Bio-Solids Application for Improving Soil Fertility and Crop Production in Jordan

First Progress Technical Report
(Nov. 2004 - Jan. 2005)

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Prepared by

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1. INTRODUCTION

Wastewater management is a continuing problem in many countries in the world, and particularly in Jordan where the need to conserve and reuse water resources is crucial. The recent changes in regulations concerning municipal wastewater management in Jordan had resulted in significant increase in reclaimed water as well as bio-solids quantities. Although reclaimed water reuse plans have been set since the eighties of the last century, still there are no definite policies and solid regulations for utilizing generated bio-solids for beneficial usages. As a result, accumulated quantities at treatment plants is being dealt with in an uncontrolled manner that may cause negative impacts on public health and the environment.

This project is aiming at investigating the feasibility of utilizing bio-solids for improving soil fertility and crop production in Jordan. The specific measurable objectives are:

- To evaluate impacts of bio-solids application on soil properties and crop yield and quality based on field-pilot experiments.
- To recommend appropriate bio-solids application procedures and rates that are suitable to local conditions.
- To work through a collaborative model with the concerned governmental organizations and academic institutions.

In October 2004 the United States Agency for International Development USAID (Washington & Jordan/ Water Resources & Environment Office- Jordan), and through a cooperative agreement with the International Arid Lands Consortium IALC / University of Arizona represented by the Badia Research & Development Center BRDC / Jordan, approved a request by the Royal Scientific Society RSS of Jordan to contribute in financing this project. A one year contract was signed by BRDC and RSS, and both parties mutually agreed that the commencement date would be November 2004.

This report is the first of a series of progress reports required by RSS, and covers the period (Nov. 2004 to Jan. 2005). The report summarizes different activities and tasks executed throughout this time period as well as projections for the anticipated subsequent activities.

2. PROGRAMMED & EXECUTED ACTIVITIES

Table (1) below shows the schedule for implementing different activities for the entire project duration (Nov. 2004-Oct. 2005). Following is a description of the activities executed throughout (Nov. 2004- Jan. 2005).

2.1 Mobilization:

Based on the project's term of reference, RSS is conducting the project in close cooperation with the National Center for Agricultural Research and Technology Transfer NCARTT. NCARTT is a local research center involved in applied research activities in the agricultural field. Both parties signed a Memorandum of Understanding MoU upon which NCARTT is offering a piece of land as a research site within the premises of a research station in the northern part of Jordan (in Ramtha city).

Table (1): Implementation schedule for the project (Oct. 2004 – Oct. 2005).

Activity	Month												
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
Site Investigation & Final Selection	X												
Land Preparation	X	X										*X	*X
Plantation		X	X	X	X	X	X	X					
Soil Sampling & Analysis	X			X				X	X	X			
Plant Sampling & Analysis					X	X		X	X	X			
Evaluation and Reporting				X			X				X	X	

* : For the next growing season.

The project team had been formulated. The following staff are directly involved in different activities since the commencement of the project:

1. Dr. Bassam Hayek: PhD in Chemical Engineering. Director of the Environmental Research Center ERC / RSS. (Role: provide overall guidance, coordinate with various parties, and act as a contact person with IALC).
2. Eng. Wa'el Suleiman: M.Sc. in Water & Environmental Engineering. Researcher at ERC / RSS. (Role: follow-up day-to-day work, supervise different activities, and participate in preparing progress and final technical reports).

3. Eng. Bayan Athamneh: M.Sc. in Agricultural Engineering / Natural Resources & Environment. Researcher at ERC / RSS. (Role: follow-up day-to-day work, and participate in preparing progress and final technical reports).
4. Ali Omari: MSc in Microbiology. Senior microbiologist at ERC / RSS. (Role: perform and supervise microbial analysis).
5. Naser Budier: B.Sc. in Agricultural Science / Soil, Water and Environment. (Role: perform and supervise physical and chemical analysis).

