Trip to Jordan for Sustainable Development of Dry Lands Project – Jordan Component

Continuation of Collaborative Meeting for Bio-solids Research Activity December 29, 2003-January 12, 2004

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I. Introduction

Karen Vitkay, a graduate student with the Department of Landscape Architecture and I arrived in Jordan together on December 31, 2003. We attended initial meetings with Dr. Shahbaz of the Badia Research and Development Project and with the ASEZA group as a matter of initial introduction when arriving in Amman and Aqaba respectively. On the evening of January 4th, I flew to Amman from Aqaba to begin my individualized efforts on the bio-solids project. The purpose of my work in Jordan during this time was to continue the meetings that Dr. Chris Choi had initiated in the areas of the bio-solids project. My primary objectives were to: 1) establish a rapport with personnel from the Royal Society of Science (RSS) with whom I will be collaborating on the bio-solids project; 2) discuss time frames involved in assembling the remote weather station, calibrating and stabilizing the moisture sensor probes and thermocouple wires; 3) initiate conversation on the environmental sampling and microbiological assay methods necessary to carry out the field experiments; and 4) gather specific information on the research site and necessary instrumentation to establish a real-time web-based data acquisition system to meet the intent of the research proposal.

For ease of reading, I have listed daily activities in Table 1, and have provided a summary of each day in bullet point format as a forward to the narrative portion of the report.

II. Table 1. Summary of Daily Activities

Date	Description of Work
12/29 - 12/31/03	▪ Travel to Amman from Tucson, Arizona
12/31/03	▪ Meeting with Dr. Shahbaz and Dr. Saad Alayyash of BRDP ▪ Purchased airline tickets to Aqaba & exchanged money
1/1/04	▪ Cultural excursion to the ruins in Jerash ▪ Updated power point presentation for Monday's meeting ▪ Reviewed Dr. Choi's Report and the Collaborative Proposal for Bio-solids
1/2 - 1/3/04	▪ Flew to Aqaba ▪ Visited the Aqaba Museum and Castle, Karen's project site and nearby antiquities and various gardens throughout the city as part of Karen's desire to learn of the architectural landscape elements utilized in the city's current parks
1/4/04	▪ Met Dr. Salim Al-Moghrabi of ASEZA ▪ Attended an introductory meeting with ASEZA personnel ▪ Toured the Aqaba Wastewater Re-use Pilot Program- visited the excavated piles of bio-solids, the existing Aqaba WWTP and the expansion plant that is under construction- 64 drying beds are included ▪ Returned to Amman

1/5/04	▪ Met with Mr. Wael Suleiman and Mr. Ali Al-Omari of the RSS ▪ My hosts provided me with a historical background of the RSS and current research related to bio-solids ▪ A tour of the laboratory facilities for the Environmental Research Center ▪ Mr. Suleiman gave a power point presentation on the current bio-solids characterization program ▪ I provided a presentation on the bio-solids research activity that has been accomplished by the ABE Department at the University of Arizona
1/5/04 continued	▪ Discussed the objectives of our collaborative efforts ▪ I provided Mr. Suleiman with a hard copy of Java script utilized by the University of Arizona to post the remote environmental data for the drying beds in Tucson, Arizona
1/6/04	▪ Traveled south to the Wadi Musa WWTP - along the way we discussed our research goals further ▪ Met with Engineer Hayder at the Wadi Musa WWTP ▪ Toured the drying bed area ▪ Retreated for the hotel at sunset where we discussed step-by-step details necessary to carry out the proposed bio-solids research work
1/7/04	▪ Returned to the Wadi Musa WWTP to tour the mechanical treatment of effluent ▪ Visited the drying beds to select the optimal beds for our research ▪ Determined placement of weather station: o Fill area- easy to stabilize unit & provide electrical ground o Along width of drying beds nearest the bio-solids storage area ▪ Power source for weather station and communication modem- o BP12 battery/regulator, trickle charged w/solar panel o Independent source of energy o Low maintenance o Will not interfere with current plant operations ▪ Reviewed line of sight between repeater location and drying beds- o Mr. Suleiman is to contact cellular providers: • Ascertain equipment compatibility • Price quote for establishing service & monthly fee
1/8/04	▪ Mr. Al-Omari and I visited the following WWTPs to understand the production methods for solid waste residuals and the current management practices afforded to bio-solids: o Assamra o Wadi Hassan o J.U.S.T.
1/9 – 1/10/04	▪ Report Writing
1/11/04	▪ Contacted Dr. Saad Al-Ayyash with BDRP to let him know that I had accomplished my objectives and that collaborations with the RSS were productive and informative ▪ Visited the Architectural and Main Library on the Campus of the University of Jordan as Karen was searching for a book on the native plants utilized in landscaping parks in Jordan ▪ Left Amman for the Queen Ali Airport by taxi at midnight
1/12/04	▪ Travel to Tucson

