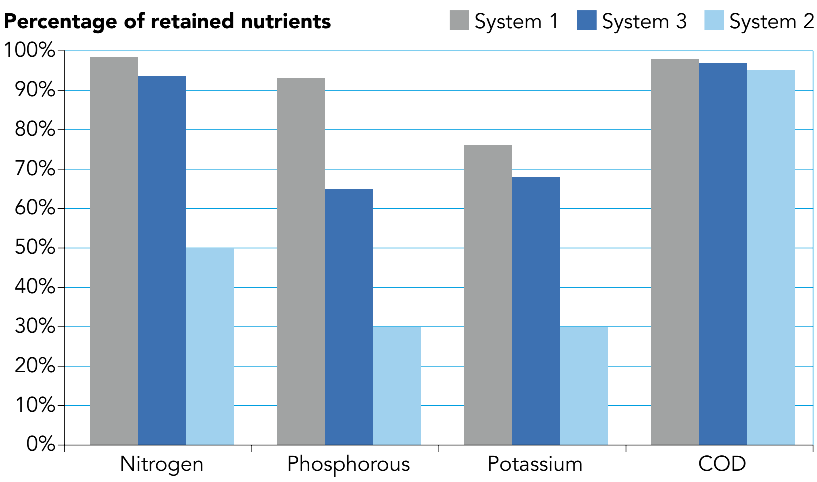
Measures for the conditioning of waste water (brown- and grey water) with Sequency Batch Reactors or Membrane Activation Systems can be utilized for the realization of waste water free real estates in Hamburg and Seoul. The purified and hygienically harmless water of a bathing or service water quality can be infiltrated, for artificial groundwater recharge, or be used for irrigation, e.g. that of intensive greenings of buildings (as above). The required constructions can be integrated—in Seoul in the area of existing septic tanks, and in Hamburg underneath a part of the courtyard—and do not limit the degree of use of real estate and buildings in the investigated housing estates. The small amount of sludge is treated in a pre-composting facility (retting container, see below).

Measures for the pre-treatment of brown- and grey water with pre-composting facilities (retting container) can be integrated in the housing estates in Hamburg and Seoul outside, below ground without additionally occupying space inside the buildings. With this measure, more than 1/3 of the contained nutrients can be separated and utilized, and the amount of sludge from the waste water treatment can be significantly reduced. The small amounts of "Rotte" (pre-composted material) are removed from the holding tanks regularly, 2 - 1 times a year, for further treatment.

Measures for the collection of yellow water (urine) can be integrated in the housing estates in Hamburg and Seoul underground, outside the buildings, without additionally requiring space inside the buildings and reduce the emissions of nutrients and micro pollutants in the environment. In the case of a country-wide application, the required amount of nitrogen in agriculture could be covered by 32% in the Republic of Korea and to 11% in Germany. The demand for phosphorous could be covered by 13% in Korea and by 11% in Germany. Hence the collected urine could be used to substitute chemical fertilizers and support organical farming. The collected yellow water is removed regularly from the housing estates with trucks, with a capacity of 15 tons. In Seoul once in a week and in Hamburg once in a month. In the case of an area wide application, 480 trucks would be required in Seoul and 80 in Hamburg each making three trips per day five times a week.

Measures for the fermentation of black water, biogas production and utilization in a combined heat and power generator requiring a comparatively large amount of space, in relation to the small volume of the treated waste water. They can only be realized outside the buildings with additional construction effort. The expenditure for the transportation of the treated residues is also relatively high and is equivalent to 4.6 times that of the collected yellow water. The emissions of nutrients and micro pollutants into the environment are reduced to the greatest possible degree. [3]

▼ *Fig. 5:*
PERCENTAGES OF THE RETAINED NUTRIENTS IN DOMESTIC WASTE WATER FOR THE DECENTRALIZED TREATMENT SYSTEMS 1 (WITH THE FERMENTATION OF BLACK WATER), SYSTEM 2 (WITH THE COMBINED TREATMENT OF BLACK WATER AND GREY WATER FROM KITCHEN) AND THE DESCRIBED SYSTEM 3 (WITH URINE SEPARATION, BROWN AND GREY WATER TREATMENT) [3]



