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WATER REUSE AND ENVIRONMENTAL CONSERVATION PROJECT

CONTRACT NO. EDH–I–00–08–00024–00 ORDER NO. 04

KINGDOM-WIDE BIOSOLIDS MANAGEMENT PLAN

July 2014

IMPLEMENTED BY AECOM

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KINGDOM-WIDE BIOSOLIDS MANAGEMENT STRATEGY
JULY 2014

Submitted to:

USAID Jordan

Prepared by:

AECOM

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LIST OF ACRONYMS

ASEZ	Aqaba Special Economic Zone
ASEZA	Aqaba Special Economic Zone Authority
BFP	Belt Filter Press
DS	Dry Solids
FBI	Fluidized Bed Incineration
GAM	Greater Amman Municipality
GOJ, GoJ	Government of Jordan
GSL	Geocomposite Clay Liner
HDPE	High Density Polyethylene
MHF	Multiple Hearth Furnace
MoEnv	Ministry of Environment
MSW	Municipal Solid Waste
MWI	Ministry of Water and Irrigation
ORC	Organic Rankine Cycle
PPP	Public-Private Partnership
RSS	Royal Scientific Society
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WAJ	Water Authority of Jordan
WWTP	Wastewater Treatment Plant

1 INTRODUCTION AND PURPOSE

The USAID Water Reuse and Environmental Conservation Project (the project) works throughout Jordan in institutional capacity building, pollution prevention for industries, solid waste and wastewater management, and water reuse. The project goal is to protect and conserve scarce resources through regulation, education, and coordination with industry, local communities and the private sector. The project is implemented by the project team and a team of international and Jordanian partners. This five-year project has four primary tasks:

- Task 1 – Institutional and Regulatory Strengthening
- Task 2 – Pollution Prevention and Industrial Water Management
- Task 3 – Disposal Sites Rehabilitation and Feasibility Studies
- Task 4 – Water Reuse for Community Livelihood Enhancement, including a Biosolids Management Initiative

As part of Task 4, the project is undertaking activities to assist in developing a Kingdom-wide biosolids strategy. While the Kingdom has and continues to significantly expand and upgrade its wastewater treatment plants (WWTPs), sludge treatment and corresponding biosolids beneficial reuse has fallen behind. The Ministry of Water and Irrigation (MWI) is moving forward with sludge management activities for the Kingdom-wide WWTPs (excluding As Samra) through an effort assisted by the German Development Bank KfW, consisting primarily of sludge treatment and dewatering/drying. The KfW program does not currently include assessment of sludge and biosolids product end use. This effort is therefore providing complementary support to encourage activities that fall within the framework of a broader Kingdom-wide strategy and to encourage beneficial use of biosolids, whether as a fuel source, or as a nutrient resource to improve degraded soils and decrease water usage, both in agriculture and in reverse desertification.

This Kingdom-Wide Biosolids Beneficial Use Strategy is organized as follows:

- Section 2 – Kingdom-Wide Biosolids Activities: The section summarizes key sludge/biosolids treatment and use activities ongoing in Jordan.

- Section 3 – Kingdom-Wide Sludge Production: This section provides a summary of WWTP facilities in the country, current sludge treatment processes, and sludge/biosolids projections.

- Section 4 – End Use Outlets: This section describes potential outlets for biosolids. Cement kilns, incineration, and land application are the primary beneficial outlets considered, with disposal at landfills also being investigated.

- Section 5 – Biosolids Disposal and Beneficial End Use Strategy: This section summarizes end use and disposal opportunities, describes potential interim strategy, and proposes next steps moving forward.

A note on the use of the words “sludge” and “biosolids”

To enhance the public image of the sludge produced from the WWTPs around the Kingdom, the word “biosolids” is routinely used in this document. “Biosolids” refers to the sludge produced from wastewater treatment that includes the stabilization process that prepares it for beneficial re-use as opposed to disposal. When referencing documents which contain the word “sludge,” and also where this word is appropriate because the sludge has not been stabilized, the project team has the word used “sludge” rather than “biosolids.”

2 KINGDOM-WIDE BIOSOLIDS ACTIVITIES

2.1 Field Pilot/Research Level Studies

Biosolids field/research level activities in Jordan have primarily focused on land application in the form of fertilizer for forage crop production and rangelands restoration. This work reinforced and confirmed extensive research and practical experience in the US, Europe, and Australia, as well as in regional countries such as Oman and Tunisia.

In 2005 the Royal Scientific Society (RSS), in cooperation with USAID and University of Arizona, conducted research at Ramtha Regional Center to investigate the use of biosolids for improving soil fertility and crop production in Jordan. The investigation concluded that regulated application of biosolids in agriculture can significantly affect the organic matter and nutrient content of the topsoil, hence increasing the biological yield of the crops under test (USAID 2006). Moreover, increases in nutrients concentrations in both soil and plant were observed. There was no evidence of heavy metals accumulation or pathogen and virus uptake in the plants grown using biosolids.

In 2007, the same team of experts in cooperation with the Badia Research and Development Center investigated the feasibility and the effect of the combined use of reclaimed wastewater and biosolids for improving soil fertility and crop production in Madaba area, in addition to investigating the fate of pathogens in land application. Soil and plant were analyzed chemically, physically and microbiologically. It was found that plant and soil characteristics were moderately affected by biosolids application when combined with reclaimed water. This was attributed to the effect of the good nutrients concentration related to irrigation with reclaimed wastewater. In addition, the plant and soil microbiological analysis showed that pathogen contents (Salmonella and IPN eggs) were not detected.

In parallel to the demonstration site at Madaba, a workshop and a capacity building program on Required Bio-solids Laboratory Training were carried out at the RSS of Jordan. The main objective of the workshop was to review and update the analytical procedures in the field of biosolids sampling and laboratories analyses.

More recently, a project has been initiated as part of The Consultative Group on International Agricultural Research (CGIAR) research program. One of the main activities under this broad program is managing agro-pastoral rangelands, aiming to develop technologies to improve the productivity and quality of rangeland forages to support the pastoral animal production and enhance the livelihoods of pastoral communities.

This five year-research project (undertaken in cooperation with NCARE) has as one of its main activities the investigation of the benefits of applying biosolids in rangeland rehabilitation by improving the soil structure and native crops quality and quantity. The pilot is located in the south of Amman city, next to Queen Alia airport. The pilot area is around 5 dunums, divided into four blocks. Biosolids are applied to one block, mixed with chemical soil conditioner (DAB) in the second block, the third block is applied with chemical soil conditioner (DAB), and the forth block is used as a control block. The International Center for Agricultural Research in the Dry Areas intends to expand and implement the biosolids pilots in other regions across the Kingdom such as Karak and Tafileh.

2.2 KfW Activities

2.2.1 Climate Change Mitigation Measures in the Wastewater Sector in Jordan

In 2012, the Water Authority of Jordan (WAJ) expanded the sludge management activities. Cooperating with the German Financial Cooperation through the German Development Bank KfW, it conducted an assessment study under the climate change mitigation measures in the wastewater sector program, to identify the sewage sludge disposal needs in Jordan. The study assessed the current sludge treatment processes for selected wastewater treatment plants in the kingdom and characterized the sludge quality and quantities produced from these WWTP's.

The study also provided an overview of the ways and methods of sewage sludge treatment as part of the treatment process inside the WWTP's, as well as of the sewage sludge disposal options. In addition, the study developed conceptual proposals for the sewage sludge treatment and disposal. Six sludge treatment and stabilization alternatives have been selected out of various technical options as feasible options for the situation in Jordan. These alternatives include i) drying beds, ii) solar drying iii) centralized solar drying, iv) liming, v) composting, and vi) reed beds. The disposal options were later developed to overlap with the treatment options. Landfilling, co-incineration, and use in agriculture were the three proposed disposal options recommend by the study. The treatment and disposal options were assessed in terms of impact on climate change mitigation, current situation, and investment and operational costs.

The study recommended further investigations for the implementation of all the selected six treatment options and the three recommended disposal options. Also, the study concluded that immediate nationwide attention at a high administrative level should be given to the country's sewage sludge management and disposal options.

2.2.2 Climate Change Mitigation Measures Program

By the end of 2013, the GoJ (represented by MWI) tendered an invitation for Expressions of Interest for consulting services proposing investment measures for improving sewage sludge treatment and disposal. This project, which involves an investment of 22-25 million euros, falls under the Climate Change Mitigation Measures Program in the Jordanian wastewater sector, and is financed through the German Development Bank KfW.

The main objective of this project is related to the improvement and optimization of sewage sludge treatment and disposal measures within the wastewater treatment plants. The program activities are divided into the following two phases:

- **Phase 1**

Conceptual and investment planning study covering in-depth analysis of the current sewage sludge treatment and disposal situation at the 28 major wastewater treatment plants in Jordan. This phase will also prioritize proposed sewage sludge improvement measures, provide conceptual design of selected investment projects, and elaborate on long-term investment planning strategy for the improvement of sludge treatment and disposal measures, comprising such options as sludge drying beds, mechanical sludge dewatering, sludge reed beds, composting, solar drying, landfill disposal and incineration in Jordan. This phase will also assess options for Private Sector Participation (PSP) for the prioritized investment projects in sludge treatment and disposal

- **Phase 2**

The second phase of the program provides consulting services for the implementation of the improvement of sludge treatment and dewatering and disposal in Jordan with a goal of reducing carbon emissions. This program has been tendered and should be awarded in mid-2014. It is intended that this Kingdom-Wide Strategy Report will inform the KfW-funded effort so that treatment and dewatering is coordinated with likely reuse activities.

2.3 As Samra Sludge Feasibility Study

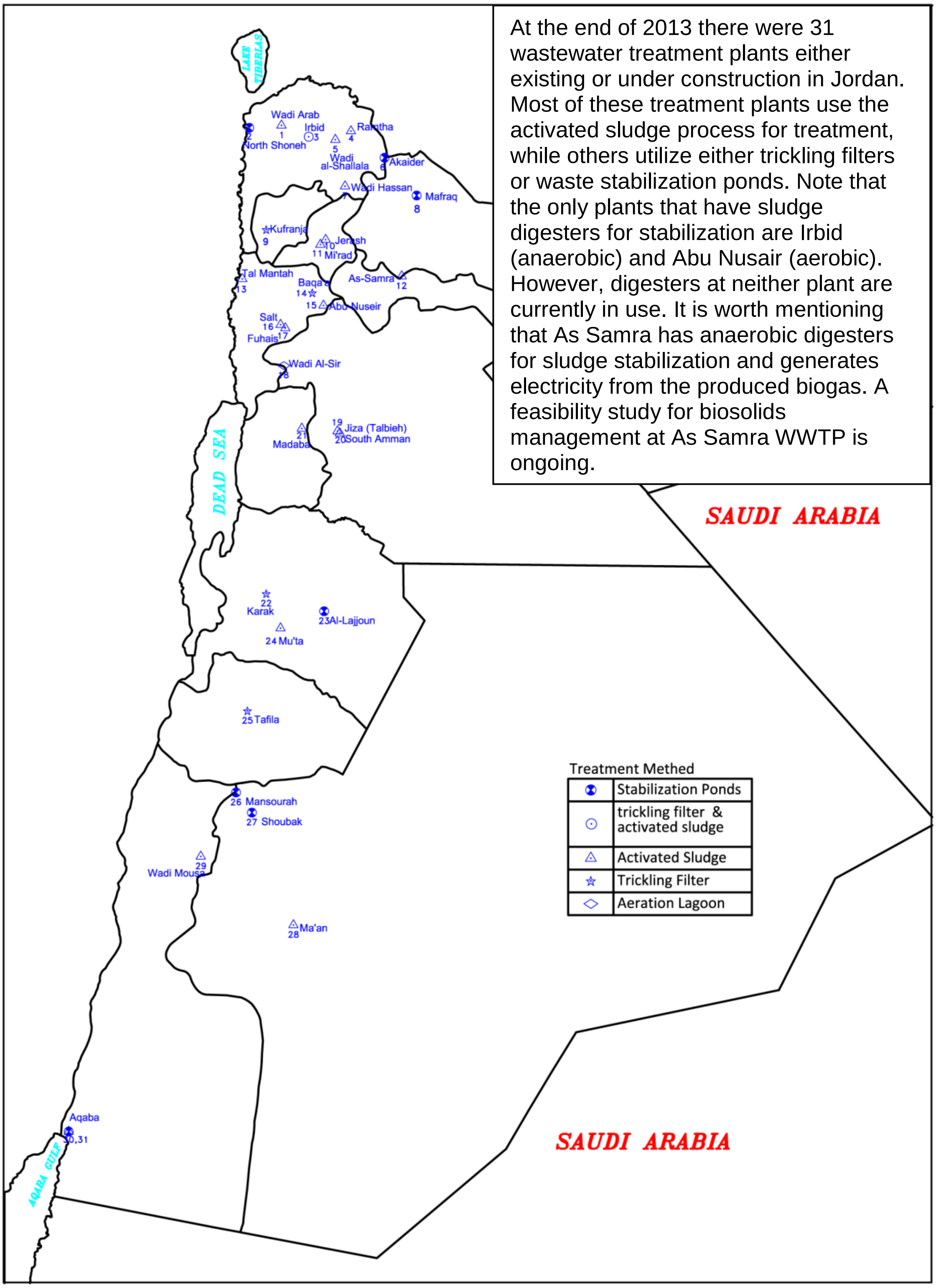
The USAID Water Reuse and Environmental Conservation Project, under Task 4, includes the As Samra Sludge Management Feasibility Study as detailed in TOR dated November 2012. The main objective of the study is to analyze the current sludge storage and management of the sludge produced from As Samra treatment plant, and to study the most feasible options to reuse and dispose of the accumulated biosolids as well as forecast amounts to be produced up to 2034.

The first phase of this effort included options analysis and selection which was finalized in April 2014 and recommended proceeding with an area type Monofill understanding that other options/markets could continue to develop over time. Other options remaining in focus are biosolids use in cement kilns and in land application. The feasibility study for the selected option was ongoing at the time of issuance of this report.

3 KINGDOM-WIDE BIOSOLIDS PRODUCTION

Figure 3-1 shows the geographic distribution of the treatment plants within the Kingdom. Table 3-1 provides an overview of the current treatment processes and design capacity.

Figure 3-1. Geographic location of wastewater treatment plants in Jordan



At the end of 2013 there were 31 wastewater treatment plants either existing or under construction in Jordan. Most of these treatment plants use the activated sludge process for treatment, while others utilize either trickling filters or waste stabilization ponds. Note that the only plants that have sludge digesters for stabilization are Irbid (anaerobic) and Abu Nusair (aerobic). However, digesters at neither plant are currently in use. It is worth mentioning that As Samra has anaerobic digesters for sludge stabilization and generates electricity from the produced biogas. A feasibility study for biosolids management at As Samra WWTP is ongoing.

Table 3-1. An overview of the current treatment processes, received wastewater flow rate and design capacity

No.	WWTP Name	Start-up Year	Treatment Process	Received flowrate, 2012 m^3/day	Design Capacity, m^3/day	Dewatering Availability
1	Wadi Al Arab	1999	AS	10,681	21,000	DB, CEN
2	North Shuneh***	2013	WSP	-	1,200	DB
3	Irbid	1987	TF+AS	8.635	11,023	DB
4	Al Ramtha	TBD	AS	4,050	5,400*	DB
5	Wadi Al Shallaleh	2013	AS	-	13,700	DB, SP
6	Al Ekeder	2005	WSP	3,232	4,000	-
7	Wadi Hassan	TBD	AS	1,238	1,600*	DB, SP
8	Mafraq	2014	AWSP	1,618	6,550**	DB
9	Kufranja	2014	AS	2,638	9,000	DB, SP
10	Jerash	TBD	AS	3,333	To be tendered	
11	Al Me'rad	2010	AS	2,297	10,000	DB, CEN
12	As Samra	2008	AS	240,926	367,000**	DP, BFP
13	Tal Al Mantah***	2005	AS	365	400	DB, SP
14	Al Baqa'a	1987	TF	11,713	14,900	-
15	Abu Nusair	1986	AS	2,401	4,000	-
16	As Salt	1981	AS	6,539	7,700	DB
17	Fuhais	1997	AS	2,305	2,400	DB
18	Wadi Al-Seir	1997	AWSP	4,053	4,000	-
19	Al Jiza	2008	AS	624	To be decommissioned	
20	South Amman	2014	AS	-	52,000	DB
21	Madaba	1989	AS	5,260	7,600	DB, SP
22	Al Karak	TBD	TF	1,852	1,600*	DB
23	Al Lajjoun***	2005	WSP	735	1,000	DB
24	Mu'ta	2013	AS	-	7,060	DB
25	Al Tafilah	TBD	AS	1,575	To be Tendered	
26	Al Mansoura***	2010	WSP	13	50	-
27	Al Shobak***	2010	AWSP	67	350	DB, Reed Beds
28	Ma'an	1989	AS	2,358	5,772	DB
29	Wadi Mousa	2000	AS	2,536	3,400	DB
30	Aqaba Natural	1987	WSP	7,220	9,000	-
31	Aqaba (Mech.)	2005	AS	8,511	12,000*	DB

* To be expanded when allocating fund ** Under expansion *** Receives only septage by tankers AS = Activated Sludge TF = Tricking Filter ASWP = Aerated Waste Stabilization Pond	WSP = Waste Stabilization Pond DB = Drying beds DP = Drying ponds (lagoons) SP = Screw Press CEN = Centrifuge BFP = Belt Filter Press

3.1 Sludge Source and Quantities

For the purposes of this study, 28 wastewater treatment plants were carried forward for consideration of sludge production. The 3 plants not considered are:

- As Samra, which receives more than 60% of the Kingdom's wastewater and is being studied separately
- Al Jiza, which will be abandoned, with flows diverted to the new South Amman plant upon its scheduled 2014 completion
- Al Ekeder (Septage Treatment Facility), which has an uncertain future and potential for mixed wastes

3.1.1 Sludge Projection and Methodology

To predict future sludge production rates from the treatment plants in Jordan, current sludge production rates were developed per capita from design reports for several treatment plants. The results showed about 0.53 Kg dry solids per capita per day. The estimated production rate matches those reported in the literature. Rulkens (2008) estimated sewage sludge production rate to be about 50 gDS/c/d and Mininni et al (2010) calculated a global sludge production rate of 54 gDS/c/d. Future sludge production rates for each treatment plant were calculated by multiplying this rate by the forecast population expected to be connected to the respective plants.

For Waste Stabilization Pond (WSP) treatment processes, the above assumption is not applicable, since the sludge remains in the anaerobic ponds for a period of five to ten years. The sludge could, however, be considered stabilized anaerobically. Therefore the estimated average quantity of sludge produced from WSP will be lower than that from an activated sludge or trickling filter process. Konate Y. et al (2010) measured the rate of sludge accumulation in anaerobic ponds at about 2.26 DS kg/c/year, which documented also as 0.037m^3/c/year. Bhattacharya M. (2009) measured volumetric accumulation rates estimated to be in the range between 0.01 and 0.05m^3/c/year. Nelson et al (2004) documented that the average sludge accumulation rates fall in the range of 0.021 to 0.036m^3/c/year.

Since Jordan has a moderate climate, average sludge accumulation will be assumed at 0.05m^3/c/year. This represents the highest value cited by Konate et al (2009) even though Morgan D. (2010) recommends a value of 0.04m^3/c/year for climates with average temperature above 20^{o}C. Assuming the average dry solids content of accumulated sludge to be 6% by weight (the same value that has been used by Konate Y. et al (2010), the dry solids production will be 3kg/c/year which is slightly greater than that documented in the Konate study. According to this assumption, the forecasted sludge accumulation rate for WSP was calculated by multiplying this rate by the forecast population expected to be connected to treatment plants. The forecasted populations for all plants for the purposes of this analysis are summarized in Table 3-2. Table 3-3 provides the projected sludge production for the respective WWTPs from 2015 to 2035.

Table 3-2. Forecast Population Expected to be Served by Individual WWTPs from 2015 to 2035

No.	WWTP Name	Forecast Population to be Served by Sewer Network				
		2015	***2020***	***2025***	***2030***	***2035***
1	Wadi Al Arab	174,128	208,954	240,745	280,834	314,534
2	North Shuneh	79,812	87,383	94,743	101,643	109,047
3	Irbid	113,298	126,893	139,583	153,541	168,895
4	Al Ramtha	136,565	153,285	172,052	193,117	216,762
5	Wadi Al Shallaleh	151,831	169,118	185,533	200,858	215,424
7	Wadi Hassan	65,381	75,795	87,868	101,863	118,087
8	Al Mafraq	42,377	47,480	52,602	57,651	62,444
9	Kufranja	67,700	72,802	78,300	84,160	93,750
10	Jerash	75,660	86,357	97,276	108,034	118,637
11	Al Me’rad	72,483	82,730	93,191	103,498	113,655
13	Tal Al Mantah	62,329	66,494	70,336	76,409	82,314
14	Al Baqa'a	224,910	248,440	269,890	289,604	308,619
15	Abu Nusair	38,502	48,634	59,431	70,835	73,028
16	As Salt	65,863	73,362	80,561	87,474	94,234
17	Fuhais	32,485	39,225	43,075	46,770	50,385
18	Wadi Al Seir	177,615	199,533	222,700	247,009	329,648
20	South Amman	430,000	511,000	604,000	710,000	831,000
21	Madaba	87,305	96,960	106,110	114,762	122,902
22	Al Karak	51,700	55,597	59,778	64,271	69,102
23	Al Lajjoun	132,151	142,364	153,367	165,220	177,990
24	Mu'ta	46,167	52,745	58,378	61,569	66,196
25	Al Tafila	35,265	47,451	61,531	77,540	95,541
26	Al Mansoura	1,240	1,404	1,569	1,729	1,883

No.	WWTP Name	Forecast Population to be Served by Sewer Network				
		2015	***2020***	***2025***	***2030***	***2035***
27	Al Shobak	38,249	42,743	47,151	51,246	54,800
28	Ma'an	43,665	50,374	57,550	63,167	68,621
29	Wadi Mousa	12,950	14,624	16,265	17,852	19,394
30	Aqaba Natural	48,164	50,000	50,000	50,000	50,000
31	Aqaba (mech.)	97,788	116,424	139,306	164,496	191,855

Table 3-3. Forecast biosolids generation for the various WWTPs from 2015 to 2035

No.	WWTP Name	Projected Biosolids, Kg/day (Dry Solids)				
		2015	***2020***	***2025***	***2030***	***2035***
1	Wadi Al Arab	9,237	11,085	12,771	14,898	16,686
2	North Shuneh	2,634	2,884	3,127	3,354	3,599
3	Irbid	6,010	6,732	7,405	8,145	8,960
4	Al Ramtha	7,245	8,132	9,127	10,245	11,499
5	Wadi Al Shallaleh	8,054	8,972	9,842	10,655	11,428
7	Wadi Hassan	3,468	4,021	4,661	5,404	6,264
8	Al Mafraq	2,248	2,519	2,790	3,058	3,313
9	Kufranja	3,591	3,862	4,154	4,465	4,973
10	Jerash	4,014	4,581	5,160	5,731	6,294
11	Al Me’rad	3,845	4,389	4,944	5,490	6,029
13	Tal Al Mantah	2,181	2,327	2,462	2,674	2,881
14	Al Baqa'a	11,931	13,179	14,317	15,363	16,372
15	Abu Nusair	2,042	2,580	3,153	3,758	3,874
16	As Salt	3,494	3,892	4,274	4,640	4,999
17	Fuhais	1,723	2,081	2,285	2,481	2,673

No.	WWTP Name	Projected Biosolids, Kg/day (Dry Solids)				
		2015	***2020***	***2025***	***2030***	***2035***
18	Wadi Al-Seir	1,460	1,640	1,830	2,030	2,709
20	South Amman	22,811	27108	32,041	37,665	44,084
21	Madaba	4,631	5,144	5,629	6,088	6,520
22	Al Karak	2,743	2,949	3,171	3,410	3,666
23	Al Lajjoun	4,361	4,698	5,061	5,452	5,874
24	Mu'ta	2,449	2,798	3,097	3,266	3,512
25	Al Tafila	1,871	2,517	3,264	4,113	5,068
26	Al Mansoura	41	46	52	57	62
27	Al Shobak	1,262	1,411	1,556	1,691	1,808
28	Ma'an	2,316	2,672	3,053	3,351	3,640
29	Wadi Mousa	687	776	863	947	1,029
30	Aqaba Natural	369	411	411	411	411
31	Aqaba (mech.)	5,188	6,176	7,390	8,726	10,178

The projected values will vary depending on actual development in the respective cities and actual network expansion rates.

WSPs receiving septage from tankers will produce sludge quantities different from those receiving fresh wastewater (conveyed by sewer lines), primarily because septage has been stabilized within septic tanks for many years. Most of the organic matter was degraded anaerobically, so the sludge production rate is expected to be higher than that produced by WSP with fresh wastewater influent. The final report (2001) of the Prince Edward Island Department of Fisheries, Aquaculture and Environment (PEIFAE) documented that septage treated by WSP process produced 34g/c/day of dry solids. The USAID/Jordan-small community project (2005) used a value of 33g/c/day as dry solids production from Shobak septage WSP treatment plant, while using a value of 37g/c/day as dry solids production from North Shouneh Septage WSP treatment plant. For both treatment plants they assumed a DS content of produced sludge in the order of 4 to 4.5 %.

For the purpose of this study a value of 33g/c/day is used for estimating the production rate of dry solids from WSP treatment plants which receive just septage conveyed by tankers.

For Fuhais, Madaba, Wadi Ash Shalallah, As Salt, Wadi Mousa, Aqaba, and Al Baqa’a, wastewater treatment plants, future population growth rates as provided by the Department of Statistics (DOS) and as shown in Table 3-4 were used. For the remaining plants, forecast population data was obtained from corresponding design reports available in MWI's main library.

Table 3-4. Forecast population growth rate from 2015 to 2035

Plant No.	Location	Annual Percent Increase for Year Shown				
		2015	2020	2025	2030	2035
5	Wadi Al Shalallah	2.71	2.18	1.87	1.60	1.41
13	Tal Al Mantah	2.76	2.18	1.89	1.67	1.5
14	Al Baqa'a	2.54	2.01	1.67	1.42	1.28
16	As Salt	2.76	2.18	1.89	1.66	1.50
17	Fuhais	2.76	2.18	1.89	1.66	1.50
21	Madaba	2.48	2.12	1.82	1.58	1.38
26	Al Mansoura	2.99	2.52	2.25	1.96	1.72
29	Wadi Mousa	2.98	2.46	2.15	1.88	1.67
30	Aqaba Natural	2.83	2.66	2.61	2.53	2.43
31	Aqaba Mechanical	2.83	2.66	2.61	2.53	2.43

Source: DOS of Jordan

3.1.2 Wastewater Treatment Plant (WWTP) Descriptions

3.1.2.1 Wadi Al Arab

Wadi Al Arab WWTP, in operation since 1999, treats wastewater using the activated sludge process. It is designed for a hydraulic capacity of 21,000 m^3/day. In 2012 the average influent wastewater flow rate was about 10,680 m^3/day.

