ABSTRACT

Title: Should economy govern wastewater reuse in agriculture?

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Abstract:
It is usually cited that wastewater reuse is limited by several technical, technological, legal, social and economic aspects, considering that there is sometimes a well-founded distrust on the part of the farmer towards cabinet decisions. Knowing that several of these aspects are set by legislation, political decisions, and water management policies, it may appear that the success of the practice is limited only by end-user acceptance, usually not well defined by rules and regulations.
The agricultural end-user, i.e. the farmer, should only proceed with the irrigation practice in combination with appropriate cultivation techniques. However, in full-scale practice, there are a number of difficulties, which is also the case, that are not well clarified by legal and water management initiatives.
This presentation describes, mainly from the point of view of agricultural economics, the limitations and benefits of reuse.On the one hand, the legislation limits itself to defining what happens if irrigation is carried out only with reclaimed water, but it does not clarify what happens from the sanitary, legal and economic points of view when mixtures of water of different origins (rain, water transfers, groundwater, desalinated, reclaimed, etc.) are used for irrigation in different proportions, varying over time.
Moreover, the crops used, fertilization needs, treatments and types of irrigation technology may vary according to the water origins and their qualities.
It is also necessary to study to what level existing legislation should be applied and whether it should apply only to reclaimed water before blending or to the final blend. In the latter case, there are serious legal doubts about some of the requirements of the EU Regulation on agricultural reuse.
This paper presents a decision tree specifying the technical, legal and economic approaches to be considered in the case of using mixtures of water from different origins.

Keywords: Economy, reclaimed wastewater, wastewater reuse, irrigation, agriculture
JEL codes: Q25; K3

1. Introduction

The increase in the use, and subsequently in demand, of water resources is due to various causes, such as the increase in living standards and the irrigation of larger areas of agricultural land, as well as the quick urbanization patterns worldwide. On the other hand, more and more human activities are related to water, especially leisure and tourism, which demand a landscape grown up with continuous contributions of water: urban grass areas, green spaces, golf courses, etc. The industrial uses contribute to the growing demand for water.

Water is a scarce resource in arid and semi-arid regions, but by analyzing water demands in some water-rich areas, problems of temporary and structural scarcity can also be detected. Medellin-Azuara et al. [1] indicate that in northern Europe, crops grow using "natural" rainwater, but because of product quality demand require irrigation during part of the growing season, at which point agriculture compete for water with other users to obtain the relevant supply. Looking at these facts from an economic point of view, these authors indicate that the value that water generates when using it in agriculture should be considered when making political, economic or financial decisions. The value of water and the ability of farmers to pay for irrigation water, in whole or in part, can be taken as a reference to assign a price to it, apart from other less relevant considerations.

It is to consider if the price should be intervened by the relevant authorities for any water supply and for any user. Conversely, the European Union (EU) considers that any costs incurred should be included in the price. In any case, it is true that water cannot be treated as a consumer good, as is essential for life on earth, and is also relevant when considering the health of the entire population and cattle, as well as safe environmental conditions. Hygiene and human health, as conceived in modern societies, depend heavily on a reliable supply of water from a qualitative and quantitative point of view.

This concept of reliable and safe supply is assumed by the legislation of a part of the EU countries, in which water is regarded as a demanial good, which cannot be privatized. However, in other countries water can be legally privatized. This is the case, for example, of Anglo-Saxon countries, which have a different water regime than the ones with Roman rules' origins.

In practice, the user has usually the right to obtain certain amount of water: this is the concept of concession. However, concessions have a number of weaknesses, which are not the subject of this work. It is worth to remember that if all the water concessions in certain rivers were used, there would be a very significant flow deficit (negative flow).

The solution to the timely, temporary or structural scarcity of water resources has been varying throughout history [2], and one of the solutions to demands' problems is to use the so-called non-conventional resources (Table 1), among which the most relevant are reclaimed water, salty or brackish water, grey and runoff waters [3].

Table 1. Water resources

Type of resource	Resource	Comments
Conventional	Surface water	Rivers, lakes. Includes water transfers. Usually require big infrastructures
	Groundwater	Aquifers, karst waters. They require prior identification and quantification of the number of resources available
Non-conventional	Grey water	Originates from the kitchen, bathroom, sinks, ... excluding excreta
	Reclaimed water	Treated wastewater including a reclamation process
	Runoff	Water flowing over the soil surface or impervious surfaces, usually after precipitation
	Saltwater, including seawater	They usually require desalination. Sometimes used directly successfully for irrigation of certain crops (see Table 2)
	Water transported by non-conventional means	Transport using boats, trains, tanker trucks, etc. in cases of drought or extreme need (disasters…)

Source: authors' elaboration

Instead of working with the supply to increase the resources available, demand can be managed; for example, in agriculture, with savings methods or by improving the efficiency of use, as specified in Table 2.

Table 2. Examples of methods of improving efficiency in the use of water resources in agriculture

Method types	Methods	Remarks
Classic	Increase effectiveness of irrigation techniques/technologies	Often require significant investments. Can lead to salinity problems
	Crop model changes	Changes in species or cultivars, rotation, etc. that consume less water whit an equivalent production
Innovative	Substitution of water (change of sources)	Adapt the water source to the necessary quality (salinity, chemistry, biology...)
	Changes in water quality	Use water of different qualities (especially in terms of salinity) depending on the vegetative stage of the crop

Source: authors' elaboration

Among the mentioned non-conventional resources, the most important in terms of quantity are reclaimed water and water with high salts content, including seawater. Runoff, especially from towns, and greywater, are increasingly being studied over the past decades in developed areas. In this work, focus will be put on reclaimed water from urban/domestic uses and its necessary treatment.