DECENTRALIZED WATER SYSTEM

In order to determine the transferability of the findings in the testing areas and to compare the existing central systems for drinking water supply and waste water treatment in Hamburg and Seoul, a system (system 3, see Figure 4) has been chosen which can be used for both housing estates and is comprised of the following single measures:

- Rainwater retention and infiltration (with reclaimed waste water) with mould—and plastic infiltration ditch systems
- Recycling of grey water from the bathrooms and service water utilization
- Waste water treatment (brown and grey water)
- Pre-treatment of brown- and grey water with pre-composting installations
- Collection of yellow water

In the framework of the research also the application of two other systems was investigated which have not been chosen for the comparison. They also comprise rainwater retention and infiltration as well as the recycling of grey water but they are based on the combined treatment of brown and yellow water. The system based on the fermentation of black water, kitchen waste, biogas production and utilization in a combined heat and power generator (system 1) has not been chosen for the system, due to the layout of the existing housing estates, the comparatively high space demand as well as the large investment costs and working expenses. The combined treatment of black and grey water from the kitchen (system 2) was not chosen due to the high content of nutrients (see **Figure 5**) and micropollutants in the treated sewage compared with the chosen ecosan based system.

Fig. 6: **IMPRESSION OF THE INVESTIGATED HOUSING ESTATE IN HAMBURG / GERMANY**

MINIMIZATION OF WATER DEMAND

The starting basis for the design of the chosen system is the minimization of the water demand. A comparably low water consumption in households without a loss of comfort without the changing behaviour of the users can be ensured by the application of water saving fittings (flow rate delimiters) and household appliances (washing machines and dish washers) and water saving toilets (with cleaning flow rates of about 2 (for urination) and respectively 3 litres (for defecation)). With these measures the water consumption can be reduced with minimal investment costs, minimal operating costs and without any loss of comfort by approx. 1/3 (in Hamburg from 117 l per resident and day to 81 litres per resident and day) and in Seoul by 38% (from 208 litres per resident and day to 129 l per resident and day). An advanced reduction of the drinking water consumption can be achieved by the substitution of drinking water with so called service water (e. g. purified rain- or grey water) which can and may be used for toilet flushing, laundry, cleaning and watering purpose, according to the legal basic conditions in Germany and Korea. The proportion of the service water demand in relation to the total water demand of these water saving households is estimated at 26% in Seoul (33 litres/r.d) and 38% in Hamburg (30 litres/r.d) for toilets. Measures for the recycling of grey water (Sequency Batch Reactors or Membrane Activation Systems) from bathrooms and the utilization of service water can cover the service water demand in the investigated housing estates in Hamburg and Seoul by 100%. Hence the drinking water demand compared to standard households can be reduced in Hamburg by 56% (from 117 to 51 litres/r.d) and in Seoul by 54% (from 208 to 96 litres/r.d). Collected rainwater is not utilized for the service water supply due to the low coverage ratio of the service water demand of 25 - 26% in Seoul and Hamburg. **[3]**

