ISSN 1020-1203

FAO WATER REPORTS

35

The wealth of waste

The economics of wastewater use in agriculture

The wealth of waste:

The economics of wastewater use in agriculture

FAO
WATER
REPORTS

35

By

James Winpenny
Wychood Economic Consulting Ltd.,
United Kingdom

Ingo Heinz
Technische Universitatät
Dortmund, Germany

Sasha Koo-Oshima
FAO Land and Water Divsion

and Case Study Authors

Miguel Salgot
University of Barcelona, Spain

Jaime Collado
ICID, Mexico

Francesc Hernandez
University of Valencia, Spain

Roberta Torricelli
University of Barcelona, Spain

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Roma 2010

ISBN 978-92-5-106578-5

Copies of FAO publications can be requested from:

SALES AND MARKETING GROUP
Office of Knowledge, Research and Extension
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome, Italy

E-mail: publications-sales@fao.org
Fax: +39 06 57053360
Web site: http://www.fao.org

Acknowledgements

This document is carried out by FAO Headquarter Programme Funds with the participation of the Mexican National Committee for the International Commission on Irrigation and Drainage (ICID), Spanish Universities of Barcelona and Valencia, the Catalonian Water Agency, Dortmund University of Germany, and James Winpenny of Wychwood Economic Consulting, Ltd., UK. The work upon which the final report is based was originally synthesized by Prof. Ingo Heinz of Dortmund University with Case Studies prepared by: Jaime Collado, Miguel Salgot, Francesc Hernandez, Roberta Torricelli, and Lorenzo Galbiati.

The review of the document was conducted by: Richard Mills of California State Water Resources Control Board; Curtis Cooper of the U.S. Environment Protection Agency, Robert S. Kerr Environmental Research Center; Natalie Fonder of Faculté des Sciences Agronomique de Gembloux; and the FAO Land and Water Division.

Many thanks are due to: James Winpenny who made substantial contributions to the task of drawing together the material to form a single coherent and authoritative document; Sasha Koo-Oshima who initiated the study and was the FAO Programme Officer in charge of Water Quality and the Environment; Pasquale Steduto, the Chief of Land and Water Division who provided the budget; and Luis Rendon, President of the Mexican ICID and Irrigation Districts Manager of the Mexican National Water Commission who facilitated the project sites. Photo-editorial and graphic design assistance was received from Bouchra El Zein and Simone Morini.

Additional appreciations are due to field mission contributors and organizers:

Mexico

Engr. Sergio Soto Priante, Deputy General Director for Hydro-agricultural Infrastructure, Mexican National Water Commission

Engr. Filemón Rodríguez, Tula Reservoir ID003

Engr. José Rodríguez, La Purisima Irrigation Module

Engr. Carlos Rascón, ID052 Durango

Engr. Miguel Calderón, Durango Municipal Water Utility

Eugenio Garcia, Presidente of Water User Association, Cortazar Irrigation Module

Ramiro Merino, Manager of Cortazar Irrigation Module

Pedro Caudillo Mendiola, Productores Agricolas de al Presa la Purisima

Ignacio Acosta Mena, Productores Agricolas de al Presa la Purisima (Presidente)

Farmers of the represented Irrigation Districts

FAO-Representation to Mexico – Norman Bellino and Maria Carmen Culebro

Jaime Collado, Vice President of ICID Mexico, Organizer of Mexico field mission

Spain

Lorenzo Galbiati, Agència Catalana de l'Aigua, Water pricing and finance

Enric Queralt Creus, Comunitat d'Usuaris d'Aigùes del Delta del Llobregat

Elena Isla, Parc Agrari del Baix Llobregat

Ramon Terricabras Maranges, Parc Agrari del Baix Llobregat

Luis Sala i Genoher, Consorci de la Costa Brava

Farmers of river deltas represented in this report, and

Miguel Salgot, University of Barcelona and EU Aquarec, Organizer of the spanish field mission

Summary

REUSE AS A RESPONSE TO WATER SCARCITY

The use of reclaimed water in agriculture is an option that is increasingly being investigated and taken up in regions with water scarcity, growing urban populations and growing demand for irrigation water. This report presents an economic framework for the assessment of the use of reclaimed water in agriculture, as part of a comprehensive planning process in water resource allocation strategies to provide for a more economically efficient and sustainable water utilization. Many regions of the world are experiencing growing water stress. This arises from a relentless growth of demand for water in the face of static, or diminishing, supply and periodic droughts due to climatic factors. Water stress is also caused by pollution from increasing amounts of wastewater from expanding cities, much of it only partially treated, and from the contamination of aquifers from various sources. Such water pollution makes scarcity worse by reducing the amount of freshwater that is safe to use. Water scarcity in all its aspects has serious economic, social and even political costs.

