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WHO

REGIONAL OFFICE FOR EUROPE

WHO EXPERT CONSULTATION ON HEALTH RISKS IN AQUIFER RECHARGE USING RECLAIMED WATER

Report on a meeting of
an expert group

Budapest, Hungary
9-10 November 2001

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Background

Water shortage

Freshwater is an important resource: population growth in water scarce regions will only increase its value. Within the next fifty years, it is estimated that 40% of the world's population will live in countries facing water stress or water scarcity[1]. This number does not include people living in arid regions of large countries where there is enough water, but distribution patterns are uneven e.g. China, India, and the United States.

In many areas of the world, aquifers that supply drinking water are being used faster than they recharge. Not only does this represent a water supply problem, it may also have serious health implications. Moreover, in coastal areas, saline intrusion of potable aquifers occurs as water is withdrawn faster than it can naturally be replaced. Increasing salinity makes water unfit for drinking and for other purposes such as irrigation.

Potable Aquifer Recharge

To remedy these problems, some authorities have elected to recharge aquifers artificially with treated wastewater, either by infiltration or by injection. Additionally, aquifers may be passively recharged (intentionally or unintentionally) by septic tanks, wastewater that is used for irrigation, and by other means. Aquifer recharge with treated wastewater is likely to increase in future because it offers the following benefits:

- Restores depleted groundwater levels
- Acts as a barrier to saline intrusion in coastal zones, and
- Facilitates water storage during times of high water availability. Aquifers frequently offer a low-cost method for storing water because the infrastructure requirements are minimal, water loss due to evaporation does not occur, and the water is protected from infestation with nuisance species (blue-green algae etc.).

Public health implications

If aquifer recharge is done haphazardly or in a poorly planned fashion, chemical or microbial contaminants in the water could impact the health of consumers. The risk may be especially important when reclaimed water is being used. Wastewater may contain numerous contaminants (many of them poorly characterized) that could have health implications if introduced into drinking water sources.

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[1] Garner-Outloaw T. and Engleman R., 1997, *Sustaining water, easing scarcity. A second update.* Washington DC Population Action International p. 2- 19

Ensuring that the use of treated wastewater for aquifer recharge does not result in adverse health effects requires a systematic science-based approach designed around critical control points. There is a need to thoroughly evaluate the best practices to achieve public health protection. Additionally, environmental and socio-cultural concerns associated with potable aquifer recharge need to be addressed. With these goals in mind, WHO decided to organize an Expert Consultation on Aquifer Recharge using Reclaimed Water.

Groundwater recharge in Europe and the Mediterranean Region

The technical practice of water reuse, particularly for the recharge of aquifers destined for the production of drinking water, may be seen as counter to the desire to protect groundwater resources from any interference that could possibly degrade the quality of the aquifer. Especially in the territories of the European Union, protection is rapidly becoming an established environmental policy goal under the Sixth Framework Action Plan.

In 1997, the Environment Directorate-general of the European Commission initiated a comprehensive, multi-sectoral study to identify which environmental issues Europe would be facing in the years to come. Recommended approaches will apply across the spectrum of environmental issues. In the specific area of ***Environment and Health,*** the objective was declared to be "*the achievement of a quality of the environment where levels of man-made contaminants … do not give rise to significant impacts on, or risks to, human health*."

A preparatory technical report prepared for the European Union[2] clearly showed that Southern and Northern European countries approach water reuse differently – largely as a result of water availability in the two regions. For example, South European countries rank '*water scarcity and pollution'* first, but North European countries rank it only fifth in a list of concerns. The report found this perception to be based at least partially on facts. GIS assessment methods that analyze precipitation, evaporation, groundwater recharge and surface flow show a clear North-South divide in water availability, as well as a large variability in the Mediterranean region.

This view was also articulated in the *Mediterranean Vision on Water, Population and the Environment*[3] which stated that overuse of groundwater by numerous independent institutions has developed throughout the Mediterranean Region, especially in coastal aquifers. This has happened in most Mediterranean countries: the level of coastal groundwater has fallen below sea level due to excessive pumping in *inter alia* Spain, Italy, Greece, Cyprus, and Libya leading to some catchments being abandoned. The share

[2] B.J. de Haan, A. Beusen, C. Sedee *Technical Report on Water Quantity and Water Quality* prepared in preparation of the main report *European Environmental Priorities: an Integrated Economic and Environmental Assessment,* contracted by the Environment Directorate General of the European Commission.

[3] J. Margat, D. Vallee: Mediterranean Vision on Water, Population and the Environment – document prepared by the Blue Plan for the Global Water Partnership/MEDTAC in the programme of the World Water Vision of the World Water Council, January 2000 page 23.

of groundwater withdrawn through overuse (exceeding average natural recharge) is considerable in many Mediterranean countries: 20% in Spain, 13% in Cyprus, 24% in Malta, and 32% in Israel[4].

Mediterranean Action Plan (MAP)

In 1975, sixteen Mediterranean countries and the European Commission met in Barcelona under the auspices of the United Nations Environment Programme (UNEP). They approved the Mediterranean Action Plan (MAP) and its component Programme for Pollution Monitoring and Research (MED POL Programme). MAP consists of three components: scientific (pollution assessment), socio-economic (prospects and integrated planning) and institutional and legal (Barcelona Convention and its Protocols). Also the Mediterranean Committee on Sustainable Development is a consultative body to the partners.

The MED POL programme was created in order to answer the specific needs to better assess, qualify and quantify the marine environmental problems of the Mediterranean sea.