The use of water in several successive processes is an historical practice, prior to Greeks and Romans and already described in the Minoan civilization. From 1960 to the present day, a period of increased reclamation, recycling and reuse of wastewater can be described [4]. This activity has endured over the centuries in many places, especially for irrigation, since the greatest demand for resources in the arid and semi-arid areas of the world corresponds to agriculture, as repeated several times.

In the last two centuries, such practices have been scientifically described, either for agriculture (priority), so as not to dispose untreated wastewater into rivers (Germany and France, for example) with a parallel agricultural use, or in industry [5]. In fact, considering water uses in modern society (Table 3), virtually all of them can be satisfied with treated wastewater.

Table 3. Possible uses of water (including reclaimed one)

Category	**Use**	**Feedback**
Agricultural and landscape, gardening and leisure areas irrigation (traditionally it has been the most studied use for reclaimed water)	Crops	Traditionally the most widespread use; can account for more than 85% of the resources used in a given area
	Commercial nurseries	Very intensive and homogeneous crops. Great added value
	Parks	In cities or leisure areas. Require excellent quality if public access is granted
	School yards	Require excellent quality. Very sensitive use from a health point of view
	Highway medians	Ideal place to use reclaimed water
	Golf courses	Use of water resources much discussed from a public image point of view. In many places it is compulsory the use of non-conventional resources
	Cemeteries	With scarcely-visited gardens. Ideal for using reclaimed water
	Green areas without access, green belts	Landscape or buffer use. Ideal for using reclaimed water
	Residential areas and private gardens	Overuse is common. It requires very good quality water. Systems with high health risk
	Windbreaks	Fast-growing vegetation is required. Accepts reclaimed or low-quality water
Industry	Conditioning water	Cooling, heating in premises

	Cooling	In energy generation, steel mills, ... Reclaimed water with adequate quality can be used
	Boiler feed	Water with few salts, requires many additives, highly polluting effluent
	Process water	Requires good quality water, with treatments that can be (very) costly depending on the industry
	Water in the product	Some very sensitive uses: fantasy drinks, drugs, ... Drinking quality. Reuse not accepted in this case
	Packed waters, spas	Includes medicinal waters, excellent sanitary quality. Reuse not accepted in this case
	Hot springs	Uses in health and heating. Disinfection problems. Reuse not accepted in this case
	Public works	Dust control, aerosols can be formed
	Transport of materials	Drag, usually in mining, without quality requirements
	Dust control	Quarries, public works, roads ...
Urban uses	Domestic supply "potable"	Uses for drinking purposes, hygiene, baths... Excellent sanitary quality required. Use for drinking water is generally not accepted, although this is currently under discussion
	Ornamental (outdoors) water	Ornamental fountains, ponds, running water (streams, canals). Can be recirculated with adequate treatment
	Firefighting	It may require a specific distribution network. Discussion on the right quality
	Public and private works	Building activities, dust control, etc. Aerosol and salinity control is necessary
	Various cleanings	Washing, toilets, vehicles, boats
	Street cleaning	Cleaning at night. Requires adequate quality, aerosol control. Health risk
	Sewer management	Obstruction control, maintenance. Relatively low quality.
	Parks and public gardens Includes ornamental fountains	Very good quality water: regular users with risk
	Private parks and gardens	Overuse is common. It requires very good quality water. Very high health risk
	Circulating waters	Rivers, urban water flow
	Zoological gardens	Good quality water for contact with animals (drinking, bathing, habitats). Dragging materials with reclaimed water.
Generation of "biomass"/ organisms	Aquaculture	Fish, shellfish, ... Excellent quality required, forbidden the use of reclaimed water for this purpose in many countries
	Conventional cattle farming	Includes slaughterhouses. Good quality drinking water required
	Biomass / wood / fodder	Includes generating support material for composting processes
	Algae crops	Require nutrients and light. Adequate reclaimed water improves productivity
	Biofuel/biofuel production	Water for irrigation of vegetation. Adequate reclaimed water improves productivity
	Flow maintenance of water bodies	Lakes, ponds, rivers, wetlands, groundwater recharge (includes urban water systems)

Environmental uses / leisure / recreation other than irrigation	Snow "manufacturing"	Ecological problems when using good quality resources from high mountain ecosystems; can be replaced by reclaimed water
	Water stockage ponds	Firefighting, birds, etc. Good quality
	Ecosystem's recovery	Flora and fauna. Adequate quality, interaction with surface and groundwater
	Recharge against seawater intrusion	In the coastline: aquifer/sea interface. Excellent quality water is often used after extraction, even if it comes from reclamation activities
	Subsidence control	In overexploitation of aquifers, reclaimed water can be used to recover levels or maintain them

Notes: Some uses appear twice, because they can be included in more than one concept
Source: Modified from Salgot, 2008

Because wastewater reuse has been the most widespread use of non-conventional water resources, the volume of related literature about this practice is very important, and its citations must necessarily be limited in any paper.

Salgot and Vergès [6] made a first approach to the conditioning factors that affect wastewater reuse from the economic point of view, which, of course, are not strictly economic:

The first consideration is to what extent is it profitable to try to use non-conventional resources, especially reclaimed water? It is to compare with several alternatives to increase the available resources, e.g. large infrastructures have to be used to bring water from hundreds of kilometers away?

The answer depends on the point of view: ecological, environmentalist, engineered, sanitary, economic… When dealing with agricultural reuse, the point of view of the end-user is basic, and of course, existing infrastructures exert an influence in the final cost. Apart there are the imponderables, intangibles and externalities, which can appear at diverse moments of the procedure of reuse implementation.