At times of serious scarcity, national authorities are inclined to divert water from farmers to cities since water has a higher economic value in urban and industrial use than for most agricultural purposes. In these circumstances, the use of reclaimed water in agriculture enables freshwater to be exchanged for more economically and socially valuable purposes, whilst providing farmers with reliable and nutrient-rich water. This exchange also has potential environmental benefits, reducing the pollution of wastewater downstream and allowing the assimilation of its nutrients into plants. Recycling water can potentially offer a "triple dividend" - to urban users, farmers and the environment.

Reclaimed water use can help to mitigate the damaging effects of local water scarcity. It is not the only option for bringing supply and demand into a better balance – and this report shows how different options can be analysed for comparison – but in many cases it is a cost effective solution, as the growing number of reuse schemes in different parts of the world testify. A recent comprehensive survey found over 3,300 water reclamation facilities worldwide. Agriculture is the predominant user of reclaimed water, and its use for this purpose has been reported in around 50 countries, on 10% of all irrigated land.

BENEFITS OF REUSE

The feasibility of reuse will depend on local circumstances, which will affect the balance of costs and benefits. The major benefit in most cases is likely to be the value of the fresh water exchanged for high-value urban or industrial use. This would lessen the cost for municipal authorities of seeking their supplies through more expensive means. In addition, reuse prevents untreated wastewater discharge to coastal and groundwater systems with ecosystem and tourism benefits.

Depending on the local situation, there could also be benefits to farmers if they can avoid some of the costs of pumping groundwater, while the nutrient present in the wastewater could save some of the expense of fertilizer. There could also be benefits to the local environment from reduced flows of untreated wastewater – though the interruption in the downstream water cycle could have other, less beneficial, effects.

The costs and benefits of reuse projects

The costs of the reuse option could include the installation or upgrade of wastewater treatment plants (WWTPs) to produce effluent of the desired standard, any addition or modification to the infrastructure for water and reclaimed water distribution, the extra recurrent costs of treatment, and the cost of any produce restrictions imposed by the use of reclaimed water in irrigation. Where climatic and geographical features are suitable, low-cost treatment of wastewater may be an option through the use of stabilisation ponds, constructed wetlands, etc. The net cost of treatment may also be reduced through the reuse of biogas for energy and power in the intensive treatment processes, or potentially through the sale of carbon offsets.

ECONOMIC JUSTIFICATION

The economic appraisal of the project should be from a regional basin viewpoint, comparing its economic costs and benefits. Judging by the evidence of our case studies, it is unlikely that schemes could be economically justified with reference only to agriculture. Although farmers may be net beneficiaries from using treated wastewater, compared with their previous or alternative sources of water, this depends very much on local circumstances, and in any event their net benefits are unlikely to offset the full costs of the scheme. On the other hand, the benefits to urban and industrial users could be relatively sizeable, and in most cases would be the principal justification for the project. The net impact of the project on the local and downstream environment will also be very site-specific, and there are likely to be both benefits and costs.

FINANCIAL FEASIBILITY

Once the basic economic justification of the project is established, the next step is to examine its financial feasibility. The distribution of the costs and benefits of the project between different stakeholders is crucial to its feasibility. Its impact on the finances of the various stakeholders – national government, regional water authority, farmers, municipal utility and/or other major players – should be assessed. Financial gainers and payers should be identified to gauge the incentives, or conversely the penalties, to be applied and the type of funding that would be appropriate. Water charges, taxes, subsidies, soft loans, environmental service payments, and other instruments could all form part of the financing proposals.

A PLANNING FRAMEWORK

The economic framework for wastewater reuse presented in chapters 3 and 4 is intended to fit within a comprehensive planning framework. A sound and methodical planning approach will assist in identifying all the relevant factors necessary for the decision to proceed with a project. Chapter 5 presents such a planning framework, its key elements being: identification of problem and project objectives; definition of study area and background information; market assessment and market assurances; identification of project alternatives; appraisal and ranking of project alternatives; and implementation. Among the major specific technical issues to be addressed are: facilities and infrastructure, balancing supply and demand, wastewater quality, and public health risks and safeguards.