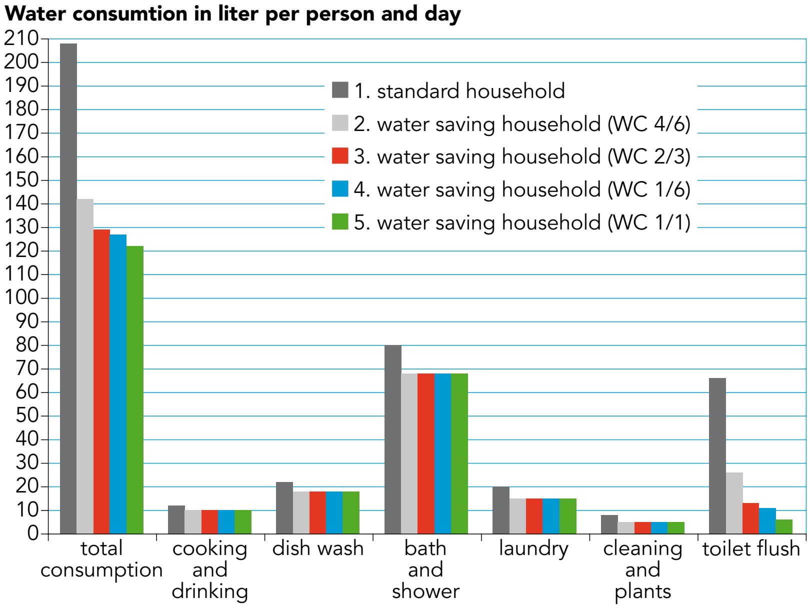
INSTALLATION OF THE SYSTEM

The installation of the required pipelines (service, grey water from the bathroom and waste water) inside the buildings requires additional effort compared to the standard installation. For the installation of the vertical ducts of the described system, additional space is needed, while the horizontal pipelines can be installed without additional space. However, according to recent research results from Germany, the space expenditure can be reduced significantly, thus allowing for a significant reduction in diameter for the waste water pipelines. Therefore, in Seoul, all the pipelines can be integrated inside the existing vertical ducts without any structural changes. This is not possible in Hamburg, where 30% additional space is required for the installation of the vertical duct, compared to the standard installation. **[3]**

INVESTMENT AND SERVICE COSTS

The minimal investment and service costs for the alternative water system would, in Seoul, be twice as high as the present charges for waste and drinking water of standard households. This is calculated surmising payments covering a period of 20 years (without interest rates) and taking present charges for waste water and drinking water as a starting point, which however do not cover the actual real production, treatment and capital costs. If one were to take the actual real cost of production, treatment and capital as a starting point of one's calculations, the total costs would be lowered to a mere two thirds of the real cost of production, treatment and capital of the current standard systems. In Hamburg, charges resulting from investment and service costs of the alternative water system (using the same financial determinates as a basis of calculation as above) would be approximately the same as those of the current standard systems. Due to the different natural basic conditions, the investment costs for measures of retention and infiltration of rainwater may vary significantly and may therefore affect the total cost for the system. **[3]**

The primary energy expenditure of the alternative water system amounts, in Seoul, to 95% of that of the standard system, and in Hamburg, to 200%, and thus is twice as high. This significant difference is caused on the one hand, by the partially decentralized drinking water supply and waste water treatment in Seoul, and on the other hand, by the energy efficient central waste water treatment and drinking water supply in Ham-



▲ *Fig. 7:*
WATER CONSUMPTION OF STANDARD HOUSEHOLDS AND OF WATER SAVING HOUSEHOLDS WITH DIFFERENT TOILET TYPES IN SEOUL [3]

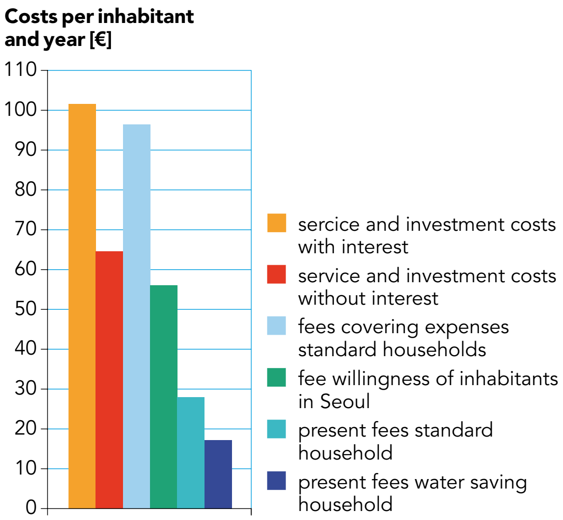
▲ *Fig. 8:*
IMPRESSION OF THE INVESTIGATED HOUSING ESTATE IN SEOUL / REPUBLIC OF KOREA [3]

burg. The primary-energy expenditure for the transportation of the yellow water (20 km) is minimal compared to that of decentralized waste water treatment. The resident specific end-energy demand for an alternative water system amounts in Seoul 0.26 kWh per resident and day, and in Hamburg 0.18 kWh per resident and day. This value is equivalent to 10% of the average consumption of electricity in private households of South Korea (2.54 kWh per resident and day) and 5% of the average consumption in Germany (3.69 kWh per resident and day). Compared with the total average end-energy demand of private households in Germany (including car, hot water, heating, household appliances, information & communication, light, drinking water supply and sewage treatment) the additional demand for the alternative water system amounts only to 0.2% of the total end-energy demand **[3]**.