Average generated sludge rate in 2012 was about 200 m^3/day at the outlet of the sludge thickener. At the end of 2013 dewatering facilities were installed but still have not been started-up. In summer, generated liquid sludge is currently either conveyed into drying beds with the resultant dried sludge periodically transported by private contractors to Al Ekader site, in winter, it is disposed of directly to the Al Ekader site as liquid by tankers. Forecasted dry solids quantity in 2035 is about 16,700 kg/day.

3.1.2.2 North Shuneh

North Shuneh WWTP was commissioned recently, in November 2013, to treat septage from nearby villages using the WSP process. It is designed for hydraulic capacity of 1,200 m^3/day. This means that the anaerobic pond will be desludged approximately every five years, so it will not considered in this study.

3.1.2.3 Irbid

Commissioned in 1986 and in operation since then, the Irbid WWTP was designed to treat wastewater by both trickling filters and activated sludge processes. It is designed for a hydraulic capacity of 11,023 m^3/day. The average influent flow rate in 2012 was about 8,640 m^3/day, representing 78% of the design capacity.

The plant processes include sludge treatment by anaerobic digestion, but due to operational and maintenance problems the digester was taken out of operation at the end of 2011. Subsequently, the sludge drying beds were taken out of operation due to odor problems. The generated liquid sludge is currently transported as liquid sludge by tankers to the Al Ekader site. The average rate of sludge production in 2012 was about 200 m^3/day. Forecast of dry solids quantity in 2035 is about 9,000 kg/day.

In November 2013, MWI signed a contract with El Concorde Construction Company to expand and rehabilitate the treatment plant, through a design-build contract; however, the contract does not include any sludge treatment units such as digester or dewatering facilities.

3.1.2.4 Al Ramtha

The Al Ramtha WWTP has been in operation since 1988. Originally, it used the WSP process, but in 2004 it was converted to the activated sludge process. It is designed for a hydraulic capacity of 5,400 m^3/day. The average influent wastewater flow rate received in 2012 was about 4,050 m^3/day. Tender documents for expansion of the plant are ready. The new plant’s service area will include nearby villages.

The existing plant had an average generated sludge rate in 2012 of about 100 m^3/day thickened sludge. In summer, generated liquid sludge is currently either conveyed into drying beds and the resultant dried sludge periodically transported by private contractors to Al

Ekader site; in winter, it is taken by tankers to the El Ekader site and disposed of as sludge liquid.

Forecast dry solids quantity in 2035 is about 11,500 kg/day. Table 3-4 shows forecasted dry solids production from 2015 to 2035 as per the new final design report of the proposed plant.

3.1.2.5 Wadi Al Shallalah

Wadi Al Shallalah WWTP is among the most recent treatment plants that have been constructed in Jordan, having been started-up in November 2013 to treat wastewater using activated sludge process. It was designed for an average influent flow rate capacity of 13,700 m^3/day. Since it has been commissioned recently no available operational data is available.

It is expected that the produced sludge will be transported to Al Ekader site after dewatering without a stabilization process. Forecasted sludge production rates are calculated depending on the population forecast adopted from the final design report.

3.1.2.6 Al Ekeder

Al Ekeder is a large waste disposal site which includes a MSW dumping area, liquid industrial waste disposal lagoons, separate lagoons for zibar, and a septage receiving/treatment facility which utilizes stabilization ponds. Currently, there is no regular dried sludge output for this facility. Once settled sludge starts to impact operational efficiency, the sludge from the facility is dredged and discharged into the liquid industrial waste lagoons for disposal, as was the case recently for the Mafraq Wastewater Treatment plant.

The liquid waste activated sludge from several northern WWTPs is also currently discharged into the liquid industrial waste lagoons, too. Historically, the MSW dumping area has routinely been used for dried sludge (from sludge drying beds) disposal for WWTPs in the north. While this is still the case, operational problems at the WWTPs have resulted in ever-increasing amounts of liquid waste sludge disposal into the lagoons rather than dried sludge disposal into the MSW site. Several donors are investigating ways of improving/upgrading the various operational areas within the Al Ekeder site both for near-term mitigation and long-term improvements.

3.1.2.7 Wadi Hassan

The Wadi Hassan WWTP has been in operation since 2001. It uses the activated sludge process and is designed for a hydraulic capacity of 1,600 m^3/day. The average influent wastewater flow rate received by the plant in 2012 was about 1,240 m^3/day. A new modified, expanded plant is proposed in order to serve nearby villages. The design is ready and is expected to be tendered as soon as funding has been allocated.

The existing plant had an average generated sludge rate in 2012 of about 100 m^3/day thickened sludge. Drying beds are used in summer, and then the dried sludge is periodically transported by private contractors to the Al Ekader site; in winter the sludge leaves the thickener without any further process and is disposed of by tanker. Depending on forecast population of the completed proposed design study, an estimate of sludge production of the proposed plant has been calculated. Forecast dry solids quantity in 2035 is about 6,260 kg/day.

3.1.2.8 Al Mafraq

The Al Mafraq WWTP uses the WSP process and has been in operation since 1988. It is designed for a hydraulic capacity of 1,800m3/day. The average influent wastewater flow rate received in 2012 was about 1,620m3/day, which means hydraulically the plant is approaching the maximum design capacity. Currently, the plant is being modified, with the treatment processes converted into aerated lagoons. Commissioning is expected early in 2014.

Forecasted dry solids quantity in 2035 is about 3,313 kg/day.

3.1.2.9 Kufranja

The Kufranjeh WWTP has been in operation since 1990. It is designed for a hydraulic capacity of 1,900m^3/day, but the average influent wastewater flow rate received in 2012 was about 2,640m^3/day, which means hydraulically the plant is over loaded. The plant is now being rehabilitated and modified plant capacity will be 9,000m^3/day. Commissioning is expected early in 2014. The existing treatment plant process is trickling filter, but the modified treatment will consist of the activated sludge process.

The average rate of sludge generation in 2012 was about 80 m^3/day at the outlet of thickener. Generated liquid sludge is currently conveyed into drying beds, and then the dried sludge is transported to the Al Ekader site. Forecasted dry solids quantity in 2035 is about 4,980 kg/day.

3.1.2.10 Jerash

The Jerash activated sludge WWTP has been in operation since 1983. It is designed for a hydraulic capacity of 3,250m^3/day. Since August 2012 influent wastewater has been diverted into Al Mera'd WWTP and the plant has been out of operation. Current planning calls for the Jerash WWTP to be demolished and a new treatment plant to be constructed. Detailed design of the new plant is expected to be completed and ready for tendering in 2014.

The plant used to generate about 100m^3/day of sludge. This quantity will now be added to sludge to be generated from Al Mera'd plant. The calculations depend on the specifics of the proposed design. The process of the new plant will be activated sludge (oxidation ditch). Sludge treatment units will include thickeners, aerobic digesters, and dewatering units.

3.1.2.11 Al Mera'd

The Al Mera'd WWTP, which uses the activated sludge process, has been in operation since 2010. It is designed for a hydraulic capacity of 10,000m^3/day. The average wastewater influent in 2012 was about 2,300m^3/day. Influent in 2013 is expected to be about 5,500 m^3/day due to temporary diversion of Jerash WWTP influent flow into the Al Mera'd plant. The Jerash WWTP will be upgraded in the near future, and upon completion of that upgrade flows will no longer be diverted to Al Mera'd. Therefore, this report will consider both plants independently, consistent with future operations.

The average rate of sludge generated in 2012 was about 100m^3/day. In the summer generated liquid sludge is currently treated using drying beds, with the resultant dried sludge periodically transported by private contractors to Al Ekader site; in winter, it is disposed of as liquid to Al Ekader site. Sludge production in 2013 is expected to be doubled due to diversion of the Jerash wastewater influent into the plant until construction of the new Jerash plant is completed. Forecast dry solids quantity in 2035 is about 6,030 kg/day.

3.1.2.12 As Samra

As Samra is the largest plant in Jordan and serves more than 3.0 million people residing in Greater Amman Municipality (GAM), Az Zarqa city and Al Hashimyyah area. Commissioned in 1986 as a waste stabilization pond plant, it was upgraded with the activated sludge process in October 2008 through a Build-Operate-Transfer contract between the Samra Project Company and MWI. The plant is now under expansion to a capacity of about 367,000 m^3/day. It will have anaerobic digesters to stabilize sludge, which will then be dewatered using the Belt Filter Press system. Given the large quantity of biosolids generated at this facility (more than 60% of biosolids generated Kingdom-wide), a separate feasibility study is underway to define options for sludge management for the As Samra facility. It is therefore not included in this study.

3.1.2.13 Tal Al Mantah

Tal Al Mantah WWTP has been in operation since 2005, and originally used trickling filters and the activated sludge process. It is designed for a hydraulic capacity of 400 m^3/day. The average influent flow rate received by the plant in 2012 was about 365 m^3/day. Two years ago, plant management decided to exclude trickling filters from the treatment process, and only the activated sludge process has been used since then. WAJ is planning to construct drying beds within the plant premises; tender documents are ready but funding is not allocated yet. The work will be tendered as soon as funds are secured.

3.1.2.14 Al Baqa'a

Al Baqa'a WWTP, which uses the trickling filters process, has been in operation since 1988. It is designed for a hydraulic capacity of 14,900 m^3/day. The average influent flow rate received by the plant in 2012 was about 11,100 m^3/day.

The average rate of sludge generation in 2012 was about 300 m^3/day at the outlet of the sludge thickener. Generated liquid sludge is currently taken by tankers to Ain Ghazal septage receiving facilities, where it is mixed with collected wastewater generated from Amman area and finally conveyed to the As Samra treatment plant. Forecasted dry solids quantity in 2035 is about 16,372 kg/day.

3.1.2.15 Abu Nusair

The Abu Nusair WWTP, which uses the activated sludge process, has been in operation since 1986. It is designed for a hydraulic capacity of 4,000 m^3/day. The average influent flow rate received by the plant in 2012 was about 2,320 m^3/day.

Average generated liquid sludge rate in 2012 was about 60 m^3/day as thickened sludge. The generated liquid sludge is currently taken by tankers to the Ain Ghazal septage receiving facilities. Forecasted dry solids quantity in 2035 is about 3,874 kg/day.

3.1.2.16 As Salt

The As Salt activated sludge WWTP has been in operation since 1981. It is designed for a hydraulic capacity of 7,700 m^3/day. The average quantity of wastewater received in 2012 was about 6,540 m^3/day. In 2012 four of the dying beds were converted into reed beds for a case study; the study has been completed and the reed beds are not in operation any more.

The average generated sludge rate in 2012 was about 150 m^3/day at the outlet of the sludge thickener. Generated liquid sludge is currently either conveyed into drying beds, in summer, and the resultant dried sludge periodically transported by private contractors; or in winter it is taken as liquid by tankers to the Ain Ghazal septage receiving facilities, where it is mixed with collected wastewater generated from the Amman area and then conveyed to the As Samra treatment plant. Forecasted dry solids quantity in 2035 was about 5,000 kg/day.

3.1.2.17 Fuhais

The Fuhais activated sludge WWTP has been in operation since 1997. The plant was designed for a hydraulic capacity of 2,400m^3/day. The average wastewater influent that received by the plant in 2012 was about 2,300 m^3/day.

Average rate of sludge generated in 2012 is about 40 m^3/day. Generated liquid sludge is currently either conveyed into drying beds, in summer, and the dried sludge periodically transported by private contractors to the Al Ekadar site; or in winter it is taken as liquid by tankers to the Ain Ghazal septage receiving facilities, where it is mixed with collected wastewater generated from the Amman area and finally conveyed to the As Samra treatment plant. Forecasted dry solids quantity in 2035 is about 2,670 kg/day.

3.1.2.18 Wadi Al-Seir

The Wadi Al-Seir WWTP, which uses the WSP process, has been in operation since 1997. The plant was designed for a hydraulic capacity of 4,000m^3/day. The average wastewater influent that received by the plant in 2012 was about 4,050 m^3/day. Due to the WSP process, the sludge is accumulated within the plant premises by desludging anaerobic ponds every five years; for this reason it will not be considered in this study.

3.1.2.19 Al Jiza

The Al Jiza activated sludge WWTP has been in operation since 2008. The plant was designed for a hydraulic capacity of 4,000m^3/day. The average wastewater influent that received by the plant in 2012 was about 624 m^3/day.

Average rate of sludge generated in 2012 was about 7 m^3/day. Generated liquid sludge is currently conveyed into drying beds in summer and stored at site; in winter it is taken as liquid by tankers to Ain Ghazal septage receiving facilities, where it is mixed with collected wastewater generated from the Amman area and finally conveyed to the As Samra treatment plant. The plant will be decommissioned as soon as South Amman WWTP starts operations; commissioning of the South Amman plant is planned for April 2014. Since the influent of the Al Jiza plant will be diverted to this new plant, where all subsequent production will occur, this study disregards the Al Jiza WWTP.

3.1.2.20 South Amman

The South Amman WWTP, which will use the activated sludge process, is currently under construction. It is located south of Amman near Al Jiza WWTP. It is designed to handle wastewater flow rate of 52,000m^3/day. After commissioning, which is expected in 2014, the South Amman WWTP will receive wastewater diverted from the Al Jiza WWTP, according to

WAJ's plan. Therefore, the Al Jiza plant is not included in Table 3-3, since it will be abandoned in the very near future and the population served Al Jiza is included in the design of the South Amman plant.

Average rate of sludge generation from Al Jiza WWTP in 2012 was about 7 m^3/day. Generated dried sludge is currently stored within the premises of the plant site.

Forecasted dry solids quantity from South Amman WWTP in 2035 is about 44,080 kg/day. The calculated quantities depend on the population forecast documented as documented in South Amman WWTP final design report.

3.1.2.21 Madaba

The Madaba activated sludge WWTP has been in operation since 1989. It is designed for a hydraulic capacity of 7,600 m^3/day. The average influent flow rate that received in 2012 was about 5,040 m^3/day.

The average rate of sludge production in 2012 was about 250 m^3/day. In March 2012 a dewatering centrifugal unit was installed with a capacity of15 m^3/hr., and all the sludge generated from the plant processes is now dewatered by this unit. After sludge treatment by centrifugal dewatering process, generated dried sludge is currently stored within the premises of the treatment plant. Forecasted dry solids quantity in 2035 is about 8,960 kg/day.

3.1.2.22 Al Karak

The Al Karak WWTP, which uses the trickling filters process, has been in operation since 1988. It is designed for a hydraulic capacity of 875m^3/day. The average influent flow rate received in 2012 was about 1,850m^3/day, which means hydraulically the plant is over loaded. A new design is in place to modify and upgrade the plant, based on the activated sludge process. Tendering for construction is expected in 2014.

The average rate of sludge production in 2012 is about 10 m^3/day. Generated liquid sludge is currently either conveyed into drying beds in summer, and the dried sludge is periodically transported by private contractors to the Al Lajjoun WWTP; or in winter; it is disposed of the plant as liquid by tankers to Al Lajjoun WWTP. Forecast dry solids quantity in 2035 is about 3,660 kg/day.

3.1.2.23 Al Lajjoun

The Al Lajjoun WWTP, which receives septage from near-by areas, has been in operation since 2005. The treatment process used is the waste stabilization pond. The plant is designed for a hydraulic capacity of 1,000m^3/day. The average influent flow rate received in 2012 was about 735m^3/day. Upgrading and expansion of the plant is completed, with the WSP process replaced by the aerated lagoon process. Commissioning will start early in 2014.

3.1.2.24 Mu'ta

The Mu'ta activated sludge WWTP is among the most recent treatment plants constructed in Jordan. It is designed for an influent wastewater flow rate capacity of 7,060 m^3/day. Since it has been commissioned only recently, in November 2013, no available data is available.

It is expected that the treated sludge will be transported to the Al Lajjoun facility. The calculation depends on the population forecast documented in the plant final design report.

3.1.2.25 Al Tafilah

The Al Tafilah WWTP, which uses the trickling filters process, has been in operation since 1988. It is designed for a hydraulic capacity of 1,600 m^3/day. The average influent flow rate received in 2012 was about 1,575 m^3/day. It is obvious that the plant reached its capacity in 2012, so MWI contracted a consultant to prepare tender documents to modify the processes. The design, which involves activated sludge (oxidation ditch), is completed and ready for tendering.

The average rate of sludge production in 2012 was about 10 m^3/day. Generated liquid sludge is currently conveyed into drying beds, and the dried sludge periodically transported off site to the Jurf Al Daraweesh area. The forecasted dry solids quantity in 2035 is about 5,070 kg/day.

3.1.2.26 AL Mansoura

The Al Mansoura WWTP has been in operation since 2010 and receives septage from near-by areas. The septage is treated using waste stabilization ponds. It is designed for a hydraulic capacity of 50m^3/day. The average influent flow rate received in 2012 was about 13m^3/day. Sludge is removed from the anaerobic ponds approximately every five years and then stored on the plant site. To date, only the first pond has been used because it did not receive enough septage quantity, and due to evaporation and seepage no wastewater has reached the second pond. Accordingly, no sludge has been produced from the plant.

3.1.2.27 Al Shobak

The Al Shobak WWTP, which uses an aeration basin, has been in operation since 2010. Designed to receive only septage transported by tankers, it treat an average septage quantity of 350m^3/day.

The average rate of sludge generation in 2012 was about 10 m^3/day. Generated liquid sludge is currently conveyed into drying beds, with the resultant dried sludge transported to a municipal solid waste landfill. Forecasted dry solids quantity in 2035 is about 2,900 kg/day.

3.1.2.28 Ma'an

The Ma'an WWTP was commissioned in 1989 to treat wastewater using WSP but has since been converted to the activated sludge process. It is designed for a hydraulic capacity of 5,772m^3/day. The average wastewater influent rate in 2012 was about 2,300 m^3/day.

The average rate of sludge generated in 2012 was about 100m^3/day. Generated liquid sludge is currently diverted into drying beds, with the dried sludge stored within the premises of the plant. Forecasted of dry solids quantity in 2035 is about 3,640 kg/day.

3.1.2.29 Wadi Mousa

The Wadi Mousa activated sludge WWTP has been in operation since 2000. It is designed for a hydraulic capacity of 3,400 m^3/day. The average influent wastewater flow rate received by the plant in 2012 was about 2,540 m^3/day.

Average generated sludge rate in 2012 was about 100 m^3/day. Generated liquid sludge is currently conveyed to drying beds, with the resultant dried sludge stored within the premises of the plant. Forecast dry solids quantity in 2035 is about 1,029 kg/day.

3.1.2.30 Aqaba Natural

There are two WWTPs located adjacent to each other at the same site in Aqaba. The first and older of the two, Aqaba Natural WWTP, has been in operation since 1987 and uses the waste stabilization process. It is designed for a hydraulic capacity of 9,000 m^3/day. The average influent wastewater flow rate received by the plant in 2012 is about 7,220 m^3/day. Sludge is removed from the anaerobic ponds approximately every five years and then stored on the plant site.

3.1.2.31 Aqaba Mechanical

The second Aqaba treatment plant, known as Mechanical Aqaba WWTP, has been in operation since 2005 and uses the activated sludge process including drying beds. Mechanical WWTP is designed for a hydraulic capacity of 12,000 m^3/day. The average influent wastewater flow rate received by the plant in 2012 was about 8,510 m^3/day.

The mechanical Aqaba plant had an average generated sludge rate in 2012 of about 150 m^3/day. Generated sludge is currently stored within the premises of the plant. Forecasted dry solids quantity in 2035 is about 12,774 kg/day.

3.1.3 Summary

Currently, sludge in most plants in Jordan, with the exception of As Samra, is not stabilized. The exception is at plants using the waste stabilization process. Additionally, most plants do not have adequate dewatering facilities, although a few new plants will be equipped with centrifuges in the near future. Several plants are able to dry sludge using drying beds during the warmer months, with sludge otherwise being trucked at significant expense to El Ekeder or Ein Ghazal.

With the exception of sludge plants utilizing waste stabilization ponds, additional dewatering, stabilization, and/or drying would be necessary for the sludge to be considered for further beneficial use.

Systematic data for quantities or qualities of sludge generated from individual WWTPs is generally not available although periodic data is available for some plants. Reuse of sludge/biosolids would require consistent management and monitoring of sludge characteristics.

3.2 Sludge Characterization

The available data regarding sludge quality was very limited, did not fully address sludge characteristics, and was not very helpful in determining the best alternative option to reuse or dispose the sludge. The evaluation of the available data shows that trace metal concentrations are well below standards limits required by the Jordanian Standard 1145/2006, as shown in Table 3-5 below. This is expected because Jordan does not have heavy industrial activities, which could contribute increasing trace metal concentrations.

Table 3-5. Heavy Metal concentrations in sludges for certain WWTP in Jordan (mg/kg DS)

Metal	Al Baqa'a	Fuhais	Irbid	Al Karak	Madaba	Kufranja	Al Salt	Al Tafila	Wadi Al Arab
As	7.5	-	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Cd	1.54	2.36	2.42	3.01	3.44	2.36	1.79	2.41	2.65
Cr	15.3	35	28	34.9	28.7	35	18	30.3	31.5
Cu	88.6	-	172	169	87.2	120	110	154	118
Mo	7.83	27.7	88.1	34	10.2	27.7	5.17	22.2	46.5
Ni	15	38.4	70.7	41.5	20.7	38.4	16.8	28.3	57.9
Se	1.7	2.5	11.9	9.2	13.8	2.5	3	10.2	11.1
Pb	26.5	33.9	62.5	43.4	36.6	33.9	36	39	27.7
Zn	984	1011	1460	1747	951	1011	1127	1497	935

Source: Efficiency Optimization in the WWTP of the Middle Governorate, Working Paper No. 224, Jordanian-German Water Program, 2013.

Table 3-6 shows average annual results conducted at WAJ laboratory for the period April 2012 to March 2013. The results show that drying sludge for a period of two years could meet Class I requirement as per Jordanian standards JS-1145/2006.

Table 3-6. WAJ sludge test analysis from WWTPs in Jordan for the period April 2012 to March 2013

Parameters	Unit	Liquid after Digestion	Cake after dewatering	Drying after Two years*	Drying after Two years**
As	Mg/kg Ds	<7.5	<7.5	<7.5	<7.5
Cd	Mg/kg Ds	1.1	1.5	2.7	1.7
Cr	Mg/kg Ds	21	26	41	22
Cu	Mg/kg Ds	163	173	248	128
Hg	Mg/kg Ds	<1.0	<1.0	<1.0	<1.0
Mo	Mg/kg Ds	15	16	14	13.2
Ni	Mg/kg Ds	26	29	38	25
Se	Mg/kg Ds	<10.0	<10.0	<10.0	<10.0
Pb	Mg/kg Ds	56	57	92	54
Zn	Mg/kg Ds	1120	1125	1723	1143
Moisture	% W/W	97.7	71.0	16.2	5.9
Fecal Coliform	MPN/gDs	6.4E5	5.4E5	55	<3
Enteric Viruses	PFU/4g Ds	<1	<1	<1	<1
Salmonella	MPN/4g Ds	<3	8.9	<3	<3
Helminthes	MPN/4g Ds	ND	ND	ND	ND

Source: Efficiency Optimization in the WWTP of the Middle Governorate (2013)

3.2.1 Sampling Program

The primary objective of the sampling program is to obtain and analyze representative samples for sludge characteristics for the 28 wastewater treatment plants, so that potential reuse can be better assessed. Three plants were selected for the sampling program. Fuhais and Aqaba Mechanical are activated sludge treatment plants while Al Baqa'a utilizes the Trickling Filter Process.

Two grab samples from each plant were collected from the sludge thickener effluent. The samples were then taken to RSS on the same day of sampling for test analysis. Analyses performed include moisture content, total nitrogen, total phosphorus, total volatile solids as well as calorific.

No samples have been collected from Stabilization Pond wastewater treatment plants. In this type of process, sludge is accumulated at the bottom of ponds and usually removed every five to ten years. Accordingly, it is very difficult to collect the samples and estimate the age of the collected sludge. In addition, after five or ten years most of the sludge will be stabilized and the expected calorific value of such sludge will be too low for the sludge to be used for any option other than land application.

3.2.2 Results and Extrapolation of Results to Other Plants

Table 3-7 below shows the test and analysis results of the sampling program.

Table 3-7. Thickener sludge effluent analyses for selected WWTPs in Jordan

Tested Parameter	Unit	Wastewater treatment name		
		Al Baqa'a	Fuhais	Aqaba (Mech)
		Trickling filter	Activated Sludge	
Moisture content	%	(97.3, 95.6) **96.45**	(98.7, 98.0) **98.35**	(99.4, 99.0) **99.20**
Total nitrogen	%	(6.3, 0.82) **3.56**	(2.64, 2.91) **2.78**	(7.29, 3.63) **5.46**
Total phosphorous	%	(1.34, 0.93) **1.14**	(0.77, 1.58) **1.18**	(2.21, 3.42) **2.82**
Total potassium	%	(0.46, 0.32) **0.39**	(1.16, 0.47) **0.82**	(0.82, 1.04) **0.93**
Total volatile solids	%	(70.1, 76.9)	(78.4)	(73.8, 75.1)
Calorific value	cal/g	(4046, 3467) **3756.5**	(3449)	(3267, 3639) **3453**

(97.3, 95.6) Test results for two samples, bold values represent the arithmetic mean.

The calorific values ranged from 3450 to 3800 cal/g, so 3500 cal/g is a reasonable value for biosolids in Jordan for the purposes of this analysis. Total volatile solids values range between 70 and 77 percent. It should be noted that several treatment plants have nitrification and denitrification process, which could affect sludge characteristics in terms of total nitrogen content. Also, operational procedures for the same plant could affect sludge characteristics.

3.2.3 Expected Quality of Sludge from WSP Treatment Plant

There are two types of WSP plants in Jordan with respect to type of influent: the first type receives fresh wastewater (wastewater conveyed to the by sewer network); the second type receives septage wastewater delivered by tankers. The quantities and qualities of sludge from these treatment plants vary depending on how long sludge remains at the bottom of anaerobic ponds and the method of desludging.

Table 3-8 shows the quality of sludge from Shobak WWTP, which receives septage transported to the plant by tankers. This can be considered a reasonable basis for similar systems in Jordan.

Table 3-8. Quality of sludge at the Shobak WWTP

Parameter (mg/kg DW)	Biosolids class (JS 1145/2006)			Analyses results (sampling date 9-Dec-2010)
	Type I	Type II	Type III	
Total Solids %	>85%	>60%	>3%	94.7%
As (mg/kg DS)	41	75	75	<7.5
Cd (mg/kg DS)	40	40	85	2.88
Cr (mg/kg DS)	900	900	3000	13.5
Cu (mg/kg DS)	1500	3000	4300	130
Hg (mg/kg DS)	17	57	57	No test at RSS
Mo (mg/kg DS)	75	75	75	36.8
Ni (mg/kg DS)	300	400	420	24.4
Se (mg/kg DS)	100	100	100	<5
Pb (mg/kg DS)	300	840	840	31.1
Zn (mg/kg DS)	2800	4000	7500	1290
FC (MPN/g DW)	1000	2,000,000	-	650

Salmonella (MPN/4g DW)	3	-	-	0.39
Nematodes (Eggs/4g DW)	1	-	-	None seen

Source: USAID/Jordan, the small communities project, Shobak WWTP (2011), ECODIT.