III.Report Narrative

A. Arrival in Amman

December 31, 2003- Arrived at Queen Ali Airport at 1:00 a.m. and at ACOR sometime later in the morning.

Met with Dr. Mohammed Shahbaz and Dr. Saad Al-Ayyash of the BRDP. Dr. Shahbaz provided a historical background on the general state of Jordan. Dr. Shahbaz relayed to us that we must try as hard as possible to be transparent in communicating with others by relaying our work to collaborative members so that they understand that work is being accomplished. The second point that he made is to involve the cooperation of all collaborative members, even if this action extends the decision- making time, it is necessary that all parties have a chance to provide their input. The third point that he made was to list the inclusion of other collaborative members' input in reports and presentations and to flesh expand on out time lines by identifying their input. He was most cordial and gracious in welcoming us to Jordan.

Dr. Al-Ayyash went over my schedule with me since we would not be meeting with Dr. Akrum Tamimi during this visit.

Karen and I were then taken to a local travel agent where we purchased airline tickets for the flight to Aqaba. I then accompanied Karen and the BRDP PR Officer to the Royal Jordanian Office of Geographies. We met with Captain Mofid and he lent his assistance in obtaining an aerial photo of the Aqaba Water Garden site.

1/1/04- Holiday – We took a cultural excursion to Jerash to view the ruins of the ancient city.

B. Aqaba

1/2/04- Boarded the Royal Jordanian airplane at 8:00 a.m. for our flight to Aqaba. We arrived at the Movenpick hotel by taxi and were able to check in after two hours time. We toured the landscaped grounds of the hotel. The vegetation was comprised mainly of non-native plants including bougainvillea, lantana, and hibiscus. The irrigation for the plants was above grade drip; the drip hoses were brown in color and were less visible as they blended in with the color of the soil.

We walked the boardwalk along the coastline. There is a strip of community gardens between the boardwalk and the coastline just past the Royal Jordanian Yacht Club. The gardens are watered with fresh water that is pumped from ground water which lies just below the gardens. It appeared as if radishes and lettuce were the vegetable of choice. These community gardens not only provided functional space to grow food, but they also offered pleasant surroundings for picnic goers. Many of the medians have flowers, palm trees and bushes planted in them and are irrigated with the above grade drip systems. We also visited the linear park which uses a variety of elevations, lights, plants and a

walkway to formulate its ambience. It also has numerous picnic tables and many people were lunching. The park has two fountains and a large water fall. When lit up at night, it becomes an inviting place for the community. Report writing and literature review for modeling the evaporation of bio-solids was accomplished later in the day.

1/3/04- Visited the Hussein Al-Bin Park with Karen for the purposes of learning what is utilized in terms of plants, architectural design and irrigation methods. The entire irrigation system is operated manually. The park uses directed furrow irrigation to water the bushes at the entry section and it uses sprayers to irrigate its grassy areas. For the furrow irrigation, the water flows out of a single large orifice and is guided through bermed channels from the north to the south end of this section. The park also includes at least four fountain structures and different channel ways for water. However, only one fountain system had water in it, the others were non-functional. In general, the plants seemed to be well maintained. The remainder of the day was spent on report writing and reviewing articles of literature written on the topic of estimating soil/bio-solids evaporation properties.