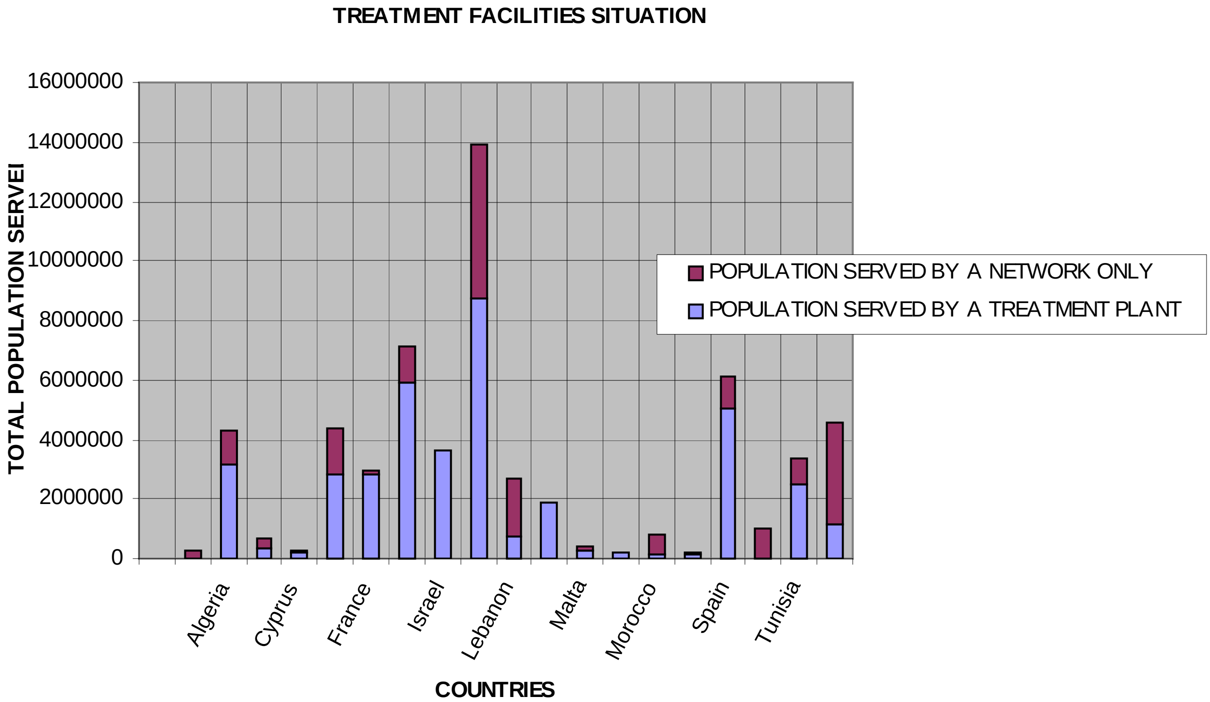
During Phase I (1975-1980) and Phase II (1981-1995), the efforts were concentrated in providing assistance to all laboratories in the region to fully participate in the Programme activities related to monitoring and research, as well as in the establishment of national monitoring programmes, the assessment of the state in the Mediterranean and the formulation of pollution control measures.

The new MED POL Phase III entitled “Programme for the assessment and control of pollution in the Mediterranean region”, which was adopted by the governments in 1995, gives more emphasis on the managerial aspects of pollution control and a more direct link with the implementation of the Dumping and Land-based Pollution Protocols. The activities for Phase III include the assessment, control and assistance components.

Following a survey on wastewater treatment plants in the Mediterranean in 2000, it was noted that more than five hundred coastal cities with more than 100,000 inhabitants, discharge their sewage into the sea, and 53% of the total volume discharged is untreated. It’s becoming more than evident that control measures of one type or another should be implied. The fact that only 8% of the treated and untreated sewage is reused, calls for more attention, also in view of the water shortage in the Southern Mediterranean countries. The Contracting Parties during their last meeting in Monaco, in 2001, decided to

[4] Ibid

reconsider the state of wastewater reuse by assessing the practices and by preparing guidelines relative to this issue.



The Directive of the European Parliament and of the European Council dated 23 October 2000 establishing a framework for Community Action in the field of water policy (EU Water Framework Directive) aims at preventing further deterioration of aquatic ecosystems, as well as protecting and enhancing their status. It promotes sustainable water use, establishes measures to cut inputs of priority substances into aquatic systems, and requires the cessation or phasing out of emissions of priority hazardous substances. Its implementation will help reduce existing groundwater pollution.

World Health Organization

The Drinking Water Quality Committee of the World Health Organization at its most recent meeting in Berlin, Germany, 5 – 9 June 2000 decided to develop a monograph on *Groundwater resources and source protection* with the double objective of providing guidance on the ***protection*** of groundwater resources and to compile the necessary information to provide appropriate guidance for the development of further Guidelines for Drinking Water Quality (GDWQ).

However, in view of the experience gained in the United States of America, Australia, China, and in certain sub-regions of WHO EURO, the GDWQ Committee recognized a need to compile a State of the Art Report on Health Risks in Aquifer Recharge by Means of Reused Water.

Expert Consultation

The Fodor Jozef National Institute for Environmental Health in Budapest, Hungary, kindly hosted the meeting from 9 – 10 November 2001. The meeting was attended by experts from nine different countries and six different organizations. A list of participants in attached in Annex.

PROCEEDINGS

The following section presents a short summary of the main points made by the different speakers. The main author is identified in each case – full contact details are contained in the list of participants for eventual follow-up.