FACTORS ESSENTIAL FOR THE SUCCESS OF REUSE PROJECTS

The feasibility of reuse projects hinges on several key factors. The physical and geographical features of the area should be conducive to an exchange of water rights between the parties concerned. The extra costs (of treatment and infrastructure) should be affordable in relation to benefits. Farmers should be supportive, which depends on the net impact on their incomes, the status of their rights to freshwater, and what are their alternatives. Public health authorities should be satisfied that the projects pose no undue risks, after reasonable precautions have been taken. Finally, the environmental impact should be acceptable: the same impact may be acceptable or not in different circumstances, and different authorities will place a different weight on specific impacts in forming an overall judgement.[1]

A REALITY CHECK – CASE STUDIES FROM SPAIN AND MEXICO

On a global scale, only a small proportion of treated wastewater is currently used for agriculture, but the practice is growing in many countries, and in some regions a high proportion of reclaimed water is used in irrigation. The variety of case material presented from Spain and Mexico provides a good field testing for the approach presented in Chapter 3 on *Methodologies of Cost-Benefit and Cost-Effective Analyses.* Chapter 4 on case study results demonstrates that the methodology presented for appraising wastewater reuse projects is viable. Although the *Cost-Benefit Analysis* analytical framework is well able to incorporate the interests of municipalities and farmers, there is an important third party at the table – the environment – which needs a champion and a custodian. Reflecting the needs of the environment, valuing its assets and services, and ensuring that its financing needs are met, is a challenge to analysts in this area. The case studies confirm that reuse is an area ripe for the application and refinement of the tools of environmental cost-benefit analysis.

The case material demonstrates that certain items of costs and benefits are more robust than others. On the cost side, the capital costs of treatment units, pumps and canals can be estimated with high confidence, and their operating costs (pumping, chemicals, labour, etc.) are also fairly evident. The technology of wastewater treatment and its future level of unit costs are liable to change, and future options should not be prematurely foreclosed.

Most of the case studies stress the perceived benefits to farmers from the nutrient properties of effluent, plus savings in groundwater pumping and the greater reliability of effluent compared with other sources of water in arid and semi-arid climates. While pumping costs are reasonably firm, the benefits of fertilization depend on local empirical evidence ("with and without project"). The value of *reliable* wastewater also needs to be demonstrated more convincingly, *e.g.*, by a closer study of farmers' response behaviour where water supply is erratic or scarce.

From the viewpoint of urban water demand, the case studies reflect the widespread view that water supply tariffs are too low, hence there is a pervasive underestimation of the benefits created by developing new solutions to growing demand. However, some of the cases illustrate the importance (stressed in chapter 3) of distinguishing genuinely new benefits, on the one hand, from the avoided costs of meeting existing demand in a different way.

The analysis of the case studies has implications for policy towards the use of reclaimed water, depending on what its principal objectives are:

- *as a feasible and cost-effective means of meeting the growing demands of agriculture for water in regions of growing water scarcity and competition for its use.* This motive also applies in situations where demand is not necessarily rising, but where periodic water scarcity is a problem for farmers planning their annual crop patterns. The case studies contain evidence (*revealed preferences*) of farmers responding positively to the use of effluent in these situations, as

[1] Local environmental policy (pollution taxes, payments for environmental services, incentives for the recovery of heat from biogas, etc.) could tilt the balance in favour of reuse schemes.

a temporary expedient or long term solution. However, effluent reuse is one amongst a number of options at farm level to minimizing exposure to water risk. Moreover, the creation of expensive distribution and storage facilities, with a high recurrent cost, in order to furnish water for low value farm purposes, is not always warranted – unless there are benefits to other sectors.

- *as an environmental solution to the growing volume of wastewater effluent and its potential for downstream pollution*. The Mexico City-Tula case is the clearest example of the mutual benefit for the City and farmers from disposing of urban sewage and effluent to agriculture – and allowing natural processes to carry out some of the purification *en route*. Reuse schemes allow the dispersion of effluent and its assimilation across a wide area, as compared to the *point source pollution* from WWTPs. The reuse of effluent nutrients in crop production, rather than their removal and effective destruction during advanced processes of wastewater treatment also has a strong appeal to many Greens. The case studies confirm these environmental benefits of using reclaimed water.
- *as a "win-win" project that is a solution to urban water demand, while also delivering the agricultural and environmental benefits stated above*. The Llobregat sites and Durango City are clear-cut examples of potential win-win propositions since in both cases it is physically and geographically feasible for farmers to exchange their current entitlements to freshwater for effluent, and for the cities to gain access to the freshwater rights that are thus "released."

Whether or not "win-win" outcomes occur depends on legal and other barriers being overcome, as well as successful negotiation over the financial arrangements between the parties to the deal. It must not be assumed that farmers will readily give up their rights to freshwater, without further consideration of their operational situations. Most farmers prefer to have several water sources as insurance against drought. A cost-benefit approach helps to set the parameters for agreements between the main stakeholders, which in this report are assumed to be farmers, cities and the natural environment. It helps to define the interests of the parties in moving towards, or resisting, agreements that change the *status quo*. Where the balance between costs and benefits for one party (*e.g.* farmers) is very fine, the existence of a large potential net benefit to another (*e.g.* city or environment) can provide "headroom" for agreement by indicating the economic or financial bounty available to lubricate the deal.

