water mining
value for society

Deliverable 11.7

Layman's report

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Table of Contents

1. Executive summary

The document presented here describes the Water Mining layman's report which aims to inform non-specialists on the interim results of the EU project Water Mining and in particular on its Case Studies and the lessons learned in the approach with stakeholder interactions. Water Mining uniquely combines social engagement with technological innovation in the assumption that this will improve social and market implementation and smooth the process for policy adaptations. The objective of the layman's report is not only to inform layman on the innovations in water management but also to provide recommendations on future research in social engagement, and how this relates to gender issues and public acceptance for innovation in water management. The layman's report describes the 6 case studies and their quantitative results and how identified stakeholders were involved in a process of social engagement and how this affected the designs and identification of important policy measures. We conclude that it is meaningful to involve stakeholders in the design and implementation of innovation as suggested changes prove to create better solutions for local needs. We also observe that the process increases attention for differences in public opinions including between genders and it contributes to creating trust. However, it is important to involve stakeholders in the case studies from an early stage onward so that the relationships could be established and maintained for a longer duration. This requires time from both social process facilitators and from technologists involved in the innovative design and operations and consequently adequate funding and time allocation. The layman's report describes the state after three years of the project and will be updated with the latest developments at the end of the project.

2. Introduction

The Water Mining project aims to demonstrate innovative and sustainable water management solutions in practice for seawater desalination, urban wastewater treatment and industrial wastewater treatment. In addition to innovative technology, the project uniquely implements stakeholder interactions on design and applications to improve social and market uptake of the innovation. The Water Mining team wishes to inform non-technological audiences on the results of both the case studies and the process of social engagement, so that we can all learn from these findings for the future. To do this we designed a concise document avoiding jargon language in a lay-out that we hope is inviting to read. The content describes the results and lessons learned until the end of year 3.

This layman's report describes the technological innovation applied in the Water Mining project and the social engagement activities, including its relation to gender issues and public perceptions. As we used the data available at the end of year 3, we have to give caution. This report does not yet include the latest results on impact analysis, perceptions, market exploitation and policy measures required to smoothly implement and benefit from the innovation. Therefore an updated version is planned to be published at the end of the project. The present Layman's report is presented in chapter 3 and should therefore be seen as an interim result.

The Layman's report will be posted on the WATER-MINING website and announced through the WATER-MINING project´s social media channels and newsletter. It will also be linked to the United Nations action plan as presented in March 2023.[3]

[3] https://sdgs.un.org/partnerships/circular-wastewater-treatment-extracting-biopolymers-wastewater-sludge-campinas-brazil

3. Water Mining Layman's report

Why do we need to improve our water management systems?

We depend on water. For our agriculture - to provide food and drinks -, for our health, for our industrial production, for our environment. The average European uses around 140 liters of water per day. Such amounts vary greatly over the world, due to climate, availability, spillage, infrastructure and human behavior. A shower of 10 minutes uses easily 160 liters of water! With more people and higher temperatures foreseen for the future, it is important that we are careful with our water consumption and that we design smart water systems to treat our wastewater. Due to changing climates, especially islands in warmer regions increasingly depend on making fresh water from seawater through desalination processes. But up till now these processes cost much energy while the left over salts (called brines), are a threat for the environment. The European Commission therefore decided to invite experts to develop smart and circular solutions for water management, addressing societal issues. The Water Mining project was funded to develop better solutions for desalination, for treating urban wastewater and for smart industrial water usage and treatment. The focus is not only on fresh water recovery and energy savings but also on nutrient and product recovery and less burden to the environment! Novel equipment such as filters, reactors with smart microorganisms, evaporators and solar energy collectors are used to make integrated treatment systems that can desalinate seawater to fresh water or treat wastewater from households or industry to win back clean water and nutrients. Smart monitor software and augmented reality software is developed to easily show the installations and check how they perform. To enable decision making on best solutions the project also includes evaluation of environmental, economic and social impacts of the new technology, but also whether and how recovered products can be sold on the market and which policies either hinder or stimulate this process. Together with local people who are involved in water management, such as local councils, citizens, farmers, politicians and wastewater treatment owners, we evaluate the different solutions and agree on the best options. To test this integral approach Water Mining developed 2 pilots for the desalination systems, 3 on recycling in urban wastewater and 1 in an industrial setting.

Sea Mining: Case study Lampedusa and Almeria: what can we improve?

