SAFE USE OF WASTEWATER IN AGRICULTURE: A WORKSHOP ON POLICY AND IMPLEMENTATION FOR IRAN

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Safe Use of Wastewater in Agriculture: A Workshop on Policy and Implementation for Iran

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UNU-FLORES (Dresden, Germany)
National Water and Wastewater Engineering Company (Tehran, Iran)
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Background

On a global scale, over 20 million hectares of agricultural land are irrigated using wastewater. This is one and perhaps the most prominent example of the safe use potential of wastewater. Water scarcity and the high cost of energy and fertilisers are perhaps among the main factors driving millions of farmers and other entrepreneurs to make use of wastewater. In order to address the technical, institutional, and policy challenges of safe water reuse, developing countries and countries in transition need clear institutional arrangements and more skilled human resources, with a sound understanding of the opportunities and potential risks of wastewater use.

As a research institute devoted to promoting sustainability, UNU-FLORES proposes employing an integrated approach to manage water, soil, and waste resources in one nexus to improve the sustainable use of environmental resources. Safe use of wastewater is one of the excellent examples showcasing this concept. UNU-FLORES has been advocating for the safe use of wastewater since the inception of its research and capacity development agenda, and has worked with many other UN as well as non-UN organisations, universities, and Member States to improve current understanding and to produce new knowledge.

Within this context, UNU-FLORES was pleased to join forces with the Islamic Republic of Iran, a Member State of the United Nations to co-organise this workshop. As our contribution to the workshop, we made arrangements to identify and bring the best possible team of experts to Tehran to share their knowledge. In addition to UNU-FLORES (Germany), these international contributors represented KWR Watercycle Research Institute (The Netherlands), International Commission on Irrigation and Drainage (India), German Association for Water, Wastewater and Waste (Germany), Humboldt University of Berlin (Germany), National Research Institute for Rural Engineering, Water, and Forestry (Tunisia), University of Jordan (Jordan), as well as an independent expert from Australia.

The co-organisers from the Member State were Shahid Beheshti University, National Water and Wastewater Engineering Company of Iran, and Tadbir Economic Development Group. They identified and made arrangements to bring the best possible audience to Tehran to benefit from this event and that included representatives from the wastewater management companies from all 31 provinces in the country, in addition to ministerial and university experts.

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Section 1: Setting the Scene

1.1 Introduction

Growing population, decreasing rainfall, increased extraction of both surface and groundwater resources, and adoption of development-oriented approaches have impeded water supply for domestic, industrial, and agricultural sectors. To make matters worse, contamination of water resources, through sewage, for instance, has deterred the supply of clean water. Safe use of waste water can be a practical solution to alleviate some of these issues.

In Iran, the National Water and Wastewater Engineering Company (NWWEC) is the lead gov-¬ernment entity responsible for managing water and wastewater. They are keen on introducing modern methods of wastewater reuse. Some of the projects managed by NWWEC to provide water for several cities in the Central Plateau actively utilise wastewater in both indus¬trial and agricultural sectors. They are also keen to expand their applications of safe use of wastewater. However, there are numerous hurdles to overcome in expanding such solutions to other parts of the country. This situation triggered the invitation from Iran to UNU-FLORES to join forces in order to organise this workshop.

1.2 Workshop Overview

In the opening session of the workshop, **Mr Sattar Mahmoudi** (Honourable Deputy Minister of Energy), **Mr Hamid Reza Janbaz** (Managing Director, NWWEC), **Dr Mohammad-Mehdi Tehranchi** (Chancellor, SBU), and **Prof. Reza Ardakanian** (Director, UNU-FLORES) provided welcome remarks.

On the first day, Prof. Reza Ardakanian and **Prof. Hiroshan Hettiarachchi** (UNU-FLORES) illustrated the capacity development aspects of the Safe Use of Wastewater in Agriculture (SUWA) initiative and the concept of a Nexus Approach to environmental resources management. This was followed by a comprehensive review of economic, social, and cultural dimensions of wastewater reuse and perceived risks of wastewater irrigation by experts. Technological basics of water reuse, the need for policy integration, and the health aspects of wastewater reuse were also explored.

Activities were continued on the second day with topics related to further technological aspects of water reuse. In addition, case studies from Iran, Jordan, Germany, and Tunisia were also presented on the second day. All presenters also participated in a panel discussion moderated by Prof. Hettiarachchi to answer questions raised by members of the audience.

On the third day, an excursion to the South Tehran Wastewater Treatment Plant took place.

Section 2: Country Status (IRAN)

2.1 Water Recourse

Mr Sattar Mahmoudi (Honourable Deputy Minister of Energy, Iran) explained how freshwater has been Iran's central concern throughout its long history. He said the country is dry in general and the droughts are mainly due to the (geographical) location and, of course, human activities have made them severe. Mr Sattar Mahmoudi argued that a bulk of engineering genius of Iran has been formed as a result of the desire to find solutions to the issues in the water sector. The 1000-year old aqueduct, the water clock, and division of water by Sheikh Bahae are testaments of this enduring fight.

According to a 33-year-old statistic, there has been about 130 billion cubic metres of renewable natural water resources. If a country is to be sustainable in regard to its water resources, it should only use a maximum of 40% of their total water resources. Based on this criterion, using more than 60% of the water reserve can be deemed as crossing the red line. Mr Mahmoudi pointed out that Iran has normally used 80% of its renewable water resources. Clearly this is not a viable option and there is obviously room for Iran to improve its water resource management.

2.2 Water Reuse

Mr Hamid Reza Janbaz (Managing Director, NWWEC) pointed out the importance of water sanitation and remarked that the treatment of wastewater is a challenge many countries are facing. The situation is especially dire in Iran's case since most parts of the country are covered with drylands with severe water shortage. The rapid growth of population is another factor mounting the tension around water supplies. This is why, he believed, that the collection and treatment of wastewater is gathering so much attention in Iran.

Despite the adversity, NWWEC has strived to bring positive changes. A large number of modern sewage treatment plants are now in operation throughout the country thanks to the company's projects. Mr Janbaz highlighted the company's cooperation with the private sector in the implementation of new sewage projects. Plus, NWWEC has agreed on many Public-Private Partnership (PPP) contracts with 150 new projects to be commenced soon. Currently, Iran has $2.5 billion worth of projects under the government-private sector partnership, of which 24 are buybacks.

Eco-friendly methods and advanced technologies are being implemented too. This was all possible due to the decision makers' keen interest on the wastewater issue. Mr Janbaz specifically referred to the current government's vision on wastewater. The President of Iran has publicly announced wastewater reuse as one of the four governmental priorities in the 2017 budget bill. As Iran's interest in wastewater grows, Mr Janbaz suggested to Prof. Ardakanian that the activities initiated with the workshop be continued on a regular basis and a permanent secretariat be formed for forthcoming meetings.

2.3 Recent Developments

Dr Hossein Gharib (TADBIR Economic Development Group) stated that the main responsibility of the Executive Committee of the Imam is to adequately manage the assets of the Supreme Leader. The organisation has paid a lot of attention to social responsibilities in particular. For instance, combatting poverty has been at the centre of its mission over the last few years. Accordingly, a special agency of the Executive Committee called "Barekat Foundation" was founded in 2009. The Committee has used its revenues from other activities to offer services to impoverished areas and to improve the condition of rural livelihoods. Among the many topics addressed by the Foundation, water crisis is of paramount importance. This is in line with the World Economic Forum, which has also selected water shortage as one of the five main crises of the world. According to the Forum, Middle East will be the region most strongly hit by the water crisis.

