

**Planning Trip for Sustainable Development of Dry  
Lands Project - Jordan Component**

**Biosolids & Wastewater Reuse**

by

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## 1. Introduction

Dr. Peter Waller and I traveled to Jordan from July 21 to July 29. The primary objective of our visit was to initiate collaborative research activities in the biosolids project and to identify potential collaborators in the areas of biosolids treatment and safe reuse. My preliminary assessment of Jordanian situations is based on the proposal (“Assessment of Biosolids Quality at Domestic Wastewater Treatment Plants of Wadi Mousa, Wadi Hassan and Jordan University of Science & Technology for Agricultural Land Application” by RSS, May 2003), on the revised scope of work for Jordan (“IALC Sustainable Development of Drylands Project - *Scope of Work for Jordan*” by Dr. Freitas, May 2003), and on the assessment reports from Jordan by Dr. Tamimi (May-June 2003). Two different versions of the presentation materials were prepared; one focused on wastewater reuse for presentation in Aqaba and another on biosolids for presentation at the Royal Scientific Society. The planned activities were delayed two days due to an unexpected British Airways strike in London. Accordingly, Dr. Tamimi rearranged the entire meeting and tour schedule. Thanks to Dr. Tamimi’s efforts, we were able to complete our trip successfully. The list of our activities in Jordan is presented in Table 1.

## 2. Aqaba

Shortly after our arrival at Queen Alia Airport near Amman, we headed for Aqaba, the only port in Jordan. Aqaba has great strategic importance as a city, resulting in the need to accommodate industry, trade, tourism and environmental conservation despite a restricted coastal line (27 miles long) with coral reefs. It took about four hours to reach the city. The scenery from the airport to Aqaba was mostly desert. However, I noticed the weather was cooler than in Tucson until we passed through the Wadi Rum area. Aqaba was hot and dry. Daytime maximum temperatures were consistently around 40°C during our stay.

Immediately after our arrival, we visited ASEZA. We had a meeting with a group that included Dr. Bilal Bashir, head of the ASEZA Economic Zone, and Dr. Robert J. Cardinalli, technical director and head of the water reuse program at PA Consulting. Dr. Tamimi introduced us to the attendees. He initiated the meeting with the formal introduction of the IALC, the objectives of our visit, and the possibility of collaborative work. Dr. Bashir explained the uniqueness of the city and the autonomous governing structure of the ASEZA Economic Zone. He noted that all regulations were independently set to promote investments and the lowering of tax barriers.

Table 1. List of Activities in Aqaba, Wadi Mousa, and Amman.