Salgot and Vergés indicated at the end of last century that the improvement of the management of water resources was still pending; assuming a sustainable management of the global water cycle in relation to the economic growth of each region. Perhaps the key point is the realization that in arid and semi-arid zones, the balance between supply and demand is quickly reached. In these areas, the two basic problems of water resources immediately appear: quantity and quality, combined with a third factor, the need for water to maintain hydrological balances.

Young [7] defends two theses:

- The external manifestations of the problems associated with water (scarcity, pollution, conflicts over water concessions, degradation, etc.) are only symptoms.

- Sufficient regularities can be found in human interactions with the water resource so that recurrent and systematic patterns of water use can be described, the sources of water-related problems diagnosed and resource allocations improved, and this can be done on an institutional basis.

More recently, some authors edited books that summarize reuse practices. We can highlight Asano et al. [8] and Jiménez and Asano [9] as well as a number of papers.

2.Sociological Analysis

The social aspects of reuse have been raising concerns in recent years, due to the societal concern and reluctance on the reuse of reclaimed water. While it is true that such concerns have been diminishing, a number of reasons still persist, which to a greater or lesser extent cause resistance to the use of these waters. According to Asano [10], the reasons of end-users for refusing the reuse used to be as follows: 1) concern about the harmful effects of reclaimed water on industrial processes, gardening or crops; (2) may possess their own water supply, which may have for them a lower cost than connecting to the municipal network or the price offered for the use of reclaimed water; (3) a disagreement in the price of regenerated water; (4) reluctance to pay for additional costs in driving or transporting reclaimed water to be driven to the reuse point; (5) the point-of-use may be located outside the limits proposed in the project, requiring negotiation with other jurisdictions; and 6) local or state health departments may disapprove of the use of reclaimed water because of the existence of public health risks.

Whatever is the attitude of users for the implementation of reuse projects with success; the community is required to be involved, informed about the origins of this water resource and know the security of the process, including also relevant associated costs for information and training. Globally, public administrations have almost always acted without a clear policy of relationship with the reclaimed water end-users. Usually, the end-user does not have direct access to the proceedings of the project nor has participated in the discussion of the performances. This approach to projects has drawbacks, as most stakeholders are increasingly aware that environmental decisions have a significant influence on their quality of life and do not easily accept proposals from water authorities. Responding to this concern, one of the EU's cross-cutting policies is communication. In other countries with environmental concerns fostered by the economic development, participation and communication policies have been initiated, as is the case in Australia, the United States or Japan.

On the other hand, the need to comply with restrictive or excessively demanding rules and regulations, even if those are from low technical quality, requires significant costs, both in infrastructure and in maintenance and control, including analytics. It should also be considered that conventional drinking water is increasingly tending not to be separated from other types, called unconventional (stormwater, regenerated, desalinated, transported by unconventional means). That is, to be considered in an integrated way all resources, allocating their use according to the actual quality of the water. [11]

In this context, communication techniques are being progressively developed and described by several authors in recent years. The objective is to train the end-user who must afterwards be able to contemplate critically the information provided to him and any possible attempt of manipulation. As an example of these environmental concerns, controversy has begun in recent years over the public's tendency to consume bottled water instead of "tap" water. Howd [12] states that in some ways it is an example of public use (by the consumer) of the precautionary principle. Consumers have heard or read information about drinking water contamination, and some of them have even analyzed their company's report or water management.

However, the most important aspect of bottled water use is the exercise of consumer choice: the public chooses what they perceive as a higher quality product, even without evidence to prove it. In this same context you can find the home devices that are connected to the taps to "theoretically" generate better quality water. This consumer concern can be defined as an erroneous association on which of the two products (bottled water and tap water) presents the least risk; mistakenly associating organoleptic quality with sanitary quality. In this context Doria et al. [13] indicate that the less quantifiable or intangible aspects of the subject, such as taste, comfort and even the fashion of consumption of a given bottled water, should not be underestimated. By applying these concepts to reuse, public acceptance has been revealed to be essential to the success of reclaimed water reuse projects.

There is growing concern from EU, USA and other developed countries on the communication about users' concerns on water quality and the impact of the media on creating fake health alarms. Public concern is also affected by the fact that, in recent years, recurring episodes of drought have sharpened the perception that there is a water scarcity problem and users want to be well informed about the whole water cycle.

As a result, communication and participation policies that aim to allow stakeholders (including end-users) to have an opinion on the environmental and water issues affecting them have been developed because.

3. Environmental Analysis

Wastewater recycling is a hazardous practice, and consequently its management must be associated with a risk analysis. The aim is to achieve the maximum quality of water resources while minimizing health, environmental, agricultural and food-related risks. In parallel, water authorities should develop strategies for managing the use of reclaimed water, including those for managing waste generated in the reclamation processes. The primary objective of this management should be the production of high-quality water with reduced, legal, levels of pathogens and chemical contaminants.

Depending on the quality of wastewater, restrictions on end-uses are required in order to control the routes of human, crops and livestock exposure to pathogens and chemical contaminants. As a result, generators, suppliers and users of reclaimed water and other types of water resources, should work together to identify and establish the potential exposure routes associated with reuse schemes. The development topics on the subject are: environmental impacts, human and animal health, safety of crops and food, and legal responsibility, apart from training and information policies.

The dangers posed are variable, depending for example (agriculture) on the physical situation (in relation to residences or watercourses, for example); land characteristics (soil types, slopes, salinity, aquifer depth, etc.); facility size (volume of regenerated water); and application and end-use techniques (golf course irrigation, food crop irrigation).

When wastewater is reused in a planned manner, water authorities take proactive actions, granting permits (authorization or concession) and becoming ultimate managers of the entire process. With these premises, water authorities want to be reasonably sure that the system does not create any hazard to the people or the environment. This safety against hazards and risks must be determined using appropriate tools. Two of those tools are considered to control what happens to the environment and citizens when reclaimed water, and in general all non-conventional water resources, reaches the environment: (a) environmental impact calculations or assessments; and (b) hazard/risk assessments in relation to the environment and humans.