Having dialogues is considered one of the best ways to increase the problem's awareness among decision makers. Scientific conferences and workshops are the centrepieces of these dialogues. Due to the complexity of the issue and limited resources, however, there is no room for action based on trial and error and it is often better to emulate the successful experiences of others. Dr Gharib added that a working group composed of senior managerial staff has been formed by the Executive Committee. One of the solutions identified by the Working Group to overcome the water crisis was to introduce various economic activities on water issues. He continued that the country is in good condition in terms of agricultural production but lacks efficiency in regard to water use. He said one of the questions that the Committee has to consider is whether to utilise unconventional water sources such as wastewater. The goal of the Working Group is to use international knowledge and experience to utilise wastewater in agriculture and industry.

Section 3: Safe Use of Wastewater in Agriculture (SUWA)

3.1 Capacity Development Perspectives of SUWA

Prof. Reza Ardakanian (UNU-FLORES), in his talk on the capacity development needs related to the SUWA activities, elaborated on important facts and figures. He presented an illustration of available water resources around the world and stated that Iran is in a region with severe water crisis. Approximately 70% of all water withdrawal is for agricultural use and about 19% for industries.

About 96% of this withdrawal is provided by freshwater resources. Instead of completely depleting the limited freshwater source, Iran can opt to use treated wastewater instead. Benefits in reusing wastewater can be found in increased food production, reduction of fertilisers, and energy efficiency. By comparing Iran with European, American, and Asian countries in regard to the ratio of treated/untreated wastewater, Dr Ardakanian concluded that wastewater treatment in Iran has not reached its potential. However, simply using wastewater sub-par may only exacerbate the situation. There are about 20 million hectares of land all over the world which are irrigated with wastewater. However, the unpromising point of this fact is that the use is not safe in most cases. He reminded that the most important point in reusing wastewater is that it should be safe; otherwise the cost of disease treatment may be greater than the cost of wastewater treatment itself.

Prof. Ardakanian pointed out to the Johannesburg Summit on sustainable development in which he had participated as the representative of Iran. It is important to note that the attendees at the summit came to the conclusion that water is the key to sustainable development and integrated management of water resources is essential to it. He defined SUWA in the context of the Water-Food-Energy nexus and remarked that the interaction among waste, water, and soil can enhance the benefits.

The history of the SUWA initiative was briefly presented in the latter part of Prof. Ardakanian's speech. During its early stage, an assessment on capacity needs was carried out via a series of workshops conducted in five regions of the world and were attended by 73 countries. In the current phase, the aim is to raise awareness and help countries fulfil their capacity development needs.

3.2 SUWA and the Nexus Approach

Prof. Hiroshan Hettiarachchi (UNU-FLORES) explained how the SUWA initiative is closely related to the Nexus Approach advocated by UNU-FLORES for the integrated management of water, soil, and waste. This management principle is aimed at maximising synergies. SUWA is an excellent example of explaining how beneficial and efficient this combination can be.

The importance of integrated resource management was emphasised by Prof. Hettiarachchi where he stated that it pushes us to think about the long-term strategic visions and link policies at different levels in order to ensure administrative coherence. When applied to wastewater reuse, the ultimate solution of the Nexus Approach could also alleviate water shortages faced by the agricultural sector in many regions.

He accentuated the changes in agricultural productivity that are going to happen in the next 60 to 70 years and the fact that many countries would have problems concerning reduction in crop yield. Since the 1960s, much has happened to improve the agricultural yield such as technological advances, global efforts to ensure sufficient irrigation, and a fivefold increase in the use of fertilisers. In spite of these efforts, we have not been able to achieve food security. He believes that uneven distribution is not the only issue.

Prof. Hettiarachchi emphasised that we should look for multiple approaches because one single approach will not work. In this perspective, the Nexus Approach could help tremendously. The beauty of the Nexus Approach is in the practicality and policy-oriented thinking. Whenever we start discussing about a project, we try our best to involve decision makers from the policy sector because that will be the only way to realise the project. He presented a few outside-the-box examples involving innovative thinking in sludge management and reuse, managed aquifer recharge/storage with treated wastewater, and microbial fuel cell technology, to show us how the Nexus Approach could be helpful.

The Sustainable Development Goals (SDGs) set by the United Nations were also briefly introduced in the final few minutes of Prof. Hettiarachchi's talk. There are 17 of them and the goal is to help countries to achieve these goals by 2030. Among the 17 SDGs, four are related to soil, water, agriculture, waste, and their combination. This clearly means that there is more work to be done in order to imbue struggling countries with this kind of new thinking.

Section 4: Technical Aspects of SUWA

4.1 Ecological and Agricultural Aspects

Dr Frank Riesbeck (Humboldt University of Berlin) discussed the ecological and agricultural aspects of wastewater irrigation. Agricultural irrigation is the single largest factor of freshwater consumption worldwide, accounting for more than 70–80% of the total makeup. In addition, demand is projected to increase by 14% in the coming years. As irrigation solely based on freshwater can be deemed unsustainable, water reuse may become a promising solution to water scarcity.

Along with the spike in demand for freshwater, climate change is also prompting us to change how we should use limited resources like water. Impacts of global warming are changes in precipitation patterns, increased saltwater intrusion in aquifers, and lower precipitation ultimately leading to worsened water scarcity around the world. This will lead to not only shifts in cultivation periods and lower yields, but also destruction of cultivation itself.

To mitigate the harmful effects of climate change, understanding water balance in soils is very important. Water balance in soils includes the following concepts: structural properties of soil (grain size and texture), water distribution and cohesion in the soil (capillarity and adsorption), and water transport within the soil (infiltration and percolation).

Not all soil water can be utilised by a plant. Field capacity (FK) refers to the maximum water retention capacity of a soil in which no further significant infiltration is possible. In arid regions, however, FK does not reach its full capacity due to lack of precipitation. Plants also differ in minimum water required for growth. For example, potatoes require a small amount of water compared to wheat or citruses. This is why irrigation should be temporally and quantitatively adjusted in accord with the water/nutrient demands of various plants. Adequate management of irrigation is necessary.

Qualitative control of water used on plants is also required. Many different conditions must be satisfied. Yield productivity must be stable. The quality (usability) of soils and the adjacent ecosystems should also be protected or even be improved in the long term. Input of toxic substances must be prevented as well. To assess the overall quality of soils in regard to these criteria, nutrients, electrical conductivity, sodium adsorption ratio (SAR), pH value, Boron-concentration, and heavy metal concentration must all be reviewed as important parameters.

Not only water but the nutrients in reused water should also be carefully monitored. Amount of nutrients must be strictly under control. Over-fertilisation should be avoided at all costs since it may lead to serious damage on agricultural produce as well as reducing the yield. An example of 'a balance for a qualitative evaluation of the nutrient content in irrigation water nutrient concentrations' can be seen in the effluent of domestic sewage treatment plants: (nitrogen 55mg/litre) / phosphorus 7mg/litre).

Dr Riesbeck also discussed the salinity aspects. Salinisation is an issue that must be addressed. Excessive evaporation of irrigation water can result in salinisation. This is why soil and the irrigational facilities must be rinsed sufficiently beforehand, in order to avoid salt accumulation. Efficient drainage technology may also contribute in keeping groundwater from increased salinity. Regarding the monitoring of salt concentration in soil and water, electrical conductivity

can serve as an effective parameter. Also, by regulating the use of water with high SAR values, sodium saturation in soil can be controlled. Classifying irrigation water based on electrical conductivity and SAR, we may find out the most suitable water quality for a specific type of soil that is prevalent in an area. To combat salinisation, selecting the most adequate irrigation technique that minimises evaporation can also be helpful.

4.2 Selecting Appropriate Treatment Technology

Mr Roland Knitschky spoke to the audience about treatment steps for water reuse and selecting the appropriate technology. He represented the German Association for Water, Wastewater and Waste (DWA). Several technological options are available for water reuse and it is important to clarify the difference between the conventional ways of wastewater treatment and the one practised by DWA. DWA's method has its focal point on distribution, storage, and usage of wastewater instead of just bringing wastewater to the water body.

