ACTIVITY 1.3.4.4 – GUIDELINES FOR DEVELOPING NATIONAL REGULATION FOR MANAGED AQUIFER RECHARGE IN TWO SWIM COUNTRIES

FINAL REPORT ON

DRAFT GUIDELINE FOR MANAGED AQUIFER RECHARGE WITH - IN PARTICULAR - TREATED WASTEWATER IN PALESTINE

Version	Title of document	Authors	Review and Clearance
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The SWIM Program (2010 – 2014)

Contributing to Sustainable Water Integrated Management in the Mediterranean

Funded by the European Commission with a total budget of approximately € 22 million, Sustainable Water Integrated Management (SWIM) is a Regional Technical Assistance Program aiming to contribute to the effective implementation and extensive dissemination of sustainable water management policies and practices in the South-Eastern Mediterranean Region in view of increasing water scarcity, combined pressures on water resources from a wide range of users, desertification processes and in connection with climate change.

The SWIM Partner Countries (PCs) are: Algeria, Egypt, Israel, Jordan, Lebanon, Libya[1], Morocco, Palestine, Syria and Tunisia.

SWIM aligns with the outcomes of the Euro-Mediterranean Ministerial Conferences on Environment (Cairo, 2006) and Water (Dead Sea, 2008) and also reflects on the four major themes of the draft Strategy for Water in the Mediterranean (SWM), mandated by the Union for the Mediterranean, namely: Water Governance; Water and Climate Change; Water Financing and; Water Demand Management and Efficiency, with particular focus on non-conventional water resources. Moreover, it is operationally linked to the objectives of the Mediterranean Component of the EU Water Initiative (MED EUWI) and complements the EC-financed Horizon 2020 Initiative to De-Pollute the Mediterranean Sea (Horizon 2020). Furthermore, SWIM links to other related regional processes, such as the Mediterranean Strategy for Sustainable Development (MSSD) and the Arab Water Strategy elaborated respectively in the framework of the Barcelona Convention and of the League of Arab States, and to on-going pertinent programs, e.g. the UNEP/MAP GEF Strategic Partnership for the Mediterranean Large Marine Ecosystem (Med-Partnership) and the World Bank GEF Sustainable Mediterranean.

The Program consists of two Components, acting as a mutually strengthening unit that supports much needed reforms and new creative approaches in relation to water management in the Mediterranean region, aiming at their wide diffusion and replication.

The two SWIM Components are:

- A Support Mechanism (SWIM-SM) funded with a budget of € 6.7 million and
- Five (5) Demonstration Projects funded with a budget of approximately € 15 million

For more information please visit http://www.swim-sm.eu/or contactinfo@swim-sm.eu

[1]The situation in Spring 2012 is that following formal EC decision, activities have been stalled in Syria while Libya has officially become a Partner Country of the SWIM Program

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List of Acronyms

ASR	Aquifer Storage and Recovery
BCM	Billion Cubic Meters
BOD	Biological Oxygen Demand
EIA	Environmental Impact Assessment
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
IWRM	Integrated Water Resources Management
MAR	Managed Aquifer Recharge
MCM	Million Cubic Meters
MEnA	Ministry of Environmental Affairs
MFI	Membrane Filtration Index or Membrane Fouling Index
MoA	Ministry of Agriculture
MoF	Ministry of Finance
MoH	Ministry of Health
MoLG	Ministry of Local Government
MoPAD	Ministry of Planning and Administrative Development
MOU	Memorandum of Understanding
OPS	Occupied Palestinian State
PSI	Palestinian Standards Institute
PWA	Palestinian Water Authority
SAT	Soil Aquifer Treatment
SWIM	Sustainable Water Integrated Management
SWIM-SM	Sustainable Water Integrated Management – Support Mechanism
TSE	Treated Sewage Effluent
TSS	Total Suspended Solids
WHO	World Health Organization
WWTP	Wastewater Treatment Plant

1 EXECUTIVE SUMMARY

Whereas a MAR-friendly policy environment emerges from official policy documents, the regulatory environment, while not un-supportive of MAR, lags behind in certain respects. The principal regulatory instrument on record – i.e., the **Guidelines for Wastewater Reuse in the Gaza Strip** (2002) – is on-target and, in combination with other legislation – notably, the **Water Law, 2014** and the **Environmental Law, 1999** – provide a pretty comprehensive coverage of the recharge and the recovery segments of the MAR regulatory cycle. There are aspects of the cycle, however, which call for fine-tuning of the existing regulatory framework as regards, notably, (a) internal coodination among the regulatory mechanisms of the legislation cited, and (b) the penalties which sanction certain illegal behaviours in regard to, notably, water pollution prevention and control, which may discourage MAR. In response, the proposed Guideline sets forth a complete regulatory framework for MAR, having Integrated MAR Licensing (IML) and Risk Management Planning (RMP) as its centrepieces. IML is designed to ensure continuity and consistency of regulatory coverage of all phases of the MAR regulatory cycle, from the procurement of wastewater as MAR source water to treatment to recharge, all the way to eventual recovery for final use.

Great pains are taken in the proposed Guideline to ensure coordination and consistency of IML with the known MAR-relevant legislation in effect, and to regulate the entire lifecycle of an integrated MAR licence all the way to the eventual demise of a MAR scheme. RMP is an integral part of IML, and its contours are sketched out in detail in a Schedule to the Guideline. PWA will play a central role in the administration, monitoring and enforcement of the proposed Guideline, with attention paid to the institutional roles and prerogatives of other key central government actors – notably, the Health Ministry, the Agriculture Ministry, and EQA. Finally, great pains are taken in the proposed Guideline to reconcile the penalties for illegal behaviours which are found in the existing MAR-relevant legislation, particularly regarding water pollution prevention and control, with the purposes of MAR in general, and with the regulatory package proposed in the Guideline in particular.

Aquifer recharge with treated wastewater must not lead to any significant and sustained degradation of the quality of the groundwater. This should be a prerequisite of any aquifer recharge project. For this reason only homogeneous aquifers (sand and gravel) should be used for aquifer recharge with treated wastewater. In these type of aquifers artificial recharge can be adequately controlled. In Palestine homogeneous aquifers are relatively scarce. The alluvial sandy deposits present in Gaza and in the area around Jericho may be regarded as homogeneous aquifers that allow for controlled aquifer recharge. Aquifers with secondary porosity such as limestone and karstic aquifers, that are found in the West Bank should be excluded, since the distribution of infiltrated water in this type of aquifers is difficult to manage. For every specific case it should be verified that the aquifer to be used for MAR can be defined as homogeneous. For the design of a safely manageable MAR system detailed knowledge of aquifers is required to enable for a custom-made design of the recharge and recovery system.

Most of the existing wastewater treatment plants in Palestine are functioning at moderate efficiency rates and above their actual capacity. The availability of wastewater with advanced treatment, which has to be regarded as a minimum requirement for artificial recharge, is limited. So there is a large need and challenge for upgrading the treatment plants, both in capacity and treatment methods.

The proposed guidelines for artificial recharge of treated wastewater in Palestine presented in this report focus on artificial recharge for non-potable use. Recharge with treated wastewater for potable use is not considered.

For the implementation of MAR with treated wastewater it is recommended to develop pilot projects to build up specific experience. This may include different techniques of artificial recharge (e.g. by ponds and by deep wells) and different combinations of treatment methods depending on the quality of the source water. A capacity building programme should be part of the pilot projects.

2 INTRODUCTION

2.1 Background and context

SWIM is a Regional Technical Support Program that includes seven Partner Countries, with Palestine being one of them. The Program is funded by the EU under the European Neighborhood and Partnership Instrument (ENPI) South/Environment. Its overall objective is to promote actively the extensive dissemination of sustainable water management policies and practices in the region given the context of increasing water scarcity, combined pressure on water resources from a wide range of users and desertification processes, in connection with climate change.
Within such context, the SWIM-Support Mechanism (SM) is addressing non-conventional water resources as a promising option to partially fill the gap and provide better balance between water supply and demand in the region. Managed Aquifer Recharge (MAR) using adequately treated wastewater, in particular, is gaining momentum as a valid option to ease the pressure on groundwater over-exploitation, to halt falling groundwater tables, to stall seawater intrusion particularly in coastal aquifers, and to check pollution of aquifers through Soil Aquifer Treatment (SAT) techniques.
Given the chronic water scarcity in most of the SWIM region, many countries are either practising or contemplating artificial recharge of their exhaustible groundwater aquifers using treated wastewater as a convenient water management measure. Artificial recharge of aquifers in most of the region, however, is practised without any regulatory framework seeking to minimize the risk to public health, to the environment, and to native groundwater from the reuse of treated wastewater for MAR purposes. Within its technical support to countries of the region, SWIM-SM developed ***Regulatory Framework Guidelines for Managed Aquifer Recharge Using Treated Wastewater as Source Water*** (March 2014), based on global experience and best practices[2].

In a bid to encourage uptake of the Guidelines by the partner countries, SWIM has designed a specific activity to adapt the Guidelines and to draft national regulations for the control of artificial wastewater recharge to groundwater aquifers in two project countries, namely, Egypt and Palestine.

This report, in particular, follows on from a visit to Palestine from 14 to 19 June 2015 by the authors, and it reflects the outcome of a National Consultation held in Ramallah on 5 October 2015, where a draft of the report was reviewed and debated by a group of stakeholders representative of government and academia, with the participation of the authors.

2.2 Structure and scope of the report

Following on from this Introduction, the MAR-relevant policy, legal and institutional context in Palestine are reviewed, and gaps and constraints hindering MAR with, in particular, treated wastewater are assessed (Part 3 of the report). This is followed (in Part 4) by the review of the technical context of MAR with, in particular, treated wastewater, including an analysis of the main techno-economic gaps and challenges that may hinder MAR, and the illustration of the "technical" substance of the proposed Guideline including, in particular, standards of wastewater effluent quality specific to MAR. The full text of the proposed Guideline setting forth a regulatory framework for MAR is given in Part 5. In Part 6, conclusions are drawn, and recommendations put forward for the consideration of the Palestinian government.

It bears emphasizing that, whereas this report and the proposed Guideline are primarily aimed at MAR with treated wastewater, at the explicit request of the Palestinian government the scope of this report – and of the proposed Guideline - has been expanded, wherever possible, to include stormwater, in combination with treated wastewater or also alone, as MAR source water.

2 The document is downloadable from http://www.swim-sm.eu/, by following the link to "Library", then to "Assessments".

3 REVIEW OF MAR-RELEVANT POLICIES AND LEGISLATION AND ASSESSMENT OF GAPS AND CONSTRAINTS HINDERING MAR

In this Part of the report the MAR-relevant policy and regulatory environment in Palestine are analyzed, and the responsiveness of such environment to the challenges posed by MAR with, in particular, treated wastewater, also in combination with stormwater, or with stormwater alone, is assessed. The analysis and assessment are based on primary and secondary sources, i.e., (a) the actual text of policy documents and of legislation, available in English, and (b) available literature in English.

3.1 Policy environment

The policy environment relevant to MAR in Palestine is evolving. The principal policy instruments of relevance here are:

- the **National Water and Wastewater Strategy (2015)**. The Strategy is the most articulate, comprehensive and authoritative statement of government policy in the matter of water and wastewater, including relevant service delivery. In the Strategy:
    - treated wastewater is regarded and dealt with as an additional water resource. The Water Law 2014 has provided legal backup to this policy
    - it is the stated policy of the government "to increase stormwater infiltration at upper elevations to recharge the aquifers" (p. 14)
    - wastewater will be treated to produce "reuse-quality water", for irrigation and/or <u>infiltration</u>, however if irrigation water is not required, treated wastewater will be used for <u>infiltration and recharge of aquifers</u> (emphasis added) (p.73)
- the **Environment Sector Strategy 2011-2013**. The Strategy was first developed by the Environment Quality Authority (EQA) in 2010, and is currently being updated to cover the 2014-2016 horizon. Expansion of the use of "alternative and non-conventional" water resources, and of the scope of "wastewater collection, treatment and reuse services" feature in a long list of "sectoral policies". They are ranked third and seventh, respectively, in a priority order of nineteen policy "interventions" to be implemented, by other institutions than EQA. No explicit reference is made, however, to managed aquifer recharge among the "reuse services" of treated wastewater. The rehabilitation of the coastal aquifer in the Gaza Strip, ranked atop the priority list of the said policy "interventions", seems relevant in this context in view of MAR with treated wastewater blended with stormwater being the only conceivable and practicable such intervention in the context of the Gaza Strip[3]
- also the **National Plan for Natural Resources and Historical Sites**, approved in 2014, is relevant as it is the lead policy instrument in the matter of land use/spatial planning. The Plan identifies, among others, "water-sensitive" areas, which include natural groundwater recharge areas. The Plan and its determinations are mandatory, and as such they are an insurmountable barrier to any land use/development activity in the country, including MAR projects in general.

