Why you shouldn´t forget about Potable Water Reuse

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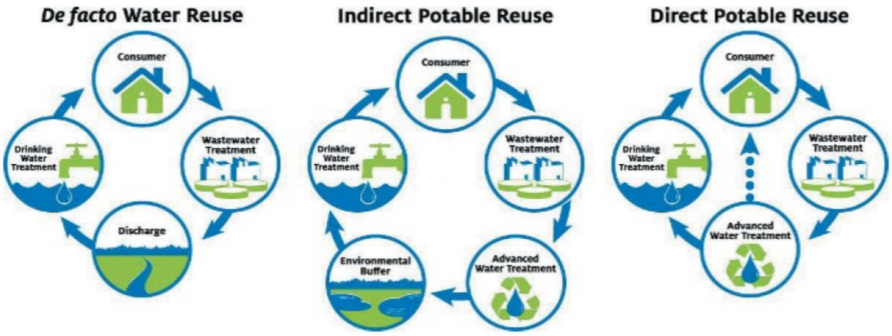
Circular economy, 3R strategy (reduce, reuse, recycle), and industry 4.0 - these are the axioms that politicians and industry leaders alike preach nowadays. Interestingly, water reuse is a practice that has been advocated for since long before those slogans became popular, and it factually embodies the principles of the circular economy.

During the past decade, potable reuse has become increasingly accepted as a practice that can, given sufficiently care is taken, be safely implemented. In this short article we aim to review how recent full-scale examples, wide-spread global industry initiatives and science advances underscore that potable reuse is a practice that certainly should be reckoned with in the portfolio of viable actions to combat water scarcity.



Conceptual difference between *de facto*, indirect and direct potable reuse. Image from: Eden et al (2016), Potable reuse of water: A view from Arizona https://wrrc.arizona.edu/sites/wrrc.arizona.edu/files/July-2016-IMPACT-Potable-AZ.pdf

The obvious benefits

There are several recognized benefits that are hardly doubted, whenever water reuse is discussed. Among those, beneficial water reuse apparently reduces the amounts of water extracted from and discharged to the natural water cycle. This can be beneficial for natural water flows downstream of large cities in water stressed watersheds regarding water quantity and quality. Apparently, it alleviates also the pressure on drinking water sources upstream by replacing parts of the water abstraction needs. Contrarily to some other alternative water sources such as urban run-off from the ground or rooftop rainwater, the effluent from our municipal wastewater treatment plants has also low variability in available water quantity and quality and such a steady supply facilitates planning and system design enormously. Finally, potable water reuse compares favourably having an energy demand per cubic metre produced in the order of one fourth to one third of that of seawater desalination, another reliable alternative water source in coastal areas.

Finally, some critics of potable reuse argue that it may be better to focus on water reuse for agricultural purposes. The reality of large cities however tends to be that agricultural areas are located far from where the bulk of the recycled water is available in the first place. Hence, construction cost of pipelines and energy use of pumping over wide distances in combination with a limited return of investment via agricultural produce often renders this option uneconomical.

Is it safe?

Citizens justifiably tend to ask if it is safe to drink recycled water. On the other hand, decision makers may be accepting of the technical feasibility and an overall low risk to public health, but they might have doubts about public acceptance and the ability to generate trust into a potable reuse scheme in the population.

The first comment there to be made is that if we are willing to look far enough, e.g. to the United States of America, Singapore or Australia, we can confidently state that by now we have accumulated an immense wealth of full-scale experience on planned potable reuse applications. From the point of water quality and safety delivered, all these full-scale schemes have been successfully delivering water of tremendously high quality on a continuous base. In fact, scientific evidence logically demonstrates that planned potable reuse applying currently employed treatment trains for advanced purification is providing a higher raw water quality for drinking water production than the practice of sometimes so-called de facto potable reuse.

De facto potable reuse is when a city abstracts raw water for drinking water production from a river where upstream wastewater treatment plants discharge treated effluent to the same river. This is the prevailing practice in many European river systems such as the rivers Rhine, Thames or Danube or the Llobregat River in Spain.

Image source: **https://commons.wikimedia.org/w/index.php?curid=34495**

Developments in water reuse

So, let’s look a bit deeper into the tools that we have at hand to ensure safe potable reuse and progress made during the past decades.

First, several technologies that can be employed in treatment trains such as reverse osmosis or advanced oxidation have achieved a tremendous degree of maturity. These advances penetrate the water industry through the whole water production process ranging from the assembly processes for reverse osmosis membrane modules to the preventative maintenance protocols employed in advanced water treatment plants. Similarly, our knowledge and technology on more traditional technologies such as ozonation, activated carbon adsorption or simply the use of chemical disinfectants has considerably increased during the past decades. At the same time, we see new or adapted technologies on the horizon such as novel membrane treatments, oxidation processes or electrochemical treatment technologies, which promise to form part of our set of tools.

Our understanding of contaminants and water chemistry has increased as well. These days fortunately it has become very rare that as a society we encounter the unpleasant surprise that a contaminant that was thought to be benign turns out to be a serious water quality hazard. One such recent incidence was when we discovered the potentially harmful effects of perfluorinated substances, previously thought to be innocuous. This tells us that we indeed need to remain watchful and aware of potentially unknown threats to water quality, but it cannot be denied that we have come a long way already.