Researchers from RSS and NCARTT met several times and visited the research station in Ramtha to decide on the site where the field-pilot experiments are to be conducted.

In addition, an *ad hoc* committee was formed. It comprised representatives of different stakeholders including governmental and non-governmental organizations as well as academic institutions. The committee will meet regularly to follow-up and discuss different aspects and up-dated results of various activities, and to firm-up suggestions and recommendations. The following list shows names of the *ad hoc* committee members:

1. Dr. Manar Fayyad: Director of the Water and Environment Research and Study Center, University of Jordan.
2. Dr. Sa'ad Al-Ayyash: Badia Research and Development Center BRDC.
3. Dr. Ziad Al-Ghazawi: Jordan University of Science and Technology.
4. Eng. Saleh Malkawi: Water Authority of Jordan WAJ / Ministry of Water and Irrigation MWI.
5. Eng. Khalil Jamjoum: National Center for Agricultural Research and Technology Transfer NCARTT / Ministry of Agriculture.
6. Eng. Husni Hamdan: Ministry of Environment.
7. Eng. Murad Za'atreh: Head of Standards & Codes Division, Aqaba Special Economic Zone Authority ASEZA.
8. Eng. Ahmad Ulimat: Directorate of Water Quality, WAJ / MWI.
9. Eng. Wa'el Suleiman: ERC / RSS.
10. Eng. Bayan Athamneh: ERC / RSS.
11. Dr. Bassam Hayek: Director of ERC / RSS.

2.2 Location:

As mentioned earlier, field experiments location was identified at Ramtha research station/ NCARTT. The site is located 70 km to the north of Amman and 5 km away from Wadi Hassan treatment plant, 32°30 north latitude and 35°59 east longitude with an altitude of 590 m above sea level (figure1). The climate in the area is characterized by cold winter and hot summer with an average annual rainfall of 232 mm for the period of (1998-2004), and the average temperature ranges from 5 °C in January to 35 °C in August. Generally, rainfall starts in early November and ends in late March to early April. Maximum rainfall occurs during January-February.

Figure (1): Map of Jordan showing the research site.

