Setting up microbiological water reuse guidelines for the Mediterranean

A. Bahri* and F. Brissaud**

* INRGREF, B.P. 10, Ariana 2080, Tunisia (E-mail: *bahri.akissa@iresa.agrinet.tn*)

** Université Montpellier II, 34095 Montpellier Cedex 05, France (E-mail: *brissaud@msem.univ-montp2.fr*)

Abstract Water reuse is a widespread practice in most Mediterranean countries. Some countries have no wastewater treatment facilities and direct reuse of raw wastewater is occurring while others have a well-established national reuse policy. Water reuse microbiological standards, when existing, significantly differ from one country to another. Some countries have adopted regulations close to the California's Water Recycling Criteria whereas other countries have chosen criteria based on the World Health Organisation (WHO) guidelines. California standards are technologically based requirements aimed at eliminating the presence of pathogens. The WHO guidelines relied on epidemiological evidences though few were available. Their revision on the basis of new epidemiological investigations and quantitative microbiological risk assessment (QMRA) provided by Blumenthal *et al.*, together with added QMRA data, helped proposing Mediterranean guidelines. Acceptable annual risks related to bathing and potable water drinking were taken as benchmarks. This proposal is designed to protect individuals against realistic maximum exposures and to provide minimum and affordable requirements which should constitute the basis of water reuse regulations in every country of the region. Inadequacies of the actual knowledge do not allow a definitive position regarding the guideline limits; other scientific and technical basis are still required.
Keywords Guidelines; Mediterranean; water reuse

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Introduction

Water reuse is a widespread practice in most Mediterranean countries. The main reuse projects in the region are dedicated to agricultural irrigation, landscape irrigation, and groundwater recharge. Industrial reuse is very seldom practised.

The management of wastewater in the Mediterranean varies from country to country. Some countries have no wastewater treatment facilities and direct reuse of raw wastewater is occurring with serious health hazards and environmental problems. In others, most communities are served by wastewater treatment plants and a national reuse policy is well-established.

Most Mediterranean countries (Albania, Algeria, Bosnia and Herzegovina, Croatia, Egypt, Greece, Lebanon, Libya, Malta, Monaco, Morocco, Slovenia, Syria, and Turkey) have neither water reuse regulations nor guidelines. Countries where reuse is developing on a rational basis, within an organised institutional setting, have elaborated and implemented their own regulations or guidelines. However the standards significantly differ between countries and even within a given country such as in Italy or Spain. Some countries (France, Tunisia) and regions (Andalusia, Balearic Islands, … in Spain, and Sicily in Italy) have adopted a set of water quality criteria based on the WHO guidelines (WHO, 1989), while other ones (Cyprus, Italy, Israel) elaborated regulations or guidelines close to the more conservative California's Water Recycling Criteria (State of California, 1978). Some countries have taken the approach of minimising any risk, whereas other ones have adopted a protective approach of reasonably anticipated adverse effects. This has led to substantial discrepancies in the standards adopted by Mediterranean countries.

The need of common regulations on water reuse in all Mediterranean countries is based on the consideration that (1) an agricultural Mediterranean market is developing with large amounts of agricultural products (vegetables, fruits, etc.) imported and exported among Europe and other Mediterranean countries; (2) tourism is an essential part of the economic activity of the region; its development might be jeopardised in the long term by disease outbreaks linked to wastewater mismanagement; (3) there is a growing concern of consumers about the food quality and health hazards; (4) unfair competition among farmers should be avoided.

Contemplating to set up Mediterranean guidelines raises several questions: (1) how to overcome the discrepancies between regulations and guidelines that exist in the Mediterranean Region? (2) should the economic development of the Region be considered when deriving health guidelines for water reuse and, if the answer is positive, how to take this into account?

The aim of the paper is to present the rationale supporting the setting of Mediterranean microbiological guidelines, a brief survey of the proposed guidelines, the limits of the work and the main research needs to provide a more sound scientifically basis for such guidelines.