1/4/04- Karen and I were picked up by ASEZA personnel at our hotel and driven to the ASEZA office. We spent a few moments with Dr. Salim Al-Moghrabi. He wondered if our bio-solids research included testing for heavy metals. Apparently there is a slightly elevated level of mercury in the bio-solids characterized from the Aqaba WWTP. The source of the mercury is not known. We were then ushered into the office of the city planner. The discussion revolved around the water garden site that Karen is working on. After this meeting, Karen and I parted ways as I met up with Engineer Taiseer Al-Masri. Engineer Al-Masri is the project manager for the Aqaba Treated Wastewater Pilot Project. Mr. Al-Masri is also a Ph.D. student working on a thesis concerning agronomy economics. He is employed by PA Government Services, Inc. which is a consulting firm contracted by ASEZA. On the way to the wastewater treatment plant we discussed various irrigation methods employed by the community and the progress towards re-use of wastewater and potential prospects for the use of bio-solids.

Utilization of Bio-solids

Before touring the wastewater treatment plant, we stopped at the administration buildings for the Wastewater Re-use Demonstration site. Here I met Engineer Hani Habbab, the site coordinator for the pilot project. I learned that this demonstration site will utilize bio-solids from the Aqaba Wastewater Treatment Plant to fertilize their trees. Chemical and microbial analysis (at the very least) as well as plant productivity will be measured.

Engineer Habbab gave me a tour of the existing wastewater treatment plant. We discussed the retention times of the current facultative and maturation ponds. For all intensive purposes, there is no industrial influent received by the plant, however, it does appear that oil from perhaps the gas stations does reach the plant and was observed to accumulate in one corner of the first maturation pond. It is my understanding that this oil

is cleaned out periodically by the staff, probably by a manual skimming operation. Beyond the facultative and maturation ponds, there are also a number of unlined evapo-transpiration beds. These beds were completely filled with water and remain so during the cooler months.

Current Production of Bio-solids

Engineer Habbab and I drove around the site to observe the existing bio-solids. During the summer months the evapo-transpiration ponds dry out periodically. When they do, the bio-solids are removed from the dried ponds and buried onsite. Deposits of bio-solids are being unearthed as part of the current excavation to accomplish construction for the new WWTP. The excavated soil is placed in piles around the current construction site. Soil containing bio-solids is separated from soil void of bio-solids. There appears to be two different types of bio-solids formed. One type is similar to the morphology that we have observed in our field experiments (in Tucson, Arizona), i.e. bio-solids, which are aerobically digested. They are black in color and clumped into

Figure 1. Bio-solids unearthed at Aqaba WWTP.

dense masses. I separated the clumped material with a rock. It appeared to be in the range of 95-97% TS. The second type of "bio-solids" appeared to be similar to a peat material, containing wood chips. There was no odor associated with either type of material.

Later that afternoon, Engineer Al-Masri arranged a meeting with the engineer constructing the new expansion of the WWTP, Mr. Zimmer of Morgan and Watson. We also met the Jordanian engineer responsible for the infrastructure of the sewer pipe and waste water re-use system that is being placed to connect new housing to the sewer system and to provide for the infrastructure for agriculture re-use water and a separate system for urban re-use water. Agricultural re-use water will be processed by the current plant (not certain of the point of diversion); while the urban re-use water will be

processed by the new plant. The new plant will have an initial capacity of 12,000 m^3 and will utilize a sand filter and UV radiation to achieve the tertiary level of treatment.

Method of Bio-solids Digestion

It is important to understand the treatment methods that will be employed by the treatment plant in order to understand the characterization of the solid residuals or bio-solids that will be produced. The following is a description of the plant from the information that I gathered from the site visit and the discussion with the engineer responsible for the construction. A new administration building and head-works station are being constructed, a stagnant detention basin will serve as the anaerobic stage, and a large oxidation ditch will function under constant aeration. The effluent will be sent to two large clarifiers and then to the sand filter and UV station (not clear as to whether chlorination is a part of the treatment process). No digestion tanks or other methods of thickening will be employed; therefore the solid residuals from the clarifiers will be directed to the drying beds. Polymers will not be utilized at this plant.