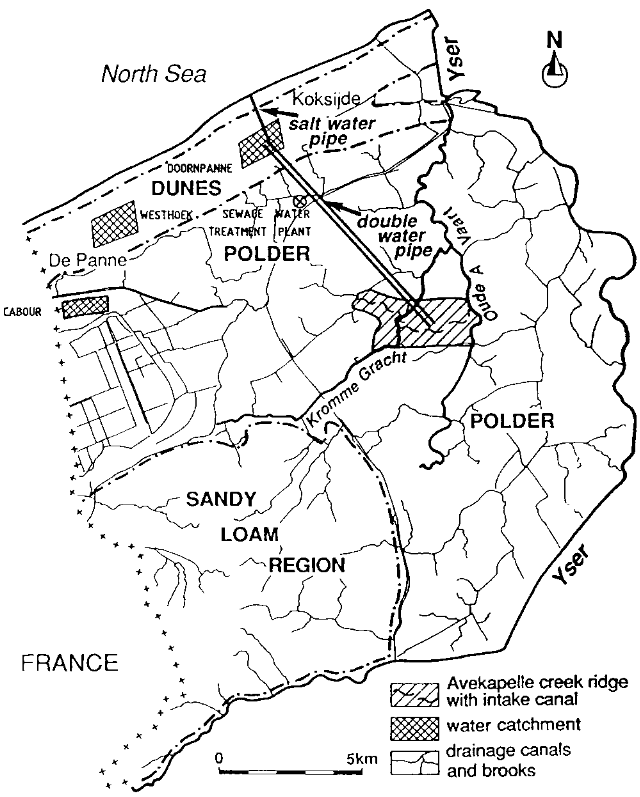
Selected activities in the WHO EURO Region

Belgium

E. Van Houtte

A report was presented on pilot studies undertaken by the Intercommunal Water Company of the Veurne region (IWVA). The company produces drinking water by extracting a dune aquifer. Subsequent treatment is through aeration and sand filtration. The groundwater extraction diminished the freshwater outflow from the dune area, and could potentially cause salinisation of the aquifer. Hence a number of pilot studies were carried out to assess the potential use of wastewater effluent as a source of infiltration water.

Amongst the examined treatment processes were microfiltration (MF), reverse osmosis (RO), and soil aquifer treatment prior to MF/RO. The quality of the resulting water was followed for a number of parameters, including hygienic qualities.



After four years of intensive pilot study, the authors concluded that reusing wastewater effluent for artificial recharge in dunes was both economically and technically feasible. MF removed suspended solids, and part of the organic load. It proved to be a good pre-treatment for RO, which desalinated the water. Standards set for infiltration water, based on the ecological value of the dunes, were easily met. The concentrate resulting from the RO and the MF backwash could be drained safely to a nearby brackish canal together with part of the effluent not used by the IWVA.

The authors concluded that reuse of wastewater effluent is feasible using membrane technologies. Out-to-in microfiltration could treat water of varying qualities, and is a good pretreatment for reverse osmosis. Biofouling could be a problem and should be prevented. Chloramination prior to microfiltration not only improved the performance of the system but seemed to control the biofouling of the reverse osmosis membranes as well. Scaling could be prevented by pH adjustment and dosing of scale inhibitors.

EU Mediterranean Region Cooperation

Ch. Thoeye

The presentation, given on behalf of Dr A. Angelakis, covered ongoing international research efforts aimed at assessing and quantifying health risks related to the reuse of municipal wastewater. This type of quantified risk analysis is generally carried out based on dose-response values and on exposure figures available from the literature. Different treatment technologies as well as different applications of the final product were considered such as drinking water, household water (i.e. cleaning, toilet flushing, garden watering), irrigation water, and industrial use.

The results of the study would also form an important tool for the integration of artificial aquifer recharge in designing sustainable schemes for recycling and reuse of municipal wastewater.

For the reuse applications considered in the study, different types of pathogens and chemicals may pose health risks through different exposure routes.

The following groups were retained during the study:

- Biological organisms: protozoa Giardia and Cryptosporidium, viri group Enterovirus, bacteria Salmonella Typhi , helminth group Nematoda
- Chemicals: metals (arsenic, lead, nitrite), pharmaceuticals, estrogens (natural and synthetic), surfactants, musks, and other chemicals including chemicals with endocrine disruptor capacity.

Study of the literature on health risk analysis shows that a quantified risk analysis is only possible for direct ingestion due to the paucity of data concerning other exposure routes.

The project is based entirely on published data, and is limited to the reuse of treated municipal wastewater. Final conclusions are expected to be reached by mid 2002.

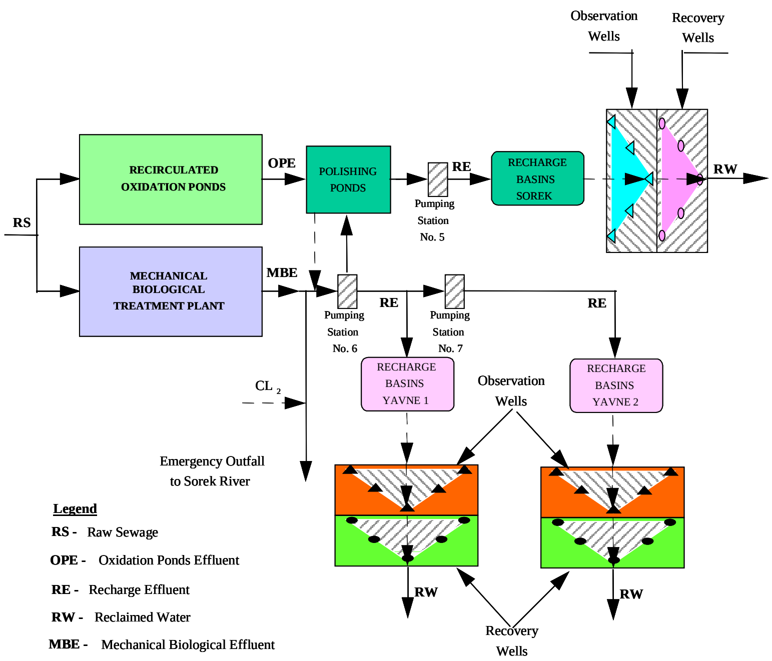
Speaker also drew the attention to the Regional Symposium on Water Recycling in the Mediterranean (Crete, Greece, 26 - 29 September 2002). http://www.nagref.gr/Symposium/prog-scient/index.htm

Israel

G. Oron

A general discussion on the management of effluent reclamation via Soil Aquifer Treatment (SAT) was complemented by a detailed description of the effluent re-use of the treatment plant of Greater Tel Aviv (Dan Region, Israel).