Rationale

Setting new guidelines should be not only justified by geo-economic considerations but also supported by a rationale based, when possible, on scientifically established data. The starting point was to understand the discrepancies between existing guidelines, which meant considering how the benchmark standards, i.e. California and WHO guidelines, have been derived. Guidelines applying to the irrigation of vegetables to be eaten raw best illustrate the respective approaches.

Existing guidelines

In 1933, the first microbial effluent standards for the irrigation of garden truck produces eaten raw were set up by the California State Board of Health at a coliform concentration of < 2.2 MPN/100 mL (Ongerth and Jopling, 1977). The limit coliform concentration was equivalent to that required for drinking water and aimed at minimising health risks. Since then, standards were continuously revised to address new reclaimed water applications and to take into account advances in wastewater treatment technology and updated knowledge in public health protection (Crook, 1998). For all types of uses resulting in a possible direct or indirect human contact, reclaimed water should be essentially free of pathogens, particularly enteroviruses, because very low virus contents can initiate human infection. This microbiological quality is characterised by a total coliform 7-day median value of less than 2.2/100 mL. However, as coliforms have proved to be inadequate indicators for those pathogens that are more resistant to disinfection and less readily removed by physical treatments, more reliance is placed on the pre-determined ability of a process to reduce all types of pathogens (Cooper and Olivieri, 1998). Turbidity should not exceed 2 NTU after filtration, on a continuous monitoring base. This criterion has been shown to determine the virus removal capability of the treatment process. It is assumed that treatment processes controlling viruses provide a water free of parasites, particularly *Giardia lamblia* and *Cryptosporidium parvum*.

In 1973, WHO recognised that applying drinking water-type standards (2.2 coliforms/100 ml) to irrigate crops to be consumed raw was unrealistic for most countries and lacked an epidemiological basis. Then, WHO proposed a guideline value of 100 coliforms/100 mL. Primary plus secondary treatments were recommended, followed by chlorination or filtration + chlorination. Implementation of such treatment technologies remained unattainable for most developing countries and led, in some circumstances, authorities tolerating the indirect reuse of untreated wastewater. Experts insisted that guidelines should be given a sounder epidemiological basis. Accumulated new epidemiological evidence, (Feachem *et al*., 1983; Shuval *et al*., 1986. Strauss and Blumenthal, 1989) allowed an evolution of the water reuse guidelines; the goal remaining no actual risk of infection to the exposed population that can be attributed to water reuse. In 1989, WHO issued a new set of microbiological quality guidelines with ≤1,000 FC/100 mL and ≤1 intestinal nematode egg/L for unrestricted irrigation.

Risk assessment, acceptable risks and guidelines

The rationales behind benchmark guidelines lack scientific basis. In the conservative approaches, the pathogen standards are not risk-based concentration limits for individual pathogens but are technologically based requirements aimed at reducing the presence of pathogens. On the other hand, literature data on epidemiological studies are rather limited and mainly evoked for microbiological contamination of bathing or drinking waters. Very few epidemiological studies were conducted on non-potable reuse: Jerusalem and Mexico studies are exceptional. Moreover, epidemiological studies are insensitive at low level exposures. Therefore, despite all limitations and uncertainties, QMRA appears to be a useful tool to develop guidelines.

Ideally, health regulations applying to different water uses should be linked consistently. Regulations and guidelines should be set in order to limit the risks to about the same level whatever the use. Therefore, infection risks considered as acceptable when related to bathing or drinking potable water, that are the most sensitive water uses, served as references for setting reuse guidelines.

Though a general trend at strengthening bathing water guidelines can be noticed, contents of 100–200 FC or *E. coli* per 100 mL seem to be a widely accepted standard for freshwaters (Ministry for the Environment of New Zealand, 2002; USEPA, 1998). These regulations are reported to be related to a seasonal gastro-intestinal illness rate of 1 to 2% considered as an acceptable risk. That this order of magnitude of risk seems to be accepted world-wide is somewhat surprising but can be explained by the high annual risk of gastro-intestinal disease in the global population. Drinking water standards constitute another key reference. Several authors have assessed the safety of reuse applications using the US EPA Surface Water Treatment Rule for domestic water supply, according to which an annual risk equal or less than 10^{-4} per person from enteric virus infection was considered as acceptable (Tanaka *et al*., 1998; Blumenthal *et al*., 2000).