WSPs are very efficient at removing all kind of pathogens. Jimenez-Cisneros B. E. (2009) documented that WSP remove up to 6 bacteria log, up to 5 viruses log and almost all the protozoa and helminthes ova. Hosetti, B. B. et al (1995) mentioned that the sludge and liquids from WSPs are cost effective byproducts useful for agriculture. He added that the sludge can be used as fertilizer at local vegetation areas, helping them become sustainable resources.

Since the calorific value of sludge from WSPs is significantly lower than from that at an activated sludge treatment plant, and because the desludging is done every five to ten years, the only viable reuse outlet for WSP sludge is land application.

4 END USE OUTLETS

This section describes potential outlets for biosolids with land application, cement kilns and incineration as the primary reuse outlets, and landfilling as a disposal option. It also presents the legal framework and preliminary stakeholder assessments which are important elements in developing a strategy moving forward.

4.1 Land Application

4.1.1 Overview

Biosolids use in land application involves the spreading, spraying, and injection of biosolids to land, either to condition the soil or to fertilize crops and other vegetation. The application of organic matter from the biosolids can improve the physical, chemical, and biological properties of the soil. Introduction of organic matter into the soil can increase the water infiltration and reduce soil erosion. In addition, biosolids contain appreciable amounts of essential nutrients for plant growth, especially nitrogen and phosphorus.

Biosolids use in land application is becoming increasingly widespread world-wide, without negative consequences for human health so long as the practice complies with the application guidelines and applicable regulations. Currently, land application of biosolids is the most commonly implemented reuse option in the United States.

Traditionally, biosolids have not been used in land application in Jordan, although the Jordanian Standard 1145:2006 (Uses for treated sludge and sludge disposal) identified two land application options for biosolids reuse in Jordan: use in agriculture and in rangeland restoration. Class 1 biosolids can be used as organic fertilizer in forage and fruit trees agriculture. Both Class 1 and Class 2 biosolids can be used as soil conditioner in rangelands restoration.

For the purpose of this report, the term "land application" will only refer to forage farms and rangelands, excluding fruit trees agriculture.

Precise information on the land application area is limited and outdated. However, based on collected data from various sources, the project team estimated the total land application area to be 4,800,000 ha. This area includes the following:

1. **Forage Farms**

In 2012, DOS estimated the forage farms area producing livestock feed as 913,000 ha, representing around 19 % of the total land application area as defined above. The cropping pattern mainly consists of barley, sorghum, clover, and vetch.

More than 90% of the forage farms' area is rain fed, and is scattered across the country (DoS, 2012). The remaining forage farms' area is irrigated with fresh and reclaimed water. The forage farms using fresh water are located in the areas of the main underground water basins such as Zarqa, Azraq, and Disi basins, with an estimated area of 55,000 ha. Forage farms using reclaimed water are concentrated around the wastewater treatment plants, with an estimated area of 3,000 ha (WAJ, 2012).

2. **Rangelands**

MoA estimated the total rangelands area at 8,100,000 ha (MoA, 2001). However, this figure was arrived at in the 1990s and is thus considered out dated (Abu Zanat, 2006). A more recent figure of 3,900,000 ha was obtained from "Abu Zanat, Survey and classification of rangeland plants of high nutritional value, case of Jordan, 2006" and will be used in this report.

This survey investigated the rangeland ecosystems and concluded that a huge reduction in the rangelands area has occurred during the last 20 years. The main reasons were overgrazing, urban expansion, land use change, climate change effects, and the environmental impacts of the Gulf War.

Rangelands are classified into two ecological zones:

- **Badia Rangelands**

The approximate area of these lands is 3,100,000 ha. The Badia rangelands are concentrated in areas that receive less than 100mm annual rainfall. These rangelands are mainly located in the eastern and southern part of Jordan. Large areas within the Badia rangelands are allocated for mining activities, tourism reserves, and military use.

- **Steppe Rangelands (marginal)**

The area of these lands, some of which are privately owned, is about 800,000 ha. They receive an average 100-200 mm annual rainfall. These lands are characterized by their steep slopes and rough topography, which makes any investment in the area very difficult (MoA, 2001).

The above estimated land application area of 4,800,000 ha includes all the forage farms and rangelands in the county. However, this figure does not present the practical land application area suitable for biosolids application. This is attributed to several reasons which will be described below.

4.1.2 Screening of Land Application Area

The above section described the total land application area in the Kingdom. However, this area was screened to achieve a more realistic and practical figure in terms of biosolids application.

The screening criteria assessed the land application area in terms to land characteristics, proximity to WWTP's, reference to Agriculture Law no. 44 for 2002 in terms of rangelands definition, and compliance with JS 1145:2006. Table 4-1 below explains how the land application area was screened.

Table 4-1. Screening of Land Application Area

Rangelands			
#	**Land Category**	**Area (ha)**	**Justification**
1	Private Owned Land	720,000	• All natural rangelands are owned by the state (Agriculture law no. 44 for the year 2002) • Various land use other than grazing
2	Military Owned Lands (assumed)	1,900,000	• All natural rangelands are owned by the state (Agriculture law no. 44 for the year 2002) • Land use of rangelands is limited to grazing (Agriculture law no. 44 for the year 2002)
3	Tourism and natural reserves	220,000	• Land use of rangelands is limited to grazing (Agriculture law no. 44 for the year 2002)
4	Mining activities	2,500	• Land use of rangelands is limited to grazing (Agriculture law no. 44 for the year 2002)
5	Urban use including mountainous rangelands	45,000	• Land use of rangelands is limited to grazing (Agriculture law no. 44 for the year 2002) • Located Within or/and close to residential communities, thus does not comply with JS 1145:2006
Forage Farms			
1	Rain Fed Forage Farms	855,000	• Seasonal agriculture • Scattered small plots, and concentrated around small rural communities. Thus far away from WWTPs. • Close to flood streams and wadis, thus does not comply with JS 1145:2006

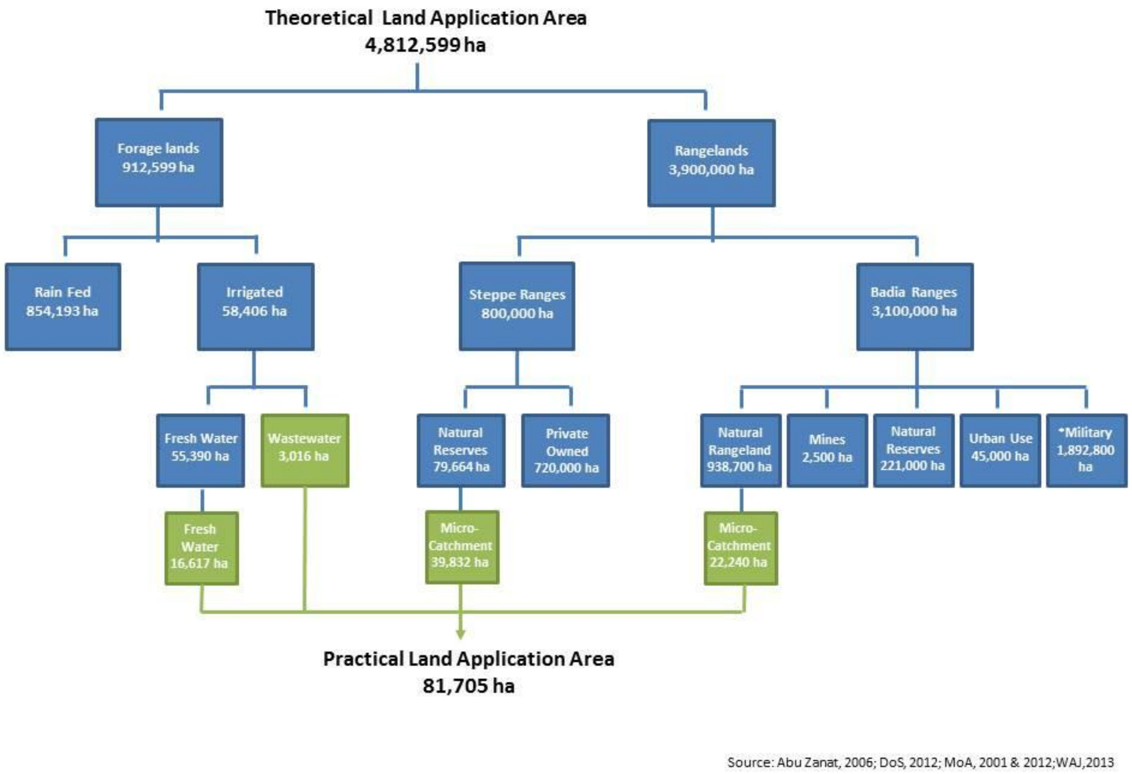
Additionally, based on field investigations and meetings with various stakeholders, the project team further assessed and screened the land application area through conservative assumptions as follows:

- Only the micro-catchment areas (230,000 ha) within the Badia natural rangelands can be used for biosolids application. This is attributed to the land physical characteristics such as soil conditions (rocky, shallow), and compliance with JS 1145:2006.
- Biosolids can be applied to only 50% of Steppe natural reserves (40,000 ha). This is attributed to the land's physical characteristics, and compliance with 1145:2006 in

terms of slop rates, proximity to water features and sources, and proximity to residential communities.
- Biosolids can be applied to only 30% of forage farms utilizing fresh water (17,000 ha). Many of these farms are concentrated in the eastern southern parts of the country, and are thus located far away from any WWTP's.

Based on the results of the screening criteria, the practical land application area where biosolids can be applied in accordance to JS 1145:2006 to improve forage crops productivity and quality, or/and to improve poor soil characteristics is estimated at 82,000 ha. This represents less than 2% of the total land application area in the country. See Figure 4.1 which shows the land application breakdown.

Figure 4-1. Land Application Breakdown



4.1.3 Map and Locations of Existing Land Application Sites

After estimating the practical land application area, the project team located and mapped all the sites that are suitable for biosolids use in land application. Figure 4.2 displays the locations of these sites, and reflects its proximities to the WWTP's.

Figure 4.2 clearly shows that forage farms utilizing wastewater effluent are concentrated around WWTP's, within a distance of less than 10 km. The total area is estimated at 3,016 ha (WAJ, 2012). The cropping pattern consists mainly of alfalfa, barley, sorghum, and vetch. The irrigations methods used consist of surface basins and furrows, sprinklers, and drip irrigation. Most of these sites are operated through Water Users Associations and are supplied with treated wastewater on contractual basis with WAJ as noted in the sections on stakeholders in Section 4.

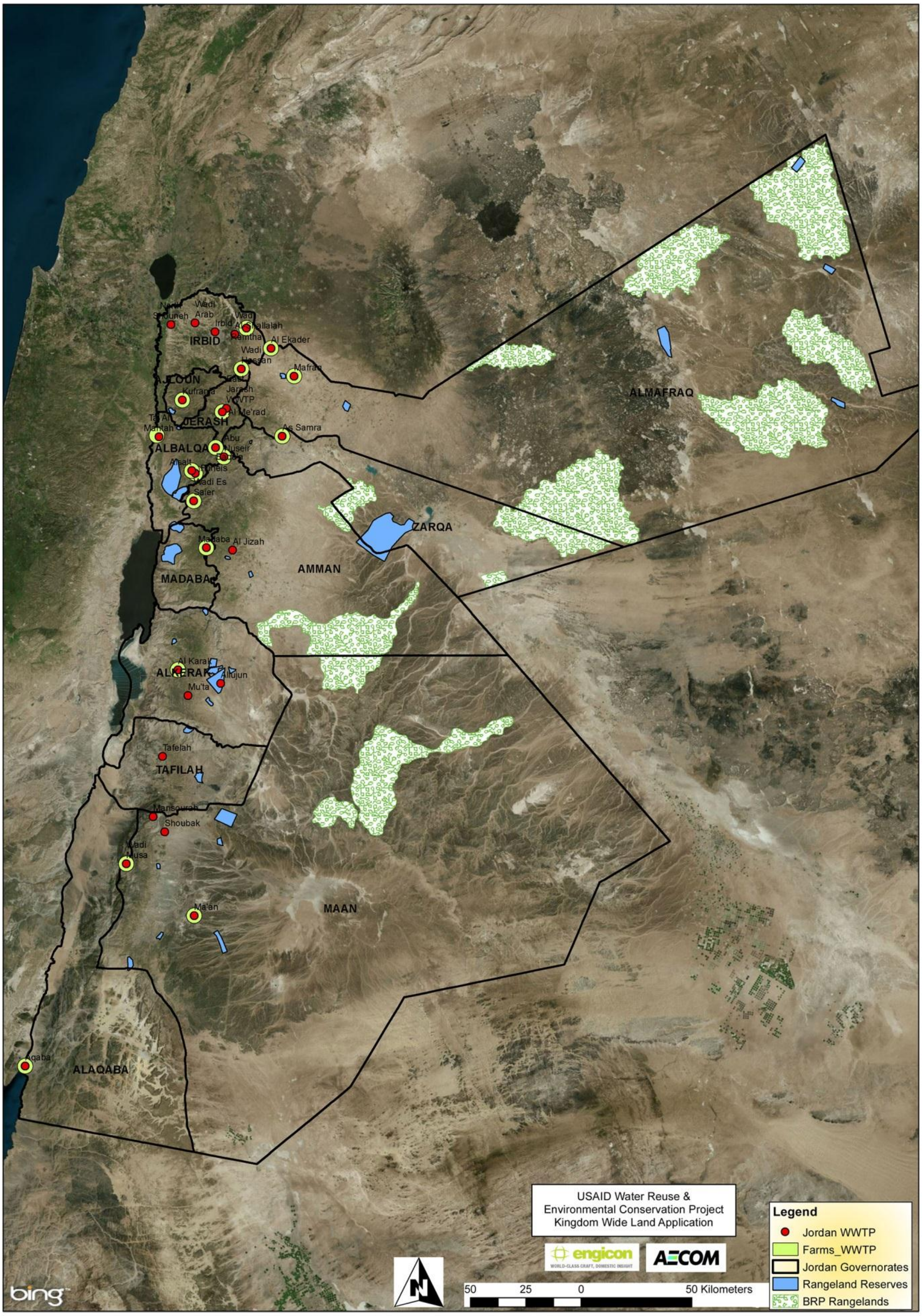


Figure 4-2. Location of sites suitable for biosolids land application

Badia rangelands are scattered in the far eastern parts of the country, and concentrated in the northern and middle governorates. The total area is estimated to 940,000 ha. However, as described before, only the micro catchments area of 23,000 ha is suitable for biosolids application. The distance between these sites and WWTP's varies from 25 km to more than 200 km. The soil is characterized as being poor in nutrients and structure, mainly due to overgrazing and climate change effects.

The figure also shows the locations of the Steppe rangelands, which consists of 34 natural rangeland reserves. These reserves are concentrated within the 200mm rainfall zone, extending from the northern to the southern parts in the country. Most of these reserves are located within a 50 km distance from WWTP's. The estimated area of these sites is 80,000 ha, but only half of this area is assumed to be suitable for biosolids application.

4.1.4 Biosolids Quantity for Land Application

Generally, the application rate of biosolids to land is best determined by the soil, plant, and biosolids characteristics. In agriculture, biosolids application rate is based on the agronomic rate, which is determined primarily by the Nitrogen (N) and Phosphorus (P) concentrations in biosolids for the crops to be grown. In rangelands rehabilitation, however, biosolids application rate is mainly based on heavy metals accumulation levels within the soil.

4.1.1.1 Biosolids Quantity for Forage Agriculture Farms

Forage production needs intensive agriculture, leading to high nutrient requirements. Also, soil in semi-arid regions is poor in terms of nutrients and organic matter. Additionally, biosolids in Jordan have relatively low heavy metal concentrations. Based on these facts, it is estimated that the annual application rate of biosolids for both forage agriculture and rangelands rehabilitation is 6 tonnes of DS per hectare per year (maximum allowable per JS 1145/2006).

Based on the above, and an estimated 20,000 ha of available forage agricultural area (as estimated after screening), it is estimated that more than 117,000 tonnes dry solids per year of Class 1 biosolids can be used as organic fertilizer in forage farms. Table 4.2 shows the biosolids quantity required for the forage farms around the WWTP's and the forage farms utilizing fresh water.

Table 4-2. Biosolids Application for Forage Agriculture

#	Governorate	Treatment plant	Forage Farms Area (ha) Radius <10 km around WWTP's	Biosolids Quantity (6 t/ha/year) Class (1)
1	Ajloun	Kufranja	81.1	486.60
2	Balqa	Fuheis & Mahis	3	18.00
3	Balqa	Tall Almantah	11.1	66.60
4	Irbed	Ramtha	130.2	781.20
5	Al Karak	Al Karak	60.8	364.80
6	Ma'an	Ma'an	35.7	214.20
7	Ma'an	Wadi Mousa	106.9	641.40
8	Madaba	Madaba	121.3	727.80
9	Mafraq	Mafraq	66	396.00
10	Zarqa	*As Samra	2400	14400.00
Total Area/Quantity			**3016.1 (ha)**	**18,097 (tonnes/year)**
Estimated forage farms utilizing fresh water			16,617	99,702 (tonnes/year)
Total Area/Quantity			**19,633 (ha)**	**117,798 (tonnes/year)**

Source: Area estimates from WAJ, 2012
*Farms around As-Samra WWTP within a radius of 25 km

4.1.4.2. Biosolids Quantity in Rangelands

In rangelands, biosolids cannot be utilized (spread and mixed) on the entire area as is the case in agriculture. This is due to the land's physical characteristics, mainly cover type and topography, and the need to comply with JS 1145:2006.

The most commonly used approach in rangelands restoration is establishing water harvesting micro-catchments coupled with forage plantation. In this case, biosolids are incorporated in the soils of the pit or in the soils of the entire ridge/furrow. Based on this application approach, it is assumed that the biosolids application rate is 600 kg per ha.

Based on the above and an estimated rangelands area of 62,000 ha, it is estimated (as shown in Table 4-3 below) that 37,243 tonnes of dry solids per year of both Class 1 and Class 2 biosolids can be used as soil conditioner in rangelands rehabilitation in Jordan.

Table 4-3. Biosolids Application for Rangelands Rehabilitation (Badia and Steppe)

Badia

#	Watershed	Total Area (ha)	Micro catchment Area (ha)	Biosolids Quantity Class 1 or 2 600 kg/ha
1	Hammad Corner	140,100	3,550	2130
2	Al Bandan	123,800	1,740	1044
3	Al Qassab	69,200	1,750	1050
4	Al Hadalat Borqu	82,400	2,050	1230
5	Salma/Aranbeh	38,900	1,000	600
6	Al Qatafi & Al Sbehi	175,000	4,400	2640
7	Wadi Butum	52,800	1,350	810
8	Wadi Al Ghadaf	109,000	2,800	1680
9	Swaga	20,000	500	300
10	Bayir	104,000	2,650	1590
11	Mafsal	17,700	450	270
Total Area		**932,900 (ha)**	**22,240 (ha)**	**13,344 (tonnes/year)**

Source: Area estimates from UNCC, 2013

Steppe

#	Governorate	Reserve Name	Total Area (ha)	Micro Catchment Area (ha)	Biosolids Quantity Class 1 and/or 2 600 kg/ha
1	Mafraq	Sabha	1,000	500	300
		Sura	400	200	120
2	Amman	Dab'a	300	150	90
		Wadi Um Quser	220	110	66
3	Karak	Al-Bi'a	5,000	2,500	1500
		Al-Thamayel	400	200	120
		Al-Lajjoun	1,100	550	330
		Nqhel	687	343.5	206.1
		Sarfa	450	225	135
		Al-Sharif	5,000	2,500	1500
		Al-Snenieh	200	100	60
4	Tafileh	Al-Twanah	1,852	926	555.6

		Al-Kamieh	1,000	500	300
5	Ma'an	Al-Fujej	1,000	500	300
		Al-Manshieh	287	143.5	86.1
		Al-Asheih	1,000	500	300
		Ran Al-Naqab	1,000	500	300
6	Al-Zarqa	Al-Azraq	200	100	60
		Berien	100	50	30
7	Ma'an	Al-Mudawara	2,000	1,000	600
		Al-Hussieneh	1,500	750	450
		Al-Hashmieh	1,500	750	450
		Al-Fesalieh	2,000	1,000	600
8	Al-Mafraq	Al-Rweshed	1,000	500	300
		Al-Rweshed	20,000	10,000	6000
		Al-Qasab	2,000	1,000	600
		Manshiet Al-Ghaiath	5,000	2,500	1500
9	Ajloun	Rajeb	438	219	131.4
10	Al-Balqa	Eira wo Yarga	4,000	2,000	1200
		Fanoush	5,000	2,500	1500
11	Amman	Bilal	1,700	850	510
		Al-Adasieh	2,000	1,000	600
12	Madaba	Maen	8,330	4,165	2499
		Al-Fesalieh	2,000	1,000	600
Total Area (ha)			**79,664**	**39,832**	**23,899 (tonnes/year)**

Source: Area estimates from MoA, 2012

Based on the above, the total estimated quantity of biosolids that can be used in land application is 155,000 tonnes of dry solids per year. Forage agriculture lands can take 117,000 tonnes of dry solids per year of Class 1, whereas, rangelands can take 37,000 tonnes of dry solids per year of either Class 1 or Class 2.

However, depending on the land use, cropping patterns and social acceptance, the above estimated quantity of biosolids that can be used in land application could be considerably less. For example, biosolids can only be applied once for rangeland rehabilitation prior and during the physical interventions, and once every growing season for fodder farms. Moreover, as was the case in the early stages of wastewater reuse in agriculture in Jordan, acceptance and adoption of reuse of biosolids for land application in Jordan may take some time to be utilized on a larger scale.

4.1.5 Biosolids Quality for Land Application

The suitability of biosolids for land application is determined by the biological, chemical, and physical analysis. Biosolids composition depends on wastewater constituents and treatment process. The agronomic value of biosolids is mainly determined by the macro nutrients content (N, P, K), and the volatile solids which provide an estimate of the readily decomposable organic matter.

As noted in the sludge characterization section, the project team conducted a sampling program to identify the properties of the biosolids produced from different WWTP’s. Based on the sampling results, it can be concluded that the produced biosolids have considerable potential for use in land application as organic fertilizer and/or soil conditioner in terms of nutrient value and organic matter content.

As shown in Table 4-4, the biosolids tested have respectable nutrient value (N, P, and K) for plant growth similar to most common organic fertilizers (animal manure) used in agriculture in Jordan. In addition, the tested biosolids have good organic matter content with an average of more than 65%. This helps to coat the soil particles (sand, silt, clay) to facilitate aggregation, which provides pores and channels in the soil that allow rainfall or irrigation water to pass through the soil and reduces the runoff of water and nutrients, and soil erosion.

Table 4-4. Nutrient Value of Tested Biosolids

Agronomic Content	Range	Average
Total N %	2.78-5.46	3.9
Total P %	1.14- 2.82	1.7
Total K %	0.39-0.93	0.7
Organic Matter %	51.35-74.45	66

4.1.6 Legal Framework

The legal framework for reusing biosolids in land application can be categorized into several parts: biosolids production, biosolids treatment and transport, biosolids reuse in land application as organic fertilizer or soil conditioner (i.e. in forage and fruits agriculture and/or rangelands restoration), and compliance with stated environmental and public health and safety requirements.

The main legislation relevant to *sludge production* is the **Water Authority Law No. 18 for 1988** which states that WAJ assumes all responsibilities and authorities related to water and wastewater in Jordan. WAJ's mandate also includes the management of WWTPs and hence any product of WWTPs. However, the Law does not include any explicit provisions regulating the means of sludge disposal and/or the production of biosolids for disposal or reuse.

JS 1145:2006 on the **Uses of Treated Sludge and Sludge Disposal)** regulates the entire cycle of biosolids production, transport, and eventually its reuse in land application. Biosolids are produced once sludge is treated in accordance to the technical specifications stated within the JS 1145:2006. Once this is done, JS 1145:2006 also regulates the process of transporting biosolids to their end use location. Furthermore, the JS 1145:2006 details the regulatory requirements for land application as soil fertilizer or soil conditioner, including but not limited to the method of application, quantities and quality of biosolids applied, cropping patterns, both environmental and public health and safety, and monitoring and control..

However, the legal framework governing organic fertilizers includes contradictory statements prohibiting the production of organic fertilizers from sludge sources. Both the MoEnv's **Instructions for Organizing the Storage, Transport and Treatment of Organic Fertilizers and their Trading for 2009** and MoA's **Instructions for the Requirements of Licensing, Preparation, Storage, Handling and Trading of Fertilizers and Plant Growth Regulators for 2011** prohibit the production of organic fertilizers from sludge produced by WWTPs. Furthermore, such restriction was also identified in the **JS 962:2011 on Organic Fertilizers and Soil Conditioner** which references both instructions and states that "organic soil fertilizers should not originate from WWTPs". Additionally, both MoA and MoEnv Instructions either refer to the JS 962:2011 explicitly (Articles 4 and 20-A of the MoEnv's Instructions for 2009), or implicitly (Article 4 of the MoA's Instructions for 2011).

With such legal provisions prohibiting the preparation and handling of organic fertilizers from WWTP products, biosolids cannot be reused for land application in accordance with **JS 1145:2006** as a soil fertilizer or soil conditioner.

It is worth mentioning that the MoA **Instructions for the Requirements of Licensing, Preparation, Storage, Handling and Trading of Fertilizers and Plant Growth Regulators** have been amended multiple times. The instructions issued in 2003 listed “sludge” in its Annex No. 3 as one form of organic fertilizer provided that MoA’s license is granted for its production and trading. However, subsequent amendments of the Instructions, specifically those issued in 2011, clearly prohibit the production of organic fertilizers originating from WWTPs.

There are also some variations in the parameters listed for soil fertilizers and soil conditioners listed in the JS 962:2011 and their corresponding values in the JS 1145:2006. Nonetheless, the JS 1145:2006 restricts the use of biosolids for fodder and fruit tree farming and rangeland restoration.

The MoA is responsible for regulating and permitting all agricultural activities in Jordan and has a clear mandate in regulating soil fertilizers and agricultural input material. Article 20-A of the **Temporary Agriculture Law No. 44 for 2002** states that “it is prohibited to produce, prepare, handle or trade with soil fertilizers and plant growth regulators for use within Jordan without a permit issued by MoA for this purpose”. Thus, MoA’s rulings will take precedence over any other in all matters related to the agricultural sector because it is MoA’s area of specialty. On the other hand, the **Instructions for Organizing the Storage, Transport and Treatment of Organic Fertilizers and their Trading for 2009** state that MoEnv’s permit shall be acquired prior to the collection and trading of organic fertilizers. With reference to the Environmental Protection Law No. 52 for 2006, MoEnv is the national entity responsible for protecting the environment in Jordan. This allows MoEnv’s rulings to override others where appropriate.