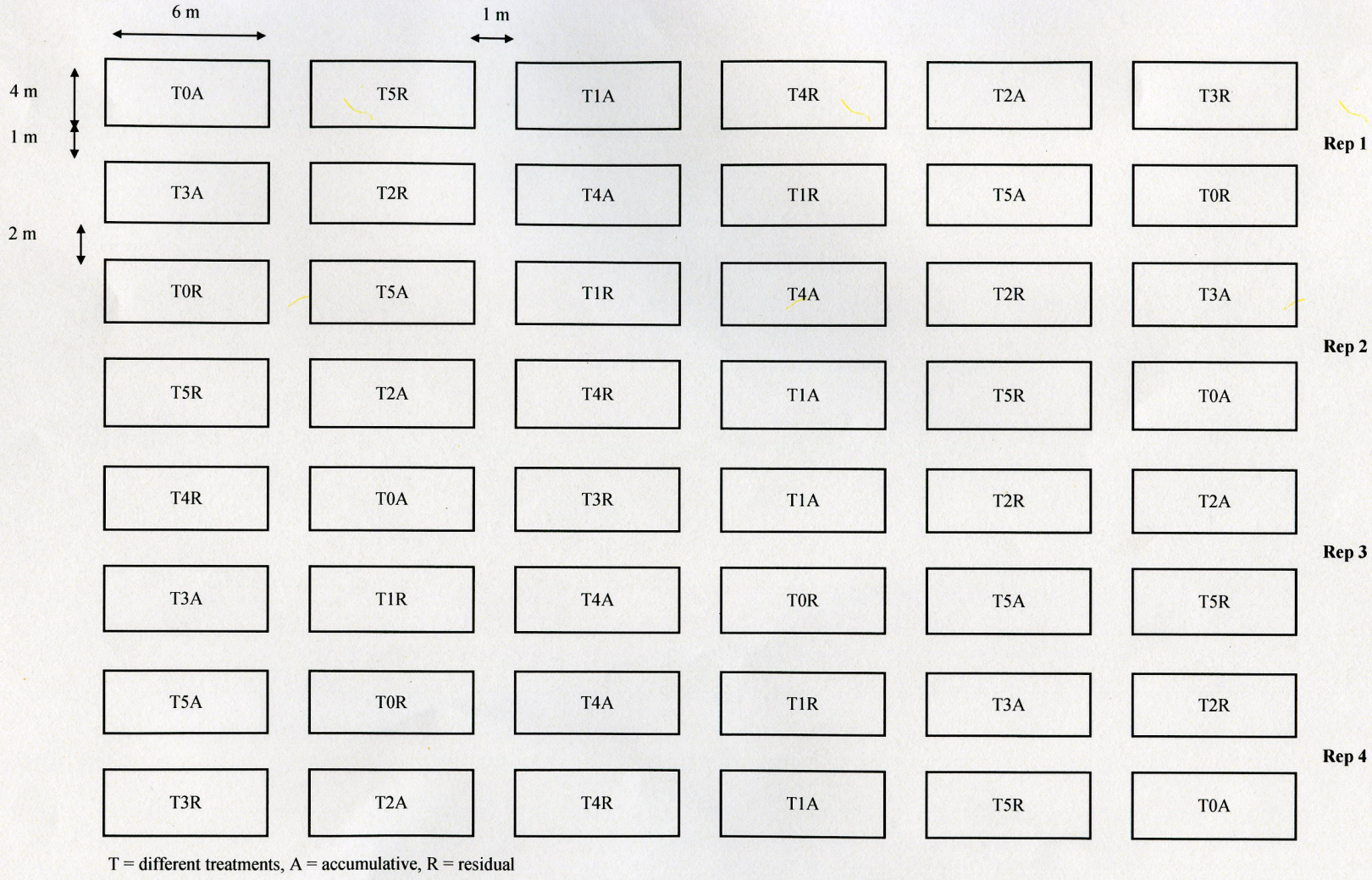
2.3 Land Preparation and Plantation:

Two shallow cultivations (10-12 cm depth) perpendicular to each other were carried out using chisel plow (duck foot model). The experiments have been established in Factorial Randomized Completely Block Design (FRCBD) with four replications. Experiment plots of 4m X 6m were established. Field layout of the experiments is shown in figure (2).

The treatments have been designed to study two factors. The first is the bio-solids different application rates, the second is the accumulative and residual effects of different application rates. Dewatered bio-solids were obtained from Wadi Hassan treatment plant. Six different treatments, zero sludge application as a control, 2, 4, 6 and 8 T/ha in addition to one chemical fertilizer treatment (di-ammonium phosphate DAP) that represents the recommended fertilizer rate, were applied manually as such to each plot prior to sowing and incorporated uniformly with soil to a depth of 8 cm. Barley was sowed using sowing machinery with a seeding rate of 100 kg/ha. Figure (3) shows the experimental site during preparation process, while figure (4) shows the site after two months of seeding.

2.4 Bio-solids Sampling and Analysis:

One bio-solids composite sample was collected from each of Wadi Hassan, As-Samra, and Central Irbid treatment plants. A dewatered bio-solids sample was



T = different treatments, A = accumulative, R = residual

Figure (2): Experimental layout

Figure (3) The experimental site during preparation process

Figure (4): The experimental site after two months of seeding.

collected from Wadi Hassan (representing bio-solids quality utilized for the field-pilot experiments), while one sample was collected from the quantities accumulated at As-Samra treatment plant throughout previous years of operation, and one sample was collected from the bio-solids coming out of the anaerobic digesters at Central Irbid treatment plant. Table (2) shows physical, chemical and microbial properties analyzed for.

Table (2): Results of bio-solids analysis.