In all reuse studies it is necessary to define: the legally established quality of reclaimed water, its system of application, the contact between water and the receiving environment including humans, the effects of the contact, what happens with the water once it reaches the environment, and what happens to the different matrices that come into contact with reclaimed water.

In general, a wastewater treatment or reclamation system has a complex relationship with the place where it is located, as described in Table 5 and Figure 1.

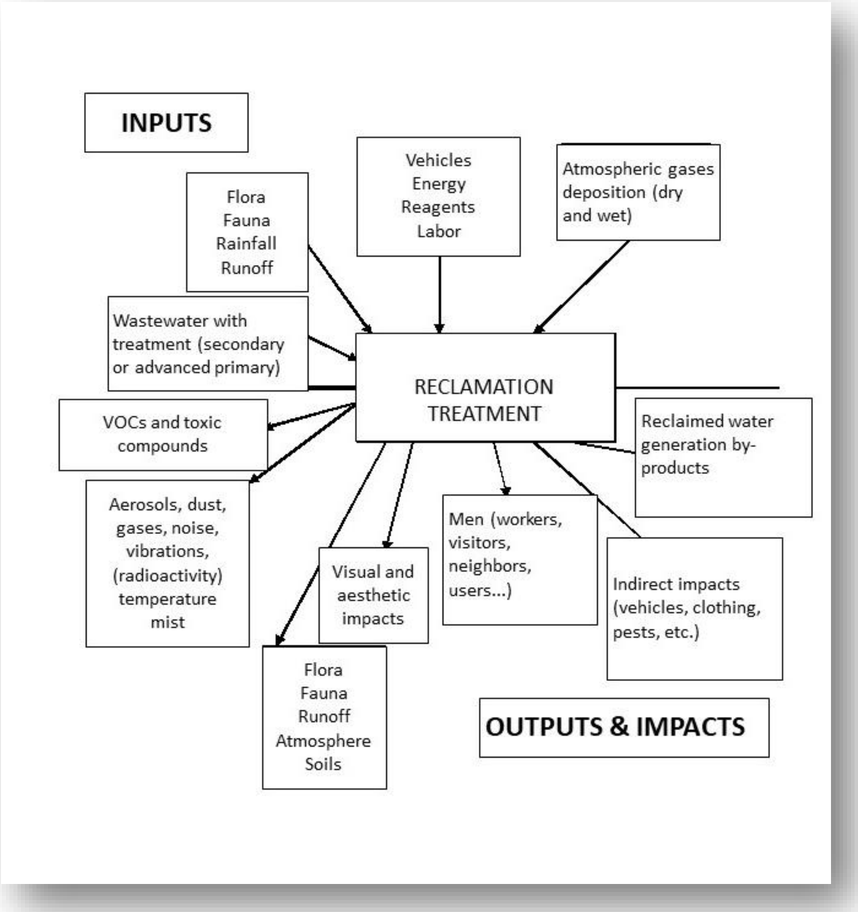
Table 5. Environmental, economic and social impacts of a wastewater treatment facility (not exhaustive)

	Primary effects	**Side/secondary effects**	**Tertiary effects**
Direct Impacts			
Short term	Soil erosion during construction	Degradation of aquifers, habitats or streams Recharge of water bodies	Reduced fish catches Landscape and leisure uses improvement
Long term	Periodic emission of harmful gases Ecosystem recovery	Increased price of agricultural lands Reduced price of adjacent properties	Changing the socioeconomic composition of the neighborhood
	Indirect Impacts		
Short term	Employment in construction tasks	Temporary homes (accommodation)	Necessary infrastructure changes
Long term	Housing developments in the service area	Increased traffic on local roads	Traffic congestion, noise, smog, ...

Source: authors' elaboration

Must be considered that treatment, reclamation and reuse systems are "physically" in the field, creating servitudes (e.g. infrastructures passing through the area) and maintenance needs. The aesthetic impacts of the installations must not be forgotten, as well as the organoleptic incidents (basically odors) that happen more or less periodically and that are both internal and external. Although those impacts are difficult to fight against, a good communication policy can help make them more acceptable.

Figure 1. Inputs, outputs, or impacts (outputs) of an active working wastewater reclamation plant.



Source: authors' elaboration.

4. Economic Analysis

In a first global approach, it may seem that the use of non-conventional water resources is beneficial, without drawbacks, thus following the institutional propaganda that presents it as a solution to drought episodes. A second approach shows that the practice also has weaknesses, such as negative environmental and health impacts.

Economics also conditions the use of non-conventional resources, especially compared to common, conventional resources. For this reason, and because each geographical

situation has specific conditions, in-depth economic studies are needed that define the cost-benefit constraints and the viability of each project.
In general (Table 6), each conventional and non-conventional water resource has specific characteristics associated with the economy. In this context, the question arises as to what the price of water should be for some of the activities described in Table 3.

Table 6. Relationship between water resources and economy: main aspects

Resource	Use	Economics
Surface water	Drinking, agriculture, other irrigation practices, industry, urban uses, landscaping, transportation, ... with or without treatment	May require regulation (reservoirs) and transportation to the point of use
Groundwater		Pumping and distribution needed
Reclaimed water	Virtually all uses except drink	Regeneration, distribution and control costs
Seawater	Cooling. With desalination: all uses	Very expensive desalination (in terms of energy)
Brackish/Saline water	Cooling or irrigation of non-sensitive crops without desalination. With desalination all uses allowed	
Rainwater/Runoff	With treatment, all uses. Without treatment agriculture-related uses	Recovery costs (collection), treatment, storage and distribution

Source: authors' elaboration

Most economic analyses of reuse have been carried out for agricultural uses. In this field, economic feasibility analyses should consider the costs involved in the alternative supplies [14], but also crop type, profit margins, local esteem for the environment, irrigation methods and supply guarantees, among other aspects. However, water quality must be analyzed before the calculations are considered and whether the quality needs to be modified to meet legal requirements. The cost of this quality change should also be taken into account in economic calculations. Comparisons with the remaining water resources, whether conventional or non-conventional, can be made from here on.