Even though the **Soil Protection Regulation No. 25 for 2005** states that the MoEnv shall coordinate with MoA as needed to develop instructions that regulate the use of biosolids for land application, JS 1145:2006 is the only direct national legal reference that explicitly addresses and regulates appropriate biosolids reuse options with emphasis on land application. Based on this technical regulation, only class 1 biosolids can be reused as an organic fertilizer for forage and fruit trees farming, whereas both class 1 and class 2 can be used as a soil conditioner in rangeland restoration.

Specifically related to rangelands in Jordan, MoA’s Law No. 44 for 2002 defines rangelands as “state-owned lands registered as such and other state-owned lands where the annual rainfall is below 200 mm without sustainable irrigation.” The Law excludes lands allocated for the public benefit or those allocated for specific state use (Article 2 and 36). Additionally, the **Instructions for the Improvement, Development, Conservation and Use of Rangelands in Jordan for 2008** grant MoA the legal mandate to conserve and improve rangelands in Jordan as well as control grazing activities.

The **Soil Protection Regulation No. 25 for 2005** indicates that the MoEnv shall carry out its tasks in cooperation with the MoA and other relevant authorities. One of MoEnv’s tasks includes undertaking measures to combat desertification. The means for “improving rangelands” and “combating desertification” do not tackle the application soil conditioners.

Subsequent to land application, relevant organizations carry out specific activities to *ensure compliance with various quality standards* which include environmental protection as well as public health and safety. JS 1145:2006 states that the monitoring bodies for biosolids land application are those deemed responsible in accordance with the national legislation in force.

To this extent, it can be concluded that environmental compliance falls under MoEnv’s umbrella by virtue of the MoEnv (**Environmental Protection Law No. 52 for 2006),** and

MWI, WAJ and JVA are responsible for the protection of water resources (**Organizational Structure of the Ministry of Water and Irrigation Regulation No. 54 for 1992, Water Authority Law No. 18 for 1988,** and **Jordan Valley Development Law No. 19 for 1988**). However, relevant to public health and safety monitoring and control, the MoH and MoMA's (through its respective municipalities and GAM) are the entities in charge (by virtue of the **Public Health Law No. 47 for 2008**, **Regulation for the Prevention of Health Nuisances and Municipal Fees Collection No. 1 for 1978 and its amendments for 2009** and the **Regulation for the Prevention of Health Nuisances and Municipal Fees Collection within Greater Amman No. 8 for 2009)**.

Furthermore, all entities issuing permits are authorized to oversee the implementation of relevant activities in accordance to the permit. JSMO's stated legal mandate includes responsibility for the issuance of specifications and technical regulations, their adoption, revision and the monitoring of their implementation for all services and products. However, despite being legally authorized to do so, JSMO delegates the responsibility of overseeing the implementation of JS 1145:2006 and JS 962:2011 to the respective bodies as explained above.

4.1.7 Preliminary Stakeholder Assessment

Stakeholders "*are persons or groups who are directly or indirectly affected by a project, as well as those who may have interests in a project and/or the ability to influence its outcome, either positively or negatively*."[1] For the purposes of this report, stakeholders can be grouped based on their levels of influence and interest into the following categories:

- Biosolids producers
- Biosolids disposal and reuse regulators
- Environment and public health monitoring bodies
- End users (local communities, CBOs, and industries)
- Facilitators

Not all stakeholder groups are significant for all the assessed biosolids reuse and disposal options. For every option, the extent of stakeholder influence and interest has been referenced against a specific legal mandate described within the legal sections of this report, and the expected benefits or negative impacts identified by the WRECP.

- **Biosolids Producers**

Biosolids producers fall under WAJ's umbrella. The operation of a number of WWTPs has been delegated to private water companies through PPPs. Nonetheless, the ultimate decision maker with regards to management of biosolids and sludge produced by WWTPs remains the mandate of WAJ. Furthermore, WAJ also controls the quality of biosolids produced by every WWTP, which in turn influences the appropriate land use.

- **Biosolids Reuse Regulators**

As explained in the legal review section, the stated legal mandate for regulating the reuse of biosolids in land application (agriculture and rangeland restoration) is given to MoA and MoEnv. Furthermore, the Agriculture Law No. 44 for 2002 explicitly states MoA as the official entity in charge of regulating the agricultural sector in Jordan. Thus, it can be concluded that MoA's mandate in regulating biosolids land application is more stringent.

[1] IFC Stakeholder Engagement Good Practice Handbook for Companies Doing Business in Emerging Markets, 2007

- **Environment and Public Health Monitoring Bodies**

The primary entity in charge of environmental inspection and compliance is the MoEnv. However, given the scarcity and high importance of the water sector in Jordan, the MWI, WAJ and JVA (within the Jordan Valley) have been assigned the specific responsibility of protecting water resources. Protecting public health and safety is primarily the responsibility of MoH. MoMA through it respective municipalities and GAM are also authorized to undertake needed measures to prevent the occurrence of health nuisances and ensure that no related harm is caused to the public. Any improper dumping of solid and/or liquid waste or substances may lead to the creation of health nuisances, which therefore leads to MoH and MoMA's interference as deemed necessary.

- **End Users**

Specifically for the land application option, end users can divided into two groups; (1) farmer communities applying biosolids as a soil fertilizer and (2) the rangeland communities applying and/or benefiting from biosolids application as a soil conditioner to enhance rangelands carrying capacities.

Furthermore, to serve the agricultural communities and facilitate their development and profit-making services, a number of cooperative Community-Based Organizations (CBOs) were established. The Jordan Cooperative Corporation (JCC) reported a total of 283 registered agricultural cooperatives across Jordan[2]. The scope of work for these cooperatives covers a variety of activities which include but are not limited to farming and animal husbandry. Not all cooperatives can be considered "active" or "have shown satisfactory performance".[3]

However, end users groups defined in this sub-section will not be undertaking biosolids land application activities independently. End user groups will work closely with regulators and their implementing arms to ensure the sound reuse of biosolids in land application as stipulated in JS 1145:2006. Therefore, acquiring the buy-in of the end users will have to be preceded with the acquiring of the buy-in of the relevant regulators and implementing arms (with emphasis on MoA, MoEnv and MWJ along with its respective authorities).

Farmers

Jordanian farming communities often develop around WWTPs to benefit from the treated effluent discharge for irrigation. Figures reported by MWI and WAJ reveal a total of 209 signed treated effluent reuse agreements with farmers and CBOs till the end of 2012 (see Table 4.5).

Table 4-5. Signed Agreements for WWTP Treated Effluent Reuse across Jordan[4]

Governorate	Treatment Plant	Number of Contracts Signed
Ajloun	Kufranja	10
Amman	Wadi Eseeir	1
Amman	Al-Jiza and Al Talbiah	No agriculture
Amman	South Amman, Future	Future
Aqaba	Aqaba WSP	4
Aqaba	Aqaba Mechanical	1
As Salt	As Salt	5
As Salt	Fuheis and Mahis	1
As Salt	Al Baqa'a	15
As Salt	Abu Nusair	1

[2] JCC, 2013, List of Agricultural Cooperatives
[3] Informal interviews carried out by USAID WRECP team with JCC offices in a number of governorates including Amman, Madaba, Mafraq, Ma'an among others (December 2013 and January 2014)
[4] MWI and WAJ, 2012

Governorate	Treatment Plant	Number of Contracts Signed
As Salt	Tall Almantah	None
Irbid	Ramtha	23
Irbid	Wadi Hassan	1
Irbid	Wadi Al Arab	None
Irbid	Alekeder	17
Irbid	Ashallalah, Future	Future
Irbid	Irbid	None
Jerash	Jerash, *Not working*	None
Jerash	Al-Merad	None
Karak	Al Karak	8
Karak	Al Lijoon	None
Karak	Mu'ta, Future	Future
Ma'an	Ma'an	8
Ma'an	Al Shoubak	No agriculture
Ma'an	Al Mansourah	No agriculture
Ma'an	Wadi Mousa	38
Madaba	Madaba	24
Mafraq	Mafraq Old	18
Mafraq	Mafraq New (Upgraded Mafraq Old)	Expected to exceed 18
Tafilah	Al Tafilah	None
Zarqa	As Samra	34
Total		**209**

Preliminary interviews conducted by the USAID WRECP team with some farming communities across Jordan revealed initial interest among those farmers to use biosolids as a source of nutrients for fodder production. Interviewed farmers stated that they perceived biosolids as a substitute for chemical fertilizers. They also noted higher yield when they used to be provided with secondary treated effluent which, as they maintained, used to contain some quantities of WWTP solid products (sludge).

Based on the preliminary interviews carried out, it can be concluded that farmer communities with a history of using secondary-treated reclaimed wastewater in fodder farming can offer the possibility for further exploring the reuse of Class (1) biosolids as an organic fertilizer in fodder farming. However, more detailed investigations will need to be carried out to further confirm the farmers' interest and willingness to land-apply biosolids as a substitute or complementary additive for chemical fertilizers.

Furthermore, it is envisioned that MoA will be one of the key GoJ partners involved in communications with farming communities and in implementing activities related to biosolids land application as a soil fertilizers.

Rangeland Communities

Rangeland communities include both the local inhabitants of the area, who also utilize it as a source of feed for their livestock, as well as the herdsmen who only visit the area for grazing. This open use of rangelands by various groups can be referenced to the Agriculture Law which states rangelands are government-owned property. However, some tribal communities residing in rangelands have claimed usage rights over their area of habitat over time. This led to conflicts among different communities and exacerbated rangeland degradation, mainly due to overgrazing and land mismanagement.[5]

[5] MoA, June 2013, Draft Amended MoA Rangeland Strategy

To conserve rangelands in Jordan, the MoA started establishing rangeland reserves since the 1940s. To-date, MoA has established a total of 32 reserves across Jordan. As indicated earlier, the total area of MoA rangeland reserves is 79,664 ha.

On the other hand, the Badia Restoration Program (BRP), financed by the UNCC and jointly implemented by the MoA and MoEnv, has allocated 11watersheds across Jordan with a total area of 932,700 ha (see Table 4-3). However, the UNCC BRP has not witnessed a lot of implementation to-date and a lot of rangeland restoration activities are still pending implementation.

MoA's efforts to improve the situation of rangelands were also channeled towards engaging the local communities in grazing management activities. One of the main approaches MoA is undertaking in that direction includes the reinforcement of the *Hima* system which utilizes tribal traditions in the implementation of sustainable grazing management plans. One of the driving factors for MoA to reinstate the *Hima* was its success story, jointly implemented with the International Union for the Conservation of Nature (IUCN) at the Bani Hashem village in Zarqa. MoA's amended Rangeland Strategy includes a reinstatement of *Hima* in the Karak Governorate. IUCN has also been exploring introducing the *Hima* in the southern governorates of Tafeeleh and Ma'an.

Preliminary conversations carried out with the communities at Bani Hashem indicated a generally positive attitude towards applying biosolids as soil conditioner to the rangelands. The community's acceptance was based on the presence of a legal reference that regulates the biosolids land application process and requirements. The community expressed their knowledge of the benefits of enhanced qualitative and quantitative rangeland vegetation cover and welcomed interventions that could assist in such improvement to the extent to which those are in compliance with the requirements of regulatory bodies.

Bani Hashem also expressed their preference for livestock grazing in rangelands compared to being fed with supplemental fodder. The feed provided by rangeland is more diverse and provides higher nutritious values to livestock and hence contributes to improving the quality of livestock products and livestock health. Such preference was also mentioned by NGOs with an experience of working closely with local communities in other locations in Jordan.

However, to be able to judge the rangeland communities' attitude towards biosolids land application for rangeland restoration, site-specific socioeconomic assessments will be needed. It is anticipated that highlighting the benefits of biosolids application on rangeland vegetation will assist in promoting social acceptance for biosolids reuse as soil conditioner. Furthermore, promoting biosolids reuse in rangeland restoration will also need to be accompanied with capacity building efforts and awareness sessions to explain the safe management, handling and application of biosolids.

As is the case for farming communities, MoA is also expected to be one of the key GoJ partners, working closely with rangeland communities and implementing activities related to biosolids land application for rangeland restoration. Furthermore, MoEnv is also expected to act as another key GoJ partner for rangeland restoration. Such activities are proposed to take place within all or a number of MoA rangeland reserves and UNCC watersheds allocated for restoration.

- **Facilitators**

Given the relevance of a wide range of stakeholders in biosolids land-application, the complexity of its legal framework, and the lack of implemented market-based and large-scale projects of this nature (only scientific and research projects were carried out for biosolids land application in Jordan), facilitators will play an important role in demonstrating and communicating the benefits of appropriate biosolids reuse as a soil fertilizer and/or soil conditioner. Facilitators will work closely with the various stakeholder groups to facilitate communication and the process of knowledge sharing.

At this stage, a number of facilitators were identified that could support biosolids land application activities as defined in JS 1145:2006 including but not limited to the Arab Countries Water Utilities Association (ACWUA), University of Jordan Water, Energy and Environment Center (WEEC), IUCN, Jordan Royal Botanic Garden (JRBG), the UNCC BRP, the National Center for Agricultural Research and Extension (NCARE), the Jordan Hashemite Fund for the Development of the Badia (Badia Fund), the Jordanian Hashemite Fund for Human Development (JOHUD), and the Royal Society for the Conservation of Nature (RSCN).

Figure 4-3 below summarizes the level of influence and interest among the relevant stakeholder groups. (More details are provided in Appendix A.) It can be concluded that a certain level of outreach activities will be required to all stakeholder groups in various scopes.

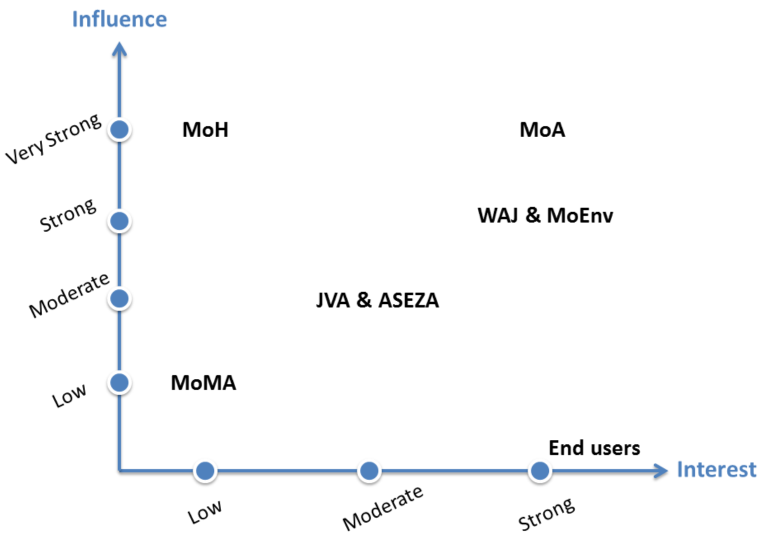


Figure 4-3. Biosolids Land Application Stakeholders Identification

The Jordan Standards and Metrology Organization (JSMO) acts as a facilitator to assemble and oversee committees to create or amend as necessary Jordanian Standards. It has limited influence, however, on respective official entities represented in its technical committees and board of directors. Nevertheless, JSMO is the entity responsible for ensuring that no contradictions are found in its technical regulations. With this as a backdrop, JSMO is obliged to undertake procedures needed for aligning the provisions of both JS 1145:2006 and JS 962:2011.

The following information should be communicated to the associated stakeholder groups:

- **Biosolids producers:** Quality of biosolids safe for reuse as defined in JS 1145:2006 (Class 1 and Class 2).
- **Biosolids disposal and reuse regulators:** Qualitative and quantitative benefits and safe reuse practices of biosolids for land application. A demonstration of success stories in the region will also help acquire regulators' buy-in. Information about the provisions of the JS 1145:2006 as a national reference regulating biosolids reuse activities.
- **Environment and public health monitoring bodies:** Measures accompanying biosolids land application to ensure compliance with various environmental and health and safety

quality standards. A demonstration of success stories in the region will also help acquire monitoring bodies buy-in. Information about the provisions of the JS 1145:2006 as a national reference regulating biosolids reuse activities with emphasis on those meant to protect the public health and safety.

- **End users (local communities and CBOs):** Qualitative and quantitative benefits of the safe biosolids reuse practices of biosolids for land application. Information about the provisions of the JS 1145:2006 as a national reference regulating biosolids reuse activities in addition to highlighting handling issues.
- **Facilitators:** Qualitative and quantitative benefits and safe reuse practices of biosolids for land application. A demonstration of success stories in the region will support better advocacy for biosolids reuse in land application. Information about the provisions of the JS 1145:2006 as a national reference regulating biosolids reuse activities.

4.1.8 Summary

As described previously, the total land application area that offers a potential for biosolids application is estimated at 82,000 ha. It includes both forage farms and rangelands. Those consist of:

(i) The irrigated farms that utilize the treated effluent from WWTP’s, and fall within a 10 km distance radius cover an overall area of more than 3,016 ha.
(ii) The irrigated farms that use fresh water, located in the northern and middle governorates, and fall within a reasonable distance from the WWTP’s, and cover an overall area of 16,617 ha.
(iii) The micro-catchments area within the Badia rangelands that is located within 25 to 200 km distance from WWTP’s. These rangelands reserves have an estimated area of 22,240 ha.
(iv) The Micro-catchments areas within Steppe Rangelands that are located within 50 km distance from WWTP’s with an estimated area of 39,832 ha.

The available land area as stated above with its given land use, offers an opportunity for biosolids land application of an estimated 155,041 tonnes of dry solids per year biosolids as organic fertilizer and/or soil conditioner.

As for the legal and regulatory framework, JS 1145:2006 covers the entire cycle of biosolids production, handling and reuse in land application. However, the statements in JS 962:2011 and the MoA and MoEnv instructions prohibiting the production of organic fertilizers originating from WWTPs have taken precedence over JS 1145:2006. This therefore creates an obstacle that does not allow for the reuse of biosolids as a soil fertilizer or soil amendment. Aligning both JS 1145:2006, JS 962:2011 and the internal MoA and MoEnv instructions is crucial for opening the market for biosolids reuse in land application.

Currently, there is significant overlap in stakeholder interests and in some cases responsibility. Therefore, in order to optimize the use of government resources, it is important that regulatory bodies coordinate their activities closely after having clearly assigned each organization’s mandate relevant to biosolids reuse in land application. Where possible, facilitators should be utilized to assist in communicating the benefits of the sound use of biosolids and appropriate means for their handling and management to the various stakeholder groups. Facilitators should be also used to ease the communication between the directly-related GoJ bodies with the end user groups.

Site-specific assessments will need to be conducted prior to biosolids land application in particular areas. It is anticipated that the extent of biosolids reuse outreach activities will vary depending on the prevailing social norms in various locations across the Kingdom.

Recognizing the above legal processes, time to adapt associated procedures, and development of the market, it is anticipated that the adoption of reuse of biosolids for land application in Jordan may take some time, as was the case of wastewater reuse in agriculture.

4.2 Landfill

4.2.1 Overview of Biosolids Disposal in Landfills

Landfilling is generally considered a non-reuse disposal option, meaning that once landfilling is chosen there will be no further utilization of the biosolids. An exception is energy production from the landfill gas. It is thus preferable that landfilling be chosen once other reuse options have been exhausted. Landfilling can, however, serve as an interim solution providing a disposal solution until end use outlets become viable.

Landfilling of biosolids falls into two categories:
1. Monofill Disposal
2. Co-disposal in a Municipal Solid Waste (MSW) landfill

Monofilling involves disposal in a landfill specifically dedicated for accepting only biosolids. The two most common methods of monofilling are the area and the trench methods. The area method generally requires stabilization prior to landfilling and consists of placing the biosolids in a natural or excavated depression or mixing them with soil and placing them on top of the existing soil layer (USEPA, 2003). This method tends to not apply daily cover and tends to change the local topography (USEPA, 2003). It further requires substantial amounts of soil, making it a less economically feasible option than trench landfilling. However, the area method can be feasible and well-suited for areas where bedrock or groundwater is shallow and where excavation is difficult (USEPA, 2003).

The trench method involves the excavation of trenches into which the biosolids are deposited and then covered with soil. Monofill trenches can be either wide or narrow depending on the solids content of the biosolids (USEPA, 2003). The trench method is the most widely used method for biosolids disposal in monofills and offers efficient use of available land space (USEPA, 2003). It is typically used in flat terrains that require a low area/volume ratio. In addition to the low area/volume ratio which reduces leachate production, the trench method requires little cover material. As such, this report regards trench monofilling as the better suited option for smaller applications in Jordan. Area monofill of municipal sludge has not been widely practiced and technical challenges exist. It may however be considered in cases where land is limited, or where it is shown that shallow groundwater exists or where excavation costs prove too high.

Co-disposal means mixing the biosolids with the municipal solid waste (MSW) at a given ratio (generally at 10 MSW: 1 Biosolids) in an approved sanitary landfill. The solids content is generally the main factor governing the mixing ratio (USEPA, 2003).

The following sections discuss the co-disposal and trench monofilling methods as relative and specific to the MSW landfills and wastewater treatment plants in Jordan.

4.2.2 Map and Locations of Existing Landfills

There are currently 17 official MSW landfills in Jordan, and 12 of these were found to be operational and serving as landfills in areas near to wastewater treatment plants. A map of the locations of these landfills relative to the locations of WWTPs can be seen in Figure 4.4.

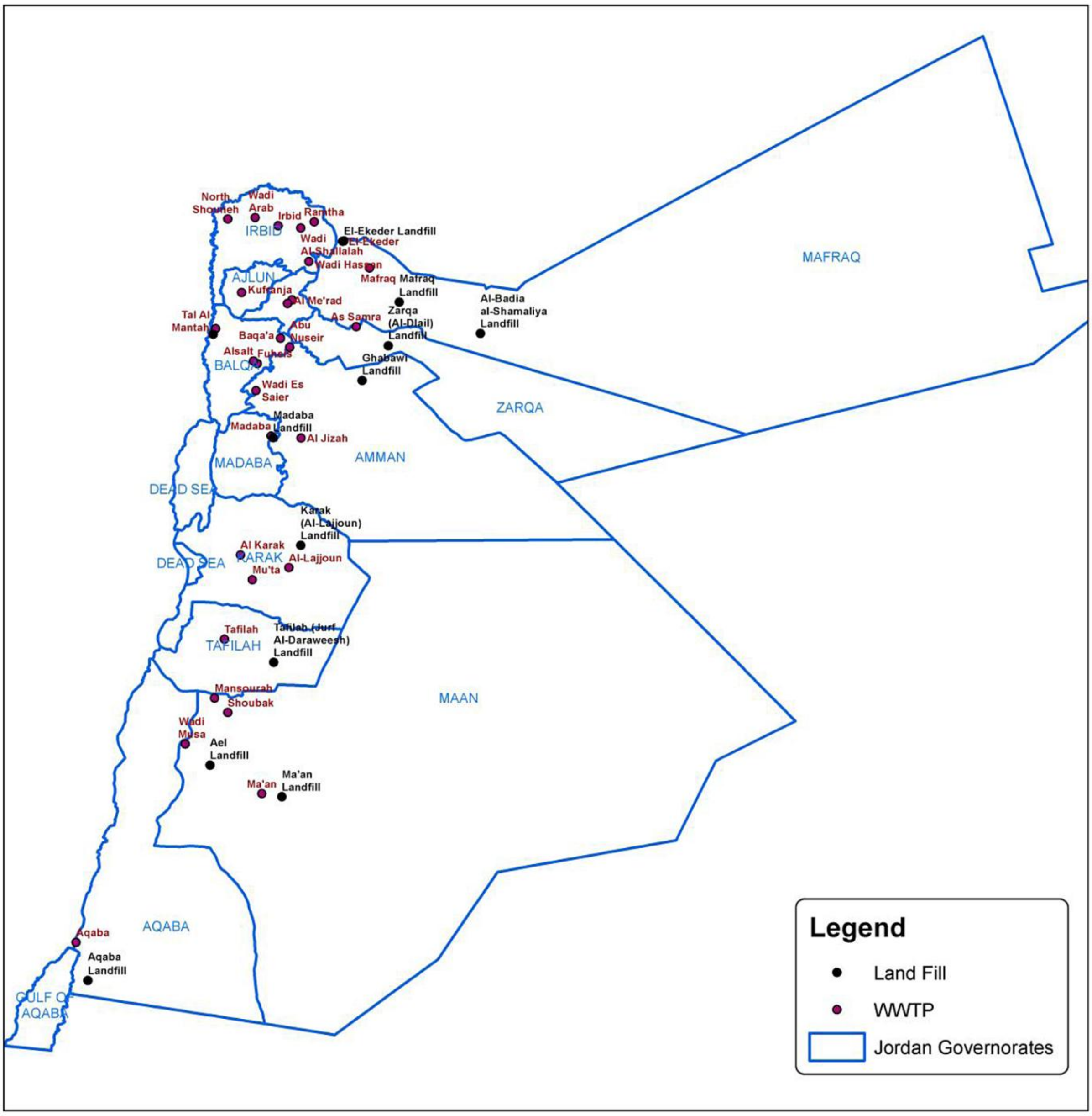


Figure 4-4. Map of Landfills and WWTPs

MSW landfills in Jordan are generally operated by the corresponding Joint Services Councils (JSCs), which are one of the implementing arms of the Ministry of Municipal Affairs (MoMA). There is one landfill that is an exception, however: Al-Ghabawi landfill is operated by the Greater Amman Municipality (GAM) and not by a JSC. Daily MSW disposal at these landfills ranges between 42 tons/day at Ael's landfill to 2,500 tons/day at the Ghabawi landfill.

With the exception of Ghabawi, where no scavenging is allowed and the cells are lined, the general landfilling process in Jordan involves excavating pits or cells with no specific design or engineered environmental controls of any sort, dumping of waste, and then allowing scavengers to pick through the dumped waste for recyclables before covering the waste. This stands in contrast to sanitary and engineered landfills where the landfills are lined, equipped with leachate and gas collection systems, a stormwater management system, a final cap and cover, and gas and groundwater monitoring systems and where daily cover is applied and proper operation and post-closure control are conducted.

To study the suitability of each of the sites to receive biosolids, the project team met with the MoEnv and the MoMA and tried to obtain reports describing each of the sites. The team found out there was no detailed documentation for landfill design, construction, and operation and that the only way to find reliable information about these sites is to do site visits to collect the data needed. Therefore, several site visits and phone calls were made to JSCs and landfills. A brief description of the relevant information about each of the landfills is presented. It is worth noting here that the JSCs were generally reluctant and are generally not open to receiving biosolids at their respective landfills.

With the exception of the As Samra WWTP, there are currently no plans to manage the sludge produced from the WWTPs in Jordan. Further, there are no plans to co-landfill with MSW, although some discussions regarding the potential to co-landfill with the new Aqaba landfill currently under design are ongoing. Particularly where vector control and/or potential contamination of aquifers pose a risk, sludge handling and disposal is a serious and pressing issue.