To be useful and efficiently contribute to the improvement of human health and the alleviation of water resource shortages, guidelines must take the local conditions into account. If, taken as a whole, countries of the North Mediterranean bank are developed, industrialised, more and more equipped with efficient wastewater treatment plants, the economy of the South Mediterranean bank – some countries excepted – lags far behind, with poor wastewater management policy, virtually no wastewater treatment plant and endemic diseases linked to the weaknesses of public hygiene. Therefore, the proposed guidelines should provide an efficient protection to the populations of both banks, including the tourists of one bank travelling to the other bank and the consumers of exported vegetables and fruits, but without requiring uselessly expensive treatments.

These views are shared by several experts, particularly by those who have recently assessed the WHO guidelines (Blumenthal *et al*., 2000). Their work was based on risk assessment using epidemiological studies supplemented by microbiological investigations and model based QMRA. Their work, together with added QMRA data, has inspired the proposal of Mediterranean guidelines drafted by the authors.

As non-potable applications are and will long remain the large majority of reclaimed water reuse projects in the Mediterranean, the proposed guidelines are focused on microbiological criteria. Three water quality criteria are proposed, nematode eggs – which is not discussed hereafter – faecal coliforms or *E. coli* and suspended solids as a control of the disinfection capability of wastewater treatment.

Proposed Mediterranean guidelines

Only four categories of reclaimed water uses are considered, apart from groundwater recharge, in order to facilitate the implementation of the guidelines and take water reuse cost-effectiveness into account (Table 1). A reclaimed water supply network must serve as many reuse applications as possible in the same area.

Category I

The applications itemized in Category I entail limited or occasional contacts with the reclaimed water (bathing in recreational impoundments has been excluded) and possible ingestion of no more than 1 mL of reclaimed water in one exposure. Following the hyphoth-

Table 1 SS and bacteriological water quality criteria for water categories I to IV

Water category	Quality criteria	
	FC or E. coli [(a)] (cfu/100 mL)	SS [(b)] (mg/L)
Category I		
a) Residential reuse: private garden watering, toilet flushing, vehicle washing. b) Urban reuse: irrigation of free admittance greenbelts, parks, golf courses, and sport fields, street cleaning, fire-fighting, fountains, and other recreational places. c) Landscape and ponds, water bodies and streams for recreational purposes, where incidental contact is allowed (except for bathing purposes).	≤ 200 [(c)]	≤ 10
Category II		
a) Irrigation of vegetables (surface or sprinkler irrigated), green fodder and pasture for direct grazing, sprinkler-irrigated fruit trees b) Landscape impoundments: ponds, water bodies and ornamental streams, where public contact with water is not allowed. c) Industrial reuse (except for food industry).	≤ 1,000 [(c)] ≤ 150 [(e)]	≤ 20
Category III		
Irrigation of cereals and oleaginous seeds, fiber, and seed crops, dry fodder, green fodder without direct grazing, crops for canning industry, industrial crops, fruit trees (except sprinkler-irrigated)[(d)], plant nurseries, ornamental nurseries, wooden areas, green areas with no access to the public.	None required	≤ 35 ≤ 150 [(e)]
Category IV		
a) Irrigation of vegetables (except tuber, roots, etc.) with surface and subsurface trickle systems (except micro-sprinklers) using practices (such as plastic mulching, support, etc.) guaranteeing absence of contact between reclaimed water and edible part of vegetables. b) Irrigation of crops in category III with trickle irrigation systems (such as drip, bubbler, micro-sprinkler and subsurface). c) Irrigation with surface trickle irrigation systems of greenbelts and green areas with no access to the public. d) Irrigation of parks, golf courses, sport fields with sub-surface irrigation systems.	None required	