While there is little economic work in the literature on wastewater reclamation and reuse, the need to include such analyses has been gradually increasing and in recent years the need for economic studies for the design and implementation of efficient water resource management policies, as set out in the Water Framework Directive itself (Directive 2000/60/EU) is becoming increasingly evident.

To initiate a comparative analysis of the costs associated with each alternative supply, which must be compared with reuse calculations, several wastewater aspects should be considered: a) Additional treatment to convert secondary effluent into reclaimed water (reclamation process): must include operation, maintenance, and cost of reagents; b) Pumping and distribution of the resource: operation and maintenance; and (c) Costs related to analysis, bureaucracy, formation and information.

Analytical costs should be considered to differ, mainly due to the different regulations and recommendations applicable to different resources. The operation concept includes energy costs. In general, the cost structure varies depending on the size of the facilities: the determination of the cost-effectiveness threshold will also indicate the minimum size of a plant so that the competitive use of the water it generates can be ensured.

To determine the potential for reuse [15], the water flow rates that can be reused should be analyzed, including the determination and calculation of: (a) potentially available "reclaimed water" resources; that is, those that can be obtained from existing plants or facilities, but after building the necessary reclamation systems through investments, or, if there is capacity, increase the volume of reclaimed wastewater produced (more than previously done); and (b) the resources of reclaimed water that could be obtained from newly built facilities.

The following points should be considered: (1) detailed analysis of wastewater treatment and reclamation processes, in order to obtain cost functions; (2) determination of the efficiency of reclamation infrastructures; and (3) determination of the existence of possible differences at cost level depending on the end-use of the effluent (specific use).

Knowledge of the costs associated with the reclamation treatment and water reuse is seen as a basic requirement for assessing the actual potential for reuse at a given site and facility. These calculations do not include the cost of conventional wastewater treatment, except where additional installations are required in order to proceed with reclamation [16]. The obvious reason is that conventional or secondary treatment must be performed by law, and should be paid by citizens with their taxes, regardless of whether the purified water is reused or disposed of into the environment at a later date.

Additional information on potential water demands will be required to analyze the reuse possibilities, for example: (a) in the case of agricultural irrigation, crop type and surface, seasonal water demand, irrigation frequency, quality (especially salinity) and availability (security of supply) of irrigation water from conventional sources; b) for urban uses, the type of use (watering parks and gardens, street cleaning, sewer management, ...), quality for each case, seasonal or continuous demand for water, and security of supply; and c) for ecological flow (minimum flow) seasonal demand and its relationship to climate, quality, ecotoxicity, etc.

The classic method of water resource management has traditionally been to meet demands by increasing supply. This type of management is currently considered obsolete and is being replaced by the so-called integrated management, which, among other things, attempts to adjust qualities to demand; that is, to use the existing water resource that is most adapted to the specific use, thus saving on treatment costs. The main economic objective is the optimization of resources (currently and potentially available) in terms of costs and in the specific area of study, with the primary purpose of efficiently meeting the different types of demand.

From a demand perspective it is important to analyze in each case: current uses, quality needs, water saving possibilities, forecasts of new needs, seasonal nature of demand, and potential uses. The underlying idea is to analyze the water supply from various origins (sources) that is used for various purposes and ensure that demand is met at the lowest possible cost.

To be able to make more complete calculations it is necessary an analysis of the price that is paid to use surface and/or underground water. In this sense, it is important to consider the availability of resources, their quality whether or not they are from aquifers, their cost of collection, etc. In addition, there are several considerations that should or should not be considered depending on the depth of the economic study: differences in economic analysis procedures, associated bureaucracy, communication costs, and positive or negative impacts on the environment.

Reclaimed water is what is called a "replacement resource"; that is, it is exchanged for another, allowing the latter to be available for other uses. If these have a higher value (e.g. for drinking water instead of agricultural irrigation) benefits of the practice can be expected.

When analysis is done at the basin level, direct or indirect benefits can be defined. Among the directs benefits we will first highlight the hydraulic infrastructures: new collection and storage infrastructures are reduced and the available water resources are increased. Among the indirect benefits we will highlight: a) Recycling of pollutants: nitrogen and phosphorus are useful for agriculture, so that their negative environmental impacts are reduced; b) Use of the resource: guarantee of supply in times of structural or seasonal scarcity and water quality adaptable to various uses; c) Environmental benefits: avoid water bodies contamination and recovery of rivers and wetlands; d) Education: contributes to the knowledge of water culture; and (e) Social benefits: new jobs, greater integration into European Union policies, maintenance of environmental quality (important for tourism) .

Regarding costs (negative impacts) among other, will be highlighted: a) Cost of reclamation infrastructures and additional costs of operation, maintenance and analysis; b) Chemical and biological health risks associated with the reuse of reclaimed water; c) Loss of value of areas near the reclamation plant and d) Costs associated with socioeconomics.

For the economic calculations is important to determine which is the beneficiary, although in some cases, it is not clear at all. Nevertheless, in those cases where the beneficiary can be both the administration and a private user (e.g. agriculture, urban reuse) a different problem arises: Costs are calculated as equal for all users, or it is considered that the private user must subsidize the public one.