4.2.2.1 Al-Ekeder Landfill

The Al-Ekeder landfill is operated by the JSC of the North. It is located in the Mafraq Governorate about 27km east of Irbid city and 1km south of the Syrian border. The site first started operation in 1980. It is the second largest disposal site in Jordan, serving about 100 towns and villages in northern Jordan. The northern part of the site is used for solid waste disposal, while the southern is for liquid waste disposal.

Municipal wastewater treatment plant sludge, olive oil mill wastewater and industrial wastewater are discharged into earthen ponds at the site and the aqueous portion is left to evaporate. Only one wastewater pond is lined. In addition, leachate from the solid waste landfill is drained to the ponds for disposal.

The solid waste part of the landfill has an area of about 806 Dunums and receives about 1000 ton/day of MSW. The waste is currently being tipped in a large excavation in the northern portion of the site. The excavated and intermediate stockpiled material is used to cover the waste at the end of each day. Upon arrival at Al-Ekeder, each truck discharges its load on an adjacent area previously filled, but close to the "working edge" of the waste. There is a contractor onsite along with his laborers who are given a limited time to scavenge recyclables prior to the waste being covered; they live in tents and shacks just outside the site boundary. The remaining waste is then bulldozed over the working edge. At the end of each working day, the waste face is covered with a thin layer of material, predominantly chalky limestone, excavated from borrow pits on the site. Limited compaction (mainly of the final cover) is done on the site. There are risks of fire onsite.

Worth noting is that the Al-Ekeder landfill is full with very limited room for expansion. It is considered an environmental “hot spot” as it contains large amounts of solid and liquid waste dumped in unlined lagoons and cells. Also the influx of refugees has greatly increased the pressure on the landfill as more and more waste is generated.

4.2.2.2 Mafraq Landfill (Al-Husainiyyat)

The Husainiyyat landfill is operated by the Mafraq JSC and was first operated in 1985. It has an area of 380 Dunums and receives approximately 200-250 ton/day of MSW. The remaining capacity of the landfill is 100 Dunums and is expected to suffice for the coming ten years. Cells are rectangular with varying dimensions and are at depths of two to six meters, while reaching up to six meters above ground level. A cover of soil is applied to the waste. There are no leachate and gas collection systems nor are the cells lined. The site receives municipal solid waste and deceased animals. The landfill site is fenced and has a gate. Vehicles carrying the waste are weighed at the entrance of the landfill and compaction of waste is conducted via the available machinery.

4.2.2.3 Balqa (Deir Alla) Landfill

The Balqa (Deir Alla) landfill is operated by the Middle Ghours’ JSC. It receives about 260 ton/day of MSW and has an area of 462 Dunums; only 60 Dunums of this have thus far been used. The area is open and there is no excavation of pits at the site. The site has been operated for fifteen years. The topography of the land is constituted of wadis and hills; the wadis are filled with two-meter waste layers, which are then leveled and covered with one meter of daily soil cover. No sludge or biosolids are received at the site nor are there plans to receive any, as mentioned by the JSC due to environmental concerns and the nature of the topography.

There was a suggestion to excavate trial pits for the disposal of wastewater from the WWTPs; however, the suggestion was not approved.

4.2.2.4 Madaba Landfill

The Madaba JSC operates the Madaba landfill which was established in 1973. The landfill covers a total area of 187 dunums; 150 dunums have been used up entirely and rehabilitated by planting olive trees. The remaining 22 dunums have been acquired to expand the landfill. The closest residential area is 100 m away and the site borders agricultural land. The closest water body is 1km away.

Madaba landfill receives between 250 and 300 tonnes/day of MSW. It only receives residential solid waste. However, small amounts of construction and demolition wastes as well as industrial and liquid wastes occasionally enter.

Landfill practices involve the excavation of pits with depths ranging from 20-25m. The pits are not lined nor are there leachate and gas collection systems or a stormwater drainage system. There are five layers of waste each with a soil cover of 1.5m. The final cover reaches street level. Available onsite machinery includes chain tractors, loaders, tippers and water tankers. A scale is available for weighing incoming waste trucks and there is a private contractor onsite for scavenging and collecting recyclables.

The Madaba JSC strictly refuses to receive sludge from the Madaba WWTP. Sludge is currently disposed of in unlined pits lacking any engineering at the WWTP. The sludge at the WWTP undergoes thickening, dewatering and solar drying.

4.2.2.5 Zarqa (Al-Dlail) Landfill

Al-Dlail landfill was first established in 1991and is expected to suffice for the coming fifteen years (until about 2030). The total area of the landfill site is 270 Dunums of which 191 Dunums have been used. The JSC owns another 150 Dunums in Al-Azraq which is planned to be used as a future landfill. The site receives wastes in the range of 250-400 tons/day. Liquid waste is received in addition to solid waste but only as brought in by the government for the destruction of damaged goods. Worth noting is the large amount of deceased cattle received at the site.

The landfill has no weighing station; it was, however, stated that trucks are weighed at the Sha'aer transfer station prior to arriving at the landfill. There are no systems onsite for leachate or gas collection or stormwater drainage. The lack of proper and updated machinery is an issue, especially given the rocky and hilly nature of the site. Pits are randomly excavated with dimensions of 300-400m×60-100m and at depths varying from seven to sixty meters. Every one meter of waste is covered with a 0.5m of soil cover and the cover is done daily. Pits in which deceased cattle are disposed of are at a depth of ten meters and have dimensions of 100m×50m. Pits are not lined and there is a serious problem with fires onsite. There is a contractor onsite for waste scavenging. The JSC does not receive sludge or biosolids and has the fear of heightened fires if it ever were to accept them.

4.2.2.6 Karak (Al-Lajjoun) Landfill

The Karak (Al-Lajjoun) landfill is located in Al-Lajjoun area within Karak governorate. It serves all the municipalities within the Karak governorate excluding the Southern Ghour which has its own separate landfill. The landfill was first established in 1996 and is operated by the Karak JSC. It receives 600ton/day of MSW in addition to fifteen tons per day of dead chicken from the National Poultry Company, 150m^3/day (fifteen tankers) of Zibar (olive mills wastewater) which are stored in three onsite ponds, and waste cloth from a factory in the nearby industrial city. The deceased chickens are buried in lined pits. There is no scale and machinery mainly includes loaders, bulldozers, trippers and tractors.

The Al-Lajjoun landfill has been expanded to a "new" landfill functioning as of late 2013 with an area of 389 Dunums, while the "old" landfill has an area of 484 Dunums and has been operated for seventeen years. The landfilling practices at the "old" landfill, which is said to have completed its lifespan, involve cells dug at a depth of ten meters with areas of ten Dunums with no liners and no systems for leachate and gas collection or stormwater drainage. Waste is said to have been covered daily. There are two layers of waste currently in place, each with a depth of 3.5m and a cover of one meter of excavated earth. The final cover reaches no more than 1.5m above street level. The "new" landfill is expected to serve for twenty years and has one excavated cell with one layer of waste and another cell undergoing excavation. Excavation involves cutting along the sides of the wadi until rock is reached. The rocky nature of the ground and the unsuitability of the machinery for this kind of topography are major challenges. There is a contractor onsite for scavenging the waste and compression is done by having a bulldozer drive over the daily cover. An average of three fires occurs monthly.

Karak has three WWTPs: one is currently operating and is expected to undergo an upgrade and expansion (Al-Karak WWTP); another has been upgraded and is currently in the trial phase (Al-Lajjoun WWTP); and a third is expected to start operation in the first two weeks of January 2014 (Mu'tah and Mazar). Solar dried sludge from the Karak WWTP is currently transferred to Al-Lajjoun WWTP for disposal. At Al-Lajjoun WWTP three pits with volumes of 300m^3 are excavated in which sludge is disposed of without liners and any leachate collection and stormwater drainage systems. Furthermore, Al-Lajjoun aquifer borders the site.

4.2.2.7 Tafilah (Jurf Al-Daraweesh) Landfill

The Tafilah (Jurf Al-Daraweesh) landfill is operated by the Tafilah JSC. It receives 200 ton/day of MSW and has an area of 454 Dunums. The moisture content at the site, as stated by the JSC, is 70%.

The landfill is expected to be able to accommodate waste for at least the coming ten years. Pits are dug at depths of fifteen meters and there are no gas or leachate collection systems. The landfill site is fenced and has a gate. Wastes are compacted once dumped and a cover of soil is applied at given height intervals. “Cells” reach a height of about eight meters above ground level.

The landfill should, in concept, receive only municipal solid waste. However, in an attempt to support the Water Authority of Jordan (WAJ) and as per its request, the landfill has come to accept septage. Once the WWTP in Tafilah has been updated, however, the landfill will no longer accept septage. Currently, a minimum of 100 cubic meters/day of septage are disposed of at the site. The septage received was initially from the municipalities within Tafilah. It has come to include septage from a prison and a military base. There are neither stormwater drainage systems nor leachate and gas collection systems. Landfilling constitutes mainly of the excavation of pits with no liner.

4.2.2.8 Ma'an Landfill / Ael landfill

The Ma'an landfill is operated by the Ma'an JSC. It first started operation in 1993 and has an area of 502 Dunums. It receives approximately ninety tons of MSW per day and is expected to remain operational for the coming 25 years. The landfill site is fenced and has a gate. Cells are dug at depths of six meters and reach up to one meter above ground level. The site receives both MSW and liquid waste. A daily cover of soil is applied to the waste, and wastes are compacted by the available machinery. There are no leachate and gas collection systems nor are the cells lined.

4.2.2.9 Ghabawi Landfill

The Ghabawi landfill is the only sanitary engineered landfill and is operated by GAM. The Ghabawi landfill is located 40km east of the center of Amman and has been operating since 2003. The landfill has an area of 1,947 Dunums and receives approximately 2,500 tons of MSW/day. The layout consists of nine engineered cells of which two are already filled to capacity, the third is being currently filled and the fourth is undergoing excavation. The landfill has proper fencing and a gate. Vehicles are weighed and stop at the Sha'aer transfer station prior to being transported to the Ghabawi landfill.

The cells are lined with a geosynthetic clay liner and an HDPE geomembrane. Cells are dug at depths of approximately seven meters and rise up to 25m above ground level. Cells have an average area of 100 Dunums and side slopes of 3:1. Waste is run over by tractors to compact and rip open closed garbage bags. A daily cover of 20-25cm consisting of fine sand and dirt is applied and a final cover of 70 centimeters.

There is a leachate collection system as well as three leachate treatment ponds; however the process is facing problems. There is also a landfill gas collection system that is still not in operation.

4.2.2.10 Aqaba Landfill

The Aqaba landfill site is located approximately 12 kilometers south-southeast of Aqaba immediately adjacent to the base of the mountains. The site area is mountainous and seems mostly composed of sand, limestone and rock. It was stated that 100m were dug onsite with no traces of groundwater.

Municipal solid waste (MSW) was first dumped at the site east of the current landfill in the 1980's and is now evident as blackened piles (the result of waste burning practices) of disturbed waste that have been scavenged for recyclables. About five years ago, waste dumping started again and continues to this day.

The current MSW generation rate in Aqaba is approximately 120 ton/day. This is disposed of in the unlined MSW landfill that has an approximate area of 120 Dunums.
In addition to being unlined, the landfill has no environmental controls whatsoever; there are neither leachate or gas collection systems nor a stormwater drainage system. The lack of daily cover also raises issues with pests. Moreover, the site lacks proper fencing and security and poses a risk of landfill fires.

There is a contractor onsite for recycling in addition to occasional visits from other scavengers. Current waste recycling practices at the site consist of a group of garbage pickers picking recyclables directly from the freshly dumped waste in the landfill before it gets compacted by the available machinery.

Note that the design for a new sanitary landfill in Aqaba is currently underway by the USAID-WRECP team. This new landfill will be adjacent to the current MSW disposal area and will be sanitary engineered, making it well suited as a potential co-disposal site. At the time of writing of this report, the project team was in discussions with the Aqaba Water Company (AWC) regarding this disposal opportunity.

4.2.2.11 Al-Badia Al-Shamaliya Landfill

The Al-Badia Al-Shamaliya Landfill is operated by Al-Badia Al-Shamaliya JSC. It receives a relatively small amount of MSW (approximately 70 tons per day) and has an area of 300 Dunums. It serves the seven municipalities belonging to Al-Badia Al-Shamaliya. Landfilling involves the excavation of pits at a depth of 2-2.5m and a weekly soil cover. The landfill is not lined nor are there leachate and gas collection systems or a stormwater drainage system. The ground is rocky. Sludge and biosolids are not accepted onsite.

4.2.3 Trench Monofilling

Trench monofilling of sludge is an alternate disposal method that addresses slope stability problems with area filling of sludge/biosolids. Trenches can be either narrow or wide. Trench widths are generally in the range of 1-15m (USEPA) and the determining factor in trench width choice is the solids concentration of the biosolids to be disposed of. For low solids content (15-28% DS as recommended per EPA), narrow trenches with widths of less than 3m are often used and application rates in the range of 2,270-10580m^3/ha are applied (USEPA, 2003). These low solids contents cannot support the machinery used to place the cover material. For biosolids with greater than 20-30%DS, wider trenches in the range of 3-15m are used and application rates are in the range of 6,000-27,000m^3/ha (USEPA, 2003).

Figure 4-5 below depicts one possible trench design with a GSL (geocomposite clay liner), a width of 5m, a depth of 2m, a side slope of 1:1 and 0.5m of cover soil. In order to use space efficiently, every two trenches have 1m distance between them and are placed at 4m intervals. This allows machinery to pass, dumping the biosolids into the trenches on either side of it. A GCL is recommended for two reasons: first, it will be easier to construct at the specified 1:1 side slopes and second, compacting clay at the required moisture content to achieve the required density is difficult in an arid climate.

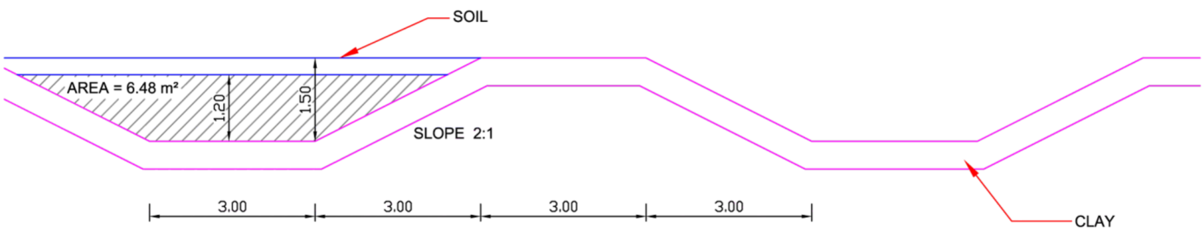


Figure 4-5. Proposed Trench Design

Based on this trench design, the areas needed to accommodate the trenches for biosolids at DS 20% and DS 50% for one and five years was calculated for each of the WWTPs and are presented in Table 4-6 below.

Table 4-6. Trench Area at WWTPs

	Trench Area (Dunams)			
WWTP	**Disposal for 1 year (DS 20%)**	**Disposal for 1 year (DS 50%)**	**Disposal for 5 years (DS 20%)**	**Disposal for 5 years (DS 50%)**
Wadi al Arab	13.8	5.5	69.2	27.7
North Shuneh, Septage	4.1	1.6	20.5	8.2
Irbid	9.0	3.6	45.1	18.0
Ramtha+villages (100%)	10.9	4.3	54.3	21.7

Wadi Al Shallaleh	12.1	4.8	60.4	24.2
Wadi Hassan (Expansion)	5.2	2.1	26.0	10.4
Mafraq Under Modification	3.4	1.3	16.9	6.7
Kufranja Under modification	5.4	2.2	26.9	10.8
Jerash to be constructed	6.0	2.4	30.1	12.0
Al Me'rad	5.8	2.3	28.8	11.5
Tal Al Mantah, Septage	3.3	1.3	16.4	6.5
Al Baqa'a	17.9	7.2	89.4	35.8
Abu Nusair	3.1	1.2	15.3	6.1
As Salt	5.2	2.1	26.2	10.5
Fuhais	2.6	1.0	12.9	5.2
Wadi Al-Seir, WSP	2.2	0.9	10.9	4.4
South Amman	34.2	13.7	171.0	68.4
Madaba	6.9	2.8	34.7	13.9
Al Karak to be modified	4.1	1.6	20.6	8.2
Al Lajjoun, WSP	6.5	2.6	32.7	13.1
Mu'ta	3.7	1.5	18.4	7.3
Al Tafila to be Modified	2.8	1.1	14.0	5.6
Al Mansoura, Septage/WSP	0.1	0.0	0.3	0.1
Al Shoubak, Septage/WSP	3.0	1.2	15.2	6.1
Ma'an	3.5	1.4	17.4	6.9
Wadi Mousa	1.0	0.4	5.2	2.1
Aqaba Natural, WSP	0.6	0.2	3.0	1.2
Aqaba mechanical	7.8	3.1	38.9	15.6
Duliel Waste Water Treatment Plant	5.7	2.3	28.5	11.4
Al Za'atari Waste Water Treatment Plant	6.4	2.6	32.2	12.9
Azraq Waste Water Treatment Plant	0.6	0.2	2.8	1.1

Given the significant space requirements for trench monofills, and where WWTPs or landfill sites have space limitations, alternate disposal locations would need to be considered, either serving individual plants or potentially establishing central disposal facilities for WWTPs in close proximity.

Unlined trench monofills can be used where the sludge to be landfilled shows arsenic, chromium and nickel levels to be within the allowable limits. Additionally, measures for vectors attraction reduction need to be employed (mainly in the form of daily cover application), as do measures for stormwater runoff mitigation and methane gas collection and monitoring. Furthermore, other criteria dictated by the authorities with regards to site selection and such must also be applied.

4.2.4 Legal Framework

This legal framework was carried out to investigate the disposal of biosolids/sludge in landfills, whether as monofills or co-disposal with MSW. The legal framework that governs disposal sites in Jordan consists of general legislation issued mainly by MoEnv and MoMA.

The legislation issued by MoMA assign the responsibility of landfill construction and operation to MoMA through JSCs as its implementing arms. However, it does not specify how this is to be done and does not require any specific environmental protection during this process. Similarly, the MoEnv regulations include provisions of protecting the environment but lack specifics of how this should be done. During the life cycle of biosolids several other legislations apply. A review of the relevant regulations is below.

The establishment, operation and closure of landfills in Jordan fall mainly under MoMA's jurisdiction through its implementing arms: the municipalities and GAM and JSCs. **The Municipalities Law No. 13 for 2011** is the legal backbone that grants MoMA's implementing arms the authority to manage municipal solid waste. Municipalities' and JSCs' responsibilities include but are not limited to waste collection, transport, and disposal and organizing these activities. The JSC Regulation No. 17 for 1983 was issued to regulate the activities of JSCs. The 1983 version was amended in 2009 to become **JSC Regulation No. 75 for 2009**. The 2009 amendment reduced the responsibilities assigned to JSCs to only include the establishment of landfills and waste disposal. Furthermore, JSCs are given autonomy and are authorized to identify, study, implement and/or manage their own projects (Article 4). As stated above, MoMA's regulations do not specify how the landfills should be designed, constructed, or operated and do not include requirements for environmental protection.

The **Environmental Protection Law No. 52 for 2006** is the main legal foundation and states that MoEnv is accountable for protecting various environmental components across the Kingdom. To ensure that MoEnv is able to do that, a set of complementary regulations and instructions were issued pursuant to the Law.

Regulation No. 27 for 2005 for the Management of Solid Waste states that solid waste management "involves all activities related to solid waste including the stages of sorting, collection, transport, storage, treatment, recycling and final disposal". Furthermore, landfills are defined as "locations approved by the MoEnv for the final disposal of solid waste". The Regulation further adds that the MoEnv shall cooperate with other relevant bodies in the planning phase of solid waste management. MoEnv shall be involved in determining the specification for landfill machinery as well as the methods for landfills rehabilitation subsequent to their closure. The Regulation clearly prohibits the incineration of solid waste or leaving it exposed without covering material.

To complement the Regulation and elaborate on some technical specifications, the **Instructions for the Management of Solid Waste for 2006** were issued. The Instructions provide further details pertaining to solid waste collection, transport and final disposal. The Instructions specify landfill selection criteria and proximity to various environmental components and populated areas. They also tackle operational aspects as well as the site closure and rehabilitation requirements.

Compliance with environmental and public health requirements is an important component for biosolids and sludge disposal. As is the case for land application, MoEnv is the main entity responsible for ensuring environmental compliance (**Environmental Protection Law No. 52 for 2006**). As means to ensure environmental compliance, MoEnv issued the **Environmental Impact Regulation No. 37 for 2005** which requires a preliminary impact assessment to be conducted for MSW landfills. However, the Regulation does not specify any requirements for landfills designated for the sole disposal of sludge and/or biosolids. On the other hand, MWI and its respective authorities are specifically responsible for the protection of water resources (**Organizational Structure of the Ministry of Water and Irrigation Regulation No. 54 for 1992, Water Authority Law No. 18 for 1988,** and **Jordan Valley Development Law No. 19 for 1988**).

The MoH is primarily responsible for the protection of public health by virtue of the **Public Health Law No. 47 for 2008**. Furthermore, municipalities and GAM, each within its area of jurisdiction, are authorized to undertake needed measures to prevent the occurrence of health nuisances as defined in Article 4 of **Regulation No. 1 for 1978 and its amendments for 2009** and the **Regulation No. 83 for 2009**. Within the ASEZ, ASEZA is responsible for ensuring compliance with both environmental and public health and safety requirements. Furthermore, the establishment of MSW landfills requires a preliminary EIA to be submitted to acquire ASEZA's environmental clearance (**ASEZ Law No. 32 for 2000**, **ASEZ Environmental Protection Regulation No. 21 for 2001** and **ASEZA Mandate within ASEZ Regulation No. 10 for 2001**).

The technical regulations for biosolids and sludge disposal are stated within the JS 1145–2006 which defines three categories of biosolids and sludge. It specifies allowable reuse options for class 1 and 2 biosolids and permits the landfilling of all three categories. (Class 3 sludge cannot be reused for any purposes and should be only landfilled.) According to the Technical Regulation, class 3 sludge should only be thickened with a minimum of 3% DS prior to its landfilling. JS 1145–2006 also stipulates that biosolids/sludge piling up prior to reuse should be done in enclosed and lined areas away from locations prone to flooding or near water bodies. The period for biosolids/sludge piling should not exceed 3 years.

Biosolids and sludge producers should prepare and present their sludge management plan to the regulatory and monitoring bodies. Additionally, Article 5-16 prohibits the disposal of any category of biosolids/sludge in water bodies, wadis, groundwater recharge locations and sewer networks (the Article excludes municipal WWTPs that receive municipal septic tanks). However, regulatory and monitoring bodies are authorized to enforce more stringent restrictions in addition to what is mentioned in the Technical Regulation JS 1145:2006 as deemed necessary.

Despite being legally authorized to issue specifications and technical regulations, ensure their adoption and review, and monitor their implementation, JSMO delegates the responsibility of overseeing the implementation of JS 1145-2006 to the respective bodies as explained above.

The **Labour Law No. 8 for 1996 and its amendments and legislation issued as a consequence of the Law** are intended to ensure occupational health and safety. MoL states requirements for the **Regulation for the Protection and Safety of Workers from Machineries and Workplaces (No. 43 for 1998)**. It also issued **Instructions for the Protection of Workers and Institutions from Workplace Risks and Hazards for 1996**, the **Instructions for Preliminary Medical Testing of Workers for 1998,** and the Instructions **for Regular Medical Testing of Workers for 1998**. MoL legislations also provide indoor air quality requirements that need to be complied with.

Within Aqaba, ASEZA is stated to be fully responsible for all activities within the ASEZ and shall issue permits as such (the **ASEZ Law No. 32 for 2000 and its amendments** and the **ASEZ Environmental Protection Regulation No. 21 for 2001**). However, neither the Law nor the Regulation includes any explicit reference to the management of WWTPs or the disposal of biosolids/sludge produced by the plants. The AWC currently operates all three WWTPs within Aqaba Governorate. Nonetheless, ASEZA's environmental clearance has to be obtained prior to WWTP or landfill operation (**ASEZ Environmental Protection Regulation No. 21 for 2001**). To this extent, ASEZA's role in the production of biosolids is only implicit through its wider scope.

4.2.5 Co-Disposal: Potential Sludge/Biosolids Co-disposal Quantities

As discussed earlier, the only landfill that is currently suitable to receive biosolids is Ghabawi. However, if other sites such as the Aqaba Landfill are expanded in an engineered manner, they would be suitable to receive biosolids. The amount of biosolids that a landfill site can accept depends on the relative MSW flow as well as the percentage of Dry Solids (% of DS) of the biosolids received from the WWTPs (EPA, 2003). Table 4-7 illustrates the amount of biosolids that could be co-disposed of with properly designed/lined MSW landfills serving the respective communities and based on current MSW flows.

Table 4-7. Quantity of Biosolids each Location/Community could receive relative to MSW Flow

Landfill Location	Landfill Area (Dunums)	MSW Input (ton/d)	Quantity of Sludge that can be Received (ton/d)					
			5% solids		20% solids		50% solids	
			Wet ton/d	Dry ton/d	Wet ton/d	Dry ton/d	Wet ton/d	Dry ton/d
Al-Ekeder	806	700	17.5	0.875	70	14	70	35
Al-Mafraq (Al-Husainiyyat)	380	250	6.25	0.313	25	5	25	12.5
Al-Balqa (Deir Alla)	462	260	6.5	0.325	26	5.2	26	13
Madaba	185	200	5	0.25	20	4	20	10
Al-Zarqa (Al-Dlail)	270	295	7.37	0.369	29.5	5.9	29.5	14.8
Al-Karak (Al-Lajjoun)	389 (the new landfill)	600	15	0.75	60	12	60	30
Al-Tafilah (Jurf Al-Daraweesh)	454	200	5	0.25	20	4	20	10
Ma'an	502	90	2.25	0.113	9	1.8	9	4.5
Ael	274	42	1.05	0.053	4.2	0.84	4.2	2.1
Al-Ghabawi	1947	2500	62.5	3.13	250	50	250	125
Aqaba	60	115	2.87	0.144	11.5	2.3	11.5	5.75
Al-Badia al-Shamaliya	300	70	1.75	0.088	7	1.4	7	3.5

Notes:

1. For sludge with 5% DS, the minimum ratio of municipal solid waste (MSW) to the wet sludge is 40:1 (EPA, 1980).
2. For sludge with 20% DS, the minimum ratio of MSW to wet sludge is 10:1 (EPA, 2003).
3. It is assumed that sludge/biosolids with 50% DS or greater will also be mixed at a ratio of MSW to wet sludge of at least 10:1.