3.2 Regulatory environment

The regulatory environment relevant to MAR in general, and to the reuse of treated wastewater for MAR in particular, in Palestine is made up of the following main pieces of legislation:

3 Sectoral policies, No.1 (1st round bullet, last square bullet, p.25; 3rd round bullet, 9th square bullet, p.26); No.4 (2nd round bullet, 4th square bullet, p.28); and Table 2, p.29-30.

Water Law, Decree No.14 of 2014[4]. As far as MAR in general, and the reuse of treated wastewater for MAR in particular, are concerned, the Water Law:

- Regards "non-conventional" water as public property, on a par with "conventional" water resources (Art.3 and definition of "Water Resources" in Art.1)
- Requires a license from PWA for the abstraction of water resources (Art.29(1)(A), (B)). Licenses are time-bound, and can be amended, suspended or revoked under given circumstances (Art.32(1)). Violation of the terms and conditions of a license results in the suspension of the license until the violation stops and its consequences have been remedied (Art.32(2))
- Sets up a Water Sector Regulatory Council (WSRC), with the task of regulating the provision of water supply and wastewater disposal services – including treatment of wastewater - through a licensing mechanism of service providers (Arts.18, 24(2))
- Directs PWA to take part in the "preparation of a list of pollutants which require licensing" (presumably prior to final discharge to a wadi or underground, however the Law is silent on the scope and purpose of the required "licensing", and this is a glaring omission which requires urgent fixing – see also further below) (Art.50(4))
- Empowers PWA to designate Protected Water Zones in situations of water resources being at risk of depletion, or of water quality being at risk of contamination. Restrictions may be imposed on water use as a result of such designation (Art.52)
- Directs any one causing pollution of water resources to remove such pollution, and directs PWA to substitute itself for a non-compliant polluter, at his/her cost (Art.53)
- Punishes with a jail term of from six months to one year, and a fine from one thousand to five thousand JD, the drilling of wells or the abstraction of water without a license
- Punishes with a jail term of from six months to one year, and a fine from one thousand to five thousand JD, also the disposal of wastewater without a prior license (Art.58(5)) – the Law however fails to (a) require a license (or permit) for the disposal of wastewater as a matter of law and policy, and (b) to determine who is competent to grant such license (or permit). These are glaring omissions in the Law which require urgent fixing
- Also punishes with a jail term of from six months to one year, and a fine from one thousand to five thousand JD, pollution of water resources, if the polluter fails to remedy it as directed by PWA (Art.58(1)).

Environmental Law – Law No.7 of 1999[5]

As far as MAR in general, and the reuse of treated wastewater for MAR in particular, are concerned, the Environmental Law:

- directs EQA to set standards for, among others, the reuse or final disposal of wastewater and stormwater, in coordination with other government agencies (Art.29)
- prohibits the discharge of any liquid substance which is not in conformity with the standards and conditions set by the competent government agencies (Art.30)
- requires an Environmental Impact Assessment of projects to be nominated (Art.45)
- conditions approval of projects and licensing of activities regulated by other government agencies to the prior EQA environmental clearance (Arts.47, 48)

4 Source: text of the Law (official English translation)

5 Source: text of the Law (official English translation)

- directs the owners of regulated facilities to self-monitor compliance and to report regularly to EQA and to other competent regulatory agencies (Art.54)
- empowers the competent regulatory agency to suspend or revoke a license if this is in breach of environmental conditions (Art.55), and conditions resumption of licensed activities to the removal of the violation, also by the regulating agency at the violator's expense if necessary (Art.56)
- empowers EQA to stop any project or the use of any material or machinery if continuation of same causes an "extreme hazard" to the environment (Art.57)
- punishes the discharge of any liquid substance not in conformity with the standards and conditions set by the competent government agencies with a fine of between two-hundred and one thousand JD, and/or a jail term of between one and six months (Art.68)
- directs the author of "environmental harm" resulting from wilful intent or negligence to compensate for the harm caused (Art.76)
- punishes with a jail term of no less than five years and/or a fine of no less than ten thousand JD the causing of an epidemic as a result of a breach of the Law, if such outcome was reasonably foreseeable by the violator (Art.60).

The EIA provisions of the Law have been implemented by **Ministerial Council Resolution No.27 of 23 April 2000**[6], setting forth an Environmental Assessment Policy, and relevant regulations. The Resolution:

- lists projects requiring an EIA (in Annex 1 to the Resolution). Whereas the list does not include MAR projects as such, "watewater treatment plants" and "major dams and reservoirs" are listed (Nos.3 and 12, respectively). Both being instrumental to MAR with treated wastewater, or with stormwater, or both, the list and the Resolution are relevant to the scope of this analysis. Moreover, projects which are not on the list, yet meet one or more from a list of criteria provided in Annex 2, are subject to screening nonetheless to determine whether an EIA is required (Art.7, last paragraph). In particular, projects which "Use a natural resource in a way that pre-empts other uses of the resource", and projects which "Generate unacceptable levels of environmental impact" or which "Create a state of public concern" (Annex 2, Nos.1, 4 and 5, respectively), resonate with MAR projects, and reinforce the conclusion that the resolution is relevant in the context of MAR despite the lack of a specific mention or reference to such projects
- conditions Environmental Approval (EA) of projects to either
    - an Initial Envionmental Evaluation (IEE), for projects the environmental impacts of which are uncertain, or for projects in respect of which compliance with environmental regulations must be ensured, and/or
    - an EIA, for projects which are likely to have significant environmental impacts
- lays down an articulate and structured administrative process for the conduct of IEE and EIA, leading up to EA (the process is described in Annex 3 to the Resolution)
- requires stakeholder consultation in the IEE and EIA process (Art.8)
- entrusts an inter-agency Environmental Assessment Committee of representatives of ten nominated government agencies with the administration of the IEE and EIA process. PWA, among others, is a member of the committee (Art.6)

6 Source: text of the Resolution (official English translation)

Guidelines for Wastewater Reuse in the Gaza Strip (2002)[7]

This guideline is for the reuse of treated wastewater from housing, municipalities, industry and commercial enterprises in the Gaza Strip, and to provide information for the collection, additional treatment, and storage of treated effluent for purposes of

- managed aquifer recharge, and
- minimizing the inflow of saline water into the coastal aquifer (Articles 1 and 2).

Although aimed originally at the Gaza Strip, the Guidelines are applied in the West Bank also and have, as a result, a nation-wide scope of application. The Guidelines provide generic economic, financial and environmental principles of wastewater reuse, as well as specific principles, as follows:

1. General Technical Principles

All wastewater shall be collected, treated and used according to the guidelines to minimize the deficit in the water balance. Treated wastewater reuse should comply with the standards and has to be transported in accordance to the guidelines (closed pipes). Dilution of wastewater to reach the required standard, and direct injection to the aquifer without treatment, are forbidden. In addition, the wastewater treatment operator shall provide information and test results of wastewater quality or any other information as requested.

2. Technical Principles for (Irrigation and) Recharge

Industrial and commercial wastewater is allowed to be used (for irrigation and) for groundwater recharge, only if compliance with the standards is guaranteed during operation. In particular, the use of wastewater for aquifer recharge is forbidden in drinking water protection zones, and is otherwise only allowed in facilities that are operated under a license from the competent authorities.

Wastewater reuse projects are subject to standard EIA procedure and requirements. Licensing is the responsibility of PWA, acting in consultation with EQA (Article 9). PWA retains primary responsibility for technical, financial and operational issues, including compliance (as to chemical and microbial characteristics, sampling, groundwater measurements, and wells). EQA is responsible for environmental supervision. The Ministry of Health is responsible for public health aspects in connection with the consumption of food products that are irrigated by direct wastewater reuse, and with employees working on the reuse system (Article 10).

Monitoring of groundwater, wastewater quality, soil quality and human health is required to ensure proper treatment, so as to avoid environmental degradation, minimize adverse health impacts and increase agricultural production in a sustainable manner. Monitoring of facilities and operations includes self-monitoring, compliance with regulations, and required record-keeping. In addition, instructions are given regarding sampling analysis and record-keeping (Articles 11, 12 and 13, and Annex 1).

The Guideline assigns to PWA responsibility for, in particular and among others:

- strategic planning for the reuse of treated wastewater
- <u>licensing the operation of groundwater recharge facilities </u>(emphasis added)
- monitoring the quality and quantity of treated wastewater.

In discharging the above responsibilities PWA is directed to work in cooperation with, in particular, EQA.

In addition**, draft Regulations** have been prepared by PWA, covering, respectively:

- protection of water resources (primarily from pollution) (2014)
- licensing of well drilling and groundwater abstraction (2014), and
- licensing of surface water abstraction (2014).

7 Source: North Gaza Emergency Sewage Treatment Project (NGESTP)-Effluent Recovery and Reuse System and Remediation Works, Annex 4 “Policy, Legal and Institutional Framework”

As such legislation is in draft form, and has not been formally enacted as yet, it has not been factored in the foregoing analysis. However, it has been taken into account as a useful reference in the drafting of the proposed Guideline for MAR (in Part 5 of this report).

3.3 Assessment of gaps and constraints hindering MAR practices

3.3.1 At policy level

Managed aquifer recharge features prominently in the **National Water and Wastewater Strategy**. In particular, MAR with stormwater, and the reuse of adequately treated wastewater for MAR purposes, alone or in combination with the harvesting of stormwater, feature there as matters of official government policy. As a result, no serious gaps or constraints can be detected in the existing policy environment.

3.3.2 At regulatory level

MAR projects are, in principle, subject to –

- Standard EIA and EA procedures and requirements of a proposed project, under the **Environmental Law No.7 of 1999 and implementing regulation** (Ministerial Council Resolution No.27 of 2000). These procedures and requirements are administered by EQA, with the effective participation of PWA and other arms of government
- Licensing of project operations by PWA, under the **Guidelines for Wastewater Reuse in the Gaza Strip**
- Monitoring of operations, primarily by PWA (but with the concurrence of EQA), also under the **Guidelines for Wastewater Reuse in the Gaza Strip**
- Licensing of well drilling and abstraction of recharged groundwater, under the general water abstraction licensing provisions of the **Water Law, 2014** and the **Regulation on licensing of well drilling and groundwater abstraction, 2014**

The sum total of these pieces of regulatory legislation makes up an internally consistent puzzle, covering the principal phases of the regulatory cycle of MAR, i.e.:

- The reuse of treated wastewater for aquifer recharge purposes, and
- the recovery of recharged groundwater from the aquifer, for final use.

At the same time, there is substantial room for improvement as regards the above-mentioned aspects of the MAR regulatory cycle. The reference is, notably to:

- the recharge segment of the MAR regulatory cycle, concerning the discharge on or under the ground of treated wastewater, and its storage in aquifers. This is regulated only by implication, and in sparse order, by the Water Law, 2014. Besides, for obvious reasons this Law does not cater for the specifics of MAR
- the recovery-of-recharged-groundwater segment of the MAR regulatory cycle, which falls under the general water abstraction licensing provisions of the Water Law, 2014 which – predictably - fails to account for the specifics of abstracting groundwater from a MAR-recharged aquifer.

In addition:

- the linkages/coordination of the **Guidelines for Wastewater Reuse in the Gaza Strip** with other legislation governing land use/building and environment protection, and with relevant required permits/clearances/approvals are not explicit

- the penalty prescribed by the Water Law, Article 58(1), for “pollution of water resources”, may be perceived as a deterrent by MAR proponents, on account of its open-endedness relative to the risk of groundwater pollution associated with MAR with treated wastewater in particular

- also the Environmental Law penalties can be perceived or act as a deterrent to MAR projects. Particularly when treated wastewater is reused, alone or in combination with stormwater, the associated environmental and/or public health risks, coupled with uncertainty of impacts, may discourage MAR proponents for fear of incurring the wrath of that Law, particularly Articles 60 and 76 (see the relevant analysis above)

- the very low level of the penalty prescribed by Article 68 of the Environmental Law for “the discharge of any liquid substance not in conformity with the standards and conditions set by the competent government agencies” may reverberate negatively on compliance by a MAR licence holder with the standards of wastewater quality prescribed in the proposed Guideline. It is open to question whether this weakness can be rectified in the proposed MAR Guideline, through stiffer penalties than those contemplated in Article 68 of the Environmental Law.