Table 7. Segregation of reclaimed wastewater uses by type of beneficiary (not exhaustive)

Private beneficiary	**Public beneficiary**	**Not attributable**
Urban uses (partial)	Urban uses (partial)	Leisure (mainly)
Agricultural irrigation	Groundwater recharge	Environmental improvement
Livestock	Potable reuse?	Water bodies
Fish aquiculture		
Industrial uses		

a) Private:

It seems that in this case, the expenses should be fully paid by the beneficiary (farmer: defined as the end user?).

However, this end user may be obliged to use reclaimed water; whether or not it replaces other resources. This is the case, for example, of golf courses and farmers, consumers of large volumes of water for irrigation.

Sometimes, the permit for the activity is conditioned to the use of reclaimed water, so it could be discussed whether the possible surcharges should be borne by this end user. Another consideration is that reclaimed water is the only water available (e.g. agriculture in arid areas), so that the user is captive if he wants to develop his activity,

b) Public

In cases such as aquifer recharge, the reclaimed water resource is used to increase resources at the basin level or to recover river ecosystems, in addition to storing water for supply. In this case, the beneficiary would be the basin, which is in the public domain.

c) Undefined

Several activities in reuse have not a well-defined end user, the beneficiary of a reuse activity. As a result, it is even more difficult to attribute costs and expenses.

In the field of water management of wastewater, and also for reuse activities, there are several possibilities: Public management, at different levels of administration; Public management by public companies (publicly owned); Private management, by contracts with the administration; and Management by companies, owned in part by public capital and also by private one.

For wastewater reclamation facilities, there are also other possibilities: User communities, can manage also the distribution systems; and Reclamation facilities (exclusively) operators.

In any case, the basis of management is the concession by the administration of a water flow.

5. Analytical tools

When it is necessary to study the social and economic impact of a given policy or project, in the context of implementing policies and selecting measures; a series of methodologies are applied as support systems, being the Cost-Benefit Analysis (CBA) one of the techniques traditionally used. As the OECD [17] states, CBA is trying to answer a main question: is it necessary (or not) to initiate a specific investment among different alternatives, and if the investment funds are limited, which one or ones should be selected.

The CBA has the purpose to describe and quantify the pros and cons of an expenditure project. The objective function of a CBA consists on the net social benefits, while the objective function of a firm are the private net benefits. Then, the immediate difference between the valuation of expenses policies based on the CBA o on private incomes is that the CBA is trying to consider all the losses and earnings from the standpoint of the society.

The maximization of the net social benefit requested with the CBA requires the identification of the entire costs and entire benefits relate do a specified project of public expenditure. For this reason, all the internal and external benefits of the project should be included, as well as the opportunity cost, which means the cost of the discarded alternative.

According to the European Union [18], performing a CBA to evaluate the economic viability of a project consists on seven steps: Description of the context; Definition of the objectives; Identification of the project; Technical viability and environmental sustainability; Financial analysis; Economic analysis; and Risk (or sensibility) analysis

Adapting it to a wastewater reuse, the previous steps could be reduced to which follows:

1)Context description: It is important at this point to clarify the scope of application of the project, i.e. the institutional framework: national, regional or local. This will clearly affect the appropriate rules and regulations, can affect the tariffs and the organization and characteristics of the water services.

It is also important to know the socioeconomic information, like the number of inhabitants of the area, population affected, economic activities of the area: agriculture, fisheries, touristic and leisure activities, etc.; also, the per capita income, the added value which involve the economic activities and its contribution to the GDP, among other.

2)Definition of the objectives and identification of the project: at this point, it is necessary to specify the type of reuse project: irrigation, reducing the aquifer stress, etc. The technical description of the project (machinery, manpower, etc.) will allow a clear identification of the internal costs, as well as the start point to identify several possible external effects. The definition of the area of study is basic to establish the influence of the project and in this way determine the impacts generated inside this area.

3)Identification of the costs and benefits: the maximization of the net social benefit as required by the CBA, makes it necessary to identify all costs and benefits related to the project, i.e. all the impacts generated by the project, which implies both the internal or private, and external impacts.

Because an inadequate management of wastewater can generate important costs both in social and environmental terms, can be considered that their adequate management and treatment imply considerable benefits, in term of avoided costs.

Additionally, other types of costs can be mentioned as “costs derived of no-action” or opportunity costs; which are benefits derived from the adequate treatment of wastewater which would be foregone in case of no treatment; not implementing the reuse program. Then, those will be the benefits derived from the reuse project.

Alternatively, it is necessary to consider also the costs and benefits derived from the action, i.e. the reuse project itself. Two types of impacts (benefits and costs) can be described: direct and indirect, depending on if they affect the stakeholders directly implied on the project or they have effects on third parties. Then, those will be the benefits derived from the reuse project. Examples of direct or indirect impacts appear in the Table 8.

Table 8. Costs and benefits in the wastewater reclamation projects (modified from AQUAREC, 2006 and De Souza, 2012). [19] [20]

Direct costs	**Indirect costs**	**Direct benefits**	**Indirect benefits**
Distribution of reclaimed water	Effects on the carbon footprint of the water cycle	Additional water supply	Environmental changes (including landscape changes)
Additional treatments (reclamation)	Public health effects	Reliable resource	Recreation (quality improvement of existing water)
Storage systems and pressure maintenance	Public perception of reduced quality	Local control	Value of nutrients (for irrigation)
Quality monitoring and evaluation (safety)	Effects on downstream flows	Avoided cost of other projects	Value of properties
Additional management (administration)	Water quality impacts (perception)	Diversion of effluent discharge (consider impacts)	Resilience (drought episodes, guarantee of supply…)
Formation and information	Effects on soil, plants and wildlife	Regulatory certainty	Greenhouse gas reduction/energy conservation
Project preparation	Effects on agriculture	Win-win approach for owners/users	Integrated resources management

4)Valuation of the benefits and costs: Once identified the benefits and costs derived from the project, is necessary to evaluate them. If all the values could be observed in terms of market prices, the measurement will be easy. Nevertheless, this is not always true, because many times the costs and benefits are intangible, and sometimes the market prices will need an adjustment, because the markets are not perfect and distortions could appear.