He enumerated integrated, interdisciplinary, and application-oriented procedures concerning water reuse and introduced a DWA document in which we find an evaluation of the treatment procedures in the form of a matrix. The complex structure and content of the matrix highlights the importance of health risks, operation costs, economic efficiency, environmental effects, and staff requirements pertaining to water reuse.

Mr Knitschky also introduced several technological examples of mechanical treatment such as trickling filters and constructed wetlands. In particular, he highly commended wastewater ponds; despite requiring a lot of space they are very efficient in aerated tanks in terms of the reducing pathogens. Activated sludge process is also very popular especially in Iranian plants. However, all these technologies become useless if they cannot be operated properly. This is why we need more specialists and a trained workforce in order to operate a sophisticated model.

At the end of his speech he talked about types and quantity of pathogens found in wastewater and methods of wastewater disinfection and also the treatment steps that are specially used in agricultural reuse. Mr Knitschky also explained how the quality requirements concerning treated wastewater may differ from case to case and the selection of suitable treatment stages.

4.3 Recent Developments in Technology

Prof. Wim van Vierssen (KWR Watercycle Research Institute, The Netherlands) addressed the technology development associated with water supply. By sharing his own experiences, he emphasised on the role of aquifer storage and recovery (ASR) in order to tackle water scarcity across Europe. His home country, The Netherlands illustrated a good example in applying ASR to address water shortage in coastal areas. According to Prof. van Vierssen, the preferable source for drinking water supply in the Netherlands comes from groundwater (60%). In the western part of the country freshwater was abstracted directly from the sandy dunes since 1854. However, due to increasing urbanisation and drinking water uses, natural replenishment became insufficient. Thus, since 1950 the groundwater in the dunes has been recharged with pre-treated surface water from the river Meuse and Rhine, which increased the capacity of water abstraction tenfold compared to natural groundwater. This, according to Prof. van Vierssen, is one of the oldest ASR applications in Europe.

Regarding the irrigation water supply, Prof. van Vierssen stated that aquifers can be the key element of water storage. In the Netherlands, the injection, storage, and recovery of rainwater in aquifers are applied in greenhouse horticulture and agriculture, reducing the damages during drought periods. Modern techniques like multiple partially penetrating wells (MPPW) in one borehole and brackish water reverse osmosis (BWRO) will optimise water infiltration in brackish or saline aquifers.

In his presentation, Prof. van Vierssen also broadened the context of water reuse in Europe in different domains such as indirect potable use, restricted/unrestricted irrigation, and urban reuse. He introduced some demo sites under the DEMOWARE project that reflect the variety of water reclamation technologies from extensive treatments to high-tech schemes. An example from Abu Dhabi, where drinking water is produced from desalinated seawater, showed the efficiency of underground water storage reservoir compared to aboveground storage. The ASR system in Abu Dhabi consists of three underground infiltration basins, holding a larger volume of water and securing water demand in case of emergency, e.g., algal blooms.

After outlining these practices at the SUWA workshop, Prof. van Vierssen concluded that ASR is increasingly applied worldwide and often considered as the technology of choice because of its reliability, sustainability, and cheaper costs. His unifying message was, "Manage the 'barrel' (aquifers) to prevent groundwater overdraft and pollution as well as to enhance the groundwater recharges."

Section 5: Economic, Social, and Health Aspects

5.1 Economic Aspects

A wastewater economist and a former employee of the International Water Management Institute (IWMI), **Dr Munir Hanjra** gave a presentation on the economic feasibility of wastewater reuse. Water scarcity in the agricultural sector is prompting many farmers to reuse their water resources. However, much of the reuse taking place is happening indirectly and informally, risking the safety of the produce irrigated with reused water. In many cases, moreover, monitoring of water, soil, and crop quality irrigated with reused water is absent. This brings up a very important question about the economic viability of wastewater irrigation, when we take the cost of proper treatment into account. Do we have other alternatives that may be safer and more cost-effective?

It is important to note some of the benefits of wastewater irrigation. Some of the advantages of wastewater reuse can be conservation of freshwater (especially in dry regions where freshwater is expensive), significant nutritional values of wastewater itself, and the low cost of land treatment. Also, reuse enables rural communities to generate livelihood opportunities for the poor and contributes to an overall decrease in the price of agricultural products.

However, wastewater irrigation also entails costs. If wastewater is properly treated before use, wastewater treatment plant (WWTP) capital and maintenance and operation (M&O) costs, cost for the upkeep of irrigational systems, and environmental costs may arise. If wastewater is not treated beforehand, this will generate health costs along the food chain and additional environmental costs for water and soil contamination. The latter part is especially important because they have long-term effects on the entire irrigational system but are often overlooked.

A framework for valuing impacts of wastewater reuse stipulates several key areas where costs can be incurred. Key areas such as public health, soil resources, property values, and the social and ecological impacts can be further divided into more detailed subcategories like insurance risk premium and medical costs. Along with the financial costs, other positive/negative impacts of wastewater irrigation will also be assessed. Put together, they will constitute the fundamental database on which various scenarios and policy guidelines will be formed.

Dr Munir underscored the importance of distinguishing financial analysis from economic analysis when assessing the impacts of wastewater reuse. While the former refers to the actual monetary benefits/costs incurred from reuse, the latter discusses benefits/costs from a more comprehensive perspective. The beauty of nature that may be compromised during a construction of a wastewater treatment plant, for instance, will be considered during an economic analysis while being disregarded for a financial analysis. Obviously, financial analysis is located within the boundaries of economic analysis.

Under closer scrutiny, we find that benefits of reuse under financial analysis are all labelled as sales revenues. From an economic point of view, on the other hand, benefits can be divided into increased community resilience and prosperity, promotion of public health, cost-savings, and so forth. Dr Munir's presentation primarily focused on the economic analyses and how, combined with the market price factor, this can be further developed into a sensitivity/risk analysis and policy guidelines.

Cost-effectiveness analysis shows that cost of wastewater treatment is minute compared to costs of other health measures like cholera immunisation. Conventional treatment is still not the most cost-effective option if we only look at human health benefits. Yet environmental health is equally important and this is why conventional treatment should be continued.

Lastly, Dr Munir pointed out that wastewater reuse business models are difficult to devise. By going through the four focal points on cost-saving strategy, wastewater reuse can become more viable and widespread in the future. The four points are reviewing various revenue sources, keeping the energy requirements low, partnering with the private sector, and investing in multiple barriers.

5.2 Health Aspects

Dr Maha Halalsheh (University of Jordan) centred her talk on the most simple yet fundamental question: 'Is treated wastewater safe enough for irrigational use?' The water chain shows us that once wastewater goes through the treatment plant, it will directly be used for farms to irrigate its produce.

She explained about a field experiment that was conducted on the banks of Zarqa River to demonstrate that properly treated wastewater does not impose any health risks. Different rows of zucchinis, cabbages, and bell peppers from the same greenhouse were given freshwater, disinfected secondary effluent, and secondary treated effluent with the same irrigation technique. When produce from each row was tested for bacteria such as salmonella, it was concluded that produce irrigated with freshwater was by no means 100% safe from pathogenic contamination. Rather, with strict treatment measures, produce irrigated with treated wastewater proved to be just as safe as the ones irrigated by freshwater. This is why, Dr Halalsheh believes, a sound sanitation safety plan that features system assessment, operational monitoring, documentation, and communication among different control bodies is needed.

5.3 Social Acceptance

The projected water scarcity in the next 10 to 30 years tells us that our planet simply cannot supply the ever-growing demand for water. According to Prof. Olfa Mahjoub (National Research Institute for Rural Engineering, Water, and Forestry, Tunisia), this is why wastewater reuse is inevitable. However, depending on the degree of treatment and dilution with freshwater, wastewater reuse can be a double-edged sword. It may be the pillar that supports agriculture and industry in many countries that suffer water shortage. On the other hand, potential dangers such as human health risks may arise from reuse of poorly treated wastewater. This is why reuse of wastewater should be based on three principles: reliable treatment for any wastewater, protection of public health, and public acceptance.