Actual sludge/biosolids loading on the landfills may be less than 10%. Addition of dewatered MSW, particularly when supplemented with solar drying achieving 50% or greater solids, is considered to have minimal impact on MSW landfill operations and capacity, with the added benefit of increased methane production for locations where gas is collected and used to generate energy.

4.2.6 Quality of Sludge/Biosolids

The mandatory technical regulation set by the JS1145-2006 requires that the sludge be disposed of meet Class 3 requirements as a minimum and that the sludge achieves minimum solids content of 3% via thickening or any other method capable of yielding the same results. EPA recommendations require that sludge be stabilized by digestion as a first step (EPA, 1980), primarily to mitigate vector and odor issues. Once stabilized, sludge meets the criterion to be called "biosolids" as per the JS1145-2006 standards. USEPA regulations, however, prohibit disposal of "free liquids" such as thickened sludge (3-4% solids) in MSW landfills without a special permit.

If the sludge is not stabilized, dewatering and drying, along with daily cover, can help mitigate odors at the landfill facility.

In landfill disposal, it is a common practice to dewater the biosolids to around 20% DS prior to landfilling as co-disposal with MSW. If an area-type monofill is used, further moisture reduction to 50% DS or more would be necessary for landfill stability reasons. For trench monofilling, 20% to 50% dry solids could be used.

Given the generally arid climate of Jordan, solar drying can increase the solids content to 50% or greater, thus greatly improving the quality of the biosolids and reducing the impacts associated with lower solids contents. This reduction of impacts includes reduction in odor issues but is mainly related to operational and stability issues, further discussed in the following section.

4.2.7 Challenges to Disposal of Biosolids in Landfills

Challenges associated with the disposal and co-disposal of biosolids with MSW relate to issues with operation, storage, gas and leachate production, and odor and capacity, in addition to legal and regulatory issues.

Potential operational problems relate to the liquid nature of the biosolids. These include the possibility of machinery and equipment slipping and/or sticking in the biosolids as well as the potential for the biosolids to drift away from the workface (EPA, 2003). These problems are intensified during wet weather. They are remediated or at least minimized by adhering to the proper MSW-to-biosolids ratios and mixing properly using the suitable equipment as per the relevant moisture/solids contents. Additionally, drying of biosolids to 50% or greater significantly reduces the operations issues.

Proper operation and handling are critical in order to prevent geotechnical instability, slope failure and liner damage. Additionally in the case of co-disposal, improper placement of the sludge within the MSW can lead to pore pressure build-up which in turn can pose safety risks. Proper operational practice requires that sludge/biosolids be either uniformly distributed throughout the MSW mass (so that the ratio of sludge to MSW is less than 1:10, ideally, about 1:20) or, if disposed of in isolated pockets, placed so that the "pockets" occur near the center of the cell with sufficient containment (lateral separation from the edges of the cell) and separation (lateral offset from the "pocket" in one lift to the "pocket" in an adjacent lift).

Site capacity must be considered when adding biosolids to a MSW landfill. However, when dried to 50%, co-disposal of biosolids with MSW would only reduce capacity by 5 or 6%. Additionally, in the case of co-disposal the moisture content of the MSW in both dry and wet weather plays an essential role: the greater the moisture content of the MSW (or in rainy seasons) the less biosolids can be accepted (EPA, 2003). This is because of the complementary role mentioned above, in which the MSW takes on some of the moisture from the biosolids and decreases leaching.

Addition of biosolids to MSW facilities can increase odor issues. Odor problems can, however, be mitigated by sludge stabilization at the WWTP, dewatering, and solar drying, or a combination of the three. Landfill gas collection can also be used to mitigate odor.

Given the ratios at which MSW and biosolids mix, it might be necessary to store the biosolids onsite until enough MSW has been received for mixing. This likely requires onsite biosolids storage facilities.

An additional challenge in the case of co-disposal with MSW that is particularly relevant to Jordanian landfills is the acceptance barrier as posed by the Ministry of Municipal Affairs (MoMA) and the Joint Services Councils (JSCs). They currently refuse to accept biosolids at the landfills. This challenge is mostly related to the prevailing perception of sludge and biosolids and to operational issues which can be mitigated through some combination of stabilization, dewatering, and drying. Public and stakeholder outreach are necessary to overcome any misconceptions in this regard.

Drying the biosolids to 50% DS or more would likely lessen the extent of these impacts as regards to operational and handling issues, odor problems and space and capacity issues. Guidance in the form of workshops and instructions, and proper landfill designs similar to those at numerous landfills in the US and elsewhere, and associated proper implementation would minimize impacts significantly.

For area monofills, slope stability and potential sheer failure are the most notable risks. Gas extraction from monofills is difficult and gas build up can compound potential sheer failure risks. It is these risks that generally make trench monofills more appealing and make area monofills extremely rare.

4.2.8 Stakeholder Assessment

As concluded in previous sections, nearly all MSW landfills in Jordan are currently deemed unsuitable and noncompliant with the Jordanian environmental legislation. Nevertheless, preliminary stakeholder assessment was carried out for the disposal of biosolids and sludge in existing MSW landfills, and also for issues associated with the mono-landfilling of biosolids and sludge as discussed above. Stakeholder assessment is clearly necessary for Ghabawi landfill, and the new Aqaba MSW landfill (currently under design), which are considered compliant given that they are properly designed/lined MSW landfills.

The relevant stakeholder groups include:

- Biosolids and sludge producers and WWTP operators (within the jurisdiction and responsibility of WAJ)
- Landfill regulators (MSW and others as applicable to Monofills)
- MSW Landfill operators
- Environmental as well as public and occupational health and safety monitoring bodies
- Electric Authorities should electricity generation become viable

End users are not considered for landfilling as it is primarily a disposal option with the exception of consideration given to gas collection and any associated electricity production. Sludge/biosolids would supplement potential gas and corresponding energy production otherwise already established in MSW landfills. Electricity production for smaller monofills is not viable. Should monofills reach sufficient size for to be viable for electricity generation, the associated stakeholders would be further investigated at that time.

With reference to the legal review, no explicit legal reference other than JS 1145:2006 for governing the disposal of biosolids and sludge per se was identified. Nonetheless, JS 1145:2006 does not detail the method of biosolids and sludge disposal. Additionally, the stakeholders involved in SWM and landfill operation are mainly governmental entities.

4.2.8.1 Biosolids and Sludge Producers and WWTP Operators

Biosolids and sludge production falls under WAJ's umbrella. Even though the operation of a number of WWTPs has been delegated to private water companies through Public Private Partnerships (PPPs), the ultimate decision maker with regards to management of biosolids and sludge produced by WWTPs remains the mandate of WAJ. WAJ is responsible for the operating WWTPs in Jordan and thus controls the quality of biosolids and sludge produced, which subsequently influences the appropriate final disposal method.

Therefore, it can be concluded, that by assuming the regulatory role over WWTPs, WAJ is responsible for ensuring the proper disposal of biosolids and sludge be it within the WWTP site or beyond it. If WAJ chooses to co-dispose biosolids and sludge with other waste material, namely MSW, close coordination with and approval by other relevant stakeholder groups (regulators and operators) will be needed.

4.2.8.2 MSW Landfill Regulators

As explained earlier, the MoEnv is the entity responsible for regulating the management and final disposal of MSW. On the other hand, while MoH regulates the public health and safety aspects, MoL is responsible for regulating occupational health and safety aspects. Close coordination between the two ministries is needed to ensure that both public and occupational health and safety considerations are fully met. Within the ASEZ, ASEZA is responsible for regulating MSW management and final disposal, which should comply with the Kingdom-wide environmental requirements at the minimum. ASEZA is also responsible for issuing environmental permits for the establishment of MSW landfills.

Furthermore, it can be concluded that MSW landfill regulators should approve the disposal of any other solid waste materials (biosolids and sludge included) within these landfills.

4.2.8.3 MSW Landfill Operators

The operators of MSW landfills are the implementing arms of MoMA: GAM and other respective municipalities and JSCs. Municipalities and JSCs are responsible for MSW collection, transport, and final disposal. Currently, there are a total of 17 MSW landfills operated by JSCs (which as concluded above, with the exception of Ghabawi, do not comply with the definition of sanitary landfills) in addition to three sites considered by MoMA to be “open dumpsites” (see Table 4-8).

Table 4-8. List of JSCs operating the selected MSW Landfills in Jordan near to WWTPs

Landfill	Responsible JSC
Al-Ekeder	JSC of the North
Al-Zarqa (Dlail)	Zarqa JSC
Madaba	Madaba JSC
Al-Tafilah	Al-Tafilah JSC
Karak (Al-Lajjoun)	Karak JSC
Middle Ghours (Dair Alla)	Middle Ghours District JSC
Northern Badia Landfill	Northern Badia District JSC
Al-Huseiniyyat Landfill (Mafraq)	Al-Mafraq JSC
Ael Landfill	Ael Subdistrict JSC
Aqaba Landfill	Aqaba JSC
Ma'an Landfill	Ma'an JSC
Al-Ghabawi Landfill	GAM

Environmental and Public and Occupational Health and Safety Monitoring Bodies

MoEnv is responsible for ensuring environmental compliance. MWI, WAJ and JVA (within the Jordan Valley) are responsible for the protection of water resources. MoH is responsible for the protection of public health, whereas MoL is responsible for the protection of occupational health and safety. It is noteworthy that MoMA, through its respective municipalities, and GAM are also responsible for the prevention of health nuisances and can therefore also play a monitoring role for public health and safety. Within the ASEZ, ASEZA is responsible for ensuring compliance with both environmental and public health and safety requirements.

Figure 4-6 below offers a summary of the relevant stakeholders based on their level of interest and influence. (More details are provided in Appendix A.)

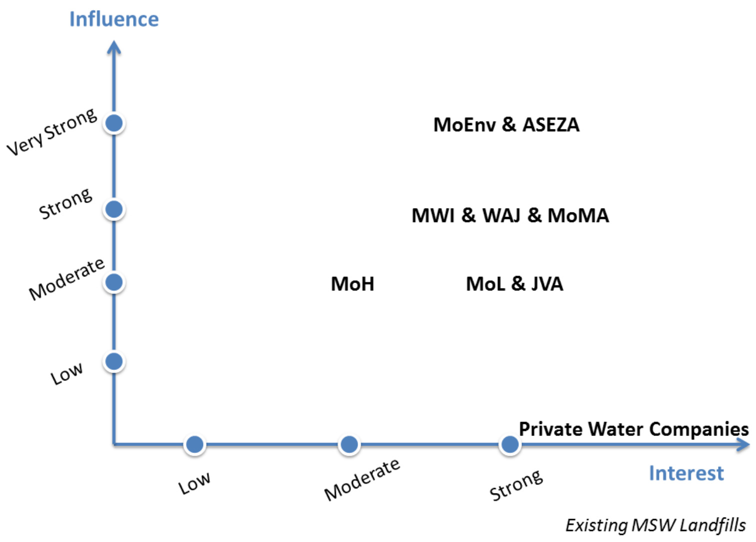


Figure 4-6. Summary of MSW Landfill Stakeholders and Stakeholders for Biosolids and Sludge Monofills

Information that needs to be communicated to the various stakeholder groups specific to biosolids and sludge disposal is summarized below:

- **Biosolids producers and WWTP operators:** Quality of biosolids and sludge safe for disposal in MWS landfills and/or monofills and in compliance with national legislations.
- **MSW Landfill Regulators:** Requirements needed to ensure the safe and environmentally-sound disposal of biosolids and sludge within MSW landfills, the potential for beneficial gas recovery, and the requirements needed to ensure both public and occupational health and safety taking into account biosolids and sludge handling.
- **MSW Landfill Operators:** Requirements needed to ensure the safe and environmentally sound disposal of biosolids and sludge within MSW landfills, the potential for beneficial gas recovery, and the requirements needed to ensure both public and occupational health and safety taking into account biosolids and sludge handling.
- **Environmental and Public and Occupational Health and Safety Monitoring Bodies:** Requirements needed to ensure the environmentally sound disposal of biosolids and sludge, requirements needed to ensure both public and occupational health and safety.

4.2.9 Summary

Based upon site investigation and the legal review, only the Ghabawi landfill and the new Aqaba MSW landfill (once design and construction are complete) are capable of accepting and receiving biosolids and/or sludge. The remaining MSW landfills were found to be non-compliant with existing environmental regulations due to the lack of lining and properly engineered environmental controls.

For MSW landfills that are constructed in compliance with environmental regulations, the amount of biosolids that each site can take will be dependent on the MSW flow and the percent DS of the biosolids exiting the WWTPs. Addition of sludge at 5% solid (free liquid) would require special EPA permitting in the US. Biosolids with 20% DS will need to be mixed at a ratio of no less than 10 MSW: 1. Jordanian standards require a minimum solids content of 3% prior to landfilling; it is, however, recommended and common practice (as per the EPA) to dewater the biosolids to 20% DS prior to co-disposal with MSW. Given optimal conditions for solar drying in Jordan, disposal of biosolids at 50% DS should also be considered.

The design of trench monofills is highly dependent on the solids content of the biosolids. It is generally recommended that sludge be stabilized prior to landfilling for the purposes of pathogen, vector and odor reduction as well as for reducing the potential for putrefaction. Trench monofilling at the WWTP site is considered a possible solution if space is available, or as an interim solution if space is limited and until strategies become developed and landfills equipped to handle co-disposal. Trench monofills could be constructed on WWTP sites, a central location for WWTPs in close proximity, or co-located on MSW landfill sites. The economic viability of further drying and transportation of the sludge would need to be further investigated specific to each WWTP and potential disposal sites.

With regards to the legal framework that governs the disposal of biosolids and sludge, JS 1145/2006 specifies the minimum DS content for landfilling to be 3%. However, JS 1145/2006 does not specify design criteria and management of biosolids and sludge monofills. Furthermore, it does not include any specifications for the co-disposal of biosolids and sludge with MSW. Article 5-18 states that in cases where biosolids and sludge are to be used in ways other than those stated within the JS 1145/2006, a comprehensive technical study shall be prepared and submitted to respective regulatory bodies.

As discussed earlier, stakeholders relevant to the disposal of biosolids and sludge are mainly governmental entities. Therefore, it is important that close communication and coordination takes place among those entities to clearly outline the mandate for each. It is also noteworthy that JSCs as MSW landfill operators do not consider biosolids and sludge their responsibility; rather they believe that the responsibility is WAJ's. JSCs expressed their reluctance to receive biosolids and sludge for multiple reasons, emphasizing that their landfills are not currently equipped for such type of waste.

In conclusion, for designed MSWs, co-disposal with biosolids/sludge is a viable disposal option. They do not require construction of additional facilities and have minimal impact on the MSW landfill design capacity, but require some operations modifications. In addition, co-disposal of biosolids can enhance the production of biogas where applicable, thereby increase energy production. Where land is available, trench monofilling can provide a long-term solution, or serve as an interim solution until such time that other disposal or end use option markets develop and become more viable.

4.3 Cement Kilns

The cement sector in the Hashemite Kingdom of Jordan has grown to meet development requirements. It is characterized by its geographical distribution in the Kingdom, taking into account vicinity to major consumption centers, and in line with national programs for development in all parts of the country. The cement industry in the Kingdom started in 1954 with the establishment of Jordan Cement Factories in Fuhais area (near the capital Amman). Then the same company established a new cement factory in Rashadya, south of Jordan. The Kingdom also produces white cement through Arab Company for White Cement Industry. During the past five years, the Kingdom has seen construction of new cement companies, namely Al Rajhi Cement Holding Qatrana Cement Company, Northern Cement Company (grinding only), and Modern Cement and Mining Company (Al Manaseer Group).

4.3.1 Location of Cement Kilns

Figure 4-1 shows the location of cement factories in Jordan, with more than half of these located north of Amman (Capital), as are more than half of WWTPs; in 2012, the WWTPs in these areas received more than 90% of wastewater generated in Jordan.

Table 4-9 and Figure 4-7 show cement factories in Jordan including coordinates and contact address.

Table 4-9. Cement Factories in Jordan

Factory Name	Coordinate	E-mail	Main office address
Al Rajhi Cement Factory Company	E:263477.82 N:1180639.30	info@alrajihicement.com	P. Box 830290 Z. Code 11183 Zahran, Amman
Arab Company for White Cement	E:273267.92 N:1167793.16	info@acwci.com	P. Box 191 Um assumaq and Khalda Z. Code 11821 Dhahieyat Al-Ameer Rashed, Amman
Fuhais Cement Factory*	E:224003.06 N:1156223.13	cement.info@jordan.laverte.com	P.Box 930019 Z. Code 111193 Amman, Jordan
Northern Cement Factory	E:262583.20 N:1129385.62	info@njcco.net	P. Box 961186 Z. Code 11196 Sport City, Amman
Modern Cement and Mining Company (Al Manaseer Group)	E:257306.54 N:1082846.33	info@mgc-canat.com	P. Box 141414 Z. Code 11814 bayader wadi esseir, Amman
Qatrana Cement Factory	E:252243.17 N:1066333.79	info@qatranacement.com	P. Box 3502 Um assumaq and Khalda Z. Code 11821 Dhahieyat Al-Ameer Rashed, Amman
Al Rashadiyyah Cement Factory*	E:210363.07 N:1009915.15	cement.info@jordan.laverte.com	P.Box 930019 Z. Code 111193 Amman, Jordan

* Fuhais and Al Rashadiyyah factories are owned by Lafarge Jordan.

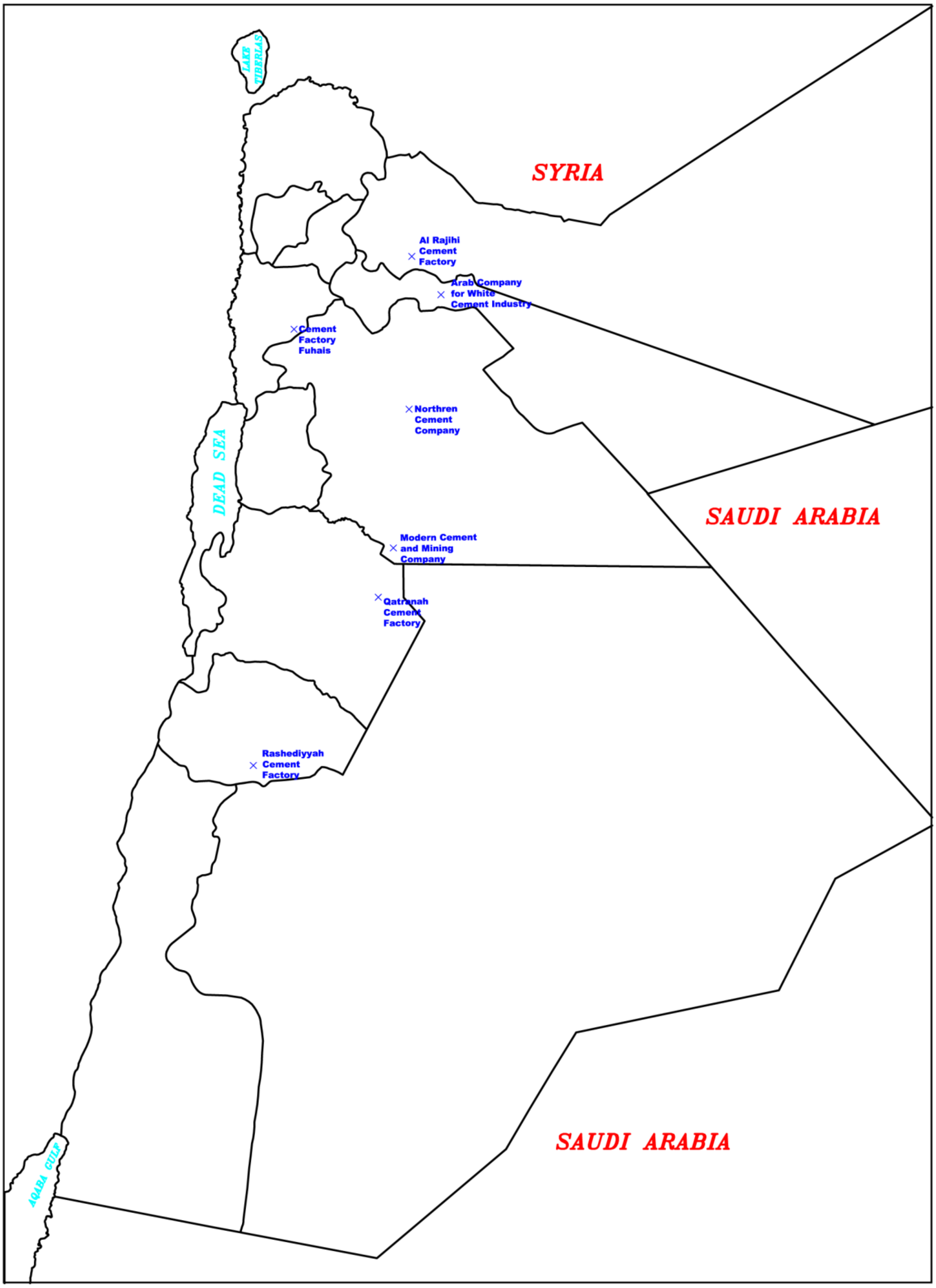


Figure 4-7. Location of cement factories in Jordan

4.3.2 Legal Framework

As was the case for the reuse and disposal options explained earlier, the legal framework that governs the use of biosolids in cement kilns also includes WAJ (by virtue of the **Water Authority Law No. 18 for 1988**). WAJ's involvement originates from it being the entity in charge of water and wastewater in Jordan. Within the ASEZ, ASEZA is responsible for issuing environmental clearance for WWTP activities (**ASEZ Environmental Protection Regulation No. 21 for 2001)**.

The **Environmental Monitoring and Inspection Regulation No. 65 for 2009** categorizes three levels of operational facilities based on their risk to cause environmental pollution. This categorization is further reflected in the needed frequency of environmental inspections. In the case where environmental inspections carried out by the MoEnv reveal violation of stated environmental quality requirements, the MoEnv is authorized to request an environmental audit from the facility which becomes obliged to submit its original audit reports to MoEnv (Article 9). This is also the case for ASEZA within the ASEZ (**Environmental Protection Regulation No. 21 for 2001**).

The main environmental impact resulting from the use of biosolids in cement kilns is in air emissions. **The Air Protection Regulation No. 28 for 2005** states that each establishment shall commit to meet relevant Technical Regulations issued in this regard (**JS 1189-2006 for Air Emissions from Stationary Sources**). Furthermore, MoEnv has the legal mandate to oblige entities with an expected risk of exceeding permissible air emission levels to install the required equipment to keep air emissions within standards. The stipulations of the MoEnv legislations have been also listed in ASEZA's **Environmental Protection Regulation No. 21 for 2001**. ASEZA also requires that establishments commit to not exceeding air emissions standards.

The JS 1189-2006 lists the maximum permissible limits for various air pollutants from stack emissions. The Technical Regulation states that Total Solids (TS) for cement stacks shall not exceed 50 mg/m3. Furthermore, **JS 1140-2006 for Ambient Air Quality** lists the maximum permissible limits for ambient air pollutants and the allowable frequency of recorded violations per each pollutant.

Additional legislation to be complied with includes the Ministry of Labour's (MoL) **Labour Law No. 8 for 1996 and its amendments thereof** as well as the legislations issued consequent to this Law. The Labour Law states some general requirements to ensure occupational safety within the workplace. Those requirements are further detailed within the **Regulation for the Protection and Safety of Workers from Machineries and Workplaces No. 43 for 1998** and the **Instructions for the Protection of Workers and Institutions from Workplace Risks and Hazards for 1996**. MoL also issued the **Instructions for Preliminary Medical Testing of Workers for 1998** and the **Instructions for Regular Medical Testing of Workers for 1998**. MoL legislation also provides indoor air quality requirements that need to be complied with.

In terms of compliance with quality standards, ensuring compliance with environmental requirements falls under the responsibility of MoEnv and ASEZA within the ASEZ.

Furthermore, MoL has the legal mandate to inspect for occupational health and safety compliance within any workplace.

MoMA (through its respective municipalities) and MoH have the legal mandate to inspect any facilities for the protection of public health and safety. Health nuisances are defined by both the creation or the contribution of unpleasant odors, smoke or dust that causes health risks or the disturbance of the general wellbeing (**Public Health Law No. 47 for 2008, Regulation for the Prevention of Health Nuisances within Municipal Areas No. 1 for 1978 and its amendments for 2009** and the **Regulation for the Prevention of Health Nuisances and Waste Collection Fees within the Greater Amman Municipality Area No. 83 for 2009**).

Moreover, as mentioned earlier, JSMO's legal mandate includes the mandate to ensure the implementation of the technical regulations it issues. However, it delegates the responsibility of overseeing the implementation of JS 1189-2006 to JSMO's relevant authorities stated above.

It is important to note that **JS 1145:2006** is the only Jordanian Standard that regulates the reuse of biosolids, but it does not address the use of biosolids or sludge in cement kilns, landfill and/or any other energy generation. Nonetheless, the Standard states that biosolids and treated sludge can be reused for other purposes provided that a comprehensive technical study is conducted and submitted to the licensing and monitoring bodies for approval. However, a technical regulation should be developed to regulate biosolids and dried sludge as a product to be used by the cement industry in Jordan. In addition to detailing the specifications of the biosolids in terms of quality, it should also detail the method for safe handling among other considerations deemed necessary for its safe use.

4.3.3 Cement Companies

Based on discussions with the cement factories, most do not currently have the potential to use biosolids as an alternate fuel source for cement kilns. A couple are planning to modify or are in the process of modifying their facilities to be able to burn alternative fuel sources such as MSW, tires, and other waste products. These steps have been taken to offset the high cost of coal, their primary fuel source.

The project team met and/or spoke with the seven cement factories in Jordan. Of the seven, only three expressed interest in the potential of using biosolids/sludge as an alternative energy source in their kilns. The following paragraphs provide a summary of discussions with representatives from the three facilities.

4.3.1.1 Modern Cement and Mining Company (Al Manaseer Group)

The Al Manaseer Group has shown enthusiastic interest in investing in a drying process to further dry sludge to accommodate the required moisture levels.

4.3.1.2 Al Rajihi Cement Factory Company

The Al Rajihi Cement Factory has shown considerable interest and is in the process of procuring a multi-purpose energy feeder for the kiln. The company insists, however, that tit will not be responsible for transportation of biosolids to its facility.

4.3.1.3 Arab Company for White Cement Industry

The Arab Company for White Cement indicated that they it cannot use biosolids because they have negative effect on the color of its product.

4.3.1.4 Northern Cement Company

The Northern Cement factory does not have a kiln to produce cement from raw materials. The Plant Manager mentioned that the company is, however, in process of constructing a kiln. The Plant Manager expected to complete new kiln construction in June 2015, and he expressed his interest to use biosolids in the cement production process. Furthermore, plant operators also expressed their willingness to purchase the biosolids to the extent to which the cost is justifiable and the option remains both technically and financially feasible.