Date	Description of Work
7/19-7/20	<ul style="list-style-type: none"> <li>• Travel delayed due to the British Airways strike</li> <li>• Akrum Tamimi rescheduled meetings and activities in Aqaba, Wadi Mousa, and Amman</li> </ul>
7/21/2003	<ul style="list-style-type: none"> <li>• Travel from London to Amman, Jordan</li> </ul>
7/22/2003	<ul style="list-style-type: none"> <li>• Arrival at Queen Alia Airport near Amman, Jordan</li> <li>• Travel to Aqaba</li> <li>• Meetings with Dr. Bilal Bashir (Commissioner for Environment, Regulation &amp; Enforcement) and three other representatives from ASEZA and with Dr. Robert J. Cardinalli and two other representatives from PA consulting</li> </ul>
7/23/2003	<ul style="list-style-type: none"> <li>• Aqaba site visits including the future cactus garden site, wastewater stabilization ponds, potential farm sites using wastewater, landscaping sites around the city of Aqaba</li> <li>• Seminar and discussion sessions at Aqaba Marine Park – PowerPoint Presentation about wastewater reuse and biosolids (about 10 attendees)</li> <li>• Discussion session with Dr. Bilal Bashir</li> </ul>
7/24/2003	<ul style="list-style-type: none"> <li>• Travel from Aqaba to Wadi Mousa</li> <li>• Tour of the Wadi Mousa WWTP guided by Mr. Hayder Rawashdeh, Manager and Sanitary Engineer</li> <li>• Meeting with PA Consulting representatives including Charles W. McElroy (Chief of Party, Water Reuse Program, PA Consulting)</li> <li>• Tour of the wastewater irrigation site and the visitor center near the Wadi Mousa WWTP</li> </ul>
7/25/2003	<ul style="list-style-type: none"> <li>• Brainstorming session with RSS representatives including Dr. Bassam Hayek (Director, Environmental Research Center) and Mr. Wa'el Suleiman (Water and Environmental Engineer)</li> <li>• Proposal planning for the IALC-RADAC</li> <li>• Preliminary budget for the RADAC proposal</li> </ul>
7/26/2003	<ul style="list-style-type: none"> <li>• Revisited RADAC proposal ideas and preliminary proposal writing</li> <li>• Travel from Wadi Mousa to Amman</li> </ul>
7/27/2003	<ul style="list-style-type: none"> <li>• Presentation to U of J, RSS, JUST, and BRDP representatives (about 10 attendees)</li> <li>• Discussion session with attendees</li> </ul>
7/28/2003	<ul style="list-style-type: none"> <li>• Visited RSS – extensive lab tours guided by Dr. Hayek and Mr. Suleiman</li> <li>• Met with the RSS director – Dr. Said Alloush</li> <li>• Met with Dr. Amal Hijaji (USAID - Project Management Specialist, Mission Environment Officer) at U.S. Embassy in Amman</li> <li>• Dr. Mohammad Shahbaz, Program Director at The Higher Council for Science and Technology</li> </ul>
7/29/2003	<ul style="list-style-type: none"> <li>• Travel from Amman to the airport</li> <li>• Jordan to London</li> </ul>

Three representatives from the PA Consulting group explained that they had recently launched a project in Aqaba. They hoped to start planting trees and shrubs by the end of the summer. We also learned of a new construction project planned for the WWTP. Wastewater was a significant topic in this meeting. Specific interests included:

- Landscape Irrigation
- Nursery Assistance, and
- Selection of Plants.

The attendees, led by Dr. Bashir, were generally interested in “immediate” implementation instead of “continuous planning.” Overall, the meeting was friendly and people were open-minded. The ASEZA people appeared well-organized, and everyone spoke fluent English.

The following day started with a series of site visits in the morning. We were scheduled to visit five different locations:

1. Treated Wastewater Pilot Project Demonstration Site
2. Aqaba Wastewater Treatment Plant
3. Civil Aviation Land (about 100 ha. planned for wastewater reuse for the fodder crops)
4. Adjacent Date Palm Farms (Al-Haq Farm - about 70 ha.) irrigated by wastewater
5. ARIE (Agricultural Industrial Estate?) – Future wastewater reuse site.

On the way to each site, Dr. Waller and I requested frequent stops to view landscape irrigation practices. Due to our frequent stops, we were unable to visit the last two sites as originally scheduled.

At the second stop, we quickly realized the current state of wastewater and biosolids in Aqaba. Our first impression was that the WWTP had a few big ponds (Figure 1). We learned that the plant has:

- Facultative ponds
- Maturation ponds, and
- A pumping station.

These ponds are probably acting anaerobically (water retention time = 17 days), producing the somewhat offensive odors I experienced at the site. The removal and reuse of the biosolids at the bottom of the ponds were of major environmental concern. At present, the trees and shrubs on the streets were irrigated using surface hoses with microirrigation emitters. The water quality does not appear adequate for agricultural and landscaping purposes, and water was provided by water tankers, as shown in Figure 2.



Figure 1. One of the ponds at Aqaba WWTP.



Figure 2. Water from Maturation Ponds and a Water Tanker.

At present, the facility produces 9,000 m<sup>3</sup> of “treated” wastewater per day. The current usage of the water was:

3,000 m<sup>3</sup> pumped to Al Haq Farm

5,000 m<sup>3</sup> irrigation for trees and shrubs

1,000 m<sup>3</sup> lost through seepage and evaporation.