In response to the above gaps and weaknesses detected in the MAR-relevant regulatory environment, it is proposed to resort to integrated MAR licensing (IML), absorbing in its scope the **recharge** phase of MAR and, as a result,

- offsetting the operation of Article 58(5) of the Water Law, 2014.

The **recovery** phase of MAR may live instead an independent regulatory life under the Water Law, 2014, however coordination links with the proposed IML will be provided in the proposed MAR Guideline. Further coordination is built-in as a result of the Water Law, 2014 being administered by PWA, and of the proposed IML being proposed for administration also by PWA.

Furthermore, upon closer analysis, the penalty clauses of the Environmental Law (EL) fit the proposed IML as they trigger the liability of the wrongdoer – in the specifics, the holder of an integrated MAR licence –

- for breach of the wastewater quality standards prescribed in the proposed Guideline, under Articles 30 and 68 of EL
- to compensate for environmental harm resulting from wilful or negligent disregard of the terms and conditions of an integrated MAR licence, under Article 76 of EL
- for the causing of an epidemic as a result of a breach of the terms and conditions of an integrated MAR licence, if such outcome was reasonably foreseeable by the violator (under Article 60 of EL).

As for the penalty clause of Article 58(1) of the Water Law in respect of “water pollution”, it is worth noting that the open-endedness of the clause is qualified by the words “if the polluter fails to remedy [pollution] as directed by PWA”. The qualifier implies that a polluter’s liability is triggered only in response to a prior remedial direction imparted by PWA. The attenuating effect of this qualifier notwithstanding, it is advisable to further attenuate exposure of a compliant integrated MAR licence holder to the penalty clause of Article 58(1) of the Water Law by exhonerating him/her from liability under that Article.

4 TECHNICAL ASPECTS OF MANAGED RECHARGE OF AQUIFERS

4.1 Wastewater

In 2005, around 66 Mm3 of wastewater was generated in the Palestinian State, of which 36 Mm3 was produced in the West Bank and 30 Mm3 in the Gaza Strip. About 35.5 Mm3 of wastewater, or 55.3% of the total wastewater volume produced in 2005, was collected by the sewage network (ARIJ, 2007, quoted in Görlach et al. 2011). Recently, the Wastewater quantities generated in the West Bank was estimated at approximately 62 MCM/yr including municipal, Industrial wastewater, in addition to 35 MCM/yr of untreated wastewater discharged by settlements and industrial zones into the West Bank environment (PWA, 2012d). The total collected quantities from the sewerage networks is either treated in Palestinian central treatment plants like Al-Bireh or small collective treatment plants like Zeita and Attil. Wastewater is also dumped into surface water streams (Wadis) and then either treated in Israeli treatment plants like Jenin, Tulkarem, West Nablus, Beit Jala, and Hebron, or disposed into Wadis. In 2011, around 15 MCM/yr of wastewater is collected from several areas and is dumped in wadis, and then treated in WWTP's by the Israelis inside the green line. This treated wastewater is reused by the Israelis.

In the West Bank there are five major WWTP's (in Tulkarem, Jenin, Ramallah, Nablus and al Tireh) and five small scale treatment plants. The capacity of the WWTP's is not sufficient to cope with the increase in wastewater and not all of them are working at high efficiency. As a partially treated wastewater is being discharged in areas surrounding the plants, causing multiple environmental and sanitary problems.

The largest Palestinian wastewater treatment plants (WWTPs) are located in the Gaza Strip, more specifically in Beit Lahiya, Gaza and Rafah. While, in Khan Younis the existing plant is just a collection pond with partially treatment. In the central part of the Gaza strip there is no treatment facility; raw wastewater is diverted to the Wadi Gaza. The total (partially) treated wastewater from Gaza, Khan Younis, and Rafah WWTP's discharged to the sea amounts to around 30 MCM/Yr. Around 8.4 MCM/y of partially treated wastewater in Beit Lahia WWTP is recharged towards the aquifer. All WWTPs in Gaza Strip are functioning at moderate efficiency rates (45-70%); they also operate above their actual capacity and need to be upgraded. A summary of the WWTP's is presented in table 1.

The treatment capacity in the West Bank in 2012 is limited to less than 10% of the total amount of wastewater from the sewer system. In 2017 this figure will be increased to some 30% according to the latest projections (see table 1A).

In table 1A a projection is given of the total amount of treated wastewater in the West Bank and Gaza for the coming years. In 2015 the total amount of treated wastewater has increased with 13% compared to 2012. In 2017 an increase of 64% is projected.

Name	Population served	Capacity (m^3/day)	Inflow (m^3/day)	Construction date	Type of treatment	Efficiency %
West Bank						
Al-Bireh	50000	5,750	5,000	1998	single stage activated sludge	95
Ramallah	25000	1400	2,400	1970's, rehabilitated 2002-2003	Aerated lagoons	30
Jenin	40000	9250	3,000	1970's, rehabilitated 2011-2012	Aerated lagoons	Not working-under rehabilitation
Tulkarem	75000	15000	4,000	1970's, rehabilitated in 2004	Aerated lagoons	20
Gaza						
Beit Lahiya	236,298	12,000	23,000	1976	Stabilization ponds and aerated lagoons	70
Gaza	446,416	70,000	60,000	1977	Anaerobic ponds followed with bio-towers	60
Middle area			> 10,000*	1998	Without treatment	
Rafah	150,725	12,000	10,000	1983	Anaerobic ponds followed with bio-towers	45
Khan Younis	200,000	10,000	> 10,000	2007	Anaerobic lagoons followed by aerobic lagoon	45

*Wastewater generated without treatment

Table 1. Main WWTP in Gaza and West bank (PWA, 2012)

Description	2012	Existing	2015	2016	2017
West Bank	5,300,000	8,200,000	9,600,000	11,100,000	15,200,000
Gaza	37,600,000	42,000,000	48,000,000	51,000,000	55,000,000
Total	**42,900,000**	**50,200,000**	**57,600,000**	**62,100,000**	**70,200,000**

Table 1A. Treated wastewater in m3/year. (PWA, 2015)

Availability and feasibility of treated wastewater for artificial recharge

The actual amounts of wastewater with advanced treatment like single stage activated sludge is limited. The feasibility of the actual sources of treated wastewater for artificial recharge is therefore still limited.

Besides the feasibility for artificial recharge the use of treated wastewater in agriculture also faces some potential constraints like there are:

- surface and groundwater pollution, if poorly planned and managed;
- marketability of crops and public acceptance;
- effect of water quality on soil, and crops;
- public health concerns related to pathogens.

In table 2 recommended criteria for effluent standards by PWA are given for restricted and unrestricted use in agriculture.

Criteria	Restricted Use1	Unrestricted Use2
BOD (Mg/l)	30	20
TSS (Mg/l)	50	30
Total-N (Mg/l)	10-15	10-15
F. coliforms	Less than 1000	Less than 200
Helminthes eggs	Less than 1	Less than 1
Intestinal nematode	Less than 1 ova per liter	Less than 0.1 ova per liter

1. Restricted crops: Cereal crops, industrial crops, fodder crops, crops normally eaten cooked and trees, etc.

2. Unrestricted crops: Crops normally eaten uncooked (vegetables), Sport fields, and parks.

Table 2. Recommended criteria for Effluent Standards (PWA)

The recovered water will be prohibited for drinking water use since it could have negative impacts on public health and farmers due to the Total-N higher than the drinking water standards that recommends a maximum value of 30 mg/l. In addition, the recovered water might also include other contaminants which are not yet recorded and have negative impacts on public health and farmers. The expected water quality can be used for unrestrictive crops or vegetables, however, due to the possibility of adverse health impacts and contaminants which are not yet recorded; it is preferable not to use the water to irrigate the uncooked crops or vegetables (EcoConServ, 2013).

Suitability of aquifers for artificial recharge of treated wastewater

Controlled artificial recharge is possible in homogeneous aquifers (e.g. sand, gravel). In karstic or fractured rock aquifers there is a limited storage capacity and a large uncertainty of the spreading of the recharged water. Therefore artificial recharge with treated wastewater is not recommended in the latter type of aquifers.

In Gaza, in the area around Jericho and at the inlet of the wadis to the Jordan Valley alluvial sandy aquifers are present that allow for managed aquifer recharge. Both in Gaza and Jericho WWTP’s are present that can provide for the water resource.

4.2 State of artificial recharge in Palestine

Most projects are related to recharge with flood water. Direct recharge is achieved through numerous retaining walls on the agricultural fields. The retaining walls hinder surface runoff and enforce downward infiltration of water. Incidental recharge occurs from a significant number of cesspits, but is associated with high nutrient and contaminant loads. In this chapter the existing (pilot) projects and ideas are briefly described.

Al Auja (flood water)

Al Auja area locates in the Lower Jordan Valley/West Bank, which is a part of shallow lower eastern aquifer located at an elevation of -220 m in the west to -280 m (b.s.l). Based on the availability of ground water, fertile soil, and warm climate during winter months 600 hectares are under irrigation. In the Al Auja area two sources of water are available: Al Auja Karstic spring that drains water from the Mountain carbonate aquifer system with a discharge rate between 0.5 and 8 MCM/year, and nine groundwater boreholes that tap water from the shallow Plio-Plistocene aquifer system, with an annual abstraction of 0.7 MCM/year.

The Mountain aquifer consists of high fractured and karstified limestone and dolomite of Upper Cretaceous age, and the shallow aquifer system consists of gravel, sand, silt, and clay layers of the Dead Sea group.

Due to the limitation of natural recharge, and over pumping from shallow aquifer system, salinity increased and caused a major shift in cropping pattern during the last 30 years, where more salinity-tolerant vegetables and trees are becoming dominant crops.

In 2011, the Palestinian Ministry of Agriculture constructed Al Auja earth dam with a maximum storage capacity of flood water of 700,000 m³. This dam is constucted for storage and direct use by the farmers and recharge as a secondary aim. In the years 2011/2012 and 2012/2013 respectively 250,000 and 200,000 m^3 were stored in the reservoir behind the dam.

Marj Sanur (flood water)

The Marj Sanur Watershed is an extensive depression that fills up once or twice a year during heavy rain. Consequently most of the water collected in the basin evaporates. Shallow groundwater is mainly used for agricultural purposes. Due to drought and overexploitation of wells groundwater levels of shallow aquifers dropped to more than 80 meters during the last ten years resulting in significant reduction of discharges from wells. The flood waters allow for artificial recharge of the shallow aquifer. In a pilot project two recharge wells are installed. They infiltrate the collected flood water in the depression within a period of approximately 15 days. Infiltration takes place in the unsaturated zone some 80 meters above the groundwater level. Direct Infiltration in the saturated zone is not considered with respect to the risk of polluting the groundwater in the shallow aquifer. In the unsaturated zone the quality of the infiltrated flood water will improve by soil aquifer treatment. So far results are promising and plans exist to expand artificial recharge with more wells.

Jericho (flood water and treated wastewater)

In Jericho an idea is proposed by PWA for artificial recharge of a mixture of flood water and treated wastewater from a new WWTP. This pilot project will be based on a mixture of approximately 100 m3/day treated effluent from the WWTP and 100 m3/day from flash flood from a nearby Wadi. For the recharge of the aquifer a basin of some 200 m2 will be constructed near the WWTP. A number of observations wells will monitor water levels and water quality.

Gaza (treated wastewater)

In the study for the North Gaza Emergency Sewage Treatment Plant artificial recharge of treated wastewater will be done by ponds. Recovery of the treated water takes place with a number of agricultural wells. The system should be designed in such a way that all artificial recharged water is recovered by the wells. The system is a controlled system where no resulting spreading of infiltrated treated wastewater takes place. In all phases, the operation of the agricultural wells in the surrounding areas of the infiltration basins should be regulated by PWA in order to ensure that all the infiltrated effluent is recovered. The quality of the abstracted water should be strictly monitored to ensure health and safety of the users. (Engineering and Management Consulting Center, 2006).

4.3 Main gaps and challenges

From the analysis above a number of gaps and challenges emerge.

The WWTPs in Gaza Strip are functioning at moderate efficiency rates (45-70%) and above their actual capacity. Furthermore the amounts of wastewater with advanced treatment, which has to be regarded as a minimum requirement for artificial recharge, is limited. So there is a large need and challenge for upgrading the treatment plants, both in capacity and treatment methods. This holds for Gaza as well as for the West Bank (see table 1).