Considering that the final objective of the CBA is to obtain the highest degree of efficacy in the expenditure behaviour, the prices at which the costs and benefits are evaluated must reflect the social valuations of the goods and resources at stake.

The main problem of this type of evaluation is that because of the characteristics of several types of goods reflect the public expenditure, it is not possible to establish market prices for them. Following this criterion, the market prices can be a poor indicator of the social costs or benefits, and cannot be accepted without modifications when evaluating costs and benefits. Then, adjustments will be required.

The different possibilities of evaluation of each group of costs and benefits will be analyzed from now on. First of all, the direct impacts (internal) will be studied considering as positive impacts the incomes derived from the sale of reclaimed water or any by-product and as negative impacts the investment, operation and maintenance costs. There are also included all the costs related to civil works, supply and installation of electromechanical equipment, design costs, salaries, energy, regents, etc.

The evaluation of this cost modality is a fundamental phase in the planning of a wastewater reuse system and is also necessary for making a comparison with other conventional and non-conventional resources. Although there are various methods for the valuation of these costs, in recent years multiple linear regression methods have been used [21].

With regard to indirect (external) impacts, it should be noted that in this case reference is made to external effects or externalities, which can be positive (benefits) or negative (costs). As an example of indirect benefits and costs of a reuse project we could highlight the modification of existing surface water and groundwater hydrology, and changes in water quality.

These impacts can affect: human health, the environment, and economic activities [22]. The valuation of health impacts includes aspects such as: medical expenses for the treatment of diseases, indirect costs derived from the disease, pain and suffering associated with the disease.

Of the three, the first has direct and clear references for its valuation, while the other two require indirect formulae. Indirect costs derived from illnesses refer to issues such as the value of lost work time, decreased productivity, etc. The most widely used method for valuing these indirect costs is the human capital method [23] [24], which calculates the expected lifetime earnings that the individual would have had if the illness or premature death had been avoided, thus using lost earnings as a proxy for lost productivity.

When dealing with non-market values, the most commonly used methods for estimating the economic value of avoided health costs derived from risk reduction associated with improvements in drinking water quality have been based on the Willingness to Pay (WTP) [25].

In the valuation of environmental impacts, it should be noted that in the case of water some environmental goods and services are traded in the market and therefore have assigned prices, for example, commercial fishing. There are, therefore, revealed preference methods, in which consumer preferences are inferred from purchases made of goods with a market price. These methods reflect the payments that consumers actually make for better quality water, for better recreational facilities, etc.

However, there are other values associated with improved water quality, such as aesthetic values and species diversity, that have no connection to markets. In these cases, other valuation methods have to be used, through hypothetical markets. These are the so-called direct preference methods, in which individuals are asked directly about their preferences on the basis of questionnaires.

Among the revealed preference methods, two are worth mentioning: the "travel cost" method and the "hedonic price method".

The “travel cost method” is commonly used to estimate the value of recreational sites. The basic premise of this method is that the time and travel cost that people spend to visit a place represent the "price" of access to this place. Thus, the "willingness to pay" for the visit can be estimated based on the number of trips people make to this place with different travel costs. This is a useful method when trying to understand the benefits of improving the environmental quality of particular places, for example, the benefits of reducing eutrophication in a lake and thus increasing the quality of its waters.

The "hedonic price" method breaks down the price of a private, market good into several characteristics. Each of these characteristics has an implicit price, and their sum determines, in an estimable proportion, the price of the market good being observed. If we take the purchase of a house as an example, this method consists of analyzing the data using regression analyses that relate the price of the house to its intrinsic characteristics and the environmental characteristic of interest, which in this case could be the quality of the water in the area. In this way, the effects of the different characteristics on the price of the property can be obtained. The regression results indicate how much house prices will change as a function of small changes in each characteristic, holding all other characteristics constant.

In the case of water this method would recognize that water quality affects home prices near a lake or river. Differences in housing prices would reflect individuals' valuation of clean water.

So-called direct preference methods, known as "contingent valuation" methods, allow the estimation of the value directly from respondents' answers. For example, the survey may ask the willingness to pay to reduce eutrophication in such a way as to increase transparency in the water or to increase fish species by a certain amount.

All of the above techniques require the collection of a significant amount of data and are sometimes expensive methods. When the cost of data collection is very high or the time available is limited, another valuation technique can be applied: the so-called “benefit transfer” [26], which consists of using the results of other similar studies already completed, although there may be difficulties in applying them to specific cases where there is no significant degree of coincidence.

Finally, we refer to the impacts on economic activities. It will be necessary in this case, to have perfectly identified those economic activities negatively affected by wastewater and, therefore, positively affected in the case of carrying out the wastewater reuse project.

There are many and varied economic activities that can be affected by the improvement of water quality, such as industrial production, crops, fishing, agriculture or tourism.

All these impacts usually have a market value and can be valued monetarily without too much difficulty by analyzing the changes in the production of each economic activity when changes in water quality occur, keeping other production factors constant.

Table 9 shows some examples of externalities and possible valuation methods in a water reuse project.