Sharp contrast concerning public awareness on wastewater reuse can be seen among different countries. Kuwait, a country suffering from chronic water shortage, nevertheless denies the use of wastewater, with only 14% of the population displaying positive attitudes. In countries such as the United States and Australia where reuse has been fairly successful, the majority of the population is in favour of the concept of wastewater reuse. Prof. Mahjoub believes that this disparity exists because insufficient education to raise public awareness is available in countries like Kuwait. Thus the more the population gets educated, the more likely it will be that they will be open to the concept of wastewater reuse.

Other factors that affect public acceptance of wastewater reuse are levels of direct exposure to wastewater, availability of alternative water resources, and religious tradition. Concerning direct exposure, it is widely accepted that people tend to accept neither potable nor irrigational reuse of wastewater due to the ‘yuck factor’. Instead, recreational use is much encouraged. Availability of alternative water resources can also hinder the reuse of wastewater. However, regions that are seriously considering the use of wastewater are the ones that have the fewest of options, which means that they will ultimately opt for clean and safe reuse of wastewater. Lastly, religious traditions must be taken into account as some religions advise against the use of wastewater.

Prof. Mahjoub also highlighted that the ‘zero risk’ does not exist in terms of wastewater reuse and that health risks should not be overlooked at the expense of economic benefits. But by rightly educating the masses on the issue with focal points on those who do not have access to sufficient water supply (women, children, impoverished farmers), wastewater reuse will turn out to be science’s greatest blessing.

Section 6: Policy Aspects

6.1 Regulations and Standards

Dr Frank Riesbeck (Humboldt University of Berlin) shared his perspectives on the regulations and standards for water reuse, at both national and international levels. In his talk, he emphasised the concerns on potential public health risks of wastewater reuse practices. According to Dr Riesbeck, the discharge of untreated wastewater and excreta into the environment through reuse practices can affect human health via several routes, namely polluting drinking water, entry into the food chain, and contact with contaminated waters. Thus, having regulations on the standard of water reuse is a must. Dr Riesbeck then introduced some of the widely used water reuse standards. At the international level, there are Guidelines for the safe use of wastewater, excreta, and greywater from World Health Organization (WHO) (2006), Guidelines for treated wastewater use for irrigation projects from the International Standard ISO 16075 (2015), and FAO water quality for agriculture (1994). Each of these guidelines has its own approach and application. The WHO guideline took into account the fact that the use of untreated or partially treated sewage is common practice and was built on a risk-based approach. The guideline gives the flexibility of selecting a range of treatment and non-treatment options along the sanitation chain to achieve health protection targets; however, implementation appears to be rather complicated. International Standard ISO 16075, on the other hand, classified treated wastewater quality into five categories according to wastewater treatment processes. The standards have been developed based on the multi-barrier concept, suggesting different number of barriers against pathogens depending on quality of treated wastewater and type of crop. At national level, Dr Riesbeck observed that there is a variety of standards with partially very high requirements on water quality. In his conclusion, Dr Riesbeck again highlighted the importance of implementing proper water reuse guidelines. He believes the risk-based approach and multi-barrier concept are promising tools to develop water reuse standards and regulations, especially for developing and emerging countries.

6.2 Policy Integration

Dr Said Neirizi (President, International Commission on Irrigation and Drainage (ICID)) stressed upon the importance of wastewater as a resource for sustainable development. He believes with proper management, wastewater reuse can contribute significantly to sustaining livelihoods, food security, and environmental protection. He dropped a fact that wastewater already irrigates approximately 49 million acres of crop land and 10 percent of the world population would starve if they do not have access to the food grown that way. However, reuse of wastewater has not received much attention by the policy/decision makers. According to Dr Neirizi, this might be due to the lack of viable models with necessary research and technology support.

There is also a need for wastewater reuse policy. Dr Neirizi pointed out some shortcomings in current policies related to wastewater. For example, national water policy often fails to include wastewater in their water budget while environmental management policies are often unsuccessful in regulating wastewater disposal to water bodies. The regulations regarding the protection of public health and environment remain big concerns. In order to develop the wastewater reuse policy, Dr Neirizi proposed some key elements that need to be taken into account such as health risks, drainage system, and soil and land management.

Dr Neirizi concluded that the strong polices and legal frameworks at national and state levels and sufficient trained manpower in the local bodies are required. The institutional manageability has to be instituted through an interdisciplinary approach, and the social participation and awareness of wastewater reuse need to be built.

6.3 Institutional Arrangements

Mr Roland Knitschky (DWA) explained multiple factors that affect the success rate of wastewater reuse. Public attitude towards reuse, conflicts between interest groups, and the existence of seed funding at the pilot phase all influence the process of reuse. However, quality and availability of water in the region are the most important factors since they invariably shape the overall water demand, thus, leaving us to decide whether to utilise wastewater or not in the first place.

Despite the unremitting efforts to provide clean and cost-efficient wastewater for irrigation, failure is always close. Lack of communication and information asymmetry between the decision maker, planner, and user often jeopardise the project from its early stage. Inadequate water quality and the absence of technology to treat this may also hamper proper reuse. Looking from the cost aspects, abnormally high water tariffs and availability of other cost-effective alternatives may hamstring wastewater reuse as well. In addition, if the scale of a reuse project is deemed too small, it may not attract enough investments.

Mr Knitschky then turns to various parties and target groups that are directly or indirectly involved in reuse projects in order to better understand the dynamics of institutional arrangements. Primary stakeholders are givers (wastewater utilities and suppliers), users (farmers and water consumers), and contractors who will be undertaking the reuse project. Secondary stakeholders are intermediary institutions, user groups, auditing organisations, and technical experts. Lastly, civil society groups and the public are categorised as external stakeholders. Compared to the primary stakeholders, secondary and external stakeholders may have less direct interests on a specific reuse project. Nonetheless, they can still exert heavy influence on the project.

Building confidence and promoting transparency among the stakeholders are also very important. We must establish a credible, independent control mechanism that oversees the whole procedure that is insulated from unjust influences of third parties. This means that the results of quality monitoring should be publicly available as well as revealing the information regarding the organisational structures to all. Aside from these measures, scenarios dealing with various situations must also be prepared in advance. One example of this control mechanism is the Sanitation Safety Planning (SSP). SSP is a risk-based management tool for sanitation systems developed by WHO. The manual assists users in systematically identifying health risks along the sanitation chain. It also guides investors to make judgements based on actual risks.

Section 7: Case Studies

7.1 Case Study 1: Germany

Mr Roland Knitschky (DWA) presented a case study from the city Braunschweig in Germany. This is one of the oldest examples of wastewater use in Europe. The city is now inhabited by 250,000 people and it is located in the central part of Germany. Traditionally the city has been a trading post and the centre of commerce. Today, Braunschweig is a city of scientific research and development.

He introduced Braunschweig's experience with wastewater by starting with a map of precipitation in Germany. There was not much rain in the city and the ground was close to being sandy. Wastewater treatment in the area employs the trickle percolation techniques on the fields of the "Gut Steinhof" in the north of Braunschweig. The technology was in use for over 100 years starting from 1895, and a third of all wastewater treated by the WWTP in 2005 is discharged on the percolation fields via a pressure pipeline and is partly used for agriculture.

Mr Knitschky explained all the components in the system: in one system it starts with the wastewater entering the WWTP, then the treated wastewater goes to percolation fields, and then to the river. In the other system, treated wastewater goes to irrigation fields for energy crops (since 2006), which are fed into a biogas plant for power generation. Meanwhile, the sludge goes to the digesters and cogeneration units. The dewatered sludge is brought to the irrigation as fertiliser in summer.