Parameter	Unit	Wadi Hassan	As-Samra	Central Irbid	JS: 1145/1996	US EPA	
						Ceiling Conc.*	Poll. Conc.**
TS	%	89	34	1.6	-	-	-
TVS of TS	%	53	46	74	-	-	-
T.kj.N	%	4.2	2.8	10.9	-	-	-
NH4-N	%	0.026	0.700	4.570	-	-	-
T-P	%	0.39	0.08	1.11	-	-	-
Available-P	%	0.10	0.01	0.92	-	-	-
K	mg/kg D.W	3299	1368	18088	-	-	-
As	mg/kg D.W.	N.D.	N.D.	N.D.	< 75	< 75	< 41
Cd	mg/kg D.W.	2.71	7.05	8.02	< 85	< 85	< 39
Cr	mg/kg D.W.	51	192	N.D.	< 3000	-	-
Cu	mg/kg D.W.	96	369	173	< 4300	< 4300	< 1500
Pb	mg/kg D.W.	56	172	139	< 840	< 840	< 300
Hg	mg/kg D.W.	N.D.	N.D.	N.D.	< 57	< 57	< 17
Mo	mg/kg D.W.	N.D.	26.44	N.D.	< 75	< 75	-
Ni	mg/kg D.W.	38.3	60.3	N.D.	< 420	< 420	< 420
Se	mg/kg D.W.	N.D.	N.D.	N.D.	< 100	< 100	< 36
Zn	mg/kg D.W.	1001	359	773	< 7500	< 7500	< 2800
Co	mg/kg D.W.	N.D.	N.D.	N.D.	< 150	-	-
Salmonella	MPN/4 gm	N.D.	92	1.7	< 3/4 gm	< 3/4 gm	
TFCC	MPN/gm	9.30E+04	9.00E+03	4.30E+06	$< 1 X 10^3$	$< 1 X 10^3$	
Nem. Eggs	Egg/gm	N.D.	N.D.	N.D.	< 1/4 gm	< 1/4 gm	

D.W. : Dry Weight.
N.D. : Not Detected.
*: Maximum concentration of each pollutant that bio-solids can contain and still be land applied. Limits are applied as maximum, never to be exceeded values.
** : Land applier has no land application requirements relative to pollutants for bio-solids meeting these limits.

As can be noticed from the table, levels of trace metals are relatively low when compared to the requirements of the US EPA Rule 503 and the Jordanian Standard (1145/1996) for utilizing bio-solids for agricultural land application. However, fecal coliform levels are exceeding the limit (1000 MPN/gm), hence these bio-solids could be classified as type (B) according to the US EPA regulations.

Bio-solids samples were analyzed following the "Standard Methods for the Examination of Water & Wastewater", 20th Edition, APHA, AWWA. Other analytical methods were also applied, especially those of the US EPA

2.5 Soil Sampling and Analysis:

Prior to seeding and in order to collect baseline data about the soil quality at the experimental site, nine composite soil samples were collected at depths of 0-15, 15-30, and 30-60 cm. Samples were analyzed in accordance to the Soil Science Society of America (1996) for general physical, chemical and microbial characteristics, results are shown in table (3).

Table (3): Baseline data for soil quality at the experimental site.