Cala Pisana, Lampedusa, Italy

As Lampedusa is a rather small island, its inhabitants and tourists are dependent on desalination for their fresh water needs. Unfortunately the process to make fresh water from sea water requires a lot of energy and the salty rest products, or brine, is polluting the Mediterranean. The new system, installed in 2022, showed that up to 92% of the energy needed for a 'Multiple Effect Distillation' can come from the waste heat from the local energy plant. This facilitates the production of high valuable salts with a purity of 90-99%, such as magnesium and calcium hydroxides, sodium sulphate and table-salt which all can be used in the market for different applications. Also the chemicals hydrochloric acid and sodium hydroxide are produced, which can be used as process reactants or for cleaning purposes but also for the desalination plant maintenance. We show that all incoming desalination brine/seawater can fully be used for product recovery, so a circular process is realized with zero pollution to the sea! Importantly, the new system provides 92% recovery of high quality potable water compared to approx. 40% of the existing desalination facility.

Almeria, Spain

In Plataforma Solar de Almeria in Spain we explore whether we can make fresh water from seawater and recover the salts by using solar energy and nanofiltration. We demonstrate that the nanofiltration removes the ions and then improves the 'Multiple Effect Distillation', powered by 100% renewable energy from the Concentrating Solar Power plant, so we can recover high quality fresh water. With the reject from the nanofiltration, we can mineralize the water for irrigation, since the ions rejected are valued as fertilizers.

A view of the site of WATER-MINING's Case Study 2 in Almería, Spain. Source: REVOLVE

Comparing pilots on treating urban wastewater in Faro, Portugal; Larnaca, Cyprus; and La Llagosta, Spain: what can we improve?

Faro, Portugal vs Utrecht, The Netherlands

Over 30 years ago experts at TU Delft discovered that wastewater treatment can be dramatically improved in terms of land-use needs and process time by making sludge granular. The improvements are related to (A) the simultaneous occurrence of several microbial process required for successful wastewater treatment within one granule, (B) very quick settling of granules and (C) the mass transfer area for granular sludge which results in high turnover rates. Our partner RHDHV commercialised the process under the name NEREDA® in 2011 in a public private partnership together with Dutch Water Authorities and TU Delft. Now over 100 plants are are in operation or construction all over the world. Recently it was discovered that the bacteria in the granules produce extrapolymeric substances, . These substances can be used as biopolymers which showed interesting properties such as a remarkable water retention capacity and it can give materials flame retarding properties . Despite different in its composition, it resembles, for some of its properties, alginate which is a well sought product presently produced from algae. The biopolymer can be extracted from granular sludge. It has been commercialized under the name Kaumera. All work related to Kaumera was so far optimised for The Netherlands in Utrecht and we can now produce circa 70 kg of Kaumera per person per year from wastewater. Kaumera has versatile applications and can replace petroleum derived polymers e.g. in composite materials, agriculture or as binder in the construction sector The pilot in Faro proved that Kaumera can be produced with high efficiency in warmer climates with different wastewater compositions using the same technology as in the Netherlands. Research on integrating phosphorus recovery with Kaumera extraction indicated that roughly 50% of the total phosphorus in the sludge can be recovered. During Kaumera extraction an organic rich waste sludge with high pH and salt content is produced. Fermentation at these conditions is challenging but with specially adapted microorganisms from soda lakes we got a very high methane yield and almost pure methane stream (>95%). This way the volume of waste is reduced and at the same time a substitute for natural gas is produced in a sustainable way. Another step towards higher circularity. We are now testing the quality of Kaumera and its use as combined water absorber and biostimulant in agriculture to drastically reduce irrigation needs for farmers in the water stressed Algarve. The investment to produce Kaumera and recycle other compounds are very likely covered by the revenue of the product sales.

Larnaca, Cyprus

Larnaca also suffers from water scarcity as an island in the south of the Mediterranean Sea. In addition underground water reservoirs are salinized while farmers need water and nutrients for irrigation, and citizens, tourists and (food) industry depend on adequate supply of potable water. So in Water Mining we look at improving water and nutrient recovery from urban wastewater testing adapted desalination technology. With filtration, adsorption and evaporation water is produced for irrigation and industry, while salts and phosphorus are recovered and sold. The BioPhree adsorption process is capable to remove phosphate to ultra-low concentrations (from 1,5 mg/l down to 0,03 mg/l). With a price of 100 €/kg removed it is cost effective as it regenerates its adsorbant and re-uses it. This is followed by a nanofiltration for the removal of calcium and magnesium salts. Reverse Osmosis consequently separates the NaCl from the high purity water stream. Over 90% of the water can be recovered this way! Further use of a 'Multi-Effect Distillation' (evaporator and crystallizer) can recover an even higher purity water and high purity NaCl crystals. This way less energy is used and the process is less polluting, while recovered phosphorus and NaCl provide an earning. It demonstrated that circularity of water can be achieved affordably!