Drying Beds

The new expansion of the treatment plant will contain 64 drying beds (initial phase capacity). The design of the individual drying beds is similar to the standardized methods referred to in Metcalf and Eddy, 2003. The beds will slope to the center at an incline of 3% towards a French drain which runs lengthwise along the bed at a slope of 1%. The drainage from these beds will be returned to the head-works of the plant. The beds will be lined with high density polypropylene (HDPE), followed by a layer of sand, a layer of gravel, and a second layer of sand. The bio-solids placed in each bed will be approximately 300 meters in depth. The beds are designed with ramps and can be accessed by a bobcat (small front-end loader) for removal of the dried bio-solids.

Characterization of Bio-solids

After the tours of the two portions of the treatment plants, we discussed the test results carried out to analyze the bio-solids on site. The bio-solids were tested for N,P,K levels as well as heavy metals and microbial quality. Again the issue of mercury was brought up; it was the one heavy metal that was above Jordanian standards. At this time, no one seemed to have an explanation for the source of the mercury. Salmonella and helminth ova were assayed, with the results indicating none present and none detected, respectively.

Communications

The distance from the new Administration buildings to the drying beds is within 1 km. The available construction plans did not provide take-offs and we were warned that "things change daily" on the construction site. Therefore, it is difficult to tell at this time whether there will be line of sight between the two points (drying beds and administration building). However, it is very probable that a communication tower will help to resolve any line of sight issues. The Administration Buildings for the Wastewater Re-use

Program were outfitted with a landline telephone system as well. Engineer Al-Masri and Engineer Habbab both used their digital cell phones extensively. Therefore, it is highly plausible that remote communication can be established; the type of equipment will depend on where the base station is located and the cost of service by the cellular phone providers.

Engineer Al-Masri and Engineer Habbab were very helpful in taking the time to accompany me on the tours of the existing treatment plant and the plant under construction, as well as arranging the impromptu visit with the engineers responsible for the plant construction and the construction of the piping infrastructure. This new facility should come on line in the year 2005. It will be an optimal place to conduct research on pathogen reduction in bio-solids in response to stress units and easily lends itself to research regarding land-application of bio-solids due to bio-solids utilization in the Wastewater Re-use pilot program.

I returned to the hotel around 4:45 p.m. and left Aqaba to depart for Amman via the commercial airlines.

C. Introductory Meeting with the RSS

January 5, 2004- I met with Mr. Wael Suleiman, Environmental Engineer, and Mr. Ali Al-Omari, Senior Analyst of the microbiology laboratory. We discussed wastewater treatment and the states of bio-solids in general in order to give me with an overview of these subjects and their status in Jordan. There are 19 wastewater treatment plants (WWTPs) in Jordan. The older plants are hydraulically and organically overloaded. However, there is continuing progress towards the mechanical treatment of wastewater influent as evidenced in Aqaba. There is also a pervasive trend to construct typical sand drying beds in each of the new WWTPs. The next treatment plant scheduled for upgrade is Assamra. The two gentlemen gave me a short tour of the chemistry and microbiology laboratories within their department. We discussed the bio-solids characterization research that the RSS has been undertaking which includes the assessment of trace elements, N,P,K, heavy metals, and pathogen/pathogen indicators of bio-solids at three different WWTPs. A copy of Mr. Suleiman's recent power point presentation on the subject was supplied to me. As mentioned in Dr. Choi's report, bio-solids in Jordan for the most part are either disposed of at land fills or stored on site at WWTPs.

I delivered my power point presentation which describes the recent research work that we had performed on aerobically and anaerobically digested bio-solids at the University of Arizona during the summer and fall months of 2003. I also integrated the goals of the collaborative proposal into my presentation, such as real-time data acquisition, and pathogen reduction relative to stress units. We discussed the proposal on a cursory basis.