The inflow of treated wastewater to the percolation fields is 270 hectares and 3,500 mm per year. By observing the water flow in the percolation fields in which the post-treatment and elimination of N and germs takes place in a 10-days retention time, scientists let the water meander through the field and discovered that the treatment capacity of the area is stronger at the border than in the middle. This leads to the conclusion that the city must build up more borders in the field.

In addition to the technological advancement with regard to percolation fields, Mr Knitschky also explained about the improved surface water quality of the Oker River and its tributaries downstream during the time period of 1956 to 1994. These changes were all concurrent with the overall improvement in the irrigation situation of the area including new irrigation methods, the construction of a biogas plant, and decrease in heavy metal load.

Percolation Fields in Braunschweig (Source: DWA Training Material)

7.2 Case Study 2: Tunisia

The second case study was presented by Prof. Olfa Mahjoub (National Research Institute for Rural Engineering, Water, and Forestry, Tunisia) showcasing good practices in wastewater reuse for agricultural irrigation in Tunisia, which could be benchmarked by Iran. According to Prof. Mahjoub, this case study was highly successful in Tunisia and is also very simple.

The study area in Tunisia is Quardanine which is an agricultural town 130 km away from Tunis, which has a semi-arid climate making the region highly vulnerable to droughts. This land is merely 75 hectares in size but is being exploited by 46 farmers. The land is subjected to the jurisdiction of the Agricultural Development Group (GDA) and the Regional Department of Agricultural Development (CRDA).

The wastewater treatment plant was built in 1993 with a capacity of 1000 m^3/d and then water storage was the next issue pointed out by Prof. Mahjoub. A storage reservoir of 1000 m^3 was built by CRDA at the request of local farmers. The farmers themselves tried to improve the quality of water by removing suspended solids by placing a plastic net at the WWTP outlet in 2003. They also improved the system by putting a removable sieve and a metallic net to replace the plastic net. In the next step, a battery of filters comprised of sand, screen, or gravel were installed and maintained by CRDA. Regarding the irrigation method, several different methods were tested. This trial and error approach was possible due to the government's financial incentives on the development of water-saving techniques, which tallies up to 60% of the initial investment cost.

Storage reservoir (1000m^3) built by CRDA (Source: Olfa Mahjoub)

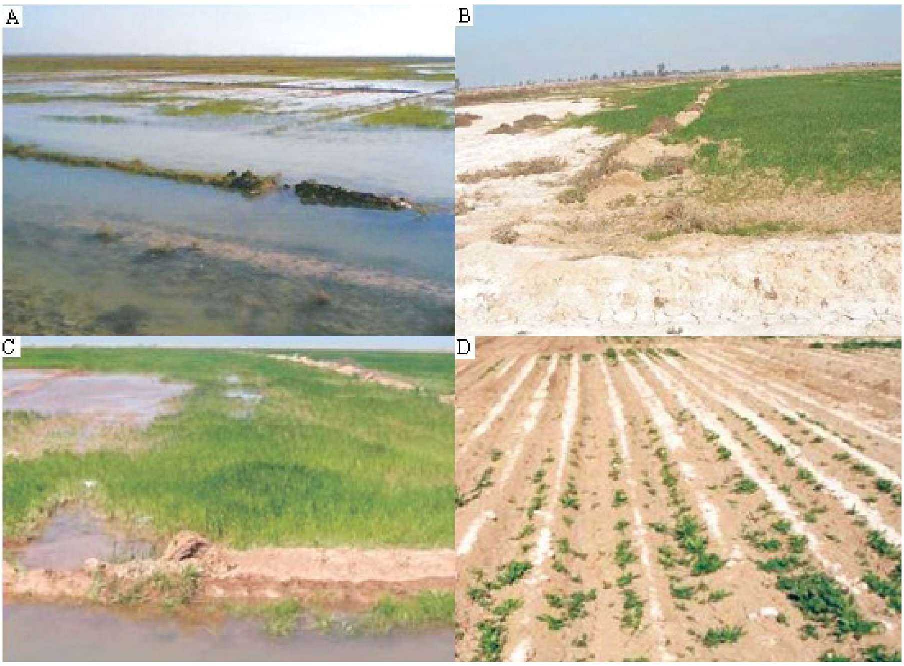
Prof. Mahjoub mentioned several criteria for sound guidelines of wastewater use. The guideline should take into consideration several factors including economic viability, environmental sustainability, social acceptability, and safety. The Tunisian Water Code follows this guideline by prohibiting the use of raw wastewater for irrigation and permitting only a handful of crops to be irrigated by wastewater.

7.3 Case Study 3: Iran

Dr Frank Riesbeck presented a case study on the water reuse and salinity issues in Khuzestan, Iran. He explained the master plan put together by the Khuzestan Water & Power Authority (KWPA) with the main objective of reducing the quantity of water used for irrigation and cut down pollution. There were also other objectives such as improving crop patterns, increasing irrigation efficiency, and reducing the amount of drainage water.

The irrigation and drainage networks in Dez, Dasht-e Azadegan, Minab, and Shushtar areas were taken into consideration by Prof. Riesbeck in his evaluation of the current situation. Water quality in Dez is good but it lacks the system to utilise drainage water. On the other hand, Dasht-e Azadegan is suffering from high rates of soil salinity which, Dr Riesbeck believed, is due to successive planting of sugarcane. He proposed a comprehensive overhaul of the irrigation system in order to irrigate the land and to desalinise the soil. In addition, Dasht-e Azadegan languishes from low groundwater level.

Dr Riesbeck also talked about the drainage channel system in Khuzestan and the geopolitical tension it engenders. He mentioned that the water volume along the Iraqi border is too great, especially in the south. The frequent flooding affects the Iraqi defence system in particular and has prompted issues. Finally, he proposed solutions for the management of water in the region. This includes the improvement of new irrigation technology, establishment of irrigation control systems, and development of an Internet-based Modular Built Expert and Management System (IRRIGAMA), and the redesign of drainage systems.



The major causes of salinity and water logging in Karkheh River Basin: Water logged (A) and severe salt build-up (B) in irrigated fields in lower KRB (Dasht-e Azadegan). Water logging and non-uniform distribution (C) and poor emergence (D) in saline water irrigated fields (Source: Frank Riesbeck)

7.4 Case Study 4: Jordan

The final case study was presented by **Dr Maha Halalsheh** (University of Jordan) and it was on the regulated use of wastewater for food production in Jordan. It was further divided into the direct and indirect reuse of wastewater.

Direct reuse occurs when wastewater does not mix with any other sources of freshwater and is used only for restricted irrigation. Only about 6% of the total Jordanian agricultural products are produced with direct use of wastewater and it is usually limited to fodders and fruits. This is because Jordanian law is strict on the direct use of treated wastewater, which encourages blending treated wastewater with freshwater. The remaining 94% of agricultural products come from 21,000 hectares of land irrigated by the indirect method. There is no restriction in this method and it is used for producing a variety of crops.

Direct reuse of wastewater in agriculture in Jordan is limited to fodders and fruit trees (Source: Maha Halalsheh)

Wastewater policies in Jordan imply that wastewater is an integral part of the Jordanian water budget (or water resources). Jordan has been practising wastewater irrigation for the past 40 years and therefore the policies are generally satisfactory. Prioritising the use of wastewater for agricultural use and monitoring crop quality cultivated with treated wastewater could be aspects Jordan should work on.

Section 8: Panel Discussion on SUWA Issues

The 90-minute panel discussion that took place on Day 2 of the workshop was one of the well-received and attended sessions. It was moderated by **Prof. Hiroshan Hettiarachchi** (UNU-FLORES) and all presenters participated as panellists. To manage limited time and to give the large audience reasonably proportioned time, the panel noted down the main questions concerns raised by the attendees. Few selected interesting points discussed by the panel are summarised in the paragraphs that follow.