Most of present recharge by (treated) wastewater is done for irrigation practices in agriculture. So far there is some experience with artificial recharge of treated wastewater by ponds and lagoons (e.g. at the WWTP at Gaza). No experience is available with artificial recharge of treated wastewater by high technology options like aquifer storage and recovery (ASR). ASR requires significant experience in set-up and maintenance, especially with regard to the prevention of clogging and may not be suitable at this point.

Basically every situation for MAR is specific and requires a custom made solution. This applies both to the necessary treatment method(s) and for the design of the infiltration and recovery system. Research is needed to determine the proper treatment. It is recommended to carry out a combination of laboratory tests and pilot studies.

The design of safely manageable MAR requires detailed knowledge of aquifers. To enable for a custom made design field investigations including exploratory drillings and aquifer test(s) will be needed to verify the aquifer characteristics and suitability for MAR. Furthermore extensive modelling will be necessary for the design of the infiltration and recovery system.

Different systems for MAR are presented in figure 1. A brief description of the MAR systems can be found in the text box.

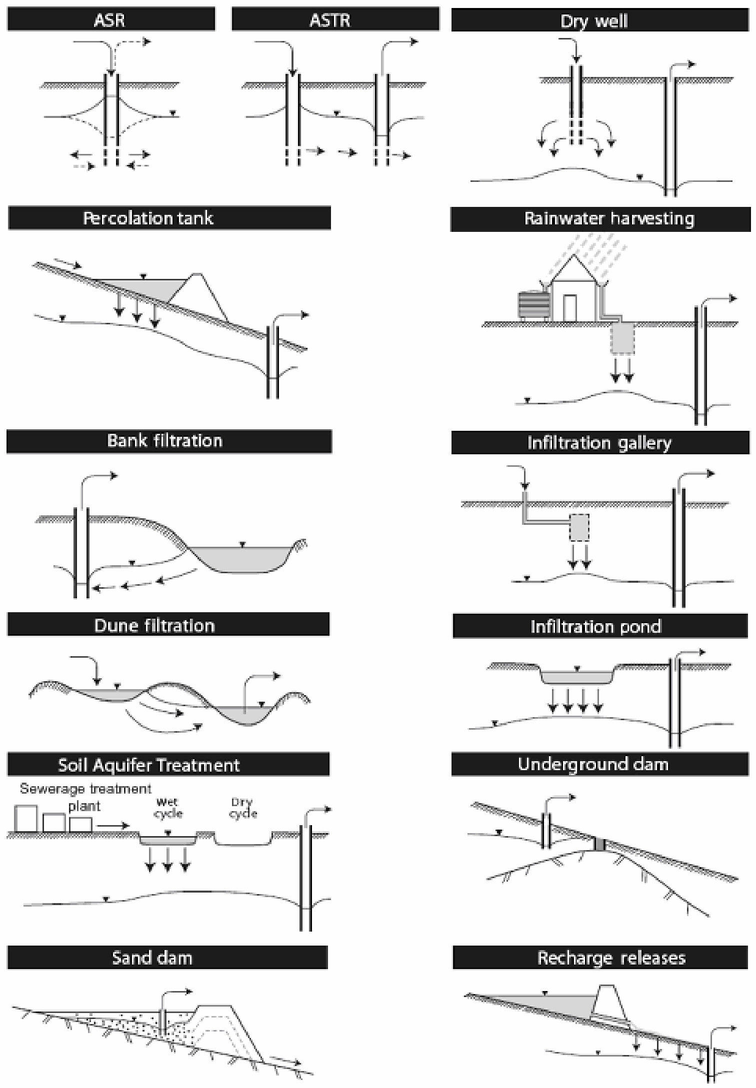

Figure 1. Systems for Managed Aquifer Recharge(see also text box)

Systems for Managed Aquifer Recharge

Aquifer storage and recovery (ASR): injection of water into a well for storage and recovery from the same well. This is useful in brackish aquifers, where storage is the primary goal and water treatment is of secondary importance.

Aquifer storage, transfer and recovery (ASTR): involves injecting water into a well for storage, and recovery from a different well. This is used to achieve additional water treatment in the aquifer by extending residence time in the aquifer beyond that of a single well.

Infiltration ponds: involve diverting surface water into off-stream basins and channels that allow water to soak through an unsaturated zone to the underlying aquifer. During passage of the unsaturated zone water quality may improve by retention, ion exchange and oxidation processes that affect organic matter, microorganisms, heavy metals and trace organic pollutants.

Infiltration galleries: buried trenches (containing polythene cells or slotted pipes) in permeable soils that allow infiltration through the unsaturated zone to an unconfined aquifer.

Soil aquifer treatment (SAT): treated sewage effluent is intermittently infiltrated through infiltration ponds to facilitate nutrient and pathogen removal in passage through the unsaturated zone for recovery by wells after residence in the unconfined aquifer.

Percolation tanks or recharge weirs: dams built in ephemeral streams detain water which infiltrates through the bed to enhance storage in unconfined aquifers and is extracted downstream.

Rainwater harvesting for aquifer storage: roof runoff is diverted into a well, sump or caisson filled with sand or gravel and allowed to percolate to the water-table where it is collected by pumping from a well.

Recharge releases: dams on ephemeral streams are used to detain flood water and uses may include slow release of water into the streambed downstream to match the capacity for infiltration into underlying aquifers, thereby significantly enhancing recharge.

Dry wells: typically shallow wells where water tables are very deep, allowing infiltration of very high quality water to the unconfined aquifer at depth.

Bank filtration: extraction of groundwater from vertical or horizontal wells near or under a river or lake to induce infiltration from the surface water body thereby improving and making more consistent the quality of water recovered.

Dune filtration: infiltration of water from ponds constructed in dunes and extraction from wells or ponds at lower elevation for water quality improvement and to balance supply and demand.

Underground dams: In ephemeral streams where basement highs constrict flows, a trench is constructed across the streambed, keyed to the basement and backfilled with low permeability material to help retain flood flows in saturated alluvium for stock and domestic use.

Sand dams: built in ephemeral stream beds in arid areas on low permeability lithology, these trap sediment when flow occurs, and following successive floods the sand dam is raised to create an “aquifer” which can be tapped by wells in dry seasons.

Selection of suitable sites for MAR and choice of method will depend on the hydrogeology, topography, hydrology and land use of the area. It is common to find similar types of MAR projects clustered in the same area due to shared physical attributes. In another area, the methods may be quite different.

The International Association of Hydrogeologists has a Commission on Managed Aquifer Recharge whose web site contains many case studies found in downloadable documents (*www.iah.org/recharge*).

4.4 Technical elements of draft Guideline for MAR

4.4.1 Introduction

In this chapter guidelines for artificial recharge with treated wastewater in Palestine are presented. First some general considerations are given. A distinction may be made between artificial recharge for non-potable and potable use. Guidelines are given for the design of a recharge and recovery system, followed by recommendations for criteria for quality of effluent to be recharged to the aquifer. Finally information on some additional requirements are formulated, like monitoring, risk assessment and environmental impact assessment.

4.4.2 General considerations for aquifer recharge with treated wastewater

Artificial groundwater recharge with treated wastewater provides a possibility of a supplement of groundwater with additional advantages such as: reduction of groundwater levels decline, improvement of water quality due to purification capacity of the subsoil, protection of underground freshwater in coastal aquifers against intrusion from the sea, and storage of reclaimed water for reuse.

Artificial aquifer recharge in general poses some challenging issues due to the range of considerations required. Water quantity and quality issues for both source water and for receiving groundwater need to be addressed in connection with any artificial aquifer recharge scheme. Water quality issues take on added significance when treated wastewater is the source water for such schemes, in view of possible reverberations of artificial recharge on human health, on the quality of groundwater in the aquifer (known as “native” groundwater), and on the environment. Against this backdrop, it appears necessary to impose requirements on artificial aquifer recharge additional to currently available regulations and guidelines for the different end-uses of water abstracted from aquifers which have been recharged with treated municipal wastewater. The risk of contamination of aquifers is one of the major concerns that has to be properly managed by the regulations and guidelines.

There is general agreement that recharge should not create a need for supplementary treatments after withdrawal for the water to meet the standards related to its intended application. Qualitative requirements at the point of use have to be satisfied within the aquifer.

Introduction of pollutants into aquifers may have long-term impacts; therefore, measures aimed at avoiding degradation of groundwater should be a prerequisite of any aquifer recharge project. Introduction of pollutants into aquifers may have long-term impacts; and should therefore be avoided. Distinction between potable and non-potable aquifers is essential and will allow development of aquifer recharge and saving of water resources. Distinction is also essential between indirect recharge, using surface spreading and direct recharge through injection wells.

Principles of sustainable use of recycled water

For sustainable use of recycled water the following main principles apply:

- protection of public and environmental health should never be compromised.
- protection of public and environmental health requires a preventive risk management approach.
- preventive measures and requirements for water quality are applicable to the source of recycled water, its intended uses and environmental values.

Adequate implementation of these principles requires:

- awareness and understanding of how recycled water-quality management can affect public health and the environment

- an organization that supports continuous improvement and cultivates employee responsibility and motivation
- permanent communication (supported by regular monitoring capacity, audits and inspections) between regulators, owners, operators, plumbers, end users, and other stakeholders.

Recharge via the vadose zone

The quality of infiltrated water in the vadose zone may improve significantly when percolating through this zone. Retention, ion exchange and oxidation processes affect organic matter, nutrients, microorganisms, heavy metals and trace organic pollutants. However, forecasting the efficiency of the treatment provided by infiltration through the vadose zone and lateral transfer in the saturated zone is very difficult. Performances depend on a number of factors such as depth of the unsaturated zone, physical and mineralogical characteristics of the soil layers, heterogeneity, hydraulic load, infiltration schedule and infiltrated water quality. Therefore, when transfer through the vadose zone is part of the treatment intended to bring injected water up to potable water quality or the set criteria for recharge of the aquifer for non-potable use, a case-by-case approach is recommended. For each project, pollutant removal tests should be performed, at the laboratory and onsite. Every category of pollutants of concern should be considered.

The quality of the water extracted from the aquifer should meet the most stringent standards related to the intended water use. In health-related standards applying to wastewater reuse, microorganisms are the main concern. For irrigation, limits can be set for other parameters such as organic matter and heavy metals. As with potable aquifer recharge, relying on the saturated zone of aquifers to improve the recharged water quality is not recommended; even if there is no doubt that filtration effects exist. The saturated zone should only be considered as an additional barrier. When recharge is direct, the recycled water should have been upgraded to meet the standards and limits required for the intended applications. Also, suspended solids and organic matter should have been drastically reduced to avoid clogging around the injection wells.

For recharge of effluent with the utilisation of natural attenuation processes, it must be considered that in case of overloading of the WWTP or accidental industrial discharge to sewer, the groundwater quality is potentially at risk of contamination if infiltration is not interrupted accordingly. For this reason appropriate management and monitoring of the facilities is considered mandatory.

Artificial recharge for indirect potable reuse

Artificial recharge for indirect *potable reuse* has been implemented in several countries. The recharge should not degrade the quality of the groundwater nor impose any additional treatment after pumping. Apart from those in Australia (NWQMS, 1995), regulations concerning aquifer recharge do not rely on the capability of the aquifer to remove pollutants to meet the water quality required within the aquifer. In practice, the recharge water reaching the saturated zone of the aquifer should have previously acquired the quality acceptable for drinking water.

If the recharge is direct by wells, then the injected water should also be potable and should, as a minimum requirement, meet the standards enforced in the country or contained in the *WHO Guidelines for Drinking-water Quality* (WHO, 1996). Moreover, the injected water should be treated to prevent clogging around the injection wells, long-term health risks linked to mineral and organic trace elements, and the degradation of the aquifer. The capacity of the aquifer to remove pollutants provides an additional barrier protecting the abstracted water quality.

Indirect artificial recharge for non-potable reuse

Indirect recharge for *non-potable reuse* requires a less treated injectant and is easier to implement. Soil aquifer treatment is regarded as an appropriate treatment method to meet the required water quality, provided it is properly designed and managed. When highly permeable or heterogeneous onsite soils are not able to provide the required treatment, infiltration percolation through calibrated sand beds filling pits excavated at the soil surface can be used as a treatment before infiltration through onsite soil layers. The quality required of the recycled water applied in infiltration facilities should depend on the site, the hydraulic load, the infiltration schedule and the quality to be reached in the aquifer. A secondary treatment is generally thought to be a minimum. So, each project must be tailored according to the local context and the water quality to be reached. It is emphasized that a different quality requirement for the recharged effluent for non-potable use can be applied only in cases where groundwater from the aquifer receiving the effluent can be excluded for drinking water.