The Jordanian microbial quality for bio-solids for the purpose of land application is <2x10^6 MPN/g. It is my understanding that they do not have a tiered classification system. The standards used for microbial assaying are the same as we utilize in the

United States. The characterization studies do involve obtaining an MPN for TFCC (Total Fecal Coliform Count), and an absent/present test for salmonella and the detection of helminth ova.

During our discussions, we reviewed our objectives in carrying out the research that was proposed. Mr. Suleiman's main objectives in addition to those governed by the proposal are to:

1) Build relationships with other institutions abroad.
2) Determine the optimal time necessary for the bio-solids to remain in the drying beds.
3) Decrease the existing holding times of bio-solids once reaching an acceptable quality.
4) Establish guidelines for WWTP operators using drying beds.
5) Have a staff member attend the University of Arizona to obtain a Ph. D. education.

We then discussed the establishment of a website, the posting of the relevant data, and the java script that the University of Arizona utilizes. I provided Mr. Suleiman with a copy of the java script. He confirmed that RSS does have the capability to establish a website and post the data as necessary.

D. Wadi Musa

January 6, 2004- Mr. Suleiman, Mr. Al-Omari and I traveled to Wadi Musa by vehicle. During our initial visit to the Wadi Musa WWTP, we met with Engineer Hayder. He gave us an introduction of the history and operation of the plant and the drying beds. Mr. Suleiman iterated to him that we were there specifically to settle on the location of our research activities regarding the monitoring of bio-solids drying. Because of time constraints, we went directly to the drying beds of which there are a total of sixteen. Twelve are presently being utilized. It is my understanding that lesser numbers are utilized during the summer season because of the reduced drying time; the cycling period for bio-solids production is much shorter.

The current management practices of the WWTP regarding bio-solids management are that the sludge is wasted from the sludge tanks to a depth of 20-25 cm into the drying beds that have been in production since the plant opened. The dimensions of each bed are 10m x 35m. Only 10-15 cm of bio-solids (depth) are wasted into beds that have experienced little use (the difference is the existing depth of the pre-placed sand and gravel). After 4-6 weeks, the bio-solids are removed manually (by shovel and wheelbarrow) and placed in front of the bed outside its walls (along the width) in a pile. The retention time in the drying beds is less in the summer season, typically 2-4 weeks. To date, none of the sand in the beds has been replaced. Some time afterwards, the bio-solids are moved to the open storage area near the far beds. The determination for bio-solids removal from the beds is time dependent, and/or based on visual observation by the operator; no quantitative measurements are made prior to removal.

Figure 2. Recently placed bio-solids at Wadi Mousa WWTP, January 7, 2004.

At the time of our visit, there were drying beds filled with bio-solids at different stages (days) of drying. A thin white layer forms on the very top of the bio-solids cake, much like we have observed in the bio-solids produced while conducting research work in Arizona. The bio-solids in the beds were cracking and shrinking. One bed had the bio-solids removed and placed just outside its walls. The material seemed to be in the range of 75% TS or less (a thick mud-like cake); it is difficult to judge. The biological results from the RSS analysis for bio-solids at this site are such that no salmonella or helminth ova were detected. TFCC was found to be in the range of 23 MPN/g to 9x10^4 MPN/g.

Figure 3. Recent bio-solids in drying beds at Wadi Mousa WWTP-January 7, 2003

Remote Data Acquisition

At this time there is no land-line telephone at the Wadi Musa WWTP. The operators communicate solely by cell phone. However, there are certain locations where even the cell phone communication does not work within the confines of the WWTP. It is my understanding that this happens near the administration building. Engineer Haidar also commented that land-line telephone system should be installed in the plant within two months.

There is direct line of sight from the drying beds to the repeater. It is approximately 1.5 km away. Mr. Wael will check with the cellular phone providers (of which there are two, Fastlink and Mobilecom) to determine which protocol is utilized by these companies and therefore the type and power consumption of the modem necessary to provide a data-link between the remote acquisition station and the RSS Office in Amman.