Question: *In relation to the use of Membrane Bioreactor (MBR) systems that is now being used in Iran, do you have any recommendations? Due to the high cost of operation after the start of treatment, do you recommend any other conventional methods?*

Mr Knitschky: Our recommendations are based on assessment of needs. Usually wastewater goes into the rivers without disinfection. When we have a unique and nice river, people tend to sit on the side of the river in summer time. We think we have to care about this disinfection aspect. But in this case we do not do anything with membrane technology. We use UV technology. Because we just have to switch it on and off. I will not say we recommend membrane technology or other technology. It does not make sense to recommend one single technology. There are some instances where it is more appropriate to use membrane technology. Membrane technology is an excellent solution because of small space requirements and its ability to clean larger quantities.

Dr Hanjra: The cost of membrane technology, as you know, has fallen 700 times during the last 50 years and it is only now becoming acceptable, also cost-wise in some settings. It is absolutely extravagant. To have the membrane technology I guess you want to match the end use to irrigation and other purposes. That is one aspect. But in some settings it is most warranted.

Question: *Please give us statistics on the number of wetlands used in small communities of less than 5,000 people in Germany (in Iran equivalent to a village) and please explain how their effluent is used.*

Mr Knitschky: Statistics do exist, but I do not have them in mind. We have about 10,000 wastewater treatment plants that are less than 5,000 cubic metres. But in some areas it is common (10–20%) to use small wastewater treatment plants for households that are not connected to a central sewer system. If you are in such a situation, then you have to seriously think about small-scale decentralised wastewater treatment options, such as a wetland that cover three or four households.

Dr Riesbeck: On the second part of the question, that depends. Germany is not a reuse country. We do not have much direct reuse. We treat water as clean as possible and bring it back to the environment. We spend a lot of effort making wastewater clean enough so people are able to swim in the rivers where treated wastewater is discharged into.

Question: *In a pilot study in our region, untreated wastewater was used for cultivation of spruce and pine trees and the results were desirable. The trees that usually take seven years to grow were ready for cutting in 3.5 years. Could this lead to environmental problems?*

Mr Knitschky: I have seen that this has been done in many countries and good results have been obtained but in Germany there is no legal permission for this.

Question: *Can you share your experience on infectious diseases caused by wastewater in Jordan? There is an amoebic disease that can be transmitted through the skin and chlorine cannot destroy it. Do you have a plan to face such problems?*

Dr Halalsheh: We have some experience gained through a research project. One example is a project conducted by the German Federal Enterprise for International Cooperation (GIZ) where the experiments were continued for eight years on the effluent collected from a treatment plant in Jordan. All the samples were collected, tested, and certified by the Jordan drug and food administration and it showed safe products. We have also managed some projects for World Health Organization (WHO) together with international consultants, also to follow up on the quality of the products, which has also shown that they are safe.

We do not use amoeba as an indicator of water quality. Usually we have faecal coliforms, some standards, and some viruses and they are indicators for the presence of pathogens. In the standards, we have a certain value for these pathogens and it gives an indication for whether there is a problem with amoeba or not.

Dr Hanjra: This question also refers to the residual risk, which cannot be controlled by the treatment alone, irrespective of the technology you use (unless UV). The sanitation planning manuals mostly focus on treatment. It seeks for interventions along the value change to take care of the residual risk. You are not obliged and WHO no longer recommends you to use UV and highly sophisticated treatment. Usually we use treated water, mixed water, and untreated water. Then it can come in the combination of others. For example, about 8,000 farmers in Accra, Ghana produce vegetables for local consumption. They use polluted water from the streams. The number of consumers of those products is about 8 million people. Now is it easy for you to go for the treatment or target the 8,000 producers or educate the public about the safety measures? So treatment alone is not the solution and you have to combine it with other aspects.

Mr Knitschky: Jordan is going forward. They have one remarkable thing and that is the clear regulations. It is easy when you have a clear and harmonised legislation. Permanent learning process is the second point and the third aspect is the combination of decentralised treatment and reuse.

Question: *What do you do with the by-products of desalination?*

Dr Riesbeck: Normally when you have Reverse Osmosis at the end you receive 40 percent drinking quality water and 60 percent waste/brine. Reverse osmosis for us is not a perfect solution. This is an ongoing discussion in the Persian Gulf and also in the Caspian Sea area. There are big desalination projects that involve transporting water over 1,000 kilometres. This is not economical. You also need a lot of energy for desalination. This might be an option for countries like Saudi Arabia.

Question: *Are control systems, like the ones you explained, capable of controlling pollution parameters? Can we use them in a smaller scale for wastewater? You have drawn an evaluation model. How can social issues affect the results of such a model?*

Dr Riesbeck: About the first question we are fighting about data from the river. Sometimes the data from some inlets or outlets and drainage is from 2008 and 2009, but it is not clear how the data was collected. Having unreliable data is our biggest problem. At the moment we are designing the monitoring system and it includes which kinds of parameters should be investigated with which method, what is continually processed and what you have to do in the laboratory, and which kind of apparatus should be used in the laboratory? The problem is that we do not really have data and you cannot model the data that you do not have. We have no data on heavy metal parameters and many other contaminants.

This is not a problem limited to Khuzestan; we have it in other provinces of Iran and also in other countries. What we need is a master plan as a whole which extends to all provinces and regions. Then the question is how to make it. It is very complicated. It also involves political process. Yesterday I also said: Before you bring water from Karun River to Isfahan, evaluate the agriculture system in Isfahan. They have the same problems like there. You reduce irrigation and improve irrigation efficiency and that means protecting all water resources. That means not just agriculture.

Question: *If the standards are not observed at the discharge point, which organisation or body will compensate for the damages caused to farmers?*

Prof. Mahjoub: If the Wastewater Treatment Plant (WWTP) does not comply with the standards, then we should just stop delivering wastewater to the irrigated area. This just has to be done. One of the issues we have here is jurisdiction. Because a wastewater treatment plant belongs to the Ministry of Environment and the rest belongs to the Ministry of Agriculture. The WWTP can simply say then that we have done our job but they are not liable to pay for any compensation if things go wrong. This is why farmers asked for a storage basin in order to have a kind of buffer zone. What we have now is a small basin. They are asking for a kind of storage basin in order to have enough water in case of breakthrough. The second thing is that there is a priority order, so if the water is limited in the irrigated area they follow the priority order. They irrigate small trees. They do not go for the nursery. They try to limit water consumption, and during winter the water is distributed to the farmers upon demand. So if someone wants to irrigate, they are provided with water, but in summer where the demand is very high there is a kind of schedule to make it reasonable. This is how it works. We try to schedule irrigation and reduce consumption at the irrigation area. The question was also related to not meeting standards. Actually, it is still in revision. Our standards were a little bit stringent. Now we are going for more permissive standards in order that treatment plants can meet them.

Question: You mentioned that in Tunisia you have some illegal discharges to the network. This is exactly the problem we have also here in Iran. A large number of industrial units discharge their effluent illegally to the network. How do you handle this problem?

Prof. Mahjoub: Well, usually industrial units have to have a kind of pre-treatment, which is not done by many of them. It is the wastewater utility that is doing some auto control. They have a department just for industrial effluent. The mission of this department is to control the industrial units. Sometimes they can do nothing because they just recognise, for example, in the early morning that water salinity is high or the colour of water has changed. They know the industries by name and know which industry discharges what. Usually the units get fined. Unfortunately, these days, some of them are happy to pay the fine and then start again. So we have to enforce the regulations. Having the right regulations is important. Then enforcing them is more important.