Controlled systems may be regarded as underground treatment systems. It has to be proved that these systems can function as closed systems of recharge and recovery and can be ended without residual pollution of aquifers. After ending treatment of treated wastewater in the system the aquifer has to be flushed several times with native groundwater.

Existing guidelines in Palestine

The Palestinian Standards Institute recommended Guidelines for Treated Wastewater Characteristics for different applications. In these recommendations also guidelines for artificial recharge of groundwater are given[8].

4.4.3 Proposed guidelines, precautionary and mitigation measures for MAR using treated wastewater

Introduction

In general it is advised to choose for a conservative approach. In this approach transfer of treated wastewater through the aquifer is considered as an additional barrier. When direct recharge is performed, the quality of the injected water should therefore meet the quality required from the water that will be subsequently withdrawn from the aquifer. This means that only potable water should be injected into aquifers for potable use. When the groundwater is to be used for irrigation, the recharged treated wastewater should meet the standards for the reuse of wastewater for restricted/unrestricted irrigation.

In case Soil Aquifer Treatment (SAT) is considered this should be regarded as a controlled water treatment unit. In that case the requirements for the quality of the recharged water to the vadose zone may be less strict. After soil aquifer treatment has been applied the treated water should comply with the standards for artificial recharge of groundwater. In most cases the water quality after SAT is insufficient for artificial recharge and post-treatment is necessary before the water meets the standards for artificial recharge to groundwater aquifers.

The proposed guidelines for artificial recharge of treated wastewater in Palestine presented in this report focus on artificial recharge for non-potable use. Recharge of treated wastewater for potable use is highly controversial in Palestine and is therefore not further considered.

Design of recharge and recovery system

For the design of a recharge and recovery system the hydrogeological conditions have to be assessed in detail. It should be verified that the aquifer to be recharged and recovered from can be defined as homogeneous. Aquifers with secondary porosity such as limestone and karstic aquifers should be excluded. For the latter type of aquifers the distribution of infiltrated water in the aquifer is irregular and very difficult to predict. The design of a properly managed aquifer recharge and recovery system is therefore generally not feasible in these aquifers.

The recharge and recovery system should be designed such that a 100% recovery of the recharged water is ensured.

[8] It is noted that the values for BOD (40 mg/l) and TSS (50 mg/l) are not aligned with the values given in the 'Memorandum of Understanding on technical Criteria for Sewerage Projects' of the Israeli- Palestine Joint Water Committee. In these guidelines the values for BOD and TSS amount to respectively 20 and 30 mg/l.

Design of a controlled MAR system with 100% recovery

A MAR-system with 100% recovery rate requires a tailor made design. Therefore extensive knowledge of the hydrogeological conditions at the proposed location will be necessary. For the design of the MAR system the set up of a detailed groundwater model is proposed. With help of this model the flow-pattern between the recharge wells/recharge area and the recovery wells, including the residence times of flow lines between recharge and recovery wells can be forecasted. The lay out of the recharge wells/area and the recovery wells including the recovery rates can be chosen in such a way that a 100% recovery can be reached. In order to achieve this the recovery rate will generally be higher than the total amount of recharge towards the aquifer. In this modeling uncertainties in the parameters of the hydrogeological system that govern the groundwaterflow should be taken into account by means of sensitivity analyses.

The present use of aquifers is often a mix between agricultural and domestic purposes. The MAR sytem for treated wastewater for agricultural use should not intefere with existing wells for domestic use. This has to be taken into account while designing the MAR system. In some cases the conclusion may be that a controlled MAR-system cannot be designed given the actual presence of existing wells for domestic use. In other cases a solution may be found by reallocation of domestic wells.

With regard to microbiological quality there must be a sufficient distance between the recharge facility and the recovery facility. A minimum residence time from the recharge facility and the recovery wells for the removal of pathogenic constituents of the effluent has to be guaranteed. This time is given for a distance, which the groundwater will flow for at least 60 days until it reaches the recovery well. The application of a residence time of 60 days in the aquifer between recharge facility and recovery wells will normally warrant that no pathogenic constituents (such as bacteria, viruses, parasites and worm eggs) will reach the recovery well.

If recharge is done by wells, clogging of infiltration wells due to suspended solids can be avoided by using infiltration water with a MFI-index of less than 3 s/l2 (Olsthoorn, 1982). (MFI = Membrane Filtration Index).

Criteria for quality of effluent for MAR (physical, chemical and biological)

In Annex 2 the criteria for the quality of the effluent for artificial recharge of groundwater for non-potable use in Palestine are summarized. The proposed criteria should be used in combination with a controlled system of recharge and recovery of the infiltrated water. As a reference also the recommended guidelines for groundwater recharge by the Palestinian Standards Institute and the Jordanian Standard for groundwater recharge are presented. The proposed guidelines are primarily derived from the recommended guidelines for groundwater recharge by the Palestinian Standards Institute and the Jordanian Standards. For concentrations of trace metals use is made of the FAO Guidelines for trace metals in irrigation water.

Criteria for quality of stormwater or flood water for MAR

Stormwater and flood water originate during precipitation events. In urban areas with large paved and impervious surfaces the initial runoff of a rainstorm is polluted with pollutants deposited on roads and roofs. This results in high levels of pollutants in the initial runoff. Also first flushes from agricultural areas will generally contain relatively high concentrations of pollutants. The remainder of the stormwater will contain less pollutants. Part of the stormwater will infiltrate into the soil and recharge the groundwater. For this natural process no specific quality criteria can be set.

In remote areas, (e.g. like in Al Auja) stormwater/flood water can be collected behind a dam and will then consequently infiltrate towards the groundwater. In these cases the quality of the infiltrated water after passing the vadose zone should meet the standards related to the intended water use.

The stormwater collected from a stormwater collection system or flood water to be used for MAR should be treated and meet the standards as described for the recharge of wastewater effluent. A further distinction between treated wastewater and stormwater/flood water is difficult to make because existing data on water quality of storm water and flood water are scarce Also the design of the recharge/recovery system should follow the same criteria as for effluent of wastewater. To avoid the use of heavily polluted stormwater as a primary source the first flush of heavily polluted stormwater should preferably not be used. In that case the standards might be reached relatively easy in some cases.

Risk assessment

As already stated in the former study on the legislative framework regulating the recharge of aquifers with adequately treated wastewater a risk assessment has to be carried out (Burchi, 2014). In this assessment the preventive measures are developed to manage the identified risks. This requires information describing the source water quality, infrastructure and proposed operations of the project, and characterization of the hydrogeology to demonstrate that all hazards have been addressed with sufficient supporting information for a management plan. Where further information is needed, a pilot project might be required. The investigations so far result in a management plan showing how human and environmental health risks can be effectively managed. The management plan often will involve drilling one or more wells, and an aquifer test by pumping to determine aquifer properties and groundwater quality, and help identify pre-treatment needed before recharge.

Environmental impact assessment (see also the relevant analysis in Part II of this report)

An Environmental Impact Assessment (EIA) is obligatory for 14 types of major development projects. Wastewater treatment plants including extensions like artificial groundwater recharge of treated wastewater are regarded as one of the major developments. As a result of the EIA measures to mitigate adverse environmental impacts or capture potential environmental benefits, including a compliance schedule may be specified. Further measures must be implemented in order to comply with relevant standards and requirements including monitoring and reporting.

Monitoring

Monitoring is necessary to assure that groundwater quality is protected and that the recovered water is suitable for its intended use, and if necessary to initiate contingency measures if a failure occurs. Monitoring is also necessary to ensure that the system performs as intended, that volumes of recharge and recovery are known and that the performance of the system is accurate. Monitoring includes water quantity as well as water quality parameters. The monitoring programme should start well before the recharge operations start in order to get a reliable reference-situation and continues after the recharge operations have ended.

4.4.4 Conclusions

- Aquifer recharge with treated wastewater must not lead to any significant and sustained degradation of the quality of the groundwater. This should be a prerequisite of any aquifer recharge project. For this reason only homogeneous aquifers (sand and gravel) should be used for aquifer recharge. Aquifers with secondary porosity such as limestone and karstic aquifers should be excluded, since the distribution of infiltrated water in this type of aquifers is difficult to manage. In this respect it will be useful to initially determine the vulnerability of the hydrogeological systems in Palestine for the risks of MAR for treated wastewater and/or stormwater/flood water.
- In Gaza and in the area around Jericho alluvial sandy deposits are present that allow for controlled artificial recharge.
- If possible, a distinction should be made between potable and non-potable aquifers. This will benefit the development of aquifer recharge with treated wastewater. For Palestine, the initial

focus should be on aquifer recharge for agricultural purposes, since recharge of treated wastewater for subsequent potable use of recovered groundwater is highly sensitive on a societal level.

- Aquifers used for artificial recharge of treated wastewater should be regarded as a controlled water treatment unit that does not affect the groundwater quality of other parts of the aquifer. The same holds when soil aquifer treatment (SAT) is used. In that case the requirements for the quality of the recharged water may be less strict. After soil aquifer treatment has been applied the treated water should comply with the standards for artificial recharge of groundwater. In some cases additional treatment before recharge to the groundwater may be necessary.
- One and preferably more pilot projects should be developed to build up specific experience with artificial recharge with treated wastewater. It is preferred that the pilot projects are defined for different techniques of artificial recharge (e.g. by ponds and by deep wells) and different combinations of treatment methods depending on the effluent quality of the source water. The pilot projects may start with prototype laboratory analyses.
- A capacity building programme should be part of the pilot projects. The programme should include regulatory as well as technical aspects (e.g. vulnerability of aquifers, design of recharge and recovery system, modelling, risk assessment and monitoring).

5 GUIDELINE FOR DRAFTING A NATIONAL REGULATION FOR MAR

What follows is a guidline for the drafting of a national regulatory framework for MAR with, in particular, treated wastewater, or also with stormwater. The guideline is intended as a source of ready reference for the preparation of a future regulatory framework for MAR in Palestine.

PART I – GENERAL

Art.1 (Definitions)

(a) Aquifer means underground layer of permeable rock or unconsolidated material (sand, gravel) that is saturated with water

(b) Controlled MAR system means a regulated system of infiltration and recovery

(c) Direct discharge means direct infiltration into the aquifer

(d) EQA means the Environmental Quality Authority

(e) Indirect discharge means infiltration via the unsaturated or vadose zone towards the aquifer

(f) Integrated MAR licence (IML) means a licence for the construction and operation of a MAR scheme

(g) MAR means Managed Aquifer Recharge

(h) MAR scheme means a system of infiltration of treated wastewater or of stormwater (“source water”) into an aquifer and subsequent recovery of the infiltrated water after passage through the aquifer

(i) MAR site means the site or location where a MAR scheme is constructed and operates

(j) Non-homogeneous aquifer means an aquifer with secondary porosity

(k) PWA means the Palestinian Water Authority

Art.2 (Reference to national policy)

This Guideline (Regulation) furthers the policies and goals set out in the National Water and Wastewater Strategy, 2015.

Art.3 (Paramount prohibitions and restrictions in relation to certain kinds of aquifers)

(1) MAR shall not be practised in the following types of aquifers:

(a) aquifers which are or will be destined for domestic use and supply, to the exclusion of any other use, and/or

(b) non-homogeneous aquifers

(2) MAR may nonetheless be practised in aquifers which are or will be destined for mixed domestic and non-domestic use, provided however that –

- a controlled system is designed in such a way that the MAR scheme will not interfere with any wells in use for domestic purposes or, failing this
- wells in use for domestic purposes can be relocated elsewhere.

PART II – INTEGRATED MAR LICENCE

Art.4 (Requirement to obtain an IML)

Any one who intends to construct and/or operate a MAR scheme shall do so subject to the prior grant of an Integrated MAR Licence, on an application which shall be filed and processed in the manner to be prescribed by PWA under this Guideline (Regulation).

Art.5 (Coordination with other required clearances under, in particular, land use/building, and environmental protection legislation)

(1) On an application under the previous Article, any one who intends to contruct and/or operate a MAR scheme shall, in addition to any other requirements as prescribed by PWA under the previous Article, provide PWA with evidence of having complied with the requirements mandated by other relevant legislation in force.

(2) Without prejudice to the generality of the foregoing, any one who intends to construct and/or operate a MAR scheme shall provide PWA with, in particular:

(a) any permits or clearances required by land use planning and building legislation

(b) an Environmental Approval required by the Environmental Law, 1999.