[(a)] FC or E. coli (cfu/100mL): faecal coliforms or Echerischia coli (cfu: colony forming unit/100 mL)
[(b)] SS: Suspended Solids
[(c)] Values must be conformed at the 80% of the samples per month, minimum number of samples 5
[(d)] In the case of fruit trees, irrigation should stop two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used
[(e)] Stabilization ponds

esis of López-Pila and Szewzyk (2000) and assuming a geometric mean content of 200 FC or *E. coli*/100 mL and no reduction of the pathogens in the environment, a rough risk assessment results in an annual infection risk evaluated between 3.2×10^{-3} and 3.2×10^{-4} for 100 and 10 exposure frequencies respectively. These figures are one order higher or of the order of magnitude of the acceptable annual risk for potable drinking water. They are one or two orders of magnitude less than the risk considered as acceptable when bathing. Despite the actual large uncertainties and approximations attached to epidemiological investigations and QMRA, the 200 FC or *E. coli*/100 mL guideline limit offers an appropriate protection to the users and the public. It is proposed to include toilet flushing in this category of applications, while some countries have adopted much more conservative standards or guidelines for this application. It should be noticed that the criterion which is enforced in Japan, the country where this application is the most developed, is TC content ≤ 1,000 CFU/100 mL (Ogoshi *et al.*, 2001), which is considered close to *E. coli.* ≤ 200/100 mL.

Whatever the process, a low SS content is required for disinfection effectiveness. Therefore, a guideline of 10 mg/L is proposed, that will imply filtration prior to disinfection in most such reuse projects.

Category II

The applications listed in Category II do not imply direct contact of humans with reclaimed water. However, the irrigation of vegetables, including those likely to be eaten raw, and pasture for direct grazing, aspersion of fruit trees are applications that require high quality water.

The most recent investigations which can be related to the validity of the WHO guideline limit of 1,000 FC/100 mL have been reviewed by Blumenthal *et al.* (2000). The results of epidemiological studies performed in Mexico suggest that the risk of enteric infection due to the consumption of vegetables is significant but low when the guideline limit is exceeded by a factor 10 in the irrigation water. Tests performed in Portugal showed that:

- lettuces sprinkler irrigated with low quality secondary effluents were initially highly contaminated but fell within the quality recommended by the International Commission on Microbiological Specifications for Food (ICMSF) 5 days after the irrigation ceased (Vaz da Costa-Vargas *et al.*, 1991);
- the microbiological quality of crops irrigated with water just exceeding the WHO guideline complied with the ICMSF standard.

In dry weather, the microbiological quality of radish and lettuce drip and furrow irrigated with water slightly exceeding the WHO guideline was well below the ICMSF standard and of better quality than that of locally sold lettuce; however rainy weather deteriorated the microbiological quality of lettuce (Bastos and Mara, 1995). Shuval *et al.* (1997) found that the annual risk to be contaminated from eating lettuce irrigated with reclaimed water meeting the WHO guideline ranged from 10^{-5} to 10^{-7} for hepatitis A, from 10^{-5} to 10^{-6} for rotavirus and was about 10^{-6} for cholera. Asano *et al.* (1992) calculated an annual risk associated with the consumption of spray irrigated food crops between 10^{-6} and 10^{-9} for a 1 virus unit/100 L and between 10^{-4} and 10^{-7} for a 100 times higher virus content; however, the assumption that the irrigation is stopped two weeks before harvesting is not always realistic. Despite uneven knowledge on the relationships between enteric viruses and faecal coliforms or *E. coli*, Blumenthal *et al.* (2000) concluded that these data support the WHO guideline limit of 1,000 FC/100 mL as being likely to produce an annual risk of viral infection inferior to 10^{-4}.

Assuming an amount of ingested water of 1 mL and an exposure frequency of 10 days, the annual risk of rotavirus infection resulting of contacts with 1000 *E. coli*/100 mL reclaimed water of landscape impoundments where public contact with wastewater is not allowed is estimated to be <2.10^{-4}. The daily risk when falling into such reclaimed water and swallowing 100 mL is estimated around 5.10^{-3}.

Category III

The applications listed in category III (restricted irrigation) exclude direct contact of humans and animals with reclaimed water (at the exception of incidental contacts with workers). Crops cultivated for the canning industry will be disinfected in the canning process. No direct grazing of green fodder will be allowed. Other crops, cereals, fibber, industrials, seeds, dry fodder . . . are harvested a long time after the irrigation has ceased. Therefore health related risks are considerably reduced.