Visitors are shown around WATER-MINING's Case Study 4 in Larnaca, Cyprus. Source: REVOLVE

La Llagosta, Spain

In La Llagosta, near Barcelona in Spain, Water Mining demonstrate that wastewater treatment of a city can be more circular and even become *resource recovery facilities* producing energy, reducing energy consumption and generating by-products for industrial or agricultural purposes. The use of a Granular Anaerobic Membrane Bioreactor proves better that the conventional use of aerobic activated sludge, as it reduces energy costs with 60% by converting organic matter to biogas. To remove the nitrogen, we replaced the energy demanding nitrification-denitrification process by a biological nitrogen removal process in two-stages. We show that in two-stages we can remove ammonium without the need for organic matter. With two innovative processes: ViviCryst followed by BioPhree the phosphorus is recovered here cost-effectively as well (at 100 €/kg removed), so it can be sold as fertilizer. Finally, a reverse osmosis membrane system is used to obtain a high-quality water using regenerated membranes, that decrease the operational cost of the process. The system now recovers over 90% of the water.

Industrial collaboration: can close-loops and leasing improve our present systems? Rotterdam, The Netherlands

In the Port of Rotterdam a lot of industrial activity depends on water: for cooling; buffers; chemical processes etc. A closed-loop water recovery could dramatically improve the water footprint and recover valuable compounds. This is being demonstrated in the chlorine cluster by NOBIAN and Westlake Epoxy in Pernis and technology developer KVT in Graz, Austria. We treat the salt residue stream (or brine) from Westlake Epoxy's plant with novel equipment, to produce high purity brine which can be a source of salt and water for Nobian's nearby Chlor-Alkali plant. The purified brine can potentially replace a part of the mined salt and freshwater in Chlor-Alkali, reducing the water consumption by 1/3, saving 25 MWh thermic and 6 kilotons of CO2 emissions, at full scale. The process design is truly circular as the chlorine produced from the residual brine is in turn used by Westlake Epoxy in its epoxy production. In this loop, the chlorine molecule can be considered as a 'chemical lease product' and as an energy carrier, able to start chemical reactions at the end-user's plant. If it is not incorporated in the end product, it can be recovered and returned to the supplier in the form of sodium chloride salt, to produce chlorine once again. With high pressure oxidation organic impurities in the residual brine are converted into CO2. Tests are ongoing to validate the potential saving.

The recirculation of salts would lead to reduced dependency of virgin raw salt, while ensuring its availability. With expected stricter environmental regulations in the future, the recirculation of water and salts may be a way to deal with challenges to producers and maintain the industrial activity, the jobs and the added value they create. Recirculating water and salts also reduces the amount of effluent treated by biological wastewater treatment with related energy for sludge incineration and release of water to the environment.

Getting it right: Why involving stakeholders in developing the best local solutions?

WATER-MINING partners involved in a WS1 workshop on research in Palermo, Italy. Source: REVOLVE

In a world where water is becoming more precious than ever, finding more sustainable ways to use it wisely within a circular economy is crucial. In Water Mining we develop pilot designs to test the best technologies, but also couple this process to stakeholder engagement to *co-create innovation through social engagement for societal embedding*. We connect knowledge and minds, local communities, and technology pioneers and gain insights, understand people's needs, and ensure the water innovations we create are practical, desired, real-world investments. Co-creation can also de-risk the transition, as decisions on choices can be made together and responsibility for the consequences can be carried together. In the process we use details on the technological designs, not only on costs and benefits, but also on environmental and social impacts, on existing and required regulations and on market opportunities.

Decision making then becomes a complicated process. Which effects are more important? With what security can a certain outcome be anticipated? What times do we consider for economic viability? Fluctuations in resource prices and operational costs may introduce financial uncertainties into the equation. What is best regulation? Regulatory compliance adds another layer of complexity. Circularity means that we re-use what was waste, and novel practices may be prevented by existing policy measures. All these uncertainties have to be incorporated in the process of negotiation. In that we also have to cope with public perception, opposition, or resistance, together with ethical considerations and the need for transparency and inclusivity. All this can significantly influence project outcomes, constituting a societal risk factor. These multifaceted risks and uncertainties underscore the need for a systematic approach to de-risk investments in water mining technologies.

De-risking this requires diving deep into the values and needs of all stakeholders of the innovation ecosystem, engaging communities in meaningful ways, and ensuring that the innovations developed resonate with societal needs. By understanding what truly matters to stakeholders, whether they are policymakers, local communities, or industries, we can together tailor our innovations to meet their expectations. We can build trust, gain essential insights, and create solutions that are not just technologically advanced but also socially and environmentally responsible. Thus, de-risking is the safety net that allows us to invest wisely, not just for immediate gains but for the long-term sustainability of our water resources and the well-being of the people who rely on them.

How do we involve stakeholders?