Table 9. Externalities related to water reuse systems and methods for their valuation

SECTION	**EXTERNALITIES**	
	IDENTIFICATION	**VALUATION METHOD**
Infrastructure	Avoids water purification costs	MP
	Building of pipes for water distribution	MP
	Infrastructure costs from regenerating and reusing water will depend on the purpose the water is used for	MP

Pollutants	Avoids drawn out treatment processes to eliminate certain useful compound such as fertilizers	MP
	Nitrogen reuse in agriculture	MP
	Phosphorus reuse in agriculture	MP
	Reuse of already digested mud for agriculture	MP
	Reuse of thermal energy	MP
Public Health	Monitoring and controlling biological pollutants present in regenerated water	MP
	Cost of monitoring and controlling chemical pollutants present in regenerated water	MP
	Risks associated to the spread of illness and disease	MP and CV
Environment	Avoids energy consumption and, in turn, gas emissions	MP and CV
	If the regeneration plant is far from the area of consumption and long pipes are required, habitat fragmentation and a loss of biodiversity can arise	CV and TC
	Decrease in nitrate pollution of aquifers	MP and CV
	Decrease in the eutrophication of waste water discharge areas	MP and CV
	Noise and smells from the regeneration plant	HP and CV
	Increase in water quality	MP and CV
	Increase in the ecological flow rate of rivers, contributing to the maintenance of biodiversity and preventing floods	CV, TC and MP
	Avoids over-exploitation of aquifers, decreasing land cave-ins and prevents salt from entering coastal area	MP
	Decrease in water pollution and increase in the aesthetic quality of the water, allowing it to be used for recreational purposes	MP, TC and CV
	Change in the use of land (transforming dry land to irrigated land) and its environmental impact	MP and CV
	Increase in the quality of beach water if located in a coastal area	MP and TC
	Decrease in the value of nearby land	MP
Education	Enhances social awareness of a new water culture	CV
	Personnel expenses in order to convince local inhabitants of the quality of the water used	MP

MP: Market price; CV: Contingent valuation; TC: Travel cost; HP: hedonic prices
Source: AQUAREC (2006)

5) *Comparison of costs and benefits*: Once all the costs and benefits derived from the project have been identified and assessed, it is necessary to compare them in order to decide whether or not to carry out the project.

So far, no account has been taken of the fact that benefits and costs may not accrue instantaneously, but over time. Certain expenditures yield immediate benefits and costs, while others yield a stream of benefits and costs over many years. They are heterogeneous magnitudes and, therefore, cannot be added or subtracted without homogenizing them, i.e. without updating the costs and benefits of future years. Only by comparing the present values of costs and benefits for each year can the most efficient alternative be chosen. It will therefore be necessary to perform discounting operations.

To be able to add up the benefits and costs that arise over the life of the project, it is necessary, as mentioned above, to homogenize their monetary values. For this purpose, the monetary value of the benefits and costs obtained in subsequent years is translated into their comparable value in year zero, i.e., all the values of future periods are updated to the present time. This updates the entire flow of benefits and costs associated with the project over time, so that it is possible to compare them. To do this, it will be essential to apply an appropriate discount rate.

6) *Decision criteria*: Once the cost and benefit streams have been updated, i.e. homogenized, a decision criterion must be used to choose the most efficient alternative.

There are three possible decision criteria: the net present value (NPV), the internal rate of return (IRR) and the benefit-cost ratio (B/C). The net present value is probably the most commonly used decision criterion and consists of maximizing the difference between total benefits and costs. For a project to be considered potentially valuable, the present value of the net benefits must be greater than zero (NPV>0).

The internal rate of return is the rate that equals the present value of the project's benefits and costs, making the net present value zero. If it is greater than the discount rate, the project is valid (IRR>Discount rate).

Like NPV, the benefit-cost ratio sums total benefits and costs using the discount rate. However, instead of subtracting costs from benefits, they are presented as a ratio of benefits to costs. A ratio greater than one indicates that benefits exceed costs and the project is economically acceptable (B/C>1).

7) *Sensitivity analysis*: Finally, in a cost-benefit analysis, it is recommended to carry out a sensitivity analysis. Sensitivity analysis allows to test, for different scenarios, the strength and robustness of the assumptions and data, and also allows to recognize the uncertainty of the expected results. The objective is to determine to what extent the outcome of the project appraisal is sensitive to changes in some of the parameters used in the analysis, such as the discount rate, financing conditions, energy costs, reclaimed water price, etc. Once the changes in the Net Social Benefit for each of the proposed scenarios have been analyzed, the robustness or true feasibility of the project can be assessed.

6. Conclusions

- Wastewater reclamation and reuse is basic for the economic development of arid and semiarid countries.
- Technology, health considerations, formation and information should be established and applied to real reuse systems.
- The economic analysis must take into account both direct and indirect impacts, which may pose valuation difficulties. Specific valuation methods will have to be used for those impacts that do not have a market.
- The economics of reuse must consider a large number of factors and circumstances, which can be classified as follows:
  a) Costs: Associated with the technology and Analytical and data interpretation.
  b) Socioeconomic aspects: Information to the public and Training of personnel and users.
  c) Services and health considerations: Determination of ecosystem services and Implementation of sanitation safety planning procedures.
  d) Definition of economic tools

  When in-depth economic analyses are carried out, the calculations or associated:

  e) It is necessary to calculate the economy of reuse processes considering: the relationship with the other existing resources available; the reclamation treatment deemed necessary; the distribution approaches; the calculable costs and the intangibles

  With respect to the issue raised in this communication, it is necessary to consider that: a) There are numerous ways of dealing with the economic characteristics of reuse; b) The conditions of; and c) The economy of scale plays an important role in reuse costs.

  In any case, the main beneficiary of reuse for irrigation is the famer or its associations.

- For all the mentioned reasons, the authors consider that the economy should govern reuse at the same level as health, technological and legal considerations.

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