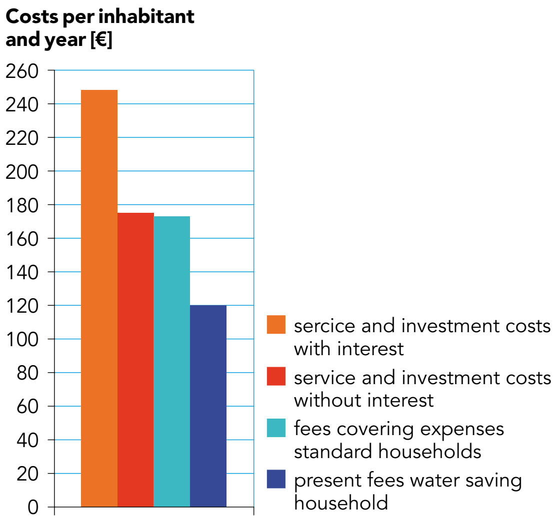
CONCLUSIONS AND RECOMMENDATIONS

According to the findings of the investigations in two existing housing estates in Hamburg and Seoul, alternative water systems based on ecological sanitation are already realizable at present; with a feasible constructive and technical effort as well as a low additional cost compared to conventional construction costs. They can be implemented area-wide and allow the appropriate treatment of the specific material flows. Furthermore they allow the reuse of nutrients which are in conventional systems either discharged with the sewage effluent or eliminated (see **Figure 11**).

Due to very different climate conditions and the transferability of the single measures which have been described in the framework of the described research, the basic conditions for a wide distribution can be fulfilled. Hence it may be expected, that alternative water systems and sewage free housing estates are realizable in many international cities with different natural and structural basic conditions. According to results from



▲ *Fig. 9:*
PRESENT FEES OF DIFFERENT HOUSEHOLDS IN SEOUL, REPUBLIC OF KOREA (ANNUAL INTEREST RATE OF 7%, INVESTMENT PERIOD 20 YEARS) [3]



▲ *Fig. 10:*
PRESENT FEES OF DIFFERENT HOUSEHOLDS IN HAMBURG, GERMANY (ANNUAL INTEREST RATE OF 7%, INVESTMENT PERIOD 20 YEARS) [3]

surveys in Seoul [5] and experiences in Germany and Europe, a high user acceptance of the system may be expected.

At present admittedly, there are many barriers to realizing alternative water systems. For Hamburg and Seoul the main barriers are both the existing infrastructure, the structure of the fees incurred by implementing the alternative system and the institutional and legal framework. In Seoul there is the added problem of the present fees for drinking and waste water which do not cover the actual real costs. While decentralized rainwater management increasingly is recognized as a sustainable measure, the acceptance of the ecological sanitation of stakeholders is low, especially in urban areas, because there is considerable doubt regarding its acceptance by end-users as well as its profitability and feasibility. According to stakeholder interviews in the Republic of Korea [6], 89% of the interviewees think that decentralized measures are not feasible yet, and 67% of them think that this will be still the case in 20 years. However decentralized environmental sound measures for waste water management are accepted by most stakeholders; presently in particular with regard to the optimization of the efficiency of central sewage treatment plants (regarding rainwater management). More than 50% of the stakeholders think that the feasibility for the decentralized treatment of urine and faeces will be good and very good in 100 years.

Scientifically supervised pilot projects and additional research regarding the integration and service of decentralized environmentally sound water and sanitation systems as well as regarding the optimization of institutional and legal frameworks can help to dispel doubts and mark the beginning of a paradigm shift in water management. This applies particularly to areas which are not yet equipped with sewer systems or waste water treatment plants.