We first identified the stakeholders for each case study location. These were invited to participate in a dedicated Community of Practices (CoP). In each CoP we ensure a balance in gender representation and inclusion of all stakeholders. The 6 CoPs were introduced to the pilot designs and objectives through movies and fact sheets developed for each pilot. To further identify needs and (local) issues and translate this into best solutions we used the Value-Sensitive Design approach in three phases. The data on the pilot performances and on impact, market opportunities and policies are coming together in this approach:

- Setting the Scene: Understanding Moral Values and Social Perceptions: In this initial phase we discussed ethical considerations surrounding water technologies. Through in-depth interviews, questionnaires, and workshops, we explored the moral values, value tensions and design indicators that underpin the Water-Mining ecosystem. Results of this phase were:

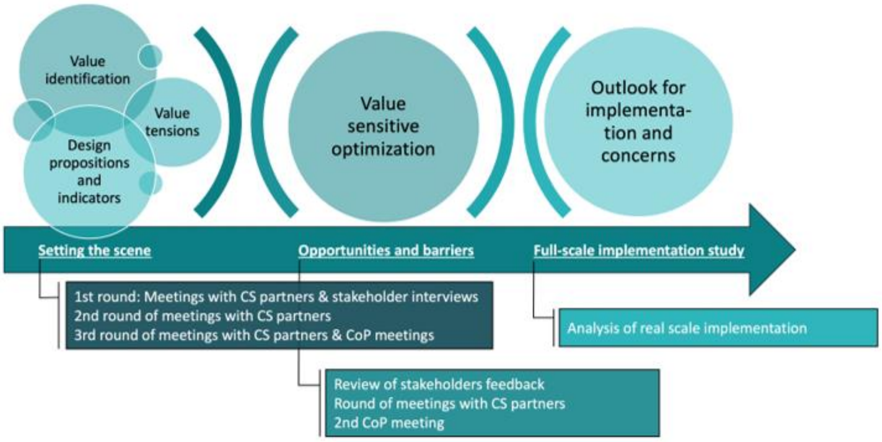
- Different views in ownership and distribution of benefits and costs
- Different sustainability concerns; costs and land-use increase versus use of renewable energy
- Uncertainty on safety of recovered water and products and acceptability of risks

❖ Value-Sensitive Optimization: The explored values and concerns were translated into different scenario's per case study related to the issues brought forward. Up to 5 scenario's per location provided information on costs (Opex and Capex), benefits, environmental footprints, etc. With the calculations provided in a next round of CoP meetings, people could better develop their visions and justify their choices. For the pilot in Faro this did not make sense as all tensions and issues related to the end-use of Kaumera, beyond the scope of the Water Mining pilot. In Rotterdam sustainability issues were raised on use of fossil resources which also go beyond the scope of the pilot to establish circular loops. The scenarios were discussed with stakeholders, generating interesting and relevant outcomes: In Lampedusa stakeholders advised to prioritise on water recovery due to the lack of a local market for recovered products such as magnesium. In Almeria the potential increase in water recovery raised questions in view of the avoidance of brines, the required increase in land and the costs associated. Also the marketability of the amount of NaCl was questioned. It was stressed that policies needed to focus on avoidance of expansion of water usage. In Larnaca stakeholders would like to see a priority to zero liquid discharge of brine, and there were concerns on price increases for water. Stakeholders in La Llagosta liked the flexibility of the system but saw regulatory barriers on using cleaned industrial wastewater for irrigation.

❖ Full-Scale Implementation: Here we focus on the integrated cases, and discuss all data considering the trade-offs and opportunities of the best design for the location. This can only be done in the last phase of the project.

Figure 1: Value-sensitive design process.

In parallel with the Value-Sensitive Design process, we also conduct *behavioral studies* to better understand how consumers and other water users interact with these innovations. This identifies factors influencing acceptance and ease of use. Here we found that during the repeating CoP meetings



people became more positive about the novel technology. Factors influencing their opinions and acceptance were whether the new system is affordable and environmentally friendly. Especially woman brought this forward. The behavioral studies also investigate sociocultural factors and gender issues so we can take these into account and develop inclusive solutions.

Does it work?

While we have built CoPs, which remain active over the duration of the project, we establish important relationships and create ongoing feedback so we stay in tune with changing circumstances and evolving stakeholder needs. We do see already that the process of stakeholder engagement often runs behind the innovation process. The development of the CoP group takes time and should start as early as possible in the process. We often also see that CoP facilitators are engineers, not trained in social engagement processes. By making a model 'best practice' for CoPs and evaluating our process we contribute to developing the approach of co-creation and its value for innovation. The 'best-practice' model will be presented at the end of the project. We also address gender issues in the process, we already saw differences in female and male values and hence weights given on important factors for decision making. In the behavioral studies we dive deeper into these differences and how to best design for inclusion.

Members of the WATER-MINING Project during the Consortium Meeting in Larnaca, Cyprus. Source: REVOLVE

Further reading:
https://watermining.eu/wp-content/uploads/2021/12/WM_D2.6_InfoSheetQuickScan_VSD_2021-11-30.pdf
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