4.3.1.5 Jordan Cement Factory (Lafarge)

Lafarge management has no intention to use biosolids at the Fuhais factory for three main reasons: firstly, proximity to residential areas and sensitive relations with the local communities within those areas; secondly, the air emissions resulting from plant operations need to be closely controlled to remain in compliance with air quality standards; thirdly, management is happy with the source of energy currently being used.

However, Lafarge managers mentioned that it may be possible to use biosolids at Al Rashadiyyah factory. They added that they are not willing to purchase the biosolids as they believe they are assisting the GoJ to get rid of such “waste”. The biosolids suitable for the current Lafarge systems should have DS content at least 85%. Lower DS content would require changes in the systems used. Lafarge expressed willingness to cover part of the investment associated to the necessary changes if the GoJ will share the costs.

4.3.1.6 Qatrana Cement Factory

The Qatrana Cement Factory emailed the study team a clear statement that the factory is not interested in using biosolids in the factory processes. Further discussions with factory officials revealed the reasons behind this, which include the inconsistency of the biosolids characteristics, the relative difficulty of biosolids integration into the process, the low financial feasibility (taking into consideration the low calorific values of the biosolids especially considering As-Samra WWTP), and finally the social acceptance of plant staff to handle the biosolids. When the project team met with facility management, plant staff were not aware that the Fatwa banning the use of biosolids in cement industry was lifted.

4.3.1.7 4.3.3.7 Additional Efforts to Engage Cement Companies

In February 2014, MWI requested a meeting with the cement companies to discuss their requirements for use of biosolids in their cement kilns. Representatives from two companies attended and indicated that within a month, they would provide proposals for potential cooperation. During the meeting, MWI indicated that the cement companies could potentially use MWI property on the As Samra WWTP site for additional drying to suit their needs. However, despite additional efforts by MWI to engage the cement companies, they had not responded.

4.3.2 Stakeholder Assessment

Based on the above sections, the stakeholder groups identified for the use of biosolids and dried sludge in cement kilns include:

- Biosolids and sludge producers,
- Operational cement industry regulators,
- Environment, public and occupational health and safety monitoring and regulatory bodies,
- End users (cement factories)

The USAID WRECP team did not identify the need to try to work with a representative facilitator stakeholder group. This is attributed to the small number of cement factories in Jordan and the limited willingness to use biosolids. Nevertheless, if the need for facilitators arises, chambers of industry, research and academic institutions as well as ACWUA can offer suitable platforms for knowledge sharing in this regard.

4.3.2.1 Biosolids and Sludge Producers

As explained earlier, WAJ is the ultimate decision maker in issues related to determining what is allowed for biosolids and sludge management, disposal and/or reuse, even for WWTPs whose operation was delegated to private water companies. Within the ASEZ, ASEZA fills this role.

4.3.2.2 Cement Industry Regulators

Within the context of the use of biosolids and dried sludge in cement factories' processes, the main regulator that offers environmental permits is the MoEnv. Within the ASEZ, ASEZA grants environmental permits. However, there are no cement factories within the ASEZ.

Furthermore, given that there is a potential for the use of both biosolids and dried sludge (unstabilized sludge) in cement kilns, MoH and MoL's permit will also have to be acquired to account for public and occupational health and safety considerations.

4.3.2.3 Environment, Public and Occupational Health and Safety Monitoring Bodies

MoEnv is the entity responsible for ensuring environmental compliance with Jordanian standards. MWI and WAJ are responsible for the protection of water resources; MoH, on the other hand, is the entity responsible for ensuring the protection of public health.

MoMA through its implementing arms (the municipalities and GAM) is given the legal mandate to prevent the occurrence of health nuisances as deemed needed.
On the other hand, MoL is the entity that ensures that the requirements for protecting occupational health and safety of the employee are met. Given the possibility of using dried sludge as well as biosolids, close coordination between the cement factory, MoEnv, MWI, MoL and MoH should take place. MoH's involvement within the sphere of occupational health and safety is intended to ensure the prevention of infectious disease spreading.

4.3.2.4 End Users

As mentioned earlier, there are seven cement factories in Jordan. The USAID WRECP team carried out interviews with all seven, but only three have expressed interest to further pursue the use of biosolids within their processes. The interest among the cement factories is explained in Table 4-10 below.

Table 4-10. Initial Attitudes of Cement Factories to Use Biosolids and Dried Sludge

Cement Factory Name	Attitude	Stated Reasons/ Additional Notes
Modern Cement and Mining Company (Al-Manaseer Group)	Positive	They expressed willingness to set up a facility of their own within the WWTP site to ensure that sludge meets the required moisture level. Feasibility study to be carried out will also account for cost of transportation.
Al Rajihi Cement Factory Company	Positive	Started to prepare a tender for process modification to accommodate the use of biosolids and sludge. Not willing to cover costs of transportation; however, willing to allocate an area for biosolids/sludge storage.
Arab Company for White Cement Industry	Negative	Biosolids and sludge use will impact product quality (color).
Northern Cement Company	Positive	Interested pending further investigation in technical and financial aspects. Noted that cement kiln is expected to be commissioned in 2015.
Jordan Cement Factory (Lafarge) in Fuhais	Negative	Proximity to residential areas is a main barrier.
Jordan Cement Factory (Lafarge) in Ar-Rashadiyyah	Neutral	One of the first companies to explore using biosolids and sludge in cement kilns. At the present time is not willing to purchase biosolids and sludge. Ready to invest in machinery equipped to receive the quality of biosolids and sludge received, provided that GoJ shares cost. Ready to cover the cost of transportation if the sludge is deemed economically feasible.
Qatrana Cement Factory	Negative	Inconsistency of the biosolids characteristics, the relative difficulty of biosolids integration into the process, the low financial feasibility (taking into consideration the low calorific values of biosolids), and social acceptance of staff to handle the biosolids.

The use of biosolids and sludge in cement kilns was religiously prohibited in 2007. There have been developments since then, however. The first factory to explore the possibility of biosolids was the Lafarge Al-Rashadiyyeh Cement Factory, which requested the Directorate of Islamic Fatwa reconsider their ruling in about using sludge originating from human waste to produce cement. The initial Fatwa issued that year banned the use of sludge in the process producing cement to be used in mosques and prayer areas. In 2012, the Fatwa banning the use of biosolids and sludge in cement kilns was lifted on the basis that high burning temperatures within the cement kilns result in the complete change of the biosolids and sludge characteristics, hence transforming it into a new material.

Discussions with cement industries as potential sludge/biosolids end users, along with other stakeholder groups should continue to further assess the opportunities and needs of this end use outlet. However, at the moment, and as discussed in 4.3.3.7 above, cement companies have not been responsive beyond their initial enthusiasm/interest.

Figure 4-8 presents a summary of the cement kilns stakeholders based on their level of interest and influence. (More details are provided in see Appendix A.)

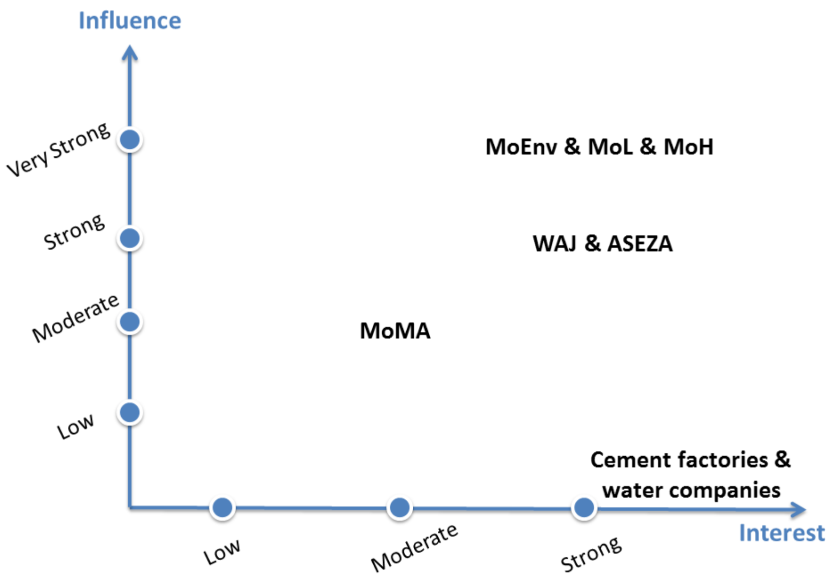


Figure 4-8. Summary of Stakeholders for the Cement Kiln Option

The information below should be communicated to the various stakeholder groups that are concerned with biosolids and dry sludge use in cement kilns:

- **Biosolids producers:** Quality of biosolids and dried sludge safe for handling and feasible for use in cement kilns; or if otherwise, necessary steps to protect workers.
- **Operational cement industry regulators:** Measures needed to ensure the protection of the environment and public and occupational health and safety.
- **Environment and public and occupational health monitoring bodies:** The management and monitoring plans designed to ensure compliance with environmental and public and occupational health and safety requirements.
- **End users (cement factories):** Feasibility of using biosolids and dried sludge as an alternative source of energy, occupational health and safety regulations, environmental quality standards.

4.3.3 Summary

Three cement companies that have expressed interest in using biosolids in their cement production process: Al Rajihi, Al Manaseer, and Northern Cement Company. Willingness and participation of these factories vary, but it seems that Al Rajihi and Al Manaseer factories are the most interested to use biosolids in their factories. Additionally, the Northern Cement factory has indicated that it might be interested once its cement kiln is commissioned in middle of 2015. Representatives from Al Rashadiyyah and Qatrana factories indicated that they are not interesting in utilizing biosolids. Effectively, the respective cement companies must themselves assess the financial feasibility of incorporating necessary changes to their facilities and purchasing sludge/biosolids, as well as covering the transportation costs. At this time, they do not appear ready to reimburse MWI/WAJ for costs associated with drying and transporting the biosolids. Communications in this regard should continue between the MWI and the cement companies.

From a regulatory standpoint, only JS 1145:2006 regulates the reuse of sludge/biosolids produced from municipal WWTPs and addresses production, handling, transporting, and possible reuse with a focus on land application. Should reuse in cement kilns be seriously considered, regulatory aspects would need to be revised. Emissions regulations would also need to be revisited.

4.4 Incineration

Incineration is a method for sludge/biosolids disposal and can potentially be a source for energy recovery. Incinerating biosolids results in ash that can be used beneficially in activities such as cement making, brick making, and asphalt mixing, or that can be disposed of in a landfill. Both multiple hearth furnace (MHF) and fluidized bed incineration (FBI) are currently used for biosolids incineration. However, new facility construction has focused on the use of FBI incineration due to higher efficiency, less operation and maintenance issues, and ability to achieve lower emissions during recover energy.

Energy recovery from incinerating biosolids is a function of the calorific value of the dry solids and the total solids (water content) of the sludge. In practicing incineration for disposal of the biosolids without energy recovery, autogenous burning is desired. Autogenous conditions are defined as where the biosolids have enough energy in the dry solids to complete combustion without addition of supplemental fuel. This autogenous condition is also a function of the incinerator or furnace efficiency. For undigested biosolids, autogenous conditions can be achieved with a solids content between 25-30% DS; with digested biosolids, autogenous conditions are usually achieved with the dry solids content around 35%. Conventional FBI incinerators for biosolids combustion are usually limited to using sludge cake of less than 40% DS.

To practice incineration, sludge dewatering is required. Furthermore, for recovering energy from the incineration process, it is recommended that the sludge not be digested and its water content lowered. Once the biosolids dryness is higher than 40% DS, rather than conventional FBIs different types of combustion are used such as gasifiers and reciprocating grate furnaces, and circulating fluidized bed. Once combusted, energy can be recovered from the flue gases and converted to electricity if feasible.

4.4.1 Sizing of Required Incineration

To practice incineration for disposal, the minimum amount of sludge should be higher than 15 dry tonnes per day. If the sludge quality (calorific value and water content) allows energy recovery from incineration, electricity can be produced using steam turbines. Organic Ranke Cycle (ORC) technology with a thermal oil heat exchanger loop can also be used to produce electricity. ORC's higher capital cost and lower electricity efficiency (18-24%) require that economic analysis be conducted to justify the capital cost investment in relation to the price of generated electricity.

To practice incineration for energy recovery, biosolids dryness must be at least 75%. Moreover, the commercially available incinerators require higher sludge throughput, greater than 50 dry tonnes per day.

4.4.2 Legal Framework

Air emissions from sludge and biosolids incineration are not specifically covered in JS 1145/2006. Furthermore, the JS 1140/2006, Ambient Air Quality Standards, does not cover emissions for incineration of municipal sludges.

It is therefore recommended that either JS 1140/2006 or JS1189/2006, as appropriate, be amended to include emission standards for municipal sludge incineration and possibly include a reference in the amended standard in JS 1145/2006. Emission standards can be adapted from the European Union Directorate or USEPA standards.

4.4.3 Requirement for Incineration Without Auxiliary Fuel

Sludge incineration usually requires some form of auxiliary fuel for complete combustion. The amount of auxiliary fuel depends on the calorific and water content of the sludge. Figure 4.9 presents the net energy in MJ per dry tonne of sludge during combustion for 1 dry tonne with a calorific value of 3,600 Cal per gram as a function of the dry solids content of the biosolids. The graph is presented for an incineration technology requiring 7.67 MJ to evaporate one kg of water in the biosolids. As shown in this Figure, if the dry solids content in the biosolids is only 20%, the amount of auxiliary fuel needed is about 12,000 MJ per tonne of dried solids. As the dry solids content is increased through removing more water from the biosolids prior to combustion, less auxiliary energy is needed. The red line in Figure 4.9 represents autogenous condition, where no auxiliary fuel is needed and there is enough energy in the biosolids itself to complete combustion. For this specific biosolids, the solids content should be about 33% for autogenous burning. If the sludge is not digested, then it should contain more colorific value and in this case the blue line moves to the left of the figure requiring less dry solids content for autogenous combustion.

Accordingly, for combustion without auxiliary fuel, it is non-digested biosolids and dewatering technologies like high solids centrifuges are recommended, where more water is removed during the dewatering process prior to incineration.

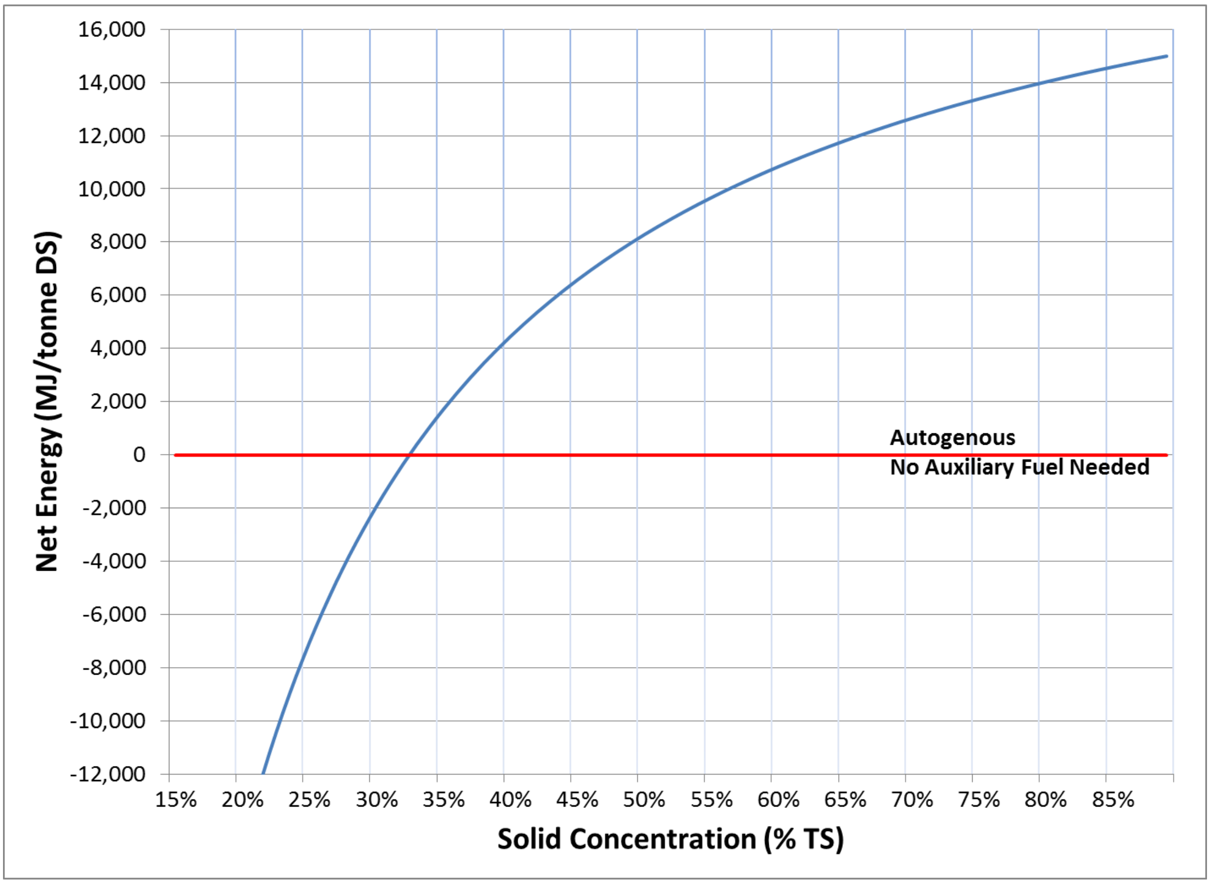


Figure 4-9. Net energy in MJ per tonne dry solids as a function of solids concentration of typical anaerobic digested biosolids with a measured calorific value of 6,300 Cal per gram.

4.4.4 Stakeholder Assessment

Preliminary Stakeholder Assessment

For the incineration option, stakeholders have been grouped, based on their levels of influence and interest, into the following categories:

- Biosolids and sludge producers
- Regulators for the Establishment of an Incineration Facility
- Power and electricity generation regulators (in the specific case of electrical energy generation)
- Ash disposal regulators and MSW landfill operators
- Environment and Public and Occupational Health and Safety Monitoring Bodies
- End users (NEPCO) (in the specific case of electrical energy generation/on-grid system)

As in the previous sections, for every option, the extent of stakeholder influence and interest has been referenced against a specific legal mandate described within the legal sections of this report, and against the expected benefits or negative impacts identified by the WRECP.

- **Biosolids and Sludge Producers**

Biosolids producers fall under WAJ's umbrella. The operation of a number of WWTPs has been delegated to private water companies through PPPs. Nonetheless, the ultimate decision maker with regards to management of biosolids and sludge produced by WWTPs remains the WAJ. Furthermore, WAJ also controls the quality of biosolids produced by every WWTP, which influences the feasibility of incineration.

- **Regulators for the Establishment of an Incineration Facility**

As explained in the legal section, in order to establish an incineration facility, it is first necessary to obtain an environmental permit from MoEnv (or from ASEZA within the ASEZ) to ensure environmental compliance. However, even though the Central Licensing Committee within the MoEnv (the Committee that reviews the EIA and grants the environmental permits) includes members from MoH and MoL, it is still necessary to get permits from the respective ministries in issues related to public and occupational health and safety.

- **Power and Electricity Generation Regulators**

As can be concluded in the legal section above, MEMR is the regulator and the entity that grants permits for power generation facilities. These mandates are further extended to the Energy and Mineral Resources Regulatory Commission (previously the ERC in issues relating to electrical energy).

Any establishment aiming to generate electricity through the incineration of biosolids and sludge should inform MEMR and the Commission of the expected power generation capacity. Accordingly, MEMR and the Commission have the mandate to require additional studies as they see needed.

Furthermore, as explained in the legal section, a gap exists regarding the classification of electrical energy produced from the incineration of biosolids and sludge (i.e. whether it counts as bio-energy and thus must follow the regulations governing renewable energy, making it subject to further incentives promoting renewable energy). Nevertheless, regardless of its classification (renewable or non-renewable), MEMR and the Commission are still the governing entities and the ones responsible for setting the tariffs and regulating the selling of the produced power. Thus it can be concluded that they are the stakeholders responsible for clarifying and filling any gaps that may exist for energy generation from biosolids and sludge incineration.

- **Ash Disposal Regulators and MSW Landfill Operators**

Ash disposal can be either within MSW landfills or in landfills specifically dedicated for this purpose. In either case, the main stakeholders and governing entities are MoEnv and MoMA. MoEnv is responsible for the management and regulation of solid waste across the Kingdom as well as issuing environmental permits for the construction of landfills. MoMA, on the other hand, is responsible through its implementing arms (GAM and JSCs) for the operation of the existing MSW landfills, which makes them the main stakeholder to be consulted in the case of co-disposal. It is worth noting, that within the ASEZ, ASEZA is responsible for issuing environmental clearances for projects with possible environmental impacts (landfill projects included).

- **Environment and Public and Occupational Health and Safety Monitoring Bodies**

MoEnv is the entity responsible for ensuring environmental compliance with Jordanian standards. MWI and WAJ are responsible for the protection of water resources; MoH, however, is the entity responsible for ensuring the protection of public health and safety.

MoMA through its implementing arms (the municipalities and GAM) is given the legal mandate to prevent the occurrence of health nuisances as deemed needed.

On the other hand, MoL is the entity that ensures that the requirements for protecting occupational health and safety of the employee are met. Given the possibility of incinerating dried sludge as well as biosolids, close coordination will have to be maintained between the incineration facility owners and operators, MoEnv, MWI, MoL and MoH. MoH's involvement within the sphere of occupational health and safety is intended to ensure the prevention of infectious disease spreading.

- **End Users**

Electricity being generated from the incineration facility can be either on-grid or off-grid. In the case of off-grid generation of electricity, the incineration facility owners are by default the end users; however, in the case of an on-grid system, the National Electric Power Company (NEPCO) would be the end user and thus the main stakeholder. NEPCO would be the entity buying the electricity generated from the incineration facility and selling it to the distribution companies. Thus it is the stakeholder with whom the terms and conditions for the feeding in and selling of the generated electric power will need to be agreed.

Figure 4-10 below summarizes the level of influence and interest among the relevant stakeholder groups (details in Appendix A).

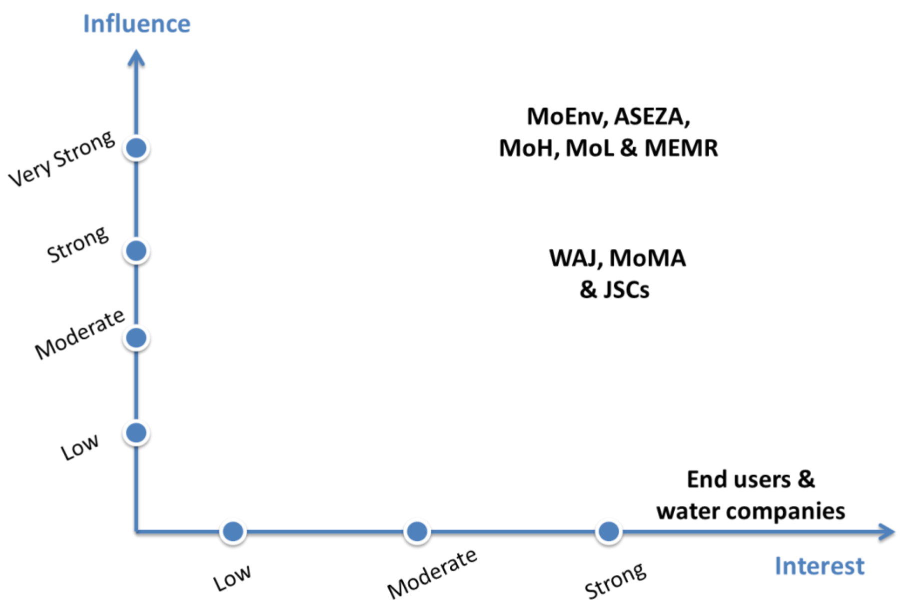


Figure 4-10. Stakeholders' influence and interest for the Incineration option

Below is some information that needs to be communicated to the various stakeholder groups:

- **Biosolids producers:** Quality of biosolids and sludge feasible for incineration, and whose responsibility it is to transport the biosolids and sludge to the incineration facility.
- **Incineration facilities owners and operators:** Feasibility of generating electric power from biosolids and sludge incineration, public and occupational health and safety regulations to be met, environmental quality standards, whether the generated power counts as renewable energy, the cost at which the electric energy will be sold, whose responsibility it is to transport the biosolids and sludge as well as the resultant ash, and the appropriate means for ash disposal.
- **Ash disposal regulators and landfill operators:** Qualitative and quantitative values for the ash to be disposed of, who is responsible for ash transportation to the designated disposal site, and public and occupational health and safety considerations to be complied with during ash handling.
- **Environment and public health monitoring bodies:** Measures accompanying biosolids and sludge incineration to ensure compliance with various environmental and health and safety quality standards. Also, the management and monitoring plans designed to ensure compliance with environmental and public and occupational health and safety requirements.
- **End users (NEPCO):** The feasibility of feeding electrical energy into the grid and the agreed on feed-in tariff and electricity selling price.

5 BIOSOLIDS DISPOSAL AND BENEFICIAL END USE STRATEGY

With a clearer understanding of potential end uses, location relative to the sludge/biosolids sources, and obstacles to end use, a strategy now needs to be developed. The paragraphs that follow discuss strategy by disposal and end use opportunity, and then opportunities for the respective treatment plants

5.1 Biosolids Disposal and Consideration for End Use Outlets

This section presents summary discussion of each of the viable outlets including opportunities and constraints, and the overall strategy in identifying near-term and long-term approaches for biosolids disposal and/or beneficial end uses. Discussion will also present steps to help outlets become viable and sustainable.

5.1.1 Land Application

In principal, biosolids have high potential for use in land application due to available forage farms and rangelands. Additionally, the produced biosolids have considerable agronomic value similar to most common organic fertilizers used in agriculture. For these reasons, and the relative proximity of many of the WWTPs to forage farms and rangelands, the use of biosolids in land application is a potentially viable and sustainable reuse outlet.

As previously discussed, constraints exist, particularly the need to align the Jordanian Standard for organic fertilizers JS 962:2011, with JS 1145/2006 (uses for treated sludge and sludge disposal) as well as associated instructions within the MoA and MoEnv. Efforts are however underway to overcome these issues. For example, the Sludge Committee will convene in the near future to address, among several items, excessive and unreasonable moisture limits. The MoEnv is also reviewing its instructions on the issue.

Potential distribution methods and associated control are also being discussed to help ensure that illegal application does not occur. Distribution would likely involve Farmers Associations in approved reuse areas adjacent to or near WWTP facilities. Use of biosolids in rangelands is by default controlled as the programs are implemented by Government and donor agencies.

There is general agreement that should Jordanian standards be revised to permit land application for fodder crops, the demand will, over time, drive the market accordingly. Additionally, interest by the donor and government organizations to restore rangelands will also add to demand for biosolids use in land application.

5.1.2 Cement Kilns

As discussed in Section 4, cement companies have showed interest in using biosolids as an alternate energy source. However, they have not expressed a willingness to pay for the biosolids and thereby help to cover the extra costs associated with drying to 75% or greater as requested by the various cement companies. At the time of this report preparation, discussions between the MWI and cement companies continued, particularly with respect to biosolids at As Samra.