City streets were generally well-maintained using this water. For long-term success of wastewater reuse, Dr. Waller and I agreed on the proper training of technicians. He proposed the concept of “water police,” based on his experience in Tucson and Phoenix. The use of aluminum and polyethylene irrigation tubing was visually unappealing. However, construction of a comprehensive irrigation system can wait until the completion of the

modern wastewater plant in Aqaba. I felt that advanced microirrigation schemes, including drip and subsurface drip irrigation for agriculture and landscape purposes, would require additional water treatment and/or filter systems to avoid physical and biological emitter clogging due to poor water quality.

We were informed about a new, USAID-supported construction of a secondary, extended aeration treatment plant with a capacity of 18,000 m<sup>3</sup>/day to support 80,000 people and reconstruction of the existing ponds to provide disinfection of the secondary effluent. This project includes the construction of a new reclaimed water pumping station, transmission mains and open reservoir, rehabilitation of the main pumping station, and instrumentation of these and three other small sewerage pumping stations. The project is scheduled to be completed by 2005.

At the Civil Aviation Land, we had an excellent conversation regarding the reuse of wastewater for agricultural crops. Crops under consideration were coconut, mango, guava, etc. Health risk issues should be under consideration for these edible crops. Dr. Waller suggested a nursery, which may be an integral part of the future landscaping projects of Aqaba. Using brackish groundwater (TDS = 2000), they were considering planting watermelon and cantaloupes this fall at another location, presumably near Aqaba. Salt buildup in soil should be carefully studied for the given crops.

In the afternoon, we went to the Aqaba Marine Park, located south of Aqaba. This seven km (out of 27 km) coastal area has been zoned as a Southern Tourist Development Area to include hotel development, and the park was strategically positioned near the future tourist attraction. We saw a few housing construction sites and small-scale hotel development. Dr. Waller and I presented PowerPoint slides related to wastewater reuse and biosolids (Figure 3). There were about 10 attendees, including Dr. Bashir. Irrigation and wastewater reuse were the main topics for the presentation. Most questions came from Dr. Bashir, who wanted to know about our specific collaborative plans. He reiterated his interests in “implementation” over “continuous planning.” In addition, he was interested in training programs for the proper implementation and maintenance of irrigation systems.

After the afternoon schedule, we went back to the area for two hours of snorkeling. It was spectacular to experience the coral reefs and see the fish in the Red Sea. During our stay in Aqaba, we engaged in a few conversations with various people, including a U.S. scientist, Dr. Michael Crosby, about environmental issues in the region, particularly about the threats to the coral reefs in the Gulf of Aqaba. I found that the destruction of coral reefs is an important issue for Jordan and Israel. Perhaps it is safe to assume that there are multiple

factors; thus, both sides must collaborate together to combat the destruction. Those factors include: (i) fish farming, (ii) phosphate export, and (iii) non-point source pollution due to urbanization, agriculture, and groundwater contamination. It appears Dr. Crosby has played an important role in organizing bi-national meetings related to these issues. He has worked with both Jordanian and Israeli scientists in the region.



Figure 3. Presentation at the Aqaba Marine Park

### 3. Wadi Mousa

Petra is known as one of the premier tourist destinations in the Middle East. We were told that Petra and the surrounding communities had grown tremendously in recent years. For sustainable economic growth and environmental protection, adequate water supplies and wastewater services were planned, and the USAID contributed financially for construction and supervision of the Wadi Mousa WWTP. The plant started its operation in April 2001. It is one of the ongoing infrastructure building projects in Jordan, which include: (i) As Samra Wastewater Plant (to be completed in 2006) and (ii) Aqaba Wastewater Treatment Plant (to be completed in 2005, as mentioned earlier). Needless to say, new As-Samra and Aqaba treatment plants will replace the existing inadequate, overloaded wastewater treatment systems in Amman and Aqaba. Thus, it is my view that successful small-scale collaboration with qualified Jordanian scientists and engineers at the Wadi Mousa WWTP can lead to larger-scale collaborative work in Aqaba and Amman in the future.