ANNEX LIST

Appendix 1: Field Visit

On the third (and the final) day of the workshop, participants visited the South Tehran Wastewater Treatment Plant. The plant is located in the southwest part of Ray, the oldest city in the Tehran province. It occupies about 31 hectares of land and has the potential to treat wastewater produced by 2 million inhabitants of Tehran. Some memories captured by camera during the field visit are presented in this Appendix.

Appendix 2: Programme Highlights

Day	Session	Time	Coverage
Day 1	**Registration**	08:00-08:30	
	Inauguration	08:30-10:30	Welcome Address by: › Shahid Beheshti University › TADBIR Economic Development Group › UNU-FLORES (10min) Country Status (Iran): Water Scarcity and Reuse The National Iranian Effluent Reuse Master Plan
		10:30-11:00	*Coffee Break & Networking*
	Session 1	11:00-12:30	S1-1 Capacity Development Perspectives of SUWA › Prof. Reza Ardakanian (UNU-FLORES, Germany) S1-2 SUWA and the Nexus Approach › Prof. Hiroshan Hettiarachchi (UNU-FLORES, Germany)
		12:30-14:00	*Lunch Break*
	Session 2	14:00-15:30	S2-1 Wastewater Economics: Cost/Benefit, Financing, Business Models › Dr Munir Hanjra (formerly at IWMI, South Africa) S2-2 Acceptance by Different Stakeholder Groups › Mr Roland Knitschky (DWA, Germany) S2-3 Social & Cultural Dimensions › Prof. Olfa Mahjoub (INRGREFF, Tunisia)
		15:30-16:00	*Coffee Break & Networking*
	Session 3	16:00-17:30	S3-1 Technological Basics of Water Reuse › Dr Frank Riesbeck (Humboldt University of Berlin, Germany)

Day	Session	Time	Coverage
Day 2	**Session 4**	08:30-10:30	Workshop Updates › Prof. Reza Ardakanian S4-1 Health Aspects › Dr Maha Halalsheh (University of Jordan, Jordan) S4-2 Implementation Issues/Need for Policy Integration › Dr Saeed Nairizi (ICID) S4-3 Safe Reuse of Wastewater in Subsurface Irrigation › Prof. Wim van Vierssen (KWR, The Netherlands)
		10:30-11:00	*Coffee Break & Networking*
	Panel Discussion	11:00-12:30	Panel Discussion › Moderator: Prof. Hiroshan Hettiarachchi › Panel: All Presenters
		12:30-14:00	*Lunch Break*
Day 3	**Session 5**	14:00-16:00	S5-1 Treatment Steps for Water Reuse: Selecting Appropriate Technology › Mr Roland Knitschky (DWA, Germany) S5-2 Case Study 3: Khuzestan, Iran › Dr Frank Riesbeck (Humboldt University of Berlin, Germany) S5-3 Case Study 4: Jordan › Dr Maha Halalsheh (University of Jordan, Jordan)
		16:00-16:30	*Coffee Break & Networking*
	Session 6	16:30-17:30	S6-1 Regulations & Standards › PD Dr Frank Riesbeck (Humboldt University of Berlin, Germany) S6-2 Case Study 1: Germany › Mr Roland Knitschky (DWA, Germany) S6-3 Case Study 2: Tunisia › Prof. Olfa Mahjoub (INRGREFF, Tunisia)
	Closing	17:30-18:00	Closing Remarks
	Field Visit	09:00-14:00	Field visit: South Tehran WWTP, the largest of its kind in operation in the Middle East, financed by the World Bank

Appendix 3: International Team of Experts

in alphabetical order

Prof. Dr Reza Ardakanian
United Nations University (UNU-FLORES)
Dresden, Germany

Prof. Ardakanian is the Founding Director of UNU-FLORES. He led the UN-Water Decade Programme on Capacity Development hosted by UNU from 2007 to 2015. He has a civil engineering background and he earned his PhD in water resources management. Before joining UNU, Prof. Ardakanian served the Islamic Republic of Iran at various levels and held many political, academic, and research positions. He has also served the international community on different fronts and most notably as a board member of UNESCO-IHP, UNESCO-IHE, and UNU-EHS and also as the Vice Rector of UNU in Europe between 2009 and 2011.

Dr Maha Halalsheh
Water and Environmental Research and Study Centre (WERSC),
University of Jordan
Amman, Jordan

Dr Halahsheh is a researcher at the Water and Environmental Research and Study Centre (WERSC) in the Water, Energy and Environment Institute of the University of Jordan. She is an expert in Integrated Water Resource Management (IWRM) with main interests in water quality issues, drinking water and wastewater treatment technologies (focusing on low-cost techniques), and anaerobic digestion and energy recovery from biogas. The research project she recently concluded for the World Health Organization on Sanitation Safety Plans for Jordan is among the many important applied research projects that she has contributed to.

Dr Munir Hanjra
(formerly an economist at IWMI, Pretoria, South Africa)
Canberra, Australia

With around 25 years of experience, Dr Hanjra is one of the leading experts in wastewater economics and has experience in wastewater-related issues from Australia, Asia, and Africa. He served as an economist at the International Water Management Institute (IWMI) in Pretoria, South Africa before becoming a freelancer recently. He has carried out several research projects on global and regional water scarcity, water quality, food security, poverty reduction, and public policy. Currently his main research interest is in the finance and economics of wastewater reuse in rural-urban interface.

Prof. Dr Hiroshan Hettiarachchi
United Nations University (UNU-FLORES)
Dresden, Germany

Prof. Hettiarachchi heads the Waste Management Unit at UNU-FLORES. His background is in civil engineering and he has conducted research and published extensively in the areas of geotechnical and geoenvironmental engineering and sustainable waste management. He is also an expert in graduate programme development and took the lead in developing the joint Doctoral Degree Programme in Integrated Management of Water, Soil and Waste offered by UNU-FLORES in partnership with Technische Universität Dresden. Prior to joining UNU, he was at the Lawrence Technological University in Michigan, USA.

Dipl.-Geol. Roland Knitschky
German Association for Water, Wastewater and Waste (DWA)
Hennef, Germany

Mr Knitschky is a Hydrogeologist and Capacity Developer in the water sector. He is currently the DWA Project Manager and the Subject Specialist for International Cooperation. He has over 20 years of German and international experience within the water and wastewater sectors and specifically in the areas of technical standards and associations as tools for self-organisation in the water sector, human resources and organisational development, "Train the Trainer" qualification and curriculum for skills development. Prior to joining DWA, he was at the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) for several years as a Technical Advisor and a Project Manager.

Prof. Dr Olfa Mahjoub
National Research Institute for Rural Engineering, Water, and Forestry (INRGREF)
Tunis, Tunisia

Interested in emerging contaminants in water resources and soil, water management and quality, wastewater reuse, and risk assessment and management, Prof. Mahjoub has years of research and teaching experience. As an agricultural engineer she has conducted research investigations in areas that allowed her to work as water quality and reuse specialist. She currently serves at the National Research Institute for Rural Engineering, Water, and Forestry (INRGREF) in Tunisia. Prof. Mahjoub has been a project coordinator and member of international consortia for research and development partnerships, such as the Tunisian-German cooperation (DAAD), Tunisian-American cooperation (USDA), and African Union commission.

PD Dr habil. Frank Riesbeck
Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences, Humboldt University
Berlin, Germany

Agrarian Engineer Prof. Riesbeck is currently the Head of Section of Ecology of the Utilization of Resources of the Agricultural & Horticultural Faculty (Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Science) at the Humboldt University Berlin. He has years of university experience as a researcher and academic. He is an expert in recultivation and ecology of locations, water protection and water pollution control, irrigation and drainage in agriculture and horticulture, engineering biology, and ecological practical investigations of biotopes. Dr. Riesbeck has carried out numerous projects within the European Union and elsewhere concerning reutilisation of contaminated sites for different activities and purposes, mainly related to agricultural activities.