It is anticipated that, as energy prices continue to increase and the demand for alternate fuels increases, cement kilns as an outlet may become viable. Should fuels rises, companies will recognize that biosolids have a real energy/caloric value and be willing to compensate the government, or otherwise be willing to invest in the drying process.

It should also be noted that treatment facilities around the kingdom are being upgraded to include dewatering facilities, bringing sludge/biosolids one step closer in the drying process.

5.1.3 Incineration

To practice incineration, a minimum of 15 dry tonnes per day must be available for processing. Due to low current and projected future sludge production from most wastewater treatment plants, incineration appears to be only practical for a group of plants within a reasonable proximity in order to minimize sludge hauling distances and associated costs. The incineration facility could be located at one plant or at a centralized location.

Incineration can be practiced as a disposal outlet and can include energy recovery from biosolids. Incineration for energy recovery requires producing dewatered cake solids, which requires high solids centrifuges and/or air drying of the biosolids without sacrificing the calorific value of the sludge. Considering incineration as an outlet either for disposal or energy recovery should be considered as a last resort when other outlets are not viable or feasible, since incineration requires high capital cost investment. It should be operated as a BOT-type facility, given the complexity of the operations and the high operating cost due to the auxiliary fuel required for complete combustion.

5.1.4 Landfills

Landfilling of sludge/biosolids is generally considered a disposal option. Therefore reuse outlets such as land application or facilities that use it as an alternate energy source such as cement kilns should be considered first where feasible and permitted. Consistent with discussions in Chapter 4, two types of landfilling should be considered for disposal of biosolids in Jordan. As previously discussed, area landfilling, except for larger plants such as As Samra, should be avoided due to risks associated with potential slip failures and the difficulty of extracting methane gas. Methods more appropriate for disposal associated with smaller plants include co-landfilling with MSW, and trench monofilling.

The potential for co-landfilling with MSW is currently limited due to a lack of properly designed municipal waste disposal sites in Jordan. Co-disposal in properly designed landfills is an accepted process all over the world, and associated biosolids methane gas production supplements MSW energy production. However, the only examples of properly designed landfills in Jordan are Ghabawi, which serves greater Amman, and Aqaba for which a landfill is currently being designed. Officials at Ghabawi have indicated that they will not accept sludge/biosolids. Discussions with Aqaba officials are ongoing. Note that co-disposal with MSW typically increases operational efforts. However, given Jordan’s dry climate, additional operational efforts can be minimized by first drying the sludge to 50% or greater solids prior to disposal.

Trench monofilling is therefore a likely scenario for smaller plants where land is available, either onsite, or nearby at other available sites such as at MSW disposal sites. Disposal sites could be grouped where practical depending on the relative proximity of multiple plants to potential disposal sites. Note that trench monofills at MSW sites would be designed and operated independently of the MSW disposal activities until such time that the MSW sites are properly designed and lined.

5.2 Summary of Potential Disposal and End Use Opportunities by WWTP

Based on the above understanding of the current biosolids situation in Jordan, a review of potential end use and disposal options was performed for the respective wastewater and septage treatment facilities. For the purpose of determining preliminary potential for the respective alternatives, the following assumptions were made:

Land Application

- Forage farms were considered when within the proximity of wastewater treatment facilities.
- Rangelands were considered within 75 kilometers of wastewater treatment facilities.

Cement Kilns.

- At the time of writing of this report, only three cement kilns had expressed some level of interest and were therefore considered: Al Rajihi; Modern; and Rashadiyyah. The cement companies were not considered as an end use option if greater than 100 km from the respective cement companies.
- Beneficial use at cement kilns of biosolids from facilities using waste stabilization ponds for treatment was not applicable, given the calorific degradation during the process.

Incineration

- For incineration to be considered, facilities of a minimum of 15 dry tonnes per day should be planned. Given the minimum practical sizing of incineration facilities, we have included proposed groupings for WWTPs within a reasonable proximity of one another. Proposed groupings are shown in Table 4-11 on the next page. Note that facilities in the south are widely spaced and not considered likely candidates for incineration.
- Incineration of biosolids from facilities using waste stabilization ponds for treatment was not applicable, given the calorific degradation during the process.

Landfill

- Assume dewatered to a minimum of 20% for trench monofills and up to 50% for co-landfilling with MSW to minimize operation impacts.
- Monofill means trench type monofill.
- Variations for monofills include:
    - Potential to locate within existing treatment facility site
    - Collocated at nearby MSW site
- Co-landfill with MSW – requires designed/lined landfill. Until other such facilities are constructed, only Ghabawi and Aqaba (design phase) can be considered at this time.

Distance considerations need to be revisited as markets develop for the respective options to determine whether transportation costs impact viability. Table 5-1 describes potential sludge/biosolids outlet options for the respective treatment facilities consistent with the above assumptions.

Table 5-1. Potential End Use Disposal Options for Jordan Biosolids

	Wastewater Treatment Plant	Options							
		Land application		Cement Kiln	Incineration (Potential Groups)	Monofill			Co-landfill with MSW
		Forage Farms	Rangelands	Distance to nearest Kiln		Within Existing WWTP Site	Distances (Proximity to waste disposal sites)	Central Facility (based on WWTP proximity)	Distance to Ghabawi
1	Wadi al Arab	NO	NO >75 KM	85km (Al Rajihi)	Incineration Group 1	No available land, but could be nearby.	43km to Ekeder landfill, 22km to Wadi Arab landfill.	Monofill 1	129km
2	North Shuneh, Septage/WSP	NO	NO >75 KM	Not applicable (WSP)	Not applicable (WSP)	It appears that land is available, but could be reserved to other purposes.	5.3 km to Al-Aghwar landfill	Landfill within WWTP more feasible option.	N/A
3	Irbid	NO	NO >75 KM	75km (Al Rajihi)	Incineration Group 1	No available land, within or nearby. (Populated area)	31km to Ekeder landfill.	Monofill 1	117km
4	Al Ramtha	YES	NO >75 KM	66km (Al Rajihi)	Incineration Group 1	No available land, within or nearby. (Agricultural area)	19km to Ekeder landfill.	Monofill 1	116km
5	Wadi Al Shallaleh	NO	NO >75 KM	75km (Al Rajihi)	Incineration Group 1	No available land within. But adjacent area is available but for WWTP expansion.	23km to Ekeder landfill.	Monofill 1	121km
6	Al Ekeder, Septage/WSP	NO	NO >75 KM	Not applicable (WSP)	Not applicable (WSP)	Current disposal onsite. Could continue with Monofill	Expected to continue the same practice.	Currently being used as a dumping site.	N/A
7	Wadi Hassan	NO	NO >75 KM	66 km (Al Rajihi)	Incineration Group 1	No available land within. But adjacent area is available.	24km to Ekeder landfill.	Monofill 2	121km
8	Mafraq	YES	YES <75 KM	30 km (Al Rajihi)	Incineration Group 1	Available land within. Agricultural area.	25km to Ekeder landfill and 26km to Mafraq landfill.	Monofill 2	92km
9	Kufranja	YES	YES <75 KM	>100km (Al Rajihi)	Incineration Group 2	No available land within. But adjacent area is available.	74km to Ekeder landfill, 112km to Ghabawi.	Monofill 2	112km

10	Jerash	YES	YES <50 KM	70 km (Al Rajihi)	Incineration Group 2	No available land, within or nearby. (Agricultural area)	44km to Ekeder landfill, 92km to Ghabawi.	Monofill 2	92km
11	Al Me'rad	YES	YES <50 KM	75 km (Al Rajihi)	Incineration Group 2	No available area within. However, surrounding land is owned by WAJ appears to be a possible option.	48km to Ekeder landfill, 91km to Ghabawi.	Monofill 2	91km
13	Tal Al Mantah, Septage/AS	YES	YES <50 KM	>100km (Al Rajihi)	N/A (Location in Jordan valley far from any grouped Incin).	Available area within that is planned to be used for the installation of drying beds. Agricultural area.	5.77 km to Al Aghwar landfill	Not applicable (Jordan Valley)	Jordan Valley (too remote)
14	Al Baqa'a	NO	YES <50 KM	70km (Al Rajihi)	Incineration Group 2	No available land, within or nearby WWTP. (Agricultural area)	55km to Al Ghabawi.	Monofill 3	55km
15	Abu Nusair	NO	YES <50 KM	60km (Al Rajihi)	Incineration Group 2	No available land, within or nearby WWTP. (Residential area)	48km to Al Ghabawi.	Monofill 3	48km
16	As Salt	NO	YES <50 KM	90km (Al Rajihi)	Incineration Group 2	No available land, within or nearby WWTP.	14km from As Salt landfill.	Monofill 4	62km
17	Fuhais	YES	YES <50 KM	80km (Al Rajihi)	Incineration Group 2	No available land within, but adjacent area is available.	60km to Al Ghabawi.	Monofill 4	60km
18	Wadi Es-Seir, WSP	NO	YES <50 KM	Not applicable (WSP)	Not applicable (WSP)	There is available land within and adjacent to WWTP but planned to be used for expansion.	58km to Al Ghabawi.	Monofill 4	58km
20	South Amman	YES	YES <50 KM	50 km (Modern)	Incineration Group 3	Available area within.	57km to Al Ghabawi.	Monofill 5	57km
21	Madaba	YES	YES <25 KM	70 km (Modern)	Incineration Group 3	Limited area available within that is currently being used for dumping sludge.	2km to Madaba landfill, 60km to Ghabawi.	Monofill 5	60km
22	Al Karak	YES	YES <25 KM	60 km (Modern)	Not applicable (facilities are too remote for grouping)	No available land within. Currently dumps the sludge at Al-Lajjoun WWTP.	37 km to Al Lajjoun landfill	Monofill 6 (at Lajjoun WWTP)	N/A
23	Al Lajjoun, WSP/WSP	YES	YES <25 KM	Not applicable (WSP)	Not applicable (WSP)	Available area within.	19km from Al Lajjoun landfill.	Monofill 6 (at Lajjoun WWTP)	N/A
24	Mu'ta	-	YES <25 KM	60 km (Modern)	Not applicable (facilities are too remote for grouping)	Limited area within but there appears to be available surrounding area.	37 Km to Al Lajjoun landfill	Monofill 6 (at Lajjoun WWTP)	N/A

25	**Al Tafila**	**-**	**YES <50 KM**	**27 km (Al Rashadiyyah)**	**Not applicable (facilities are too remote for grouping)**	No available area within but in the process of acquiring land for expansion.	**32km to Tafilah landfill (already dump their sludge there).**	**WWTPs in the south are too far apart for a central facility.**	**N/A**
26	**Al Mansoura, Septage/WSP**	**-**	**YES <50 KM**	**Not applicable (WSP)**	**Not applicable (WSP)**	No available area within wwtp but there is adjacent to it (in the desert).	36 km to Al Bassta landfill (Ma'an)	**WWTPs in the south are too far apart for a central facility.**	**N/A**
27	**Al Shoubak, Septage/WSP**	**NO**	**YES <50 KM**	**Not applicable (WSP)**	**Not applicable (WSP)**	No available area within but there appears to be available surrounding land (in the desert).	**34km to Al Bassta landfill (Ma'an), 38.4km from Tafilah landfill.**	**WWTPs in the south are too far apart for a central facility.**	**N/A**
28	**Ma'an**	**YES**	**YES <50 KM**	**75km (Al Rashadiyyah)**	**Not applicable (facilities are too remote for grouping)**	No available area within wwtp but there is adjacent to it (in the desert).	**11km to Al Bassta landfill (Ma'an).**	**WWTPs in the south are too far apart for a central facility.**	**N/A**
29	**Wadi Mousa**	**YES**	**YES <50 KM**	**60 km (Al Rashadiyyah)**	**Not applicable (facilities are too remote for grouping)**	There appears to be no available area within or nearby.	**24km to Al Bassta landfill (Ma'an).**	**WWTPs in the south are too far apart for a central facility.**	**N/A**
30	**Aqaba Natural, WSP**	**NO**	**NO**	**Not applicable (WSP)**	**Not applicable (WSP)**	Very limited area within wwtp or nearby; it could be at nearest mountains.	**30km from Aqaba landfill.**	**Monofill 7**	**New Aqaba Landfill**
31	**Aqaba mechanical**	**NO**	**NO**	**>100km (Al Rashadiyyah)**	**Not applicable (facilities are too remote for grouping)**	Very limited area within wwtp or nearby; it could be at nearest mountains.	**30km from Aqaba landfill.**	**Monofill 7**	**New Aqaba Landfill**

Notes:

1 Shaded areas indicate that outlets are not currently applicable based on assumptions at the time of writing this report.

2 WSP: Waste Stabilization Ponds

5.3 Biosolids Disposal and End Use Strategy

Based on the information and conclusions reached in this study, end use outlets for sludge/biosolids cannot currently be implemented due to regulatory impediments and a need to gain stakeholder buy-in on practices that are regionally and internationally accepted. However, given both the agronomic and energy value of biosolids, market demand should develop over time in both agriculture and as an alternate energy source. Recognition for the need to revise regulations associated with land application to permit reuse for fodder crops and rangelands restoration exists within the Jordanian professional community and within government organizations, and efforts are underway to make revisions accordingly. Similarly, as energy prices continue to rise, biosolids as an alternate energy source will become viable.

In the interim, and for where potential reuse outlets are less viable, sludge/biosolids must be disposed of. The ideal disposal scenario as discussed under section 5.1.3 above is co-disposal with MSW. However, until such time that designed MSW landfills are constructed, trench monofills exist as a viable option. A notable benefit of trench monofills is the ability to construct trenches in smaller segments, effectively “as you go,” limiting the impact of upfront capital costs. Further, and ideally, the need and fill rate would reduce over time as end use markets develop, or until a designed MSW landfill is constructed in the area. Finally, given Jordan’s arid climate, drying sludge after dewatering should be considered, thereby reducing potential impacts to landfill operations.

5.4 Next Steps

In order to overcome challenges associated with making end use outlets in Jordan viable, markets need to be developed and obstacles in Jordanian regulations overcome. Additionally, environmentally sound interim disposal solutions need to be developed. The following are steps which can support achieving these goals:

- *Informing decision makers*. There are notable misconceptions regarding use of biosolids from domestic wastewater treatment plants in agriculture. Extensive work within Jordan and the region has been done demonstrating safe use of biosolids in land application that further support decades of biosolids use in much of the rest of the world. This effort could occur through a series of workshops on relevant topics, and potentially a regional study tour demonstrating use of biosolids in other Arab countries.

- *Supporting efforts during upcoming regulatory reviews.* As discussed earlier in this report, a review of JS1145/2006 will occur in the near future.

Subsequent support should be made available to help provide technical support during regulatory reviews.

- *Proceeding with controlled pilot/demonstration activities.* Demonstration activities would be particularly beneficial in helping inform communities and businesses/farmers in the use of biosolids in agriculture, particularly in forage production around WWTPs. They could also provide direction in developing controls on biosolids and helping develop associated instructions within the Ministries.

- *Potential for use in Cement Kilns*. Communications with cement companies should continue, particularly as they modify their facilities to utilize alternative energy sources, making biosolids use more viable with infrastructure in place.

- *Stakeholder Communication regarding sludge/biosolids landfilling.* Discussions are needed with the respective stakeholders and in particular coordination between and cooperation of the Ministry of Municipal Affairs and associated Joint Services Councils (JSC), and MWI/WAJ. Municipal Solid Waste sites can also support disposal of sludge/biosolids, either through co-landfilling or by utilizing trench monofills. Workshops with the stakeholders would help introduce potential solutions and help overcome concerns regarding co-landfilling of sludge/biosolids with MSW. The project team is holding discussions with the concerned stakeholders in Aqaba to introduce them to the potential of including biosolids in the newly designed landfill, with the idea that Aqaba could act as a demonstration facility for the rest of Jordan.

An introduction of the overall situation, issues, opportunities, and proposed next steps should be presented to stakeholders so that they can actively undertake activities moving beneficial end use and disposal of biosolids forward. The Project Team will coordinate a workshop to initiate these activities.

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7 APPENDICES

This section contains one Appendix:

Appendix A: Preliminary Stakeholder Assessment

A - Preliminary Stakeholder Assessment

For each sludge/biosolids end use and disposal option, the extent of stakeholder influence and interest has been referenced against specific legal mandates described within the legal sections of this report, and the expected benefits or negative impacts identified.

Land Application

Specific to land application, **four levels of stakeholder influence** are referred to as follows:

Level	Reference
Very strong	*Explicit* reference to biosolids reuse and *explicit* reference to regulating agricultural activities
Strong	*Explicit* or *implicit* reference to biosolids reuse, regulation of agricultural activities, or regulation and/or operation of WWTPs
Moderate	*Explicit* reference to the regulation and monitoring of environmental components or *explicit* reference to the regulation and monitoring to protect public health and safety
Low	*Explicit* or *implicit* reference to a component directly affected by biosolids reuse in land application

Three levels of stakeholder interest were identified as follows:

Level	Reference
Strong	*Direct* benefits from biosolids reuse
Moderate	*Indirect* benefits from biosolids reuse
Low	*No or very minor direct or indirect* benefits from biosolids reuse

Stakeholders	Category (Relevant to Land Application)	Level of Interest		Level of Influence (Legal Mandate)
		Expected Benefits (+) Impacts (-)	Benefits	
WAJ	Regulator	Strong (+)	Biosolids management plan	Strong
Private water companies	Biosolids producers	Strong (+)	Biosolids management plan	*No legal mandate*
MoA	Regulator	Strong (+)	Improved productivity of agricultural sector (economic growth) and rangeland restoration	Very strong
MoEnv	Regulator	Strong (+)	Conserve biodiversity in Jordan	Strong

Stakeholders	**Category (Relevant to Land Application)**	**Level of Interest**		**Level of Influence (Legal Mandate)**
		Expected Benefits (+) Impacts (-)	**Benefits**	
MWI and JVA (within the Jordan Valley)	Monitoring body	Moderate (+)	To the extent to which it poses no environmental pollution to water resources. Improved soil stability will lower risk of non-point sources of pollution	Moderate
ASEZA (within the ASEZ)	Monitoring body	Moderate (+)	To the extent to which it poses no threat to the environment or public health. Improved soil stability will lower risk of non-point sources of pollution	Moderate
MoH	Monitoring body	Low	To the extent to which it poses no threat to the public health and safety	Very strong
MoMA (through respective municipalities and GAM)	Monitoring body	Low	To the extent to which it poses no threat to the public health and safety	Low
End users (farmers and rangeland local communities)	End user	Strong (+)	Improved yield of agricultural production and enhanced rangeland carrying capacity	*No legal mandate*
NGOs, academia and research institutions, knowledge exchange and communication platforms	Facilitators	Moderate (+)	Indirect benefits of improving community livelihoods, WWTPs performance, improving ecosystems, income generating service, etc.	*No legal mandate*

Landfilling

No legal reference governing the disposal of biosolids and sludge per se was identified. Stakeholders involved in MSW and landfill operations are relatively easy to identify as they consist of mainly of governmental entities. **Three levels of stakeholder influence** are referred to as follows:

Level	Reference
Very strong	*Explicit* reference to the regulation of MSW and landfills
Strong	Explicit or implicit reference to the regulation and operation of WWTPs, MSW or sludge/biosolids-only landfill operation and/or disposal
Moderate	*Explicit* or *implicit* reference to environmental monitoring and control or the protection of public and occupational health and safety

In addition, **three levels of stakeholder interest** were identified as follows:

Level	Reference
Strong	Direct benefits or impacts from biosolids and sludge disposal in MSW landfills or sludge/biosolids-only landfills (monofills)
Moderate	Indirect benefits or impacts from biosolids and sludge disposal in MSW landfills or monofills
Low	No/very minor direct and indirect benefits or impacts from biosolids and sludge disposal in MSW landfills

Stakeholders	**Category (Relevant to Landfills)**	**Level of Interest**		**Level of Influence (Legal Mandate)**
		Expected Benefits (+) Impacts (-)	**Benefits**	
MWI and WAJ	Regulator/ monitoring	Strong (+)	Biosolids and sludge disposal	Strong
Private water companies	Biosolids producers	Strong (+)	Biosolids and sludge disposal	*No legal mandate*
MoEnv	Regulator/ monitoring	Strong (-)	High risk of environmental pollution – Existing MSW landfills are noncompliant with legislations	Very strong
MoMA (GAM, municipalities or JSCs)	Operators	Strong (-)	High risk of environmental pollution due to the operation on noncompliant MSW landfills	Strong
MoH	Regulator/ monitoring	Moderate (-)	Moderate risk to public health and safety – Most existing MSW landfills are located relatively far from populated areas. Moderate risk associated to the spreading of infectious diseases (linked to occupational	Moderate

Stakeholders	Category (Relevant to Landfills)	Level of Interest		Level of Influence (Legal Mandate)
		Expected Benefits (+) Impacts (-)	Benefits	
			health)	
MoL	Regulator/ monitoring	Strong (-)	High risk to occupational health and safety due to noncompliant MSW landfills	Moderate
ASEZA	Regulator/ monitoring	Strong (-)	High risk of environmental pollution and public and occupational health – Existing MSW landfills are noncompliant with legislations	Very strong
JVA	Monitoring	Strong (-)	High risk of pollution of water bodies – Existing MSW landfills are noncompliant with legislations	Moderate

Cement Kilns

Given the lack of any explicit legal reference regulating the use of biosolids and dried sludge in cement kilns, as well as the simplicity of stakeholder involvement (no overlap, gaps or contradictions were identified in the relevant legal framework) for this option, only **three levels of stakeholder influence** were referred to as follows:

Level	Reference
Very strong	*Explicit* reference to environmental permitting or *explicit* reference to the regulation and protection of public and/or occupational health and safety
Strong	*Explicit* or *implicit* reference to the regulation and/or operation of WWTPs
Moderate	*Explicit* or *implicit* reference to environmental monitoring and control or the protection of public health

In addition, **three levels of stakeholder interest** were identified as follows:

Level	Reference
Strong	Direct benefits or impacts from biosolids and dried sludge use in cement kilns
Moderate	Indirect benefits or impacts from biosolids and dried sludge use in cement kilns
Low	No/very minor direct and indirect benefits or impacts from biosolids and dried sludge use in cement kilns

Stakeholders	**Category (Relevant to Land Application)**	**Level of Interest**		**Level of Influence (Legal Mandate)**
		Expected Benefits (+) Impacts (-)	**Benefits**	
WAJ	Regulator	Strong (+)	Biosolids and sludge management plan for WWTPs	Strong
Private water companies	Biosolids producers	Strong (+)	Biosolids and sludge management plan for WWTPs	*No legal mandate*
MWI	Monitoring body	Moderate (-)	Improper handling of biosolids and sludge might pose a risk to water bodies	Moderate
MoEnv	Regulator/ monitoring body	Strong (+) or Strong (-)	(+) Pollution prevention through providing WWTPs with alternatives for biosolids and sludge disposal (-) Exceeding permissible limits for air emissions	Very strong
MoL	Regulator	Strong (-)	If occupational health and safety requirements are not met	Very strong

Stakeholders	**Category (Relevant to Land Application)**	**Level of Interest**		**Level of Influence (Legal Mandate)**
		Expected Benefits (+) Impacts (-)	**Benefits**	
ASEZA (within the ASEZ)	Regulator/ Monitoring body	Strong (+)	Biosolids management plan for WWTPs	Strong
MoH	Regulator/ Monitoring body	Strong (-)	If public and occupational health and safety requirements are not met	Very strong
MoMA (through respective municipalities and GAM)	Monitoring body	Moderate (-)	If results in the creation of health nuisances	Moderate
End users (cement factories)	End user	Generally strong (+)	A cheaper source of energy to the extent to which it does not impact the quality of the product	*No legal mandate*

Incineration

For the incineration option, stakeholders were assessed taking two scenarios into consideration:

1. Incineration and ash disposal
2. Incineration, generation of electrical energy and the disposal of ash

Specific to incineration, **three levels of stakeholder influence** were referred to as follows:

Level	Reference
Very strong	*Explicit* reference to environmental permitting or *explicit* reference to the regulation and protection of public and/or occupational health and safety or *explicit* reference to power generation
Strong	*Explicit* or *implicit* reference to the regulation and/or operation of WWTPs or *explicit* or *implicit* reference to the operation of MSW landfills
Moderate	*Explicit* or *implicit* reference to environmental monitoring and control or the protection of public health

In addition, **three levels of stakeholder interest** were identified as follows:

Level	Reference
Strong	Direct benefits or impacts from biosolids and dried sludge incineration
Moderate	Indirect benefits or impacts from biosolids and dried sludge incineration
Low	No/very minor direct and/or indirect benefits or impacts from biosolids and dried sludge incineration

Stakeholders	Category (Relevant to Land Application)	Level of Interest		Level of Influence (Legal Mandate)
		Expected Benefits (+) Impacts (-)	Benefits/Impacts	
WAJ	Regulator	Strong (+)	Biosolids management plan	Strong
Private Water Companies	Biosolids Producers	Strong (+)	Biosolids management plan	*No legal mandate*
MoEnv	Regulator	Strong (-) or Strong (+)	(+) pollution prevention through providing WWTPs with alternatives for biosolids and sludge disposal (-) Exceeding permissible limits for air emissions as well as other possible environmental impacts	Very strong

Stakeholders	**Category (Relevant to Land Application)**	**Level of Interest**		**Level of Influence (Legal Mandate)**
		Expected Benefits (+) Impacts (-)	**Benefits/Impacts**	
			(-) Possible environmental impacts if the disposal of ash is not done properly (-) Possible environmental impacts if the new landfills are not properly designed and operated	
ASEZA (within ASEZ)	Monitoring Body	Strong (-) or Strong (+)	(+) pollution prevention through providing WWTPs with alternatives for biosolids and sludge disposal (-) Exceeding permissible limits for air emissions as well as other possible environmental impacts (-) Possible environmental impacts if the disposal of ash is not done properly (-) Possible environmental impacts if the new landfills are not properly designed and operated	Very strong
MoH	Monitoring Body	Strong (-)	If public and occupational health and safety requirements are not met	Very strong
MoL	Regulator	Strong (-)	If occupational health and safety requirements are not met	Very Strong
MoMA and JSCs (including GAM)	Monitoring Body	Strong (-) And Low	- If it results in the creation of health nuisances (air pollution or noise) - Low for municipal solid waste landfills, as ash is dry and unlikely to cause issues related to co-disposal	Strong
MEMR and the Commission	Regulator	Strong (+) or Strong (-)	(+) In the case of electricity generation especially if it counts as a source of renewable energy	Very strong

Stakeholders	**Category (Relevant to Land Application)**	**Level of Interest**		**Level of Influence (Legal Mandate)**
		Expected Benefits (+) Impacts (-)	**Benefits/Impacts**	
			(-) In the case of flawed monitoring and management practices	
NEPCO	End Users	Strong (+) Or Strong (-)	- Negative in the case of improper grid impact assessment being carried out - Positive if it accounts as a source of renewable energy	*No legal mandate*