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

Second Progress Technical Report
(Feb. - Apr. 2005)

Contract No. (133/2004)

Prepared by

Water Quality Studies Division
Environmental Research Center
Royal Scientific Society
Amman – Jordan

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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 second of a series of progress reports required by RSS, and covers the period (Feb. to Apr. 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 (Feb. - Apr. 2005).

2.1 Mobilization:

As previously mentioned in the first progress report, RSS is conducting the project in close cooperation with the National Center for Agricultural Research and Technology Transfer NCARTT. Both parties are cooperating on the basis of 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			
Plant Sampling & Analysis					X	X		X	X	X			
Evaluation and Reporting				X			X				X	X	

* : For the next growing season.

The following RSS staff have been 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).

In addition, Eng. Loai Al-Quraan and Eng. Said El-Zuriqi, researchers at NCARTT Ramtha research station, follow up with RSS staff field-pilot experiments.

An *ad hoc* committee was formed and comprised of representatives of different stakeholders including governmental and non-governmental organizations as well as academic institutions. The committee meet regularly to follow-up and discuss different aspects and up-dated results of various activities. 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. Ahmad Ulimat: Directorate of Water Quality, WAJ / MWI.
8. Eng. Wa'el Suleiman: ERC / RSS.
9. Eng. Bayan Athamneh: ERC / RSS.
10. Dr. Bassam Hayek: Director of ERC / RSS.

2.2. Location:

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 (figure 1). The climate in the area is characterized by cold winter and hot summer.

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

2.3. Crop Measurements and Plantation:

As mentioned in the first progress report, the experiments have been established in Factorial Randomized Completely Block Design (FRCBD) with four replications. Field layout of the experiments is shown in figure (2).

Figure (3): Random samples taken from ($1m^2$) area in each plot.

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 (DAP and Urea) that represents the recommended fertilizer rate, were applied manually as such to each plot. Barley was sowed using sowing machinery with a seeding rate of 100 kg/ha.

One of the major activities that was carried on at this phase of the project was crop measurement. Random samples were taken from ($1m^2$) area in each plot (Figure 3) at tillering stage. The following parameters were determined: number of plants $plot^{-1}$, number of tillers $plant^{-1}$, number of fertile tillers $plant^{-1}$(Table 2). Data was subjected.