Nowadays, computational methods are more and more extended and very useful in partially replacing expensive experimentation with in-silico generated data. These computational methods comprise a wide field of applications and only a few are listed in the following: One example would be the establishment of quantitative structure-activity relationships (QSAR) to predict in-silico the fate of known and unknown contaminants based on real and even invented molecule properties in treatment processes to cover for all conceivable eventualities. Computational fluid design assisted process development can help design biological wastewater treatment, photoreactors applying ultraviolet radiation for contaminant abatement and many more. We can also simulate year-long operational data for whole treatment trains evaluating the impact of stochastic equipment failure or other incidents by Monte Carlo simulations on water quality risks. Machine learning to learn from past operation experience is certainly arriving finally to the industry as well.

In summary, we know that a correctly functioning and aptly designed and operated treatment train will be able to control water quality risks adequately. There is also good guidance on risk management available, whereby most guidelines orient themselves on the method of Hazard Assessment and Critical Control Point (HACCP) initially developed by the food industry. Specifically, the water industry has worked hard on identifying and developing sensors that ensure the correct functioning of individual barriers in treatment trains, which is needed for the implementation of the Critical Control Point concept.

The available international success stories should not be only looked at from a purely technical and water quality point of view. All these cases also teach us about how citizens can be effectively communicated with, what the role of education plays and many more aspects. In fact, we can also learn from those cases, where potable reuse projects were proposed but not implemented due to opposition met, lack of political will or other reasons.

Getting back finally to the question on safety of potable reuse: We are not saying “unworry and relax” – we are just saying that we have many tools in hand that can help us feel more confident that the likelihood of failure or false assessment is very low, if we make good and conscious use of the available tools.

Is it efficient? Economically feasible?

So, if you read until here, you are probably ready to ask the million-dollar question: How expensive and/or efficient is potable reuse?

Let us first give a slightly evasive answer on purpose by asking you a couple of questions: What is a justified price for drinking water? Are you willing to spend more on your mobile phone bill or on your water bill?

Answering more directly to the question about cost and energy use, it is evident that the requirement to access this alternative water supply source is considerably higher than drinking water production from comparably pristine sources. But then again, compared to other alternative water sources that sometimes may seem more palatable (e.g. rainwater harvesting) the reliability of potable reuse may be higher and cost may be less as well. The so-called full advanced treatment train including prefiltration by a low-pressure membrane, reverse osmosis filtration and further downstream oxidation or at least disinfection can be operated at less than 1 kWh/m^3. Other, less energy hungry treatment trains, e.g. trains that include ozone and biofiltration, are currently under intense scrutiny regarding their suitability for safe potable water reuse. In any case, potable water reuse expends less energy than seawater desalination, water supply schemes that involve long-distance pumping and many decentralized small-scale solutions, where unfavourable economies of scale often lead to high energy consumption due to the inherent inefficiencies of small-scale equipment. Often the temporary nature of operation of decentralized systems also may reflect negatively on the capital cost in comparison to well-planned centralized systems with a near 24/7 operational regime.

Reverse osmosis membranes at the Orange County Groundwater Replenishment System, California, USA.
https://www.ocwd.com/gwrs/the-process/

Are there other benefits?

We have talked about the apparent water quantity related benefits, about water quality and safety, and a tiny bit about cost and energy use. What about other, perhaps more hidden benefits and opportunities?

In the 21st century and in the context of the circular economy, we generally advocate for our wastewater treatment plants to transition to resource recovery facilities. Traditionally, wastewater treatment operators have focused on the opportunities for nutrient recovery. At the same time nutrient removal can assist the operability of many advanced water treatment technologies (e.g. assisting in the control of calcium phosphate scaling in reverse osmosis filtration). It would certainly appear that there are apparent opportunities to develop synergies between nutrient and water recovery. Similarly, one should think about how energy recovery connects to water and nutrient recovery. And who knows? Perhaps in the future, metal recovery from wastewater will become feasible and specifically recovery from RO brines or other concentrated streams will presents itself as the opportunity to bring these processes to the market.

Finally, wastewater treatment plants have since long been regarded as hotspots of anthropogenic pollution of receiving water bodies with nutrients and other inorganic and organic chemicals. In times, where we now widely recognise the polluter pays principle (dictated in the Water Framework Directive), beneficial water reuse provides an important opportunity to alleviate environmental pressures exerted by urban areas. Specifically, one of the biggest risks of wastewater discharges relates to the propagation of antibiotic resistance genes. In this context, advanced treatment of secondary effluents may become rather a necessity, not merely an option.

Image source: https://commons.wikimedia.org/w/index.php?curid=45828357

The role of science

As a final note, we would like to list a few of the tasks that we can contribute to as scientists without claiming that this list is exhaustive.

First, despite the availability of several mature unit operations, we should not cease to develop novel innovative treatment technologies and strategies. In an increasingly complex urban water cycle that connects centralized and decentralized solutions to optimize environmental, social and economic performance, we will need solutions for many different settings and types of water. As outlined above, we need to contribute to creatively explore and develop the potential synergies in such an urban water cycle with multiple connections following the proposed paradigms of a circular economy.

Secondly, there are unresolved knowledge gaps regarding environmental impacts of wastewater discharges and opportunities of advanced treatment to mitigate those effects while simultaneously enabling beneficial reuse. Some of these knowledge gaps relate to threats that are among the big challenges of the 21st century, e.g. antibiotic resistance.

Finally, when it comes to communicating and discussing solutions for society, we should partake in this conversation and act as ambassadors of knowledge.

At the Catalan Institute for Water Research (ICRA) we have experts related to many aspects of Potable Water Reuse; engineers working on treatment technologies, chemists analysing the risks related to emerging contaminants and disinfection by-products and microbiologists investigating mechanisms of transferring antibiotic resistance. As a group of scientists, we are certainly keen to contribute to the positive development of society. So, come and talk to us.

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