Schematic layout of the treatment plant of Greater Tel Aviv (Dan Region, Israel)



The following table summarizes the results before and after the SAT stage for 1999:

Parameter (mg/l)	Before SAT	After SAT	Removal percentage
BOD	6	<0.5	92<
COD	46	7	85
TSS	7	0	100
DOC	11	2.8	75
Detergents	0.241	<0.108	55<
Mineral Oils	0.4	0.3	25
Phenols	4	1	75
Ammonia as N	8.23	<0.02	99<
Total N	12.0	5.4	55
Phosphorus	2.72	0.05	98

Problems encountered in this reuse include:

- Increased amounts of effluent vs. decreasing available land for expanded recharge
- Optimization of the wetting and drying cycle of the recharging beds
- The dilemma of disinfecting the effluent prior to recharge thus killing also part of the microbial community responsible for the further biodegradation process in the soil
- The effluent viscosity that affects very much the infiltration and migration processes in the sandy soil
- The chemical composition of the suspended solids, which might affect the clogging rate of the soil aquifer.
- The risk of heavy metal release from plastic and metal piping in the recharged effluent
- Pathogens content in the disposed effluent for recharges and anticipated removal during migration processes and ultimate reuse.

The above problems notwithstanding, the author concluded that effluent recharge during soil aquifer treatment is a promising technology to obtain high quality waters, to minimize pollution phenomena, and to increase water availability. Due to shortage of land and changes in the soil property, advanced treatment methods are recommended.

Italy

L. Sinisi

Italy has one of the highest per capita water resource availabilities of all European countries: 980 m^3/c/y compared to a European average of 600 m^3/c/y. Groundwaters account for about 1/3 of the total available water resource providing about the 85% of national drinkable waters along with other uses.

However, resources are distributed very unevenly over the national territory: approximately ½ of the resource is located in the North supplying about 90% of local population, while in the South drinkable water is mainly guaranteed by superficial catchment basin.

If in the North problems are correlated with overuse and bad quality (contamination) of the resource, South and big islands are characterized by water scarcity mainly due to climatic conditions – with desertification trend in some areas – and smaller availability of water resources: the amount of superficial waters and ground waters is respectively about ¼ and ½ compared to availability in the North.

Furthermore, there is a general trend of increasing consumption rate up to 35% in the last two decades, while continued use of old equipment results in average losses of up to 20% of produced water.

Problems identified as important for the improved management of groundwater resources include:

- The necessity to improve information, through the development and implementation of appropriate monitoring programmes, for defining priorities and planning interventions
- Contamination of groundwater resources by nutrients, heavy metals, pesticides, and organic materials from human activities including illegal dumping
- Overuse of the resource, leading to saline intrusion and (local) subsidence

Conjunctive use of surface and ground waters offers the best for optimising water use and guarantees the sustainability of water resource, then a correct aquifer management will require the development of river basin management plans that will address a number of specific issues such as:

- Underground storage availability
- Production capacity of the aquifer and natural recharge of the aquifer
- Natural recharge of the aquifer
- Induced natural recharge
- Artificial recharge
- Comparative economic and environmental benefits

Stress quality factors (point and diffuse contamination from human activities)
- Comparative economic and environmental benefits

The author summarized in detail both recent Italian environmental legislation pertaining water resource protection and European water framework directive

Spain - mainland

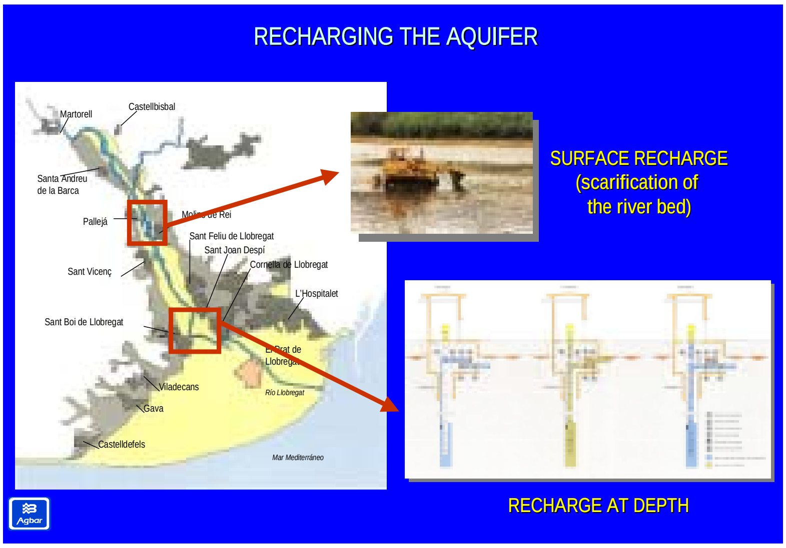
J L Armenter Ferrando

A review was presented on current artificial recharge in the Barcelona area. The following table summarizes the characteristics of the exploitation:

Table 1: Characteristics of the Exploitation	
No of supplied inhabitants	2.800.000
Nr of supplied municipalities	23
Distribution of network length	4.300 km
Average daily consumption	680.000 cu.m
Annual volume of water produced	
From Ter river	120 hm3
From Llobregat river	100 – 120 hm3
From Llobregat wells	10 – 30 hm3
Volume of recharged water	2.5 – 15 hm3

Artificial recharge in the Barcelona region aims to achieve the following goals:

- Increase the available water reserves
- Use of the aquifer as a distribution system
- Improve water quality
- Provide a hydraulic barrier against seawater intrusion



Recharge of the aquifer is undertaken through surface recharge, particularly where the aquifer is easily accessible through the riverbed. Besides the mechanical maintenance of the riverbed, the following issues are being considered: flow 10 – 35 m^3/s, turbidity below 100 NTU, NH_3 below 1 mg/l, Cl^- below 350 mg/l.

Artificial recharge at depth is practiced through 7 wells originally designed for extraction but currently being used for recharge, 5 wells constructed specifically for recharge. Recharge capacity per well are 50 l/s or 100 l/s with a total recharge capacity of 75.000 m^3. Water losses incurred during operations, for example through cleaning, reach 0.2 – 0.4 %.