Although it is possible that a land-line telephone system will be installed at the Administration building within two months, there is not line of sight between the drying beds and the administration building. Communications via a RF link will require a tower and a separate weather enclosure to mount and house the RF radio. A base station consisting of a Com210 modem, two RF radios and a second telephone line will have to be established if this is method of choice. I recommend pursuing the cellular phone link as the means of providing remote communication.

The WWTP closes at 1600 hours; therefore we adjourned our meeting and returned to the hotel. We later continued our discussions into the late evening and over dinner, regarding specific issues on how we intend to carry out the research project. We discussed the list of instruments which will comprise the remote weather station and communication system. The RSS will build the tripod with local materials and gather stakes, the grounding rod, and copper wire and clamp for the grounding rod as well. Mr. Wael is deciding on the use of one versus two drying beds. Perhaps the depth of the bio-solids placement will be varied for the second drying bed. This parameter can be integrated into determining a mathematical model for pathogen reduction and for developing guidelines to assist WWTP operators in the optimal depth versus the time needed to achieve the desired quality of bio-solids. For now, we decided that four water content reflectometry probes are a suitable quantity for carrying out the research. We discussed the need to stake down the weather station and provide an electrical ground to stabilize the station and prevent it from being blown over by the wind. It was also suggested that after the RSS receives the instruments for the weather station and communication equipment, that an electronic technician from the RSS assemble the weather station at the RSS laboratory and test its operational and communication capability. The justification for using a technician is that this move will allow the RSS to become very familiar with the idiosyncrasies of the equipment and will enable them to troubleshoot electronic hardware or software problems rather efficiently and as the need arises. A two week time period to set-up the remote station would be a fair assessment of allotted time. In this time period, the technician should also develop the "EDLOG" program to control the sampling and storage periods for the environmental data that is to be collected. I will be available by email and telephone for consultation while the remote station is being assembled. Once the system is operating, I can travel to Jordan where we (the electronic technician and I) can test the equipment one more time and then disassemble the individual instruments and pack them for travel. We will then site and ground the weather station, re-wire the instruments, and re-test the operations of the sensors and the communication system at the Wadi Mousa WWTP. At this time, we will also secure the water content reflectometry probes and thermocouple wires.

The other issues that we discussed involved securing of the water content reflectometry (WCR) probes in the beds so that they will not become dislodged during the pour of the bio-solids and throughout the duration of the field experiment. (Our plan is to secure the head of the probes with a strap and stake assembly onto the floor of the sand of the drying bed bottom). Also, the WCR probes must be calibrated with bio-solids from the Wadi Musa WWTP. Calibrating probes after placing them into the beds and during the field experiment is a near impossible task as we discovered with our research at the University of Arizona. Instructions for calibrating the WCR probes are contained within the specifications and manual for WCR probes provided by Campbell Scientific.

The methods and time tables for sampling were also discussed. We talked about taking three grab samples to make one composite sample and taking two composite samples (regional, north and south) from each bed. We also discussed taking the sample from the top of the bio-solids' cake down to the bottom to represent the entire depth of bio-solids.

Personnel will have to enter the bed in order to obtain the samples. The number of grab samples necessary to produce a composite sample is worth further discussion.

Finally, we talked about the microbial analysis that will take place in conjunction with the monitoring of the environmental data. Mr. Al-Omari will coordinate the sampling and testing as well as supervise the laboratory work. Samples will be taken on Day 0 and then two times per week thereafter. The expected drying time for the beds during the summer months is 4 weeks. The tests to be carried out are the MPN test for fecal coliform, and the MPN test for salmonella. The microbial tests must be quantitative in order to provide relevant information for the formulation of the mathematical model. It may be possible to test for salmonella on a weekly basis rather than bi-weekly. Also, the idea of testing for helminth-ova on Day 0 and then again at the end of the field experiment was discussed. Biosafety and methods of sampling in relation to this topic were also included in our conversations. When a staff person enters the drying bed, that person will wear rubber boots for protection. Of course gloves will be utilized at all times by his staff, and water will be available at the drying beds to allow for "washing" of the equipment and boots as needed. In addition, we discussed having individual sets of autoclaved sampling equipment to procure the composite samples. (Two separate sets will be needed if one drying bed is utilized, four separate sets will be necessary if two drying beds are utilized). Bio-solids samples will ultimately be placed in sterilized containers or bags and placed on ice while they are transported to the RSS laboratory. The microbiological assays will be initiated within 24 hours of sampling.