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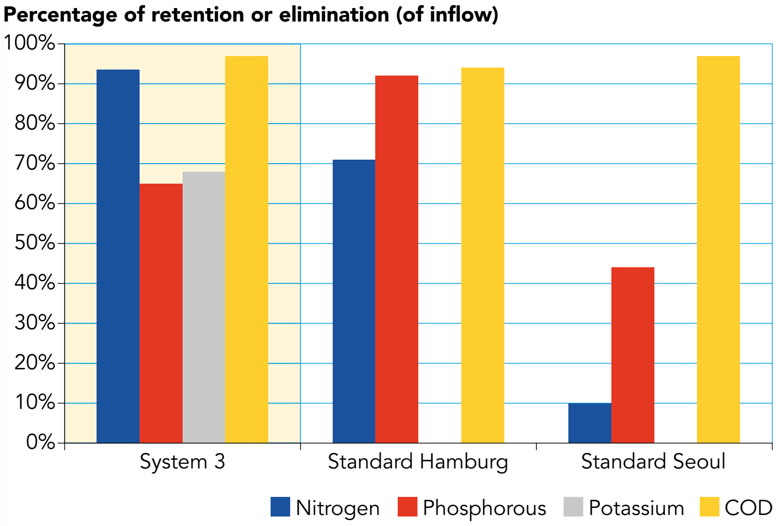
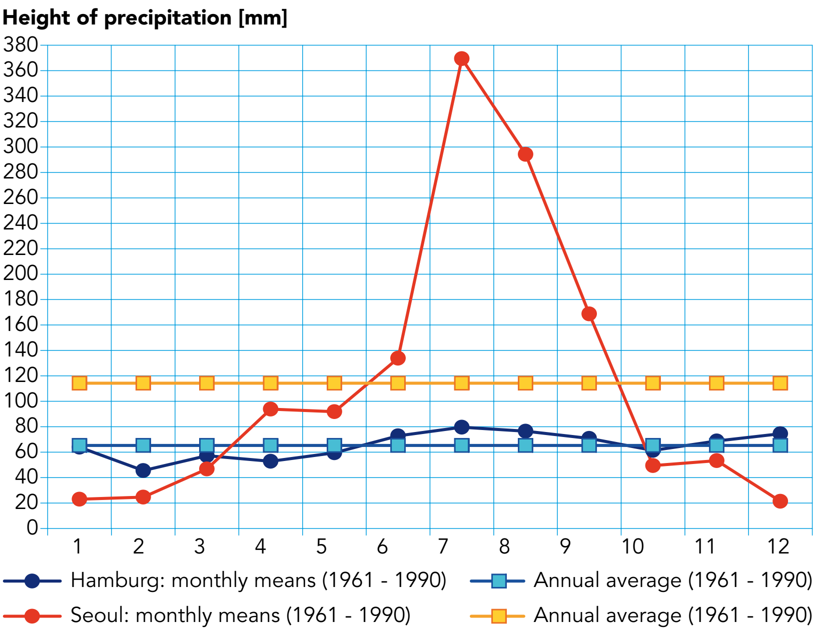


▲ *Fig. 11:*
PROPORTION OF THE RETAINED AND RECYCLABLE RESOURCES OF NITROGEN, PHOSPHOROUS, POTASSIUM AND THE CHEMICAL OXYGEN DEMAND (COD) OF THE DESCRIBED SYSTEM 3 (LEFT), HAMBURG (MIDDLE), SEOUL (RIGHT) [3]



▲ *Fig. 12:*
AVERAGE OF PRECIPITATION IN HAMBURG AND SEOUL FOR THE PERIOD 1961 - 1990 [3]

ZERO-M

SUSTAINABLE CONCEPTS TOWARDS A ZERO OUTFLOW MUNICIPALITY

MEDA Water

CONTRACTING AUTHORITY	EUROPEAN COMMISSION / Delegation of the European Commission in Jordan
PROGRAMME	EURO-MEDITERRANEAN PARTNERSHIP Euro-Mediterranean Regional Programme For Local Water Management Budget Line B7-4100

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