It is proposed not to include any bacterial limit for restricted irrigation. Essential eventual health risks are not related to crop consumption but to workers and neighbours contamination in case of sprinkler irrigation. Therefore, in case of aspersion, setback distances between irrigation sites and residential areas, roadways, sports fields, must be established. This measure is preferred to setting a bacterial limit of 10^5 FC/100 mL as suggested by Blumenthal *et al.* (2000), though such a quality would be reached after the minimum treatment required to meet the SS guideline limit. Including a distinction between sprinkler irrigation and flood and furrow irrigation, with a limit of 10^3 FC/100 mL for the latter does not look relevant in Mediterranean countries. However, where frequent contact of children or workers with wastewater is observed and cannot be avoided, such a limit should be set and enforced.

Category IV

A water category IV is proposed when the combination of the irrigation technique and the agricultural practice results in very low microbiological health risks. The applications include:

- irrigation and cultivation practices which guarantee the absence of contact of vegetables and fruits with wastewater and the absence of aerosols and run off;
- irrigation with techniques able to prevent aerosols and run off of crops listed in category III and of green areas where the public has no access;
- irrigation of green areas open to the public and sports fields which guarantees the absence of contact of the public with the irrigation water.

Given the very low level of health risks related to the applications listed in category IV, none microbial guideline is set.

Uncertainties and research needs

To assure the public and protect the public health, there is a need to ensure that the standards are supported by current scientific data and sound risk assessment methods and to validate the effectiveness of reclaimed water management practices.

More surveys on the microbiological quality of raw and treated wastewater, using relevant sampling programs, statistical and analytical methods, should be carried out in the Mediterranean Region. More knowledge is needed on the elimination of pathogens through conventional disinfection and extensive low cost techniques. More investigations are still needed on the changes of reclaimed water quality in storage and distribution systems. Monitoring programs of water quality at the point of use should be undertaken, together with the control of the quality of irrigated agricultural products. There is a growing demand for the introduction of a viral indicator that can be used in water reuse regulations. This demand should urge further investigation and the development of detection methods sensitive, reliable and cost-effective.

Carefully well designed epidemiological investigations that examine exposure and health impacts to exposed populations (workers, reclaimed water users, farmers, communities near land application sites, etc.) would help assessing the risks related to water reuse in the Mediterranean region. Epidemiological studies on illnesses related to bathing in Mediterranean countries should also be performed.

More research should be performed in order to increase the effectiveness of QMRA. Several issues should be particularly considered: dose-response relationships, environmental persistence of pathogens on soil and crops after application of reclaimed water, exposure assessment and relationships between pathogen and microbial indicators.

The concept of acceptable risk should be assessed, with the view of reducing inconsistencies between the different uses of water; the meaning of this concept should be clarified.

Conclusions

Establishing Mediterranean guidelines for municipal water reuse is a challenge because of the absence of comprehensive international guidelines and of a scientific consensus on the approach that should be adopted to issue such guidelines. This has led to inconsistencies between the guidelines that are already implemented in Mediterranean countries. However, a number of potential benefits may be gained in providing minimum requirements which should constitute the basis of water reuse regulations in every country of this region threatened by water scarcity and where food exchanges and tourism are increasingly developing.

These guidelines have been prepared making a large use of the recent assessment of the WHO guidelines by Blumenthal *et al.* (2000) and of model based QMRA data that have been obtained and compared to acceptable annual risks related to bathing and potable water drinking.

Uncertainties and approximations in the actual knowledge are far from allowing a definitive position regarding the guideline limits. In order to fill knowledge gaps and address public health concerns and uncertainties, other scientific and technical bases are still required. Needs of epidemiological investigations, exposure assessments studies and QMRA methods and tools should be emphasised.

International organisations should foster efforts for more consistency between the different regulations and guidelines related to water quality. For the sake of integrated water management and to gain public understanding and acceptance, water reuse regulations should be part of a set of consistent water regulations applying to drinking water, bathing water, irrigation water, discharge.

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