The overall message the report seeks to convey is that the recycling of urban wastewater is a key link in Integrated Water Resource Management (IWRM) that can fulfill several different, but interrelated objectives. These are expressed as *win-win* propositions, delivering simultaneous benefits to farmers, cities and natural environmental systems, part of the solutions to the urgent global problems of food, clean water, the safe disposal of wastes and the protection of vital aquatic ecosystems. The traditional "linear society" is not a sustainable solution and the "circular society" has to become the new standard.

The annex to the report contains an extensive bibliography, testimony to the large and growing interest amongst the professional and policy communities in this important topic.

List of Acronyms

ACA	Catalonian Water Agency
BAT	Best Available Technology
BCR	Benefit-Cost Ratio
BOD	Biological Oxygen Demand
BOT	Build Operate Transfer
CBA	Cost-Benefit Analysis
CEA	Cost-Effective Analysis
CRF	Capital Recovery Factor
DALY	Disability Adjusted Life Years
DBOT	Design Build Operate Transfer
EA	Economic Appraisal
EDR	Electrodialysis Reversal
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FYRR	First Year Rate of Return
HACCP	Hazard Analysis and Critical Control Points
IRR	Internal Rate of Return
IWRM	Integrated Water Resources Management
MCA	Multi-Criteria Analysis
NDMA	N -nitroso-dimethyamine
NPV	Net Present Value
OC	Opportunity Cost
PES	Payment for Environmental Services
QALY	Quality Adjusted Life Years
QMRA	Quantitative Microbial Risk Analysis
SEEAW	System of Environmental-Economic Accounting for Water
STP	Social Time Presence
WFD	Water Framework Directive
WHO	World Health Organization
WTP	Willingness to Pay
WWTP	Wastewater Treatment Plant

Contents

List of figures

List of maps

List of tables

List of boxes

Chapter 1

Introduction to wastewater reuse

1.1 BACKGROUND, CONTEXT AND KEY ISSUES

The reuse of treated wastewater in agriculture is an option that is increasingly being investigated and taken up in regions with water scarcity, growing urban populations and growing demand for irrigation water. Many regions of the world are experiencing growing water stress. This arises from a relentless growth of demand for water in the face of static, or diminishing, supply and periodic droughts. Climate change is adding to these pressures: it is estimated that a global warming of 2 degrees Celsius could lead to a situation where 1 to 2 billion more people may no longer have enough water to meet their consumption, hygiene and food needs.

Water stress is also caused by pollution from the growth of wastewater and run-off from expanding cities, much of it only partially treated, from the release of agricultural fertilizer, and from the contamination of aquifers from various sources. This pollution causes eutrophication of surface water, one result of which is the formation of algal blooms, such water pollution makes scarcity worse by reducing the amount of freshwater that is safe to use by humans. The same factors are causing hypoxia (oxygen depletion) in estuaries and coastal waters, causing harm to fisheries and other aquatic life and negatively impacting ecosystem integrity. This is concern both to the environment and to local economies dependent on tourism and fisheries.

Water scarcity has heavy economic, social and political costs. The drought in Kenya in 1998-2000 is estimated to have reduced GDP by 16% over this period, falling with particular severity on industrial output, hydropower, agriculture and livestock. The cost of mitigating water crises is currently entailing huge sums in regions as diverse as California, Northern China and Australia.

At times of serious scarcity, national authorities are inclined to divert water from farmers to cities since water has a higher economic value in urban and industrial uses than for most agricultural purposes. In these circumstances, the reuse of treated wastewater for agriculture enables freshwater to be exchanged for more economically and socially valuable purposes, whilst providing farmers with reliable and nutrient-rich water. This exchange also has potential environmental benefits, reducing the release of wastewater effluent downstream, and allowing the assimilation of its nutrients into the soil.

Wastewater reuse projects can therefore offer a potential double or even triple "dividend" - to urban users, farmers and the environment. In typical situations of growing water stress the use of reclaimed water must be considered as an available option. In such cases the "without project" scenario will incur costs that will grow over time, and alternative solutions have serious costs of their own. To reject the reuse option could be costly in such situations.

1.2 PURPOSE OF THE REPORT

Agriculture accounts for around 70% of global water use, mainly in the growth of crops for food and raw materials and for processing agricultural products. When rainfall is insufficient to sustain crops, irrigation is necessary and adds to the cost of agricultural operations.