Recharged water at depth is monitored on different parameters against pre-determined criteria as shown in the following table

Parameters	Units	Acceptable values
Color	.mg Pt/l (sc. Pt/Co)	<= 3
Turbidity	UNF	<= 0.2
Odor	Dilution Index	2 (25°C)
PH		6.5 – 8.5
Sulphates	.mg SO_4/l	<= 200
Magnesium	.mg Mg/l	<= 30
Sodium	.mg Na/l	<= 200
Aluminium	.mg Al/l	<= 0.15
Nitrates	.mg NO_3/l	<= 20
Ammonia	.mg NH_3/l	<= 20
TOC	.mg C/l	<= 3
Detergents	µ LSS/l	<= 100
Total coliforms	In 100 ml	0 (FM), < 1 (MPN)
Faecal coliforms	In 100 ml	0 (FM), < 1 (MPN)

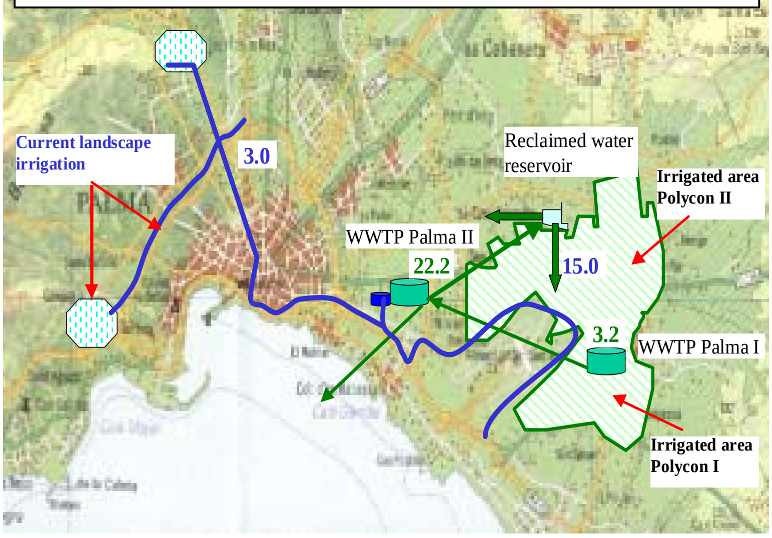
Spain – islands
F. Brissaud

Mallorca is the biggest island in Spain with a surface area of 3640 km^2. Mallorca 95 km in the N-S direction and 200 km in the E-W direction. The island suffers serious water scarcity. There are no permanent surface water bodies. At least 95% of the supply is obtained from groundwater. Most aquifers are over-exploited and water quality is deteriorated by seawater intrusion. The water pumped from the two main aquifers (Pont d' Inca and Na Burguesa) must be desalinated in a 30 000 m^3/d reverse osmosis treatment plant operating since 1995. During a severe draught from 1995 till 1997, 17 million m^3 was shipped from the mainland.

Addressing water supply to Palma requires the formulation of an overall policy for management of the aquifer, prior to the eventual implementation of recharge schemes. Such schemes should prevent jeopardizing the quality of the aquifer during recharge, and should also take into account advanced techniques to produce potable water from impaired aquifer water.

Different scenarios of water resources management based on water reuse were assessed and compared with seawater desalination. The protection of aquifer resources was amongst the main goals of several scenarios investigated in a study of the water supply of Palma de Mallorca. The study finally advocated not to apply aquifer recharge, but the offset of the aquifer water by reclaimed water for non potable uses (landscape and agricultural irrigation).

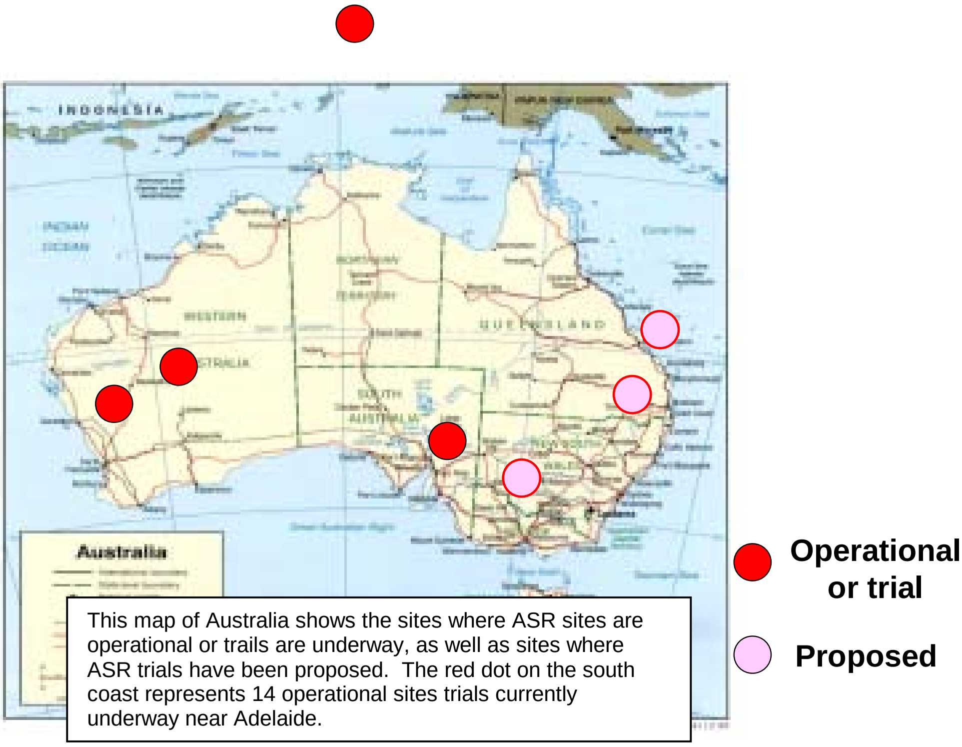
Current and potential use of reclaimed water in Palma de Mallorca



Australia

P Dillon

Australia has adopted a National Water Quality Management Strategy, which is a set of principles and a series of national guidelines founded on them. These include Guidelines for Drinking Water, Groundwater, and Sewage



This map of Australia shows the sites where ASR sites are operational or trails are underway, as well as sites where ASR trials have been proposed. The red dot on the south coast represents 14 operational sites trials currently underway near Adelaide.