(3) An application under this Article shall not be entertained by PWA unless and until the requirements of sub-section (2) have been met, to the satisfaction of PWA.

Art.6 (Evidence of wastewater supply)

On an application under Article 4 of this Guideline (Regulation), any one who intends to construct and/or operate a MAR scheme with treated wastewater shall, in addition to any other requirements as prescribed by PWA under Article 4 of this Guideline (Regulation), provide PWA with contractual or other appropriate evidence of a suitable supply of wastewater, treated or untreated.

Art.7 (Standard contents and features of IML)

(1) An IML shall be granted subject to such terms and conditions as PWA, acting in consultation with other Ministries and Authorities as prescribed in Part VI of this Guideline (Regulation), may determine.

(2) Without prejudice to the generality of the foregoing, an IML shall carry terms and conditions as to the following:

(a) a term of duration, which may be extended for equivalent periods on request of the IML holder

(b) specifications as to the construction and operation of the proposed scheme, with particular regard to the technologies and processes which are proposed to be employed

(c) standards and criteria of wastewater or stormwater treatment and quality, which shall be in conformity with those prescribed in Schedule 2 to this Guideline (Regulation)

(d) the Risk Management Plan prescribed in Part V of this Guideline (Regulation)

(e) monitoring and reporting obligations of the IML holder, as prescribed in Part VII of this Guideline (Regulation)

(f) the de-commissioning of a MAR scheme, under the circumstances of Article 10 of this Guideline (Regulation).

(3) The recovery/abstraction of groundwater from a recharged aquifer shall be governed by the groundwater abstraction licensing provisions of the Water Law, 2014, as supplemented by the provisions of Part IV of this Guideline (Regulation).

(4) Unless otherwise agreed in consultations between EQA and PWA, an IML shall incorporate the prescriptions and recommendations, if any, of an Environmental Approval granted under the authority of the Environmental Law, 1999.

Art.8 (Review and variation of IML)

(1) An IML shall be subject to review by PWA, at such intervals as it may determine.

(2) If the review results in a variation by PWA of the terms and conditions of the IML, and if such variation entails (an excessive) cost to the IML holder, PWA shall/may help offset such cost to the IML holder, from Public Treasury funds.

Art.9 (Suspension or termination of IML)

(1) Subject to subsection (2), PWA may suspend or cancel an IML, in whole or in part, if the licence holder -

(a) fails to abide by any of the terms or conditions of the licence;

(b) is found to be in breach of any provisions of this Guideline (Regulation);

(c) fails to commence implementing a MAR scheme within the period specified in the terms and conditions of the licence; or

(d) stops the implementation of the MAR scheme, or stops MAR operations, for a continuous period of one year.

(2) Before PWA suspends or cancels an IML the license holder must be given an opportunity to be heard and to make representations in respect of the proposed suspension or cancellation.

(3) Suspension or cancellation of an IML under this Article shall not entail a right of the licence holder to claim compensation from PWA.

Art.10 (De-commissioning of terminated or discontinued MAR scheme)

(1) The holder of an IML which has been terminated in accordance with the preceding Article, or which has been otherwise discontinued, shall take all appropriate and necessary measures as directed by PWA, acting in consultation with the Ministry of Health and with EQA, with a view to minimizing the risk to public health, to the environment and to groundwater in the affected aquifer from the de-commissioning of the scheme and of the relevant facilities.

(2) In default, PWA shall substitute itself for a non-compliant IML holder and take the measures described in sub-section (1), and it shall recover the relevant costs from the non-compliant IML holder as a civil debt in the courts of law.

PART III – AQUIFER RECHARGE

Art.11 (IML to offset separate wastewater discharge requirements under Water Law or other Law)

(1) For aquifer recharge purposes, whether with treated wastewater, alone or in combination with stormwater, or with stormwater alone, an IML shall offset the requirement of a wastewater discharge licence implied by Article 58 of the Water Law, 2014, and any other independent wastewater discharge authorization or comparable requirements under any other Law or Regulation in force.

(2) The provisions of sub-section (1) shall operate regardless of the technique or process employed in aquifer recharge and, in particular, regardless of whether recharge is carried out by direct or indirect discharge techniques or processes.

Art.12 (Aquifer recharge to be carried out under terms and conditions spelt out in IML, with particular regard for prescribed standards and criteria of wastewater/stormwater quality)

Aquifer recharge operations shall be carried out in conformity with the terms and conditions set out in the IML, including, in particular, as regards the standards and criteria prescribed in Schedule 2 to this Guideline (Regulation), which must be met by the wastewater or stormwater prior to discharge to an aquifer for recharge purposes.

Art.13 (Prohibition to discharge untreated wastewater or stormwater for aquifer recharge purposes)

It is forbidden to discharge to an aquifer untreated wastewater or stormwater for recharge purposes, whether the discharge is by injection wells or otherwise.

Art.14 (Holder of IML to be excused from liability to Art.58(5) of Water Law)

By virtue of the provision of Article 11 of this Guideline (Regulation), the holder of a valid IML shall be excused from liability to Article 58(5) of the Water Law, 2014.

Art.15 (Holder of IML to be excused from liability to Art.58(1) of Water Law under given circumtances)

The holder of a valid IML, who is in compliance with all the terms and conditions prescribed in the licence, shall be excused from liability to Article 58(1) of the Water Law, 2014.

PART IV – RECOVERY OF GROUNDWATER FROM MAR-RECHARGED AQUIFER

Art.16 (Recovery forbidden for domestic use of groundwater)

It is forbidden to recover groundwater from a MAR-recharged aquifer and use it for domestic purposes.

Art.17 (Recovery subject to abstraction licensing under Water Law)

Without prejudice to the preceding Article, the recovery of groundwater from a MAR-recharged aquifer shall be subject to a groundwater abstraction licence as prescribed by the Water Law, 2014, and to the provisions of Articles 18 and 19 of this Guideline (Regulation).

Art.18 (Recovery for use in agriculture subject to prescribed water quality standards)

The recovery of groundwater from a MAR-recharged aquifer and its subsquent use in agriculture and, in particular, for irrigation shall be subject to the observance of the quality standards, if any, in effect for the reuse of wastewater for agricultural and, in particular, for irrigation purposes.

Art.19 (Recovery for all permissible uses subject to special terms and conditions)

(1) Recovery of groundwater from a MAR-recharged aquifer shall be subject to the following terms and conditions:

(a) all the treated wastewater or stormwater which is recharged to the aquifer must be recovered from it, and

(b) the residence time of recharged wastewater or stormwater in the aquifer shall be of a minimum sixty days, before it can be abstracted and used.

(2) Additional conditions may be attached regarding:

(a) the maximum allowable recovery/abstraction per year

(b) the avoidance of undesirable cross-aquifers effects, and

(c) quality standards for the intended final use of recovered groundwater, other than the standards referred to in Article 18 of this Guideline (Regulation).

(3) The terms and conditions under the preceding sub-sections shall be entered in a groundwater abstraction licence, and shall be an integral part of such licence.

PART V – RISK MANAGEMENT PLAN

Art.20 (Risk Management Plan to be submitted by IML applicant)

(1) An applicant for an IML under Part II of this Guideline (Regulation) shall develop and submit with his/her application a Risk Management Plan aimed at identifying and minimizing the risks to human health and to the environment from a proposed MAR scheme.

(2) A Risk Management Plan shall be prepared in accordance with the criteria listed in Schedule 1 to this Guideline (Regulation)

Art.21 (Status of approved RMP)

An approved Risk Management Plan shall be an integral part of an IML and shall bind the relevant holder.

PART VI – ADMINISTRATION

Art.22 (PWA to administer IML system, in consultation with other Ministries and Authorities as required)

(1) PWA shall administer the IML provisions of Part II of this Guideline (Regulation).

(2) In the exercise of its authority under this Article, PWA shall consult with, and obtain the advice of:

(a) the Ministry of Health, regarding the public health implications of a proposed MAR scheme

(b) the Ministry of Agriculture, whenever a MAR scheme is proposed for the eventual use of recovered groundwater for agricultural purposes, and

(c) EQA, regarding the environmental implications of a proposed MAR scheme.

(3) Unless otherwise agreed by the parties concerned, the consultation obligations arising from the preceding sub-section, third sub-paragraph shall be deemed to have been met through the Environmental Impact Assessment procedures mandated by the Environmental Law, 1999.

(4) PWA and EQA shall coordinate the exercise of their respective functions and authorities under Part VII of this Guideline (Regulation).

PART VII – MONITORING AND INSPECTION

Art.23 (Monitoring and reporting obligations of IML holder)

The holder of an IML shall monitor MAR operations, and shall submit reports to PWA and to EQA, with the frequency and the modalities prescribed in the IML.

Art.24 (Monitoring duties of PWA)

(1) It shall be the duty of PWA to conduct regular monitoring of MAR sites and relevant operations.

(2) The monitoring duties of PWA shall be without prejudice to comparable duties of EQA under the authority of the Environmental Law, 1999 and of other pertinent legislation in force, if any.

(3) In the exercise of its duties under sub-section (1), PWA shall act in coordination and in consultation with EQA.

Art.25 (Law enforcement powers of PWA, EQA officers)

(1) Duly authorized officers of PWA and EQA shall have authority to enter and inspect the premises where MAR operations are conducted, and to take samples and other evidence of, or resulting from, such operations as deemed necessary.

(2) The evidence of wrongful behaviour collected during an inspection shall be forwarded to the competent law enforcement authorities for further disposition.

PART VIII – PENALTIES

Art.26 (Penalty for offences under this Guideline (Regulation)

Any one found in breach of Articles (Requirement to obtain an IML), (De-commissioning of terminated or discontinued MAR scheme), (Prohibition to discharge untreated wastewater or stormwater for aquifer recharge purposes), (Recovery forbidden for domestic use of groundwater), (Recovery subject to abstraction licensing under Water Law), shall be guilty of an offence and liable to …

Art.27 (Penalty for non-observance of prescribed standards and criteria of wastewater or stormwater quality)

The holder of an IML who operates a MAR scheme without regard to the standards and criteria of wastewater or stormwater quality prescribed in Schedule 2 to this Guideline (Regulation) shall be liable to the penalties prescribed in Article 68 of the Environmental Law, 1999.

Art.28 (Penalty for breach of the provisions of this Guideline (Regulation) or of the terms and conditions of IML)

(1) The holder of an IML who is found to be in breach of any of the provisions of this Guideline (Regulation), or of any of the terms and conditions of his/her IML, other than the standards and criteria of wastewater or stormwater quality prescribed in Schedule 2 to this Guideline (Regulation), shall be liable to…

(2) In the circumstances described in Article 60 of the Environmental Law, 1999 the holder of an IML who is found to be in breach of any of the provisions of this Guideline (Regulation), or of any of the terms and conditions of his/her IML, shall be liable to the penalties prescribed in that Article.

(3) Without prejudice to the penalties prescribed in sub-sections (1) and (2), and pursuant to Article 76 of the Environmental Law, 1999, the holder of an IML who is found in breach of any of the provisions of this Guideline (Regulation), or of any of the terms and conditions of the relevant IML, shall compensate the environmental harm resulting from his/her unlawful behaviour.

Art.29 (Stoppage of non-compliant MAR scheme)

(1) Pursuant to Article 57 of the Environmental Law, 1999, and in the circumstances provided for therein, EQA, acting on its own motion or also at the request of PWA, may stop, temporarily or permanently, the operation of a MAR scheme which is found to be in breach of the provisions of this Guideline (Regulation), or of the terms and conditions of the relevant IML.

(2) A temporary stoppage shall not be lifted unless and until the holder of the relevant IML has rectified his/her wrongful behaviour and remedied any adverse consequences arising therefrom, as directed by EQA acting in consultation with PWA.

PART IX – FINAL AND TRANSITIONAL

Art.30 (Existing MAR schemes to comply with Guideline (Regulation) within grace period)

Any MAR scheme which is in existence at the time this Guideline (Regulation) comes into effect shall comply with the terms thereof within a grace period of (12 to 24) months from the coming into effect of this Guideline (Regulation).

Art.31 (Relationship of this Guideline to the Guidelines for Wastewater Reuse in the Gaza Strip, 2002)

The Guidelines for Wastewater Reuse in the Gaza Strip, 2002 shall continue to have full force and effect in the Gaza Strip, as complemented by this Guideline (Regulation) in regard to the reuse of treated wastewater for the specific purposes of MAR.