Bio-solids Quality

January 7, 2004- We revisited the WWTP in order to take the tour for the treatment process concerning wastewater influent and to gain a better understanding of how the solid residuals are formed. Engineer Haider described the flow of influent as a batch flow rather than a continuous flow because of the low number of tourists in the region and also due to the low amount of water usage per capita of the local people. In addition to creating operational challenges, these occurrences also create higher BOD levels. The designed treatment process for solid residuals at this plant are such that the activated sludge is held in tanks where thickening and anaerobic stabilization occur. The stabilization process typically yields bio-solids that are on the order of 6% TS when released to the drying beds.

Prior to leaving the WWTP, we revisited the drying beds to select the optimal beds for the experiment. We decided on the last two beds (which have not been used to date) that are nearest the dried bio-solids storage area. This location has direct line of sight to the repeater located on the nearby hill and it is relatively isolated from ordinary traffic. We will have to make use of a DC battery, trickle-powered by a solar panel since AC power is not readily available in a nearby location.

There exists another Wastewater Re-use site, a pilot program that is being administered by PA consulting. A variety of trees and other plants are being irrigated with the re-use wastewater from the WWTP. It may be that the bio-solids produced from the plant will

be land-applied onto this project in the future after our collaborative research has been carried out.

We visited Petra on our way home to Amman after completing our work at the WWTP.

E. **Tour of WWTPs north of Amman**

January 8, 2004- Mr. Al-Omari and I visited the Assamra, Wadi Hassan, and J.U.S.T. wastewater treatment plants to understand the production methods for solid waste residuals and the current management practices afforded to bio-solids.

The Assamra WWTP

Engineer Mohammed provided us with a brief background of the processing methods utilized by the treatment plant. This plant handles the majority of wastewater influent for all of Jordan. It is located north of Amman and services Amman, as well as Zarqa and surrounding villages. Its current volumetric load represents 75% of all the wastewater produced in the entire country. The treatment plant was built in 1985 and is now handling 3 times its design capacity. The WWTP consists of 30 stabilization ponds of

Figure 4. Seven year-old bio-solids dredged from primary ponds at Assamra, photo taken January 8, 2004

which there are 3 separate pathways. At the head-works, influent flows serially through bar screens and grit chambers as well as fine screens located after the grit chambers. Beyond this equipment there is no mechanical treatment, and the water flows in succession into the next 10 ponds by gravity. Bio-solids are "formed" in the initial two ponds by solid waste settling. These ponds have scum on the surface and there is also some vegetation scattered within. Seven years ago the sludge from the bottom of these ponds was pumped into nearby unlined earthen detention basins. I estimate the depth of the bio-solids in these basins to be 30 cm. The bio-solids appear pure black (with no white crusting on top) and are moist (it has been raining now for two days) but there exists large shrinkage cracks. It is my understanding that the bio-solids have been there since they were dredged from the initial ponds and there are no plans at this time to move them or utilize them. The new WWTP will provide mechanical treatment for the effluent. Characterization analysis of bio-solids from this plant would be very informative for future use. The Assamra plant is surrounded by 20,000 olive trees and a variety of other trees in addition. The trees are irrigated with re-use wastewater from the plant. Contractors harvest the olives from these trees.