Management. The principles, such as the conservation and protection of all environmental values of water, give rise to a differential protection policy for groundwater. In 1996 guidelines for the quality of stormwater and treated wastewater for injection into aquifers for reuse were established. These guidelines make provision for demonstrated sustainable attenuation capacity of aquifers and in so doing differ from similar guidelines in the USA.

The current status of Aquifer Storage and Recharge is as follows:

- Stormwater
  - 12 sites
  - 1000 ML/year now
  - 4000 ML/year in 3 years
  - 10 – 25 US c/KL
- Reclaimed water – 2 pilot sites
  - potential for 14000 ML/y
  - 5 – 12 US c/KL
- Mains water
  - 1 town water supply
  - 3 irrigation supplies
  - large potential

In order to understand pathogen inactivation better, two research studies are currently under way in Australia. The first, the Bolivar reclaimed water aquifer storage and recovery project, involves injection of irrigation quality reclaimed water into a brackish aquifer and, among other objectives, observing the fate of injected constituents. Superimposed on this site and in laboratory studies are evaluations of the attenuation of pathogens, disinfection by-products, endocrine disruptors and changes in natural organic matter. These activities are part of a much wider research programme operating in 5 sites in the USA, 4 in Australia, and 1 in the Netherlands.

Speaker also drew the attention of the participants to the work of the International Association of Hydrogeologists' Working Group on Management of Aquifer Recharge reachable through www.iah.org/recharge

Results will be presented at the forthcoming 4th International Symposium on Artificial Recharge scheduled to be held from 22 – 26 September 2002 in Adelaide, Australia. More information on www.groundwater.com.au/conf/isar4

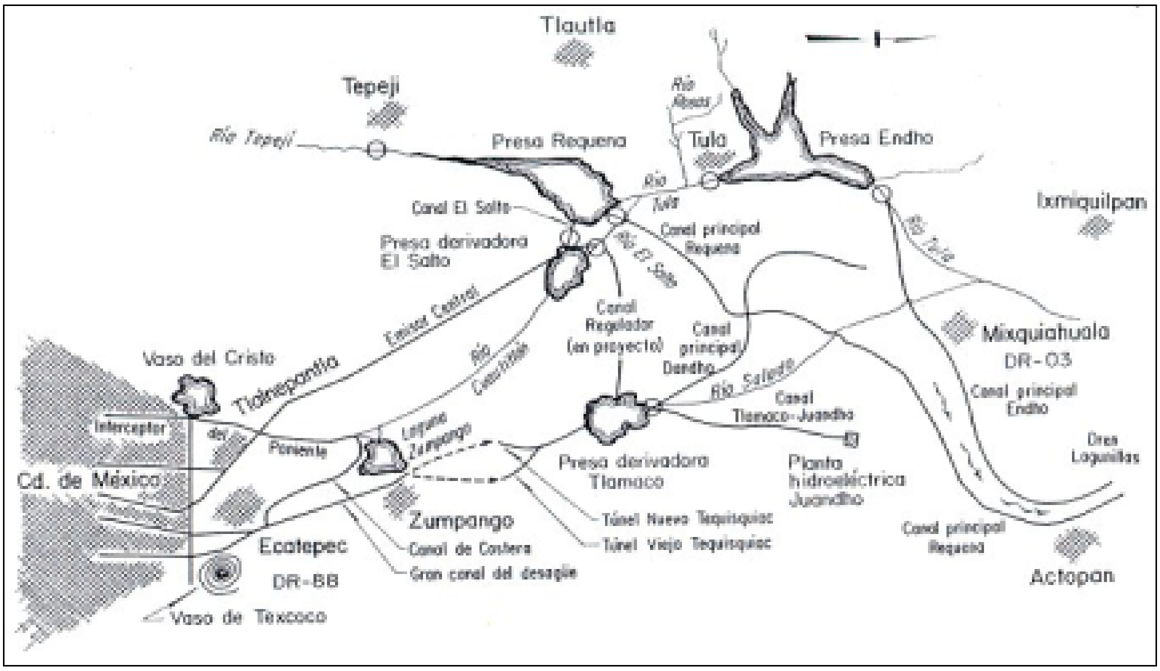
Mexico

B. Jiménez

Mexico is a country with apparent water sufficiency at the national level. However, two thirds of the territory suffers from lack of water. Frequently, domestic waste water is used for irrigation. In 1995, a total of 102 m^3/s of wastewater was used to irrigate 256,827 ha in the country.

An example of this practice is the Metropolitan Zone of the Valley of Mexico (MZVM) where rain and wastewater have drained from the south to the Mezquital Valley (MV) in the north since the end of the last century. Wastewater without any treatment has been used for irrigation of several crops and has allowed economic development of the region. This is the largest and oldest scheme for agricultural irrigation using urban wastewater in the world.

As a result of this practice, the level of the water table in the aquifer underlying the irrigation zone has increased. In the study presented to the meeting, the quality of water in the drinking water supply wells in the region and in the aquifer were analyzed.



Hydrological system of the Mezquital Valley

The results show that soil filtration removes a significant portion of wastewater constituents, especially organic compounds. Preliminary results indicate that the excess volumes of water in the aquifer could be used for human consumption if some ions and nitrate were removed, although precautions should be taken concerning remaining unknown organics.