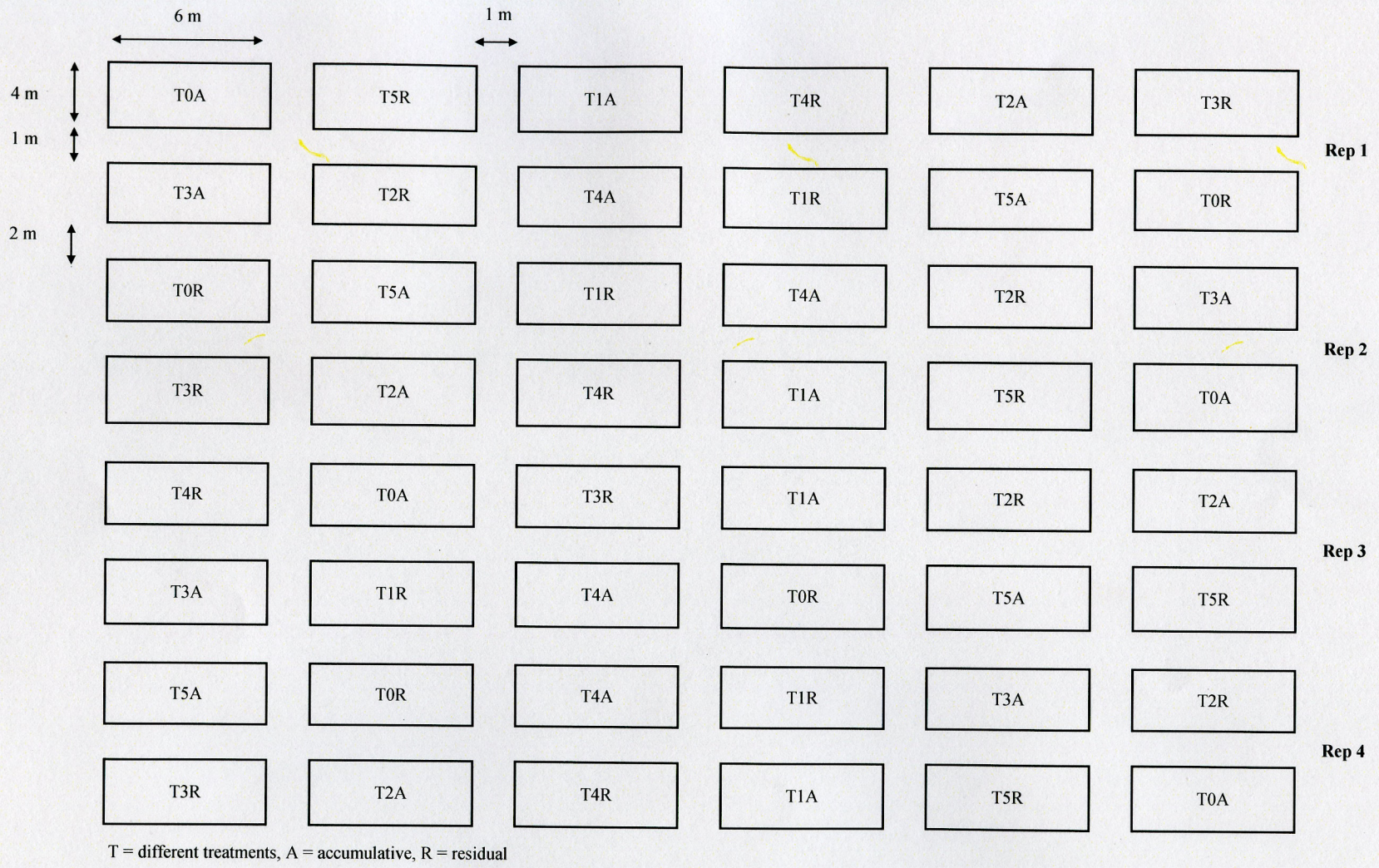

Figure (2): Experimental layout

to analysis of variance (ANOVA) using MSTATC PROGRAM (Michigan State University). To determine the main effect of each factor, the LSD .05 was used to separate treatments mean.

2.3.1. Number of plants per square meter

The effect of different treatments on number of plants per square meter is presented in Table (2). The analysis of variance shows no significant effects of different treatments on number of plants m^{-2}.

2.3.2. Number of tillers per plant

Preliminary analysis shows that number of tillers per plant was significantly influenced by biosolids application at 4 ton/ha biosolids (table 2). Number of tillers increased from (3.2) at the control (zero bio-solid application) to (4.3) tillers per plant at (4 ton/ha biosolids). There was no significant difference in number of tillers between different biosolids application rate, and there was no significant difference observed between biosolids treatments and commercial fertilizer treatment (table 2).

Table (2): Number of plant m^{-2}, tillers $plant^{-1}$, and fertile tillers $plant^{-1}$ of barley as affected by different treatments.

Treatment. (ton/ha)	Ave no. of plant/ m^2	Ave no. of tillers /plant**	Ave no. of fertile tillers /plant**
0	106.1 a	3.2 b	2.1 c
2	99.1 a	3.6 ab	2.2 c
4	95.3 a	4.3 a	2.6 bc
6	107.0 a	4.0 ab	2.5 bc
8	99.1 a	4.4 a	3.2 a
fertilizer*	110.2 a	4.2 a	3.1 ab
LSD .05	14.53	0.73	0.53

* chemical fertilizer treatment (DAP & Urea) that represents the recommended fertilizer rate.
** means that have different letters are significantly different at the 0.05 level of probability.

2.3.3. Number of fertile tillers per plant

Preliminary analysis shows that biosolids application causes significant increase in the number of fertile tillers per plant over the control at higher biosolids application rate (8 ton/ha). Results also show that applying biosolids at 4, 6, 8 ton /ha application rates had no significant difference over the commercial fertilizer treatment (table 2).

2.4. Plant Analysis

Figure (4): Random plant samples taken from each plot.

The plant "barley" samples were taken randomly from each plot at tillering stage. Samples were dried at 68 C^{o} for 48 hrs, then ground to a fine powder using a laboratory mill with 0.5 mm sieve. The milled products were mixed thoroughly, kept in glass jar and used for the chemical analysis. All samples will be analyzed for total nitrogen, protein content, total phosphorus, total potassium, and trace metals, in addition to some biological analysis (Salmonella spp., TFCC, and intestinal pathogenic nematodes eggs).

2.5. Bio-solids Sampling and Analysis:

Biosolids sampling activities from each of Wadi Hassan, As-Samra, and Central Irbid treatment plants were continued. Table (3) shows the results of the physical, chemical and microbiological properties for two samples collected from each site.

Table (3): Results of bio-solids analysis.