SCHEDULE 1

CRITERIA FOR PREPARING A RISK MANAGEMENT PLAN (RMP)

(Article 20(2))

A managed aquifer recharge risk management plan is a documented system for the management of aquifer recharge. It should include the following features:

- register of relevant regulatory requirements
- names and contact details of stakeholders
- a process diagram of the entire managed aquifer recharge system (capture, pretreatment, injection, storage, recovery, post-treatment and end use)
- operational procedures and process controls
- critical control points, quality control points and associated critical limits
- incident and emergency response procedures
- training programs and records for employees and contractors
- monitoring information (baseline, operational, validation and verification of data)
- communication with authorities concerning system performance and monitoring results

In particular:

A. Assessment of the MAR system

To identify and manage all health and environmental hazards and associated risks in a managed aquifer recharge system, proponents must submit evidence of a thorough documented knowledge of the entire managed aquifer recharge system, from sources of recharged water to uses of recovered water and the fate of recharged water in the aquifer, including the potential effect on treatment systems of hazardous events that may affect human health and the environment, such as:

- storms
- sewer overflows
- power failures
- illegal disposal of contaminants.

The method used to identify and assess hazards must be structured, consistent and comprehensive. Hazard identification typically involves the following steps that help to classify the managed aquifer recharge system:

- hazard identification
- dose–response and exposure assessment of the identified hazards
- risk characterisation.

B. Preventive measures for recycled water (sewage effluent/wastewater) management

Preventive measures for the management of recycled water in general, and of sewage effluent and wastewater in particular, include all actions, activities and processes used to:

- exclude hazards (exclusion barriers)
- reduce hazard concentrations (e.g. by treatment above or below ground)
- manage water usage (end-use restriction barrier).

In order of priority, a RMP for MAR schemes contemplating the use of sewage effluent/ wastewater would cover:

- treatment (e.g. engineered processes and time in aquifer storage)
- management at the end use (e.g. withholding periods or irrigation method selection) to minimize exposure.

. In this same context, a RMP is to include:

- *critical* and *non-critical control points* (also referred to as *quality control points*), based on operational monitoring requirements or on appropriate water quality parameters, and
- the *critical limit*, which is the maximum (or minimum) value to which a hazard must be controlled at a critical control point to reduce its risk to an acceptably low (or high) level.

The adopted critical control points, critical limits and target criteria for risk management form the basis of the operational procedures and process controls that are adopted (discussed below).

C. Operational procedures and process control

During the operation of a MAR system, operational procedures and process control monitoring is performed to check the performance of preventive measures discussed above. The procedures should be designed to identify nonconformance with target criteria and to indicate a decline in system performance.

Operational monitoring does not solely encompass treatment indicators; it should also include aspects of the system that require regular checking to ensure that preventive measures are applied. Examples include operating pressures, groundwater levels and subsurface residence times.

D. Verification of water quality and environmental performance

Operational procedures and process controls above verify that the MAR system poses very low (acceptable) risks to human health and the environment. Verification of the recovered water quality assesses the overall performance of the MAR system in relation to specific uses of the water.

A RMP would include provision for decommissioning of the MAR operation, including the verification monitoring that needs to be undertaken until the aquifer has been restored to its ambient environmental values.

E. Management of incidents and emergencies

Responses to incidents or emergencies can compromise the operation of a MAR system. The development of preventive measures appropriate to the risks should be documented as part of items A and B in the system's RMP.

Management of incidents and emergencies for MAR operations would include response to:

- disruption to pretreatment or post-treatment processes that result in the production of nonconforming water
- disruption to power supplies that affects treatment or injection and recovery systems
- protocols for communication between suppliers, users and other stakeholders
- any other incident that could affect the safe operation of a MAR operation.

F. Operator, contractor and end user awareness and training

All operators, contractors and end users who work with MAR systems must be given appropriate training. Training and awareness programs for such systems should include induction programs for new employees, site visitors and contractors, and employee training in the principles of risk management. All employees should be aware that any observable problems must be reported in a timely manner, instead of waiting until the equipment or process fails.

G. Community involvement and awareness

Community consultation is essential in planning water recycling for use in MAR schemes. Community engagement should begin during the development of the RMP for the MAR scheme. However, engagement will vary with the scheme's nature, location and scale, and the risks involved. Establishing appropriate processes for engaging and communicating with stakeholders is an important step in the planning of a MAR scheme and, in particular, in the development of a RMP.

H. Validation, research and development

Validation involves investigating the effectiveness of preventive measures in reducing risks posed by hazards or hazardous events discussed at (B) above. It can be achieved by obtaining evidence about the performance of preventive measures, and by making sure that information supporting the MAR RMP is correct.

Validation plays an important role during establishment of a MAR system. For example, during the commissioning phase for a new system, the operator needs to demonstrate the system's capability to consistently produce recovered water of the quality required for the planned uses. Validation is also required whenever new processes or equipment are introduced, or when significant changes to the MAR system take place.

Formal investigation or research may be needed if there is insufficient knowledge of the effectiveness or reliability of the barriers within the system to maintain recovered water quality within critical limits, or if the environmental impact of hazards is unknown.

I. Documentation and reporting

The RMP will contain most of the recorded documentation relating to the MAR system's operation, including monitoring information, as proof of plan compliance.

Routine reporting of operational monitoring data should be kept to the minimum required to identify adverse trends or declining operational performance. Evaluation of results and internal and external audits (discussed below) should be reported to everyone responsible for operational procedures and process controls.

Routine external reporting requirements for regulators would be also specified in the MAR licence.

J. Evaluation and audit

Where third party certification does not exist, the RMP would be audited regularly. This should preferably be done by an external party with appropriate certifications (if available) or by the regulator; internal auditing is also an option. Auditing is essential to ensure the maintenance of standards and encourage continuous improvement (see the next item below). Based on the results, the evaluation period may stretch beyond an initial one year; however, to account for changes in the source-water conditions and changes in pressures on the aquifer system, the period should not exceed five years.

K. Review and continuous improvement

A RMP should be internally reviewed periodically, to ensure that it accurately reflects the current understanding of the system's risks and controls discussed at (A) and (B) above. Reviews should be overseen by the scheme operator and should include all components of the system, including end uses. All monitoring data, particularly environmental parameters subject to long-term degradation (e.g. groundwater quality) should be included.

The outcome of each review should be documented. It will inform the periodic review of a MAR licence, and may result in the variation of the latter's terms and conditions as to, in particular, required improvements in operational procedures and process controls, including a timeframe for implementation before the next review falls due.

SCHEDULE 2

STANDARDS AND CRITERIA FOR MAR WITH TREATED WASTEWATER/STORMWATER

Quality parameter (mg/1 except otherwise indicated)	Recommended Guidelines by the Palestinian Standards Institute for Treated Wastewater Characteristics	Jordanian Standard (JS:893/2002)	FAO Guidelines (for trace metals in) irrigation water	IB (Dutch Guidelines for soil protection, (IB))	Recommended Guidelines for Treated Wastewater[i] in Palestine	Remarks
	Groundwater Recharge	**Groundwater Recharge**		**Groundwater recharge (for potable use)**	**Groundwater Recharge**	
BOD	40	15	<=20		20	
COD	150	50			150	
DO	> 1.0	> 2.0			> 1.0	
TDS	1500	1500	< 450		1500	
TSS	50	50	<=20		30	
pH	6-9	6-9		-	6-9	
Color(PCU)	Free of colored matter				-	
FOG	0	8.0			0	
Phenol	0.002	< 0.002			< 0.002	
MBAS	5	25			5	
NO^{3}-N	15	30	< 9.5[1]	5.6	15	
NH-N	10	5			10	
O.Kj-N	10				10	
PO-P	15	15		0.4	15	
Cl	600	350	<400	200	250	
SO	1000	300		150	300	
Na	230	200		120	150	
Mg	150	60			150	
Ca	400	200		-	400	
SAR	9	6			9	
Al	1	2	5.0		2	
As	0.05	0.05	0.10		0.05	
Cu	0.2	0.2	0.20	0.015	0.2	

F	1.5	1.5	1.0	1	1.0	
Fe	2	5.0	5.0		2.0	
Mn	0.2	0.2	0.20		0.2	
Ni	0.2	0.2	0.20	0.015	0.2	
Pb	0.1	0.2	5.0	0.015	0.1	
Se	0.02	0.05	0.02		0.02	
Cd	0.01	0.01	0,10	0.0004	0.01	
Zn	5.0	5.0	2.0	0.065	2	
CN	0.1			0.01	0.1	
Cr	0.05	0.02	0.10	0.002	0.02	
Hg	0.001	0.002		0.00005	0.001	
Co	0.05	0.05	0.05	0.02	0.05	
B	1.0	1.0	<5.0[1]		0.4	
FC(CFU/100ml)	1000	<2.2	<= 1000[1]		<2.2	
Pathogens	Free				Free	
Amoeba & Gardia (Cyst/L)	Free				Free	
Nematodes (Eggs/L)	< 1	< 1			< 1	
Pesticides				0.0005		Sum parameter of all pesticides
Mineral oil				0.2		

i Criteria also to be used for recharge of treated stormwater

6 CONCLUSIONS AND RECOMMENDATIONS

There is potential for MAR with treated wastewater and/or with stormwater in Palestine. In Gaza in particular, MAR with treated wastewater is a matter of sheer necessity. Whereas the policy environment is favourable to MAR, the regulatory framework needs to be better aligned with the policy environment. Existing laws and regulations need to be aligned with the specifics of MAR as regards, notably, the recharge and the recovery phases of the MAR regulatory cycle. This is particularly true of the penalties prescribed for certain breaches of laws and regulations, notably in connection with water pollution prevention and control, which risk working against MAR. However limited due to the prevailing natural characteristics of most aquifers, the potential of MAR with, in particular, treated wastewater in the West Bank is no doubt destined to be stifled by a regulatory environment which (a) does not fully capture the specific characteristics and requirements of MAR, and (b) risks discouraging MAR on account of penalties which sanction MAR-relevant behaviours.

In response to the above shortcomings, **it is recommended that** –

1. the Guidelines for Wastewater Reuse in the Gaza Strip, 2002 be upgraded by complementing them with the additional and complementary MAR-specific provisions of the proposed Guideline
2. the proposed Guideline for drafting a national regulation for MAR be given consideration, as a source of inspiration and guidance in the conceptualization and drafting of a future specific regulatory framework governing MAR with, in particular, treated wastewater in Palestine.

As complement, and in line with the Guidelines for Wastewater Reuse in the Gaza Strip, **it is recommended that** -

3. PWA play the lead role in administering and ensuring compliance with the proposed Guideline, and the MAR-specific regulatory mechanisms provided in it.

It is also recommended that -

4. other central government administrations, notably, the Health Ministry, the Agriculture Ministry and EQA, play their respective established institutional roles in the administration, monitoring and enforcement of discrete aspects of the proposed MAR Guideline.

For effective administration, implementation and enforcement, **it is further recommended that** -

5. the capacities required of PWA be upgraded in context with the eventual uptake of the proposed Guideline, and that the Government in general pursue with vigour compliance with the Guideline by MAR scheme operators, once the Guideline has come into effect.
6. One and preferably more pilot projects be developed to build up specific experience with artificial recharge with treated wastewater. It is preferred that these pilot projects are defined for different techniques of artificial recharge (e.g. by ponds and by deep wells) and different combinations of treatment methods depending on the effluent quality of the source water. The pilot projects may start with prototype laboratory analyses.
7. A capacity building programme be part of the pilot projects. The programme should include regulatory as well as technical aspects (e.g. vulnerability of aquifers, design of recharge and recovery system, modelling, risk assessment and monitoring).

Flexibility and pragmatism **are recommended** as regards MAR schemes in existence, as they transition from the current regulatory regime to the new and more complex regime provided for in the proposed Guideline, if and when it comes into effect.

No recommendation is offered regarding the user-level perspective of abstractors/users of recovered water from a MAR-recharged groundwater pool, as such perspective is captured and catered for in the proposed Guideline.

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ANNEX 1: HYDROGEOLOGY AND GROUNDWATER SYSTEMS IN PALESTINE

The groundwater resources in the West Bank and Gaza Strip are derived from four aquifer basins: Eastern Aquifer Basin, Northeastern Aquifer Basin and the Western Aquifer Basin in the West Bank and the Coastal Aquifer Basin in the Gaza Strip. The aquifer basins are briefly described hereafter.