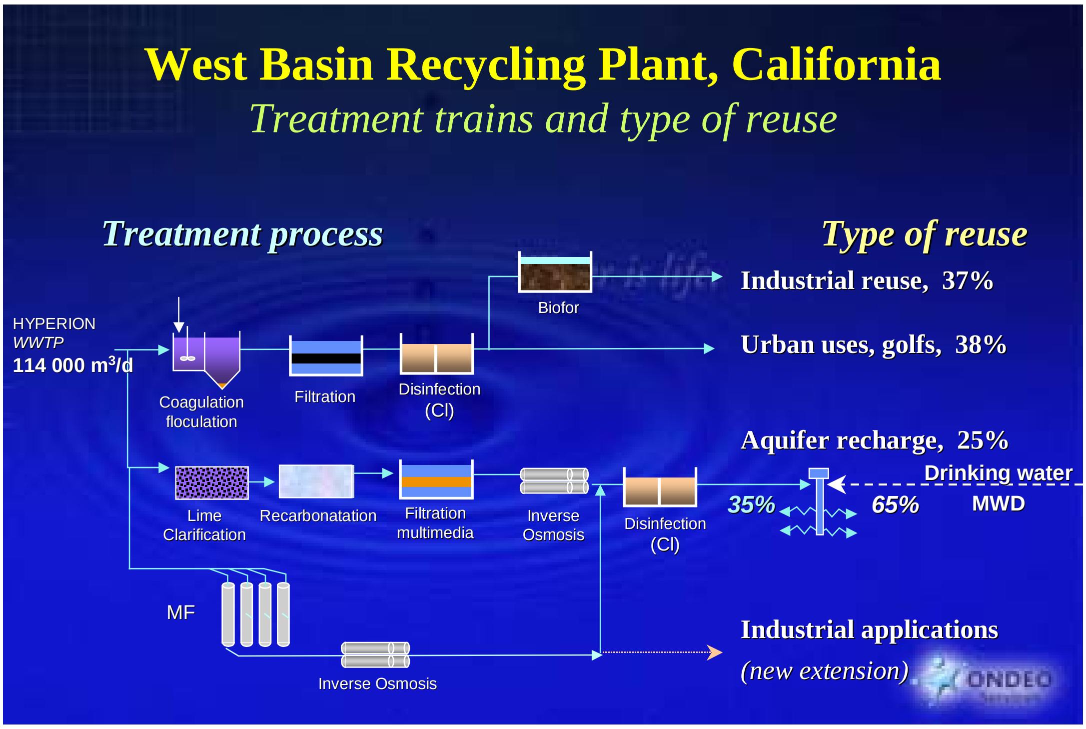
United States of America

D. Hranislavljivic

A presentation was given of research currently under way at the West Basin Recycling Plant, CA. Reuse of the water produced by this plant is 37% industry, 38% urban uses incl. golf courses, 25% aquifer recharge including for the production of drinking water, and a variety of industrial applications.

A description of the water quality control goals and monitoring programme was given.

Particular attention was given to removal of trace organics. Membrane filtration (MF)/Reverse Osmosis (RO) was found to have a higher efficiency for removal of trace organic compounds than lime/RO.



Emerging parameters identified included nitrosodimethylamide (NDMA) and organo tin compounds (OTC).

The technical challenges of aquifer modeling using tracer studies and WINGEO model development were discussed for the control of water quality, seawater intrusion, application of draw down or level rise limitations, control of recycled water residence time, and management of the barrier.

The presentation offered the following conclusions:

Better understanding of treatment efficiency

- Lime clarification favors the occurrence of organics (Base Neutral Organic Compounds) with direct health and treatment implications
- Membrane Filtration (MF)/ Reverse Osmosis (RO) is more efficient than Lime RO membranes to remove trace organics (related to pretreatment and nature of the RO membranes)

Development and use of new analytical tools

- Boron appears to be a viable solution to monitor recycled water in West Coast aquifers
- BNA broad spectrum analysis including large volume extractions has shown to be an appropriate tool to monitor for regulated and non-regulated trace organic compounds (lower detection limits)
- Organo-tins may not be an issue for the water barrier train

General conclusions

- A pluridisciplinary approach has to be applied to implement, control, and optimize indirect potable reuse projects
- Recycled water is a sound alternative resource with well controlled quality compared to the risk of non-point source pollution of aquifers
- Boron isotopes are appropriate, natural, and low cost tracers
- Advanced modeling tools needed to enable better description of aquifer behaviour and saline intrusion

Water reclamation and groundwater recharge in the USA

J Cotruvo

To increase the natural supply of groundwater, artificial recharge of groundwater basins is becoming increasingly important in groundwater management, and particularly in situations where the conjunctive use of surface and groundwater resources is considered.

Reuse of municipal wastewater including groundwater recharge for a variety of applications is feasible and it can be safely undertaken if appropriate planning, treatment, assessment and precautions are followed. It provides the opportunity for much more efficient multiple use of this essential resource that is in limited supply in many parts of the world. End uses may include irrigation of food and non-food crops, irrigation of facilities such as green spaces, parks and golf courses, sanitation, industrial processes and cooling, seawater intrusion barriers, and ultimately drinking water. The intended use will determine the required quality and management control level of the water so as to be protective of human health and the environment.

Several constraints limit expanding use of reclaimed municipal wastewater for groundwater recharge. The lack of specific criteria and guidelines governing the artificial recharge of groundwater with reclaimed municipal wastewater is currently hampering the implementation of large-scale groundwater recharge operations. Thus, the establishment of policies and guidance for planning and implementing new groundwater recharge projects is being proposed.

Speaker reviewed the health and regulatory aspects associated with groundwater recharge with reclaimed municipal wastewater, particularly in the light of the development of the WHO Guidelines on Drinking Water Quality, and discussed in detail the proposed State of California Criteria for Groundwater Recharge and Reuse Projects.