At the Wadi Hassan WWTP we were greeted by Engineer Jalal. This is a very modern plant that utilizes the activated sludge method of oxidation ditches operating aerobically and anaerobically to achieve secondary treatment of its wastewater influent. The plant is also controlled by computer automation that also allows the engineer not only the freedom of remote control but also the ability to acquire and maintain historical data regarding chemical and operational information. This plant also uses typical drying beds for sludge dewatering. The bio-solids are wasted into the drying beds (utilized only during the summer) and dried for a period of 2-4 weeks. The bio-solids are then removed by hand and trucked off to a designated dumping site. In the winter time, sludge from the sludge tanks are removed daily by tankers (see Figure 5) and taken to a nearby site designated for dumping.

Figure 5. Bio-solids tanker from the sludge tank at Wadi Hassan WWTP, photo taken January 8, 2004

The RSS performed characterization studies of the bio-solids produced at this plant. The biological characteristics demonstrated no salmonella or helminth ova eggs were detectable. The density level of TFCC (total fecal coliform count) ranged between 920 MPN/g and 1.6 x 10^6 MPN/g.

J.U.S.T.

The Jordanian University for Science and Technology (J.U.S.T.) was the last WWTP that we visited. It treats the wastewater influent for the campus and neighboring villages. It receives its influent from both gravity pipes and lift stations. This is an older plant that utilizes surface rotating biological contactors to achieve the biological processing for treating the water. This plant has very small loads, and therefore a very limited amount of solid residuals are produced. The sludge is held in a retention tank and is removed periodically by tankers trucking it to landfill sites. The expansion plans for this site do include the construction of drying beds. However, there is no definite date for the expansion. The RSS also performed biological analysis on the plant's liquid sludge. No salmonella or helminth ova were detected. The TFCC ranged between 7000 MPN/g and 3x10 ^5 MPN/g.

IV. Final comments

As noted in Dr. Choi's report, it is imminent that the re-use or recycling of bio-solids will become a key issue in Jordan as WWTPs are upgraded to mechanical methods of treatment. The ongoing research concerning the characterization of bio-solids is very important in establishing baseline information on the fertigation aspects, the biological quality and the level of heavy metals of bio-solids produced by the different WWTPs in Jordan. However, the development of a stress unit (mathematical model) that quantifies and predicts pathogen quality in bio-solids in terms of environmental parameters will help ensure the safe production of bio-solids during different seasons and in the case of rain events. The collaborative efforts between the RSS and the University of Arizona will be crucial in establishing this mathematical model. The results will be very beneficial in allowing the safe re-use and recycling of bio-solids in both Jordan and the United States. The mathematical model will help develop a unit of measure that can be commonly utilized and understood by those in the industry and in academics to label the quality of bio-solids during the drying process. The model will also help establish written guidelines for WWTP operators regarding the management and production of a safe quality of bio-solids. Finally, the model in conjunction with educational programs will help provide confidence in the re-use of bio-solids for agricultural land-application.

As a follow-up to this trip, I will do the following:

1) send to Mr. Suleiman's attention, a sketch of the tripod unit (to scale) and list of materials necessary to construct and ground the weather station;

2) send a booklet or copy of the booklet describing the specifications, wiring, set-up and programming for the WCR probes. Utilizing this information, an electronics technician will be able to gain an idea of what will be expected of him/her; and
3) after hearing from Mr. Suleiman regarding the protocol and the modem specifications that are necessary to achieve remote cellular communication, I will be able to begin ordering the sensors, datalogger and power supply.

In summary, as Jordan upgrades its WWTPs from stabilization ponds to mechanical treatment systems, drying beds are being constructed as a method of sludge dewatering. The drying beds also allow for the opportunity to reduce the pathogen level and therefore the health and environmental risks associated with the disposal or recycling of the bio-solids. Drying beds located at the Wadi Musa WWTP will be an excellent site to carry out the collaborative bio-solids project. The drying beds are representative of the typical method of dewatering sludge and the climate is similar to that in Tucson, Arizona. In addition we will be able to conduct our field experiment with no interference to the regular routine of the operators at the WWTP. At the same time, it appears that we have the full cooperation of the personnel at this site. Very importantly, I can also state with confidence, that Mr. Suleiman and Mr. Al-Omari and I have forged a healthy relationship and we understand that we must maintain open and constant communication in order to meet the objectives of this research project.