Dr Said Neirizi
International Commission on Irrigation and Drainage (ICID)
New Delhi, India

Dr Saeed Nairizi is currently the president of the international Commission on Irrigation and Drainage (ICID) and also the CEO of Toossab Consulting Engineers Company, one of the major Iranian consultants in water works. He obtained his PhD in Civil Engineering (water resources) in 1977 from Southampton University, UK. Dr. Nairizi served as a member of the scientific board at Ferdowsi University of Mashhad and also as a consultant in water works until 1988. He was then appointed by the Iranian Ministry of Energy as the Managing Director. He has been collaborating with ICID form 1994, since then he has assisted this commission in different capacities.

Prof. Dr Wim van Vierssen
KWR Watercycle Research Institute
Groningenhaven, The Netherlands

Since 2007 Prof. van Vierssen holds the position of Director of the KWR Watercycle Research Institute in The Netherlands and since 2009 he has also been appointed as Rathenau Professor at Delft University of Technology. Biophysicist by profession, Prof. van Vierssen has taken the lead in several initiatives and projects within The Netherlands and elsewhere that allowed him to build an extensive professional network representing both private and public sectors in the areas of water and environmental science/ engineering. He also made notable contributions to academia as the Rector of International Institute for Infrastructural, Hydraulic and Environmental Engineering (IHE) in the late 1990s.

Appendix 4: List of Attendees who Received a Certification of Completion

information provided by NWWEC

List of Participants

No.	Title	First name	Surname	Designation	Organization
1	Mr	Sattar	Mahmoudi	Vice Minister	Ministry of Energy
2	Mr	Bahram	Taheri	Advisor to Minister	"
3	Mrs	Mariam	Marandi	Head of W&WW Quality Monitoring Systems	"
4	Mr	Alireza	Samadi	Expert, W&WW Quality Monitoring Systems	"
5	Mr	Seyed Mohammad Mehdi	Noorbakhsh	Head of Administration and Supervision of Operations	"
6	Mr	Mohammad	Ebrahimnia	Director General, W & WW Macro Planning	"
7	Mr	Ali	Heidari	Head of Water Resources Planning and Allocation	"
8	Mrs	Shamila	Firoozmanesh	Effluent Expert	"
9	Mr	Masoud	Najafi	Environment Assessment Expert	"
10	Mrs	Sedigheh	Torabi	-	"
11	Mrs	Elham	Rasoulpour Shabestari	-	"
12	Mr	Shahir	Kanaani	-	"
13	Mr	Reza	Hosseinirad	-	"
14	Mr	Hamid Reza	Janbaz	Chairman and Managing Director	NWWEC

No.	Title	First name	Surname	Designation	Organization
15	Mr	Seyed Shahab	Pakzamir	Manager, MD Office	"
16	Mr	Ali Asghar	Ghane	Deputy Planning and Development	"
17	Mr	Hamid Reza	Tashauoei	Deputy, Operations	"
18	Mr	Shahin	Pakrouh	Deputy, Finance and Logistics	"
19	Mr	Seyed Hamid Reza	Kashfi	Manager, Bureau for Mobilization of Funds	"
20	Mr	Hossein	Aboutorab	Manager, Bureau for Technical Studies	"
21	Mr	Mohammad	Khalilipir	Manager, Public Relations and International Affairs	"
22	Mr	-	Moharamirad	Manager, Security and Confidential Affairs	"
23	Mr	Mojtaba	Ahmad Khan	Interpreter	"
24	Mrs	Fariba	Golrizan	Expert, Bureau for Mobilization of Funds	"
25	Mrs	Behnaz	Derakhshani	"	"
26	Mr	Morteza	Barfi	"	"
27	Mr	Seyed Majid	Amin	"	"
28	Mr	Ramin	Alipour	"	"
29	Mrs	Mariam	Zerang	"	"
30	Mrs	Maliheh	Eskandari	"	"
31	Ms	Ghazaleh	Khoshroo	"	"
32	Mrs	Saeedeh	Ramezani	"	"
33	Ms	Narges	Bahrami	"	"
34	Mr	-	Vakili	Manager, Supervision of WW Operations	"
35	Mr	Mohammad	Ghassemian	Expert, Supervision of WW Operations	"

No.	Title	First name	Surname	Designation	Organization
36	Mr	Vahid	Hosseinzadeh	"	"
37	Mrs	Mariam	Yazdi	"	"
38	Mr	Morteza	Mojthedi	Manager, Research and Industrial Self Sufficiency	"
39	Mr	Kamran	Esmaeili	Manager, Bureau for Supervision of W&WW plans	"
40	Mr	Kaveh	Alinejad	Expert, Bureau for Supervision of W&WW plans	"
41	Mr	Mohammad	Sabouhi	"	"
42	Mr	Amir Hossein	Raghimi	Manager, Bureau for Planning W&WW Plans	"
43	Mr	Asghar	Jahani Behnamiri	-	Water Res. Mgt.
44	Mr	Javad	Hassan Nejad	-	"
45	Mr	-	Mehrnia	Manager, National Plan for Effluent Reuse	Tehran University
46	Mr	-	Zand	Head of Agro Research, Training and Promotion	Mgt. & Plan. Org.
47	Mr	-	Adl	Head of Water, Agriculture and Nat. Resource	"
48	Mr	-	Pourmohammadi	Deputy, Development of Production Affairs	"
49	Mr	Fariborz	Ansari Mahbadi	Expert, Infrastructural Budget Affairs	"
50	Mr	Mohsen	Dehghan Menshadi	"	"
51	Mrs	-	Talayeh Rahsepar	"	"
52	Mr	Abbas	Zeraat	Dean	Kashan University

No.	Title	First name	Surname	Designation	Organization
53	Mr	Hossein	Khorasanizadeh	Head of Research on Water, Draught & Climate Change	"
54	Mr	Eghbal	Rostami	Head of Wastewater Group	Dep. of Env.
55	Mrs	Elham	Sofalaei	Expert, Surface Waters	"
56	Mrs	Seyedeh Leyla	Khavar	Expert, Wastewater	"
57	Mrs	Atefeh	Abdolhai	Expert, Treatment plant	Pars Peyab Consult.
58	Mr	Masoud	Farahi	Senior Expert Water and Wastewater Installations	Yekom Cons. Eng.
59	Mr	Mohammad	Nazemzadeh Naraghi		Pars Consult Eng.
60	Mr	Reza	Abbaspour	Deputy Managing Director	Moj Ab Co.
61	Mr	Mojtaba	Golkari	Process Expert	W&WW Research & Plan
62	Mr	Behzad	Nikbakht	Structural Expert	Pars Ab Tadbir Co.
63	Mr	Saeed	Neyrizi	Managing Director	Toos Ab Cons. Eng.
64	Mrs	Atiyeh	Ardakanian	Expert	"
65	Mr	Masoud	Mashhadipour	Supervisor of Dams and Networks Section	Rey Ab Cons. Eng.
66	Mr	Ebrahim	Raeesi	-	Mahab Ghods Cons. Eng.
67	Mr	Hooman	Liaghati	-	Shahid Beheshti University
68	Mr	Mohsen	Nosrati	-	Pars Jouyab Cons. Eng.
69	Mr	Seyed Ali	Mahmoudian	Secretary	IWA National Committee
70	Mr	Ramin	Jamshidian	-	Qeshm Water & Power Inst.
71	Mr	Mohammad Reza	Jangjoo Mehranguiz	Manager, Environment	Municipality Zone 19
72	Mr	-	Rafiei	Manager, Environment	Municipality Zone 20

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ADVANCING A NEXUS APPROACH TO THE SUSTAINABLE MANAGEMENT OF ENVIRONMENTAL RESOURCES

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