INTERNATONAL PROGRAMMES

The UNESCO International Hydrological Programme (IHP)

The representative of Unesco – IHP detailed the plan for Phase IV of the IHP (2002 – 2007). The following areas were found to be particularly relevant –

Theme	Focal Area
Global changes and water resources	Global estimation of resources – water supply and water quality
	Global estimation of water withdrawals and consumption
	Integrated assessment of water resources in the context of global land-based activities and climate change
Integrated watershed and aquifer dynamics	Extreme events in land and water resources management
	International river basins and aquifers
	Endorheic basins
	Methodologies for integrated river basin management
Land habitat hydrology	Drylands
	Wetlands
	Mountains
	Small islands and coastal zones
	Urban areas and rural settlements
Water and society	Water, civilization and ethics
	Value of water
	Water conflicts – prevention and resolution
	Human security in water-related disasters and degrading environments
	Public awareness raising on water interactions
Water education and training	Teaching techniques and material development
	Continuing education and training for selected target groups
	Crossing the digital divide
	Institutional development and networking for WET

Eight activities have been identified to have the highest priority in IHP – IV:

- Guidelines for the delineation of protection zones around public groundwater supplies and management policy
- Development of groundwater policy and management for wetlands protection and biodiversity conservation
- Effects of global changes on groundwater recharge, especially in arid and semi-arid regions in relation to water resources management
- Methodologies for risk assessment of wastewater re-use on groundwater quality
- Development of methodology (data acquisition and analysis) for studying responses of aquifers to extreme hydrological events
- Study of the dynamics of groundwater flow and chemistry in closed basins including long-term effects, especially in arid zones
- Evaluation of the impact of land-based sources of pollution on coastal zone resources
- Methodology for enhancing communication between water specialist, decision makers and communities to strengthen public participation in groundwater protection.

The speaker highlighted collaborative efforts between UNESCO and other agencies such as IAEA, and informed the participants of the coordinating role and the development of groundwater resource indicators. In line with these ongoing inter-agency cooperation and mandate of Unesco, speaker would welcome strengthened cooperation with WHO.

World Health Organization

A scientific contributor to the announced WHO Guidance Document *Protecting Groundwater for Health: Managing the Quality of Drinking Water Sources* reviewed the basic principles on which this work is based, particularly the Hazard Analysis and Critical Control Points (HACCP) and Critical Control Points (CCP).

He then introduced the proposed outline of the document as follows:

Section 1: scientific background information

- Groundwater system: hydrological and hydro-geological processes
- Health relevance, transport and attenuation of pathogens and chemicals in the subsurface
- Naturally occurring constituents

Section 2: information needs for the characterization and assessment of the catchment environment

- Basic understanding for current or past human activities and their potential pollutants
- Socio-economic and institutional conditions

- Type of information needed for assessing potential of groundwater contamination
- How to compile information
- Situation assessment

Section 3: management approaches

- Aspects of policy and law frameworks, enforcement, institutional capacity building and public participation
- General protection concepts (protection zones, wellhead protection)
- Good management practices (GMP) for avoiding groundwater contamination from specific human activities
- HACCP principles

CONCLUSIONS AND RECOMMENDATION

Participants to the meeting

1. appreciated the work done in terms of including source protection as one of the activities under the GDWQ by WHO and noted similar efforts by UNECE and UNESCO. In line with earlier statements in different international forums, they recommended that ways for closer co-operation between the different UN agencies be explored.
2. nevertheless observed that in may countries recharge of aquifers is being practiced for a variety of final applications, and that the health risks associated with this practice are not fully understood.
3. recommended therefore that a State of the Art report be produced and submitted to critical review before final publication.

Participants also identified the Regional Symposium on Water Recycling in the Mediterranean (Crete, 26 - 29 September 2002) or the 4th International Symposium on Artificial Recharge scheduled to be held from 22 – 26 September 2002 in Adelaide, Australia as suitable venues for follow-up.

Annex 1. State of the Art Report

INTRODUCTION

Chris Thoeye, Aquafin Belgium
Blanca Jiminéz, UNAM, Mexico

Water cycle:
Water cycle, relevant components for drinking water supply.
Water not created nor destroyed.
Driving forces:
Water scarcity, contaminants of concern, storage, saline intrusion
Recharge types:
Natural, unintended, planned recharge.

HEALTH CONSEQUENCES OF DIFFERENT TECHNIQUES

Blanca Jimiéz, UNAM, Mexico

Potential pollutants
Treatment process :

Multiple barriers, protection against system failure

Treatment performance

Recharge methods :

Surface spreading/Soil Aquifer Treatment,

Direct injection,

Advanced treatment

Aquifer :
Retention time, dilution,
Chemical conversion, microbiological processes, natural attenuation

HEALTH RISK ASSESSMENT

Chris Thoeye, Aquafin Belgium
Gideon Oron, Institute for Desert Research, Israel

Health risk prevention:

Comparative cost benefit analysis (water diseases prevention)

Model approach:

Mathematical models

Quality management approach: HACCP
Parameter approach:
microbial ;*chemical parameters***:** (what to measure, individual/group indicator parameters, toxicological screening/testing, biomonitoring)
Monitoring
Types, frequency, breakthrough. Monitoring and risk management

BEST PRACTICES FOR HEALTH PROTECTION

Wastewater source control (industrial pre-treatment, sewage treatment)
Barriers and risk management

IMPACT ASSESSMENT

Luciana Sinisi, ANPA, Italy

Human health

Population surveillance, long-term health studies

Ecology-environment

MANAGEMENT ASPECTS

Gideon Oron, Institute for Desert Research, Israel

Economic aspects

REGULATORY FRAMEWORK

Francois Brissaud, Université Montpellier II, France
Blanca Jiminiéz, UNAM, Mexico

Criteria for wastewater for reuse:

Wastewater sources control (industrial pretreatment)
Re-use regulated legislation for aquifer recharge

PUBLIC AWARENESS, ACCEPTANCE

Luciani Sinisi, ANPA, Italy

Risk communication, public acceptance, social aspects

CONCLUSIONS

Takashi Asano, University of California at Davis, USA
Jo Cotruvo, NSF USA

Water quality goals
Selection criteria for treatment
Risk and benefits – site specific

NOTE: Case studies to be included BRIEFLY

Annex 2: List of Participants

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