Parameter	Unit	sampling depth (cm)		
		0-15	15-30	30-60
Soil Texture: Sand	%	9	8	6
Silt	%	40	36	35
Clay	%	51	55	59
Texture	SU	clay	clay	clay
pH 1:1	SU	8.38	8.38	8.52
EC 1:1	dS/m	0.359	0.368	0.925
CEC	cmol/kg	37.1	35.2	35.0
Organic matter	%	1.58	1.26	1.62
T.kj.N	mg/kg D.W	853	678	476
NH4-N	mg/kg D.W	5.01	4.47	4.01
NO3-N	mg/kg D.W	11.1	13.3	11.3
available-P	mg/kg D.W	11.83	5.90	2.63
CaCO3	%	9.67	11.00	11.33
available-K	mg/kg D.W	817	587	406
available-Na	mg/kg D.W	105	167	392
available-Mg	mg/kg D.W	816	1009	1186
available-Ca	mg/kg D.W	7790	7441	6974
As	mg/kg D.W	N.D.	N.D.	N.D.
Cd	mg/kg D.W	N.D.	N.D.	N.D.
Cr	mg/kg D.W	42	32	22
Cu	mg/kg D.W	13	11	7
Pb	mg/kg D.W	45	36	22
Hg	mg/kg D.W	30	33	N.D.
Mo	mg/kg D.W	N.D.	N.D.	N.D.
Ni	mg/kg D.W	32	20	18
Se	mg/kg D.W	N.D.	N.D.	N.D.
Zn	mg/kg D.W	58	61	61
Co	mg/kg D.W	28	33	28
Salmonella	cell/gm	N.D.	N.D.	N.D.
TFCC	MNP/gm	N.D.	N.D.	N.D.
Nem. Eggs	cell/gm	N.D.	N.D.	N.D.

D.W. : Dry Weight.
N.D. : Not Detected.

The preliminary analyses show that the soil is alkaline, pH ranges between 8.38-8.52, with relatively low organic matter content, while trace elements levels are within normal low range.

Another episode of sampling was conducted two months after the application of bio-solids to identify major impacts on the soil quality (analysis results will be provided in the next progress report).

2.6 Quality Assurance Schemes:

Quality control schemes were followed so as to ensure a high degree of confidence of the analyses results. Those include, but not limited to, the following: analysis of duplicate and spiked samples (not less than 10%), analysis of external samples (certified reference materials); internal and external calibration of analytical instruments. Moreover, split soil samples were collected that will be analyzed at NCARTT laboratories.

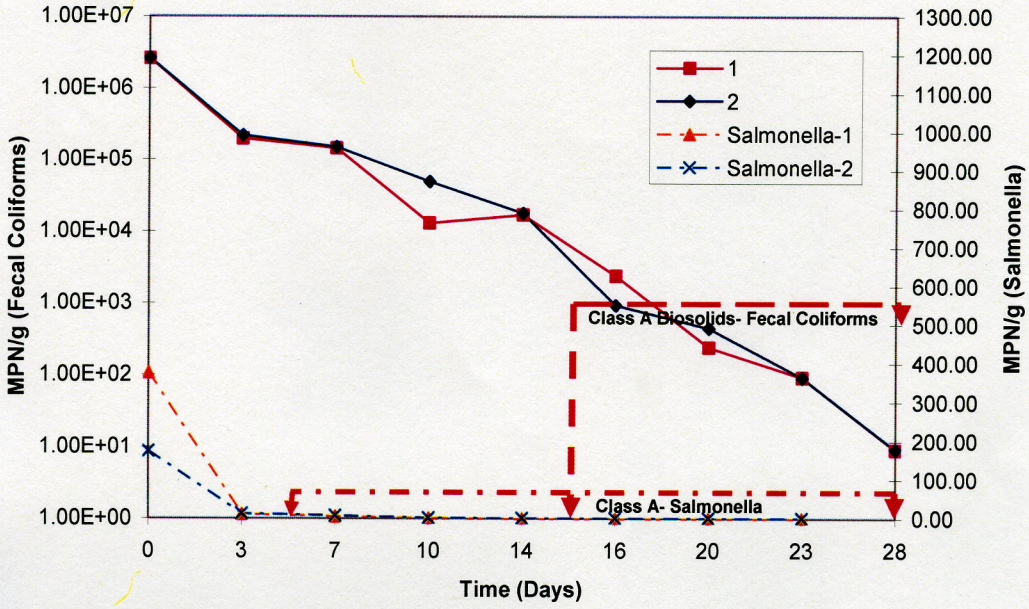
2.7 Other Activities:

In order to investigate potentials of bio-solids pathogen reduction in correlation to environmental factors while being dewatered in the drying beds, a Weather Station was provided by IALC/ University of Arizona and built near-by a drying bed within the premises of Wadi Hassan treatment plant in August 2004 with the help of a researcher from the university (Mrs. Susan O' shaughnessy). The station consists of rainfall gauge, wind speed and direction sensor in addition to a solar radiation panel. The station is compiled with thermocouple sensors to measure bio-solids temperature, sensors to measure bio-solids moisture levels, in addition to a sensor to measure the drying bed moisture content. Bio-solids coming out of the holding tank at the treatment plant was drained to the drying bed to a depth of (25 cm).

The first cycle of experiments (representing summer period) started in August 2004. Composite bio-solids samples were collected on weekly basis from two locations within the drying bed (designated location1 and 2) and analyzed for fecal coliform and salmonella. Within about (20) days, bio-solids of type (A) was obtained based on microbial properties as shown in figure (5), while the percentage of total solids achieved was about 97% .

The second cycle, representing winter experiments, started in November 2004 and the same analyses were carried out for both locations. Within two months of experiments, the microbial quality of bio-solid did not improve to achieve type (A) bio-solids. This is mainly attributed to rainfall events during that period.

Figure (5): Pathogen density levels vs. time



2.8 *Ad hoc* Committee meetings:

The *ad hoc* committee held its first meeting on Jan. 6th, 2005 with the presence of all members in addition to a representative of the USAID/Amman- Water Resources & Environment Office (Dr. Amal Hijazi) and a representative of the University of Arizona (Dr. Chris Choi). RSS research team presented major activities conducted, and Dr. Choi also presented some facts regarding bio-solids management in the United States, and briefed the committee about research studies being carried out at the university in the field of bio-solids treatment and reuse.

Different aspects were discussed, among these is the issue of analyzing some bio-solids samples generated at Central Irbid wastewater treatment plant. This plant is utilizing anaerobic digestion for treating bio-solids, the same treatment process that will be utilized for the new As-Samra treatment plant.

3. INTERNATIONAL SCIENTIFIC VISITS

Two of RSS research team, Eng. Wa'el Suleiman and Ali Omari, participated in a two-weeks technical scientific visit (Dec. 3rd-18th, 2004) to the University of Arizona where they got the opportunity to learn more about issues related to bio-solids management and the development of bio-solids regulations in the United States and in Arizona State. Both researchers got exposure to experiences and practices of bio-solids application at different sites within the State. Recently developed and modified bio-solids microbial analytical procedures were also introduced by staff of the university.

In addition, one of the staff of the University of Arizona, Dr. Chris Choi, visited Jordan during Jan. 2005. He, together with RSS research team, visited the field

experiments sites as well as some other sites such as treatment plants at Aqaba and As-Samra to investigate potential opportunities for future cooperation.

4. ADMINISTRATIVE ACTIVITIES

Management of this project is the responsibility of ERC/RSS. A project leader, and researchers specialized in different fields are directly involved in all activities related to the project. RSS is conducting this project in close cooperation with NCARTT through a memorandum of understanding signed by both agencies.

5. PROJECTIONS

Referring to the project execution plan (Table 1), the following activities will be conducted throughout the coming three months (Feb.-Apr. 2005) when the second progress report will be issued:

(A) Bio-solids Analysis:

Composite bio-solids samples will be collected periodically from Wadi Hassan, As-Samra and Central Irbid treatment plants and analyzed for general chemical, physical and microbiological characteristics as per the requirements of the project proposal.

(B) Participation in a Regional Workshop:

One of the research team, Eng. Bayan Athamneh, will participate in a regional workshop entitled "Bio-solids Use in Agriculture" that will tackle various aspects related to bio-solids management in the region.

(C) Crop Measurements:

Some crop measurements will be conducted, among these are the following: number of plants, number of tillers per plant, dry weight, and number of fertile tillers per plant.

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