Hydrogeology of Gaza

The coastal aquifer of the Gaza Strip is part of a regional groundwater system that stretches from the coastal areas of Sinai in the South to Haifa in the North. The coastal aquifer is generally 10-15 km wide, and its thickness ranges from 0 - 200 m at the East and the coastline, respectively. In Gaza groundwater is the only source of fresh water (domestic, agricultural and industrial). There are more than 5000 water wells, most of them are for agricultural purposes with an average depth of 40-70 meters and the water table lies between 20-50m below the ground surface. The total annual renewable water is estimated at about and around 55-60 Mm3/year. Currently, more than 100 MCM is utilized annually from this aquifer Basin. The overexploitation of the aquifer has caused irreversible degradation of the water quality due to the invasion of seawater and by pollution especially nitrates from the overuse of fertilizers and infiltration of sewage (Murad, 2004).

Figure 2. Location map Gaza strip (Courtesy of Wikipedia)

The coastal aquifer is composed of Pliocene-Pleistocene age calcareous sandstone, unconsolidated sands, and layers of clays, where it overlies Eocene age chalks and limestone or the Miocene-Pliocene age Saqiye Group. The Saqiye Group is a 400 - 1000 meter thick sequence of marls, marine shales, and clay stones. Approximately 10 to 15 km inland from the coast, the Saqiye Group pinches out, and the coastal aquifer rests directly on Eocene chalks and clastic sediments of Neogene age. Figure 2 presents a generalized geological cross-section of the coastal aquifer.

Near the coast in the Gaza Strip, clay layers subdivide the coastal aquifer into four separate sub-aquifers (Figure 3). They extend inland about 2 to 5 km, depending on location and depth. Further east, the marine clays pinch out and the coastal aquifer can be regarded as one hydrogeological unit.

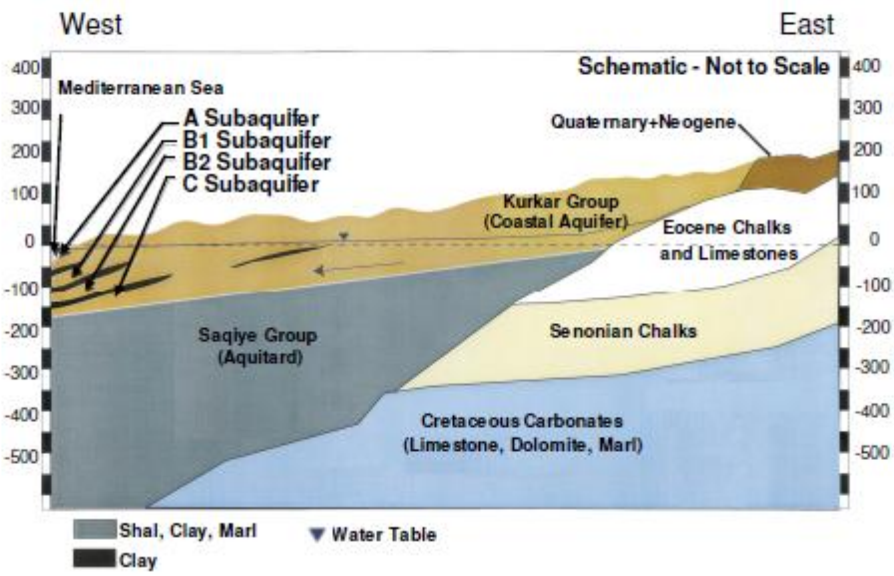

Figure 3. Generalized geological cross-section of the coastal plain Gaza (Metcalf and Eddy, 2000)

Groundwater quality in Gaza

Due to sea water intrusion and irrigation return flow groundwater quality is decreasing. The major documented water quality problems are elevated chloride (salinity) and nitrate concentrations in the aquifer. The main sources of the nitrates are fertilizers and domestic sewage effluent.

The reference level over which the water is to be considered a source and under which the water is to be considered a sink is set as follows based on the WHO drinking water guidelines: 50 mg/l for NO3, and 250 mg/l for Chloride. Generally, the chloride concentrations in the abstracted water exceed 250 mg/l in most of the coastal aquifer. In Gaza only few wells are unaffected by high nitrate concentrations and only about 10 % of the municipal water supply remains below the WHO drinking water standard of 50 mg/l. Concentrations rise up to over 400 mg/l at some places.

Hydrogeology of the West Bank

In the West Bank three hydrogeological aquifer basins are distinguished, the north-eastern basin, the western basin and the eastern basin (figure 4). The Western and North Eastern aquifer basins flow to Israel where it constitutes one of the main groundwater resources. The majority of Palestinian water supply in the West Bank comes from these aquifer basins either by wells or springs. The total renewable groundwater resources are estimated as 578-814 Mm3/year. In the West Bank, groundwater resources are contained in deep (karstic) limestone and dolomite aquifers. Most wells are 200-800 meters deep and the water table lies between 100 and 450m below the surface. Shallow alluvial aquifers are found mainly in the Jordan Valley along the outlets of major wadis. These fans are recharged after large floods. The deeper aquifers generally consist of limestones and dolomite.

At present some 87MCM/Yr or 14 % of the renewable groundwater resources is abstracted by the Palestinians from the upper aquifer (figure 5). This is insufficient to meet the West Bank's 2.65 million inhabitants demand for water.

The larger part of the abstraction from the aquifer basins is abstracted by Israel from the deeper aquifers. In fact there is overexploitation, which is particularly marked in the southern part of the Eastern aquifer, where nearby Palestinian wells are significantly affected. In some places, the drawdown has been more 70m in just ten years in southern part of the West Bank and this is considered as great threatening to the groundwater system in this area (PWA, 2012b).

Aquifer-Basin	Area within West Bank (Km^2)	Average rainfall (mm) 2010/2011	Recharge Volume 2010 /2011 (MCM)	Long-term Average Recharge (MCM)
Western Aquifer	1,767	407	311	318-430
Northeastern Aquifer	981	433	134	135-187
Eastern Aquifer	2,896	281	153	125-197
West Bank Total	5,644	347	598	578-814
Coastal Aquifer	365	225	33	55-60
Palestine Total	6,009		631	633-874

Table 1. Aquifer basin characteristics (PWA, 2012)

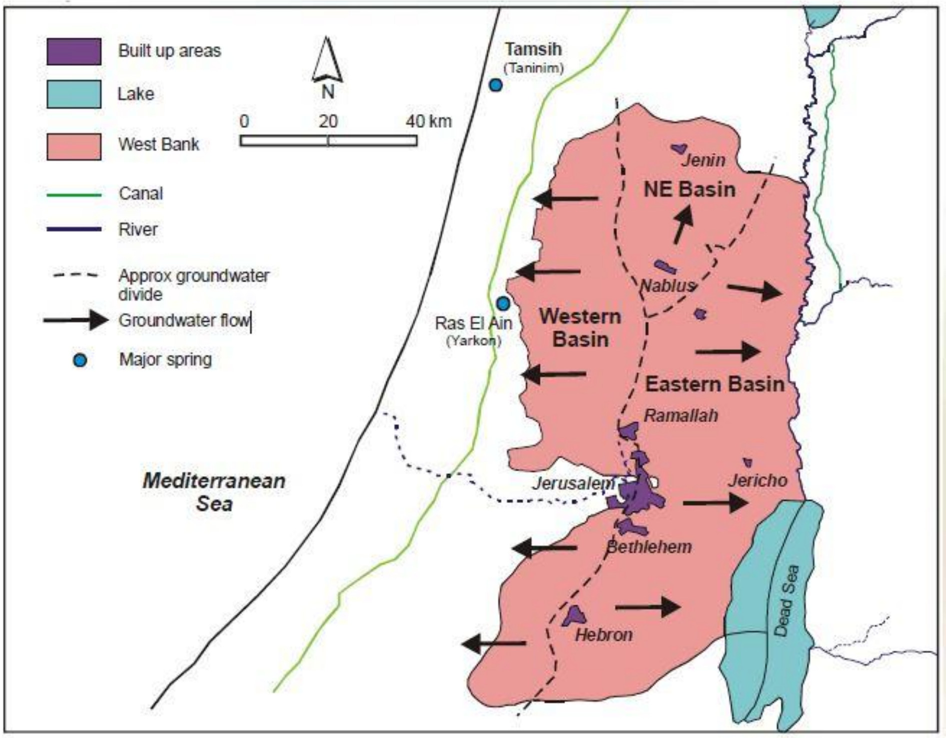

Figure 4. The West Bank aquifers (Amjad Aliewi, 2006)

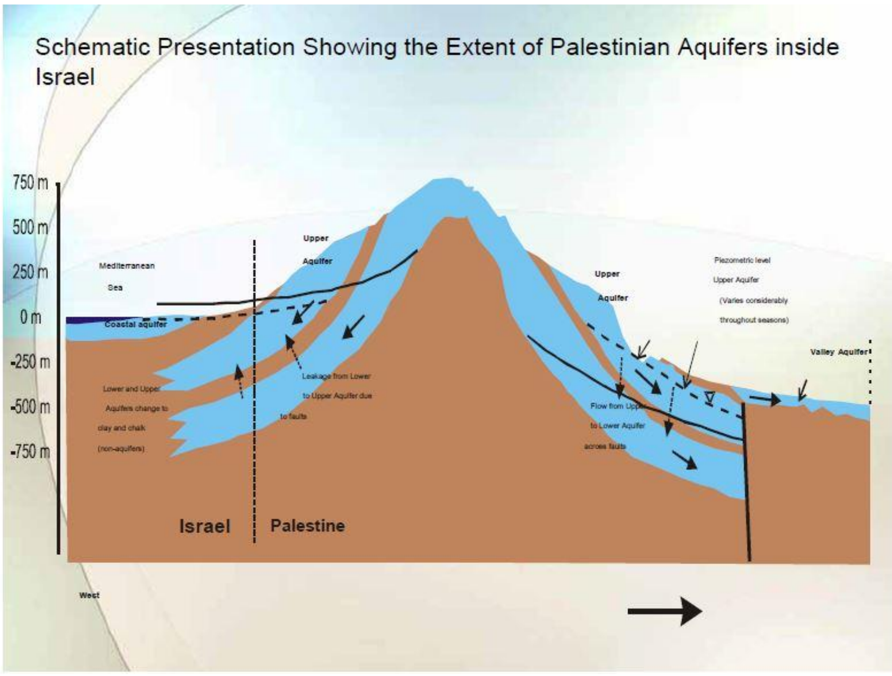

Figure 5. Hydrogeological cross-section West Bank (Amjad Aliewi, 2006)

Groundwater quality in the West Bank

The combination of poor wastewater facilities, uncontrolled intensive chemical fertilizers use for agriculture, Israeli wastewater settlement and aquifer vulnerability (karstic aquifers) are causing nitrate contamination. This is illustrated in figure 6.

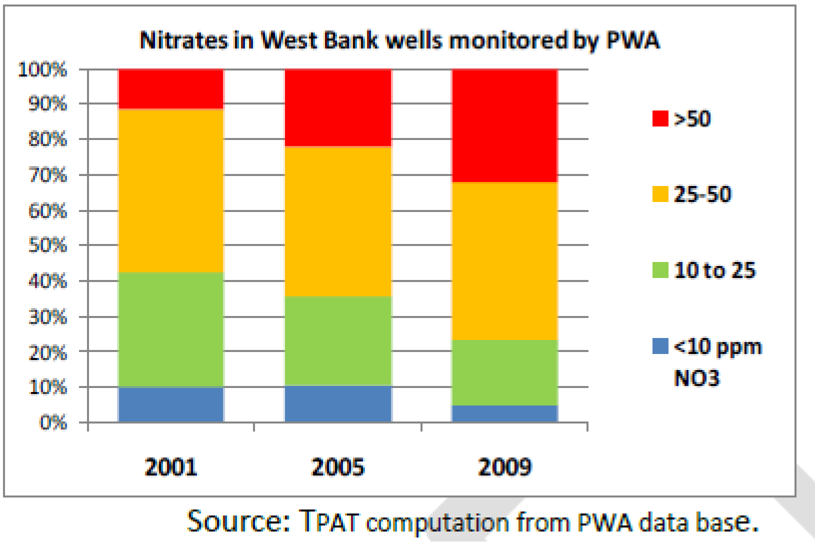

Figure 6. Nitrate concentrations in wells in the West Bank (PWA, 2012)

Chloride concentrations in the shallow aquifer are generally low; 50 – 70 mg/l. Locally concentrations may rise up to 2200 mg/l in areas influenced by salt domes, hypersaline brines and/or inflows from Dead Sea water. In the deeper aquifers chloride concentrations are found ranging from 20 – 150 mg/l (PWA, 2004).