Parameter	Unit	Wadi Hassan		As-Samra		Central Irbid		JS: 1145/1996	US EPA	
		10/01/2005	08/03/2005	10/01/2005	08/03/2005	10/01/2005	08/03/2005		Ceiling Conc.*	Poll. Conc.**
TS	%	89	2	34	91	2	2	-	-	-
TVS of TS	%	53	70	46	39	74	74	-	-	-
T.kj.N	%	4.2	7.1	2.8	1.5	10.9	7.6	-	-	-
NH4-N	%	0.03	0.45	0.70	0.12	4.57	1.05	-	-	-
T-P	%	0.39	1.85	0.08	0.28	1.11	1.91	-	-	-
Available-P	%	0.10	1.26	0.01	0.02	0.92	0.45	-	-	-
K	mg/kg D.W	3299	20000	1368	18541	18088	22096	-	-	-
As	mg/kg D.W.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	< 75	< 75	< 41
Cd	mg/kg D.W.	2.71	N.D.	7.05	5.52	8.02	N.D.	< 85	< 85	< 39
Cr	mg/kg D.W.	51	N.D.	192	107	N.D.	N.D.	< 3000	-	-
Cu	mg/kg D.W.	96	68	369	317	173	195	< 4300	< 4300	< 1500
Pb	mg/kg D.W.	57	N.D.	172	260	139	N.D.	< 840	< 840	< 300
Hg	mg/kg D.W.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	< 57	< 57	< 17
Mo	mg/kg D.W.	N.D.	N.D.	26.44	N.D.	N.D.	N.D.	< 75	< 75	-
Ni	mg/kg D.W.	38	N.D.	60	85	N.D.	126	< 420	< 420	< 420
Se	mg/kg D.W.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	< 100	< 100	< 36
Zn	mg/kg D.W.	1001	458	359	4885	774	200	< 7500	< 7500	< 2800
Co	mg/kg D.W.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	< 150	-	-
Salmonella	MPN/4 gm	<3	4400	92	44	172	600	< 3/4 gm	< 3/4 gm	
TFCC	MPN/gm	9.30E+04	2.40E+06	9.00E+03	3.00E+00	4.30E+06	4.30E+06	< 1 X 10^3	< 1 X 10^3	
Nem. Eggs	Egg/gm	N.D.	N.D.	N.D.	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 (table 3), 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 and Salmonella levels are exceeding the recommended limits, 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

2.6 Quality Assurance Schemes

Quality control schemes were followed so as to ensure a high degree of confidence of the analyses results. Those included, 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.

2.7. Ad Hoc Committee Meetings

Figure (5): Field trip with the ad hoc committee to the project sites

The ad hoc committee continued its meetings. A field visit to the research site was organized on 17/4/2005 where the committee was briefed on the progress of the project and field activities. The issue of upgrading the Jordanian standards of biosolids reuse in agriculture was discussed. It was agreed that there is an urgent need for that, and the committee started working on preparing a draft proposal that will be forwarded to the Jordan Institution of Standardization and Metrology to gain its approval. At this stage, different regional and international guidelines will be reviewed. During July and August the draft will be prepared based on the results of the first growing season of the research project.

3. INTERNATIONAL SCIENTIFIC VISITS

One of the research team, Eng. Bayan Athamneh, attended an International Workshop on "Biosolids Use in Agriculture", held in Sydney, Australia during the period March 7-10, 2005. The event was attended by other Jordanian, Palestinian and Israeli delegation. Bayan Athamneh represented RSS in the Jordanian delegation. She presented a paper entitled "Biosolids Characterization, Land Application, and Treatment in Jordan". The event was organized and funded by USDA and USEPA.

Dr. Akram Tamimi, IALC representative, visited RSS during April 2005, where different aspects of the project were discussed with RSS research team. Among these are the preparation of scientific papers, the preparation for the scientific trip of Dr. Susan O'Shanghnessy (researcher at the University of Arizona) to Jordan, and reviewing of updated analytical results of bio-solids, soil and plant samples. A field trip to the research sites was also organized.

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 institutions.

5. PROJECTIONS

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

(A) International Scientific Visits:

Representatives of IALC/University of Arizona will visit RSS during May 2005 to follow-up some activities with the research team at RSS. Among these activities are bio-solid sampling and microbial assay (Salmonella and Helminth Ova), and finalizing scientific papers related to the project.

(B) 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.

(C) Crop Measurements:

At maturity, a 1.0 m^2 area in each plot will be sampled randomly. Plant will be manually harvested from the sampling area. Total biological yield (Kg/ha) will be recorded as the

total weight of the above-ground parts (grain and shoot). The harvested samples will be threshed, cleaned then the grains will be weighed to determine the grain yield (Kg/ha).

(D) Plant Analysis:

Further plant sampling and analysis will be conducted at harvesting stage, and will be analyzed for total nitrogen, protein, total phosphorus, total potassium, trace metals in addition to some microbial analysis (Salmonella spp., TFCC, and intestinal pathogenic nematodes eggs).

(E) Soil Analysis:

Upon harvesting, composite soil samples will be collected at two different depths (that is, 0-15 cm and 15-30 cm) from each plot. These composite samples will be analyzed for soil texture, pH, EC, CEC, organic matter, mineral nitrogen (NH_4 and NO_3), available phosphorus, exchangeable potassium , Na, DTPA extractable micronutrients and trace metals, in addition to some microbial analysis (Salmonella spp., TFCC, and intestinal pathogenic nematodes eggs).

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