Immediately after our arrival in Wadi Mousa, we visited the WWTP. Hayder Rawashdeh, Manager and Sanitary Engineer, guided us through the WWTP. Dr. Bassam Hayek, Director of the Environmental Research Center from the Royal Scientific Society, and Mr. Wael Suleiman, Water and Environmental Engineer, also from RSS, joined the tour. Two professors, Drs. Hani Saoub and Jamal Sawwan, from the University of Jordan also joined us.

Overall, the plant was very impressive. It appears that it was well designed, constructed, and maintained. A scrubber unit was installed at the beginning of the wastewater process; thus, there was no foul smell in the vicinity of the WWTP. The aerobic process time was about 17 days, while the anaerobic process time was approximately half a day. The effluent quality appeared to be adequate for microirrigation irrigation technologies.

My main interests at the site were the biosolids drying beds and production. Solid contents of the biosolids introduced to the beds were about 4-6 percent. Eight conventional sand drying beds were constructed at the site, as shown in Figure 4, as a means of sludge dewatering. Due to the sand layers, I was unable to observe the drainage units. However, I was told that drainage gravels and tubing were installed. Therefore, these are somewhat equivalent to the new Green Valley WWTP drying beds near Tucson, Arizona.

The sludge was not mixed with polymers at the moment. The total drying time was estimated at about 3-6 weeks during the summer. No one was sure about the drying time during the winter. The dried biosolids were manually removed to the nearby storage area (Figure 5). It appears no one checked the microbial quality of the biosolids. Thus, there was no way to determine whether the dried biosolids meet Class A standards or not. There was significant concern about the health risks if used for edible crops. At the WWTP, workers applied dried biosolids around poplar trees. Mr. Rawashdeh mentioned that these trees appeared to grow “very fast” due to the biosolids application. An ongoing comparison study (biosolids applied to poplar trees vs. control) in Spain under the supervision of Prof. Miguel Salgot (The University of Barcelona) should be informative.

The daytime temperature appeared about 5°C lower than Tucson during our visit, and the relative humidity appeared to be low. Thus, the weather conditions should be ideal for the biosolids drying process. The entire area is securely fenced and located far away from residential areas. Wadi Mousa is located approximately 200 km away from Amman, a distance that can be covered in the span of a day. Dr. Hayek indicated that he can send RSS personnel to the site once a week or so for biosolids sampling. Thus, it is an ideal location to set up a data acquisition system including a weather station, radiofrequency units, data loggers, a cell phone, etc.

At the site, we had a meeting with PA consulting, RSS, and U of Jordan people (including Mr. Charles W. McElroy, Chief of Party, PA Water Reuse Program for the USAID project, and Dr. Robert J. Cardinalli, technical director and head of water reuse program at PA Consulting). The meeting generally focused on the water reuse program and the construction of the visitor’s center. Then, we visited the demonstration garden, wastewater

reuse site for agricultural crops, and the visitor's center site. I was told that the maintenance was not easy due to inconsistent labor forces. I felt that the garden and wastewater projects could be completed on a commercial scale with abundant treated water resources. I was sure that the construction cost of the visitor's center could be expensive. The current budget for the construction of the center is approximately US \$ 20,000. These topics are further described in Dr. Waller's report.



Figure 4. Conventional Sand Drying Beds at the Wadi Mousa WWTP.



Figure 5. Biosolids Storage at the Wadi Mousa WWTP.

#### **4. Research Needs and Collaboration Plan**

For the rest of the stay in Wadi Mousa, we focused on research proposal development. Dr. Hayek and Mr. Suleiman summarized the current status of the wastewater and biosolids. In Jordan, recent changes in regulations concerning municipal wastewater treatment in Jordan have resulted in a magnitudinal increase in treated domestic wastewater quantities and, accordingly, biosolids quantities. Total generated domestic wastewater quantities had increased from  $57.6 \times 10^6 \text{ m}^3$  in 1992 to about  $88.6 \times 10^6 \text{ m}^3$  in 2002; that is, an increase of about 54 % in a decade. This is primarily due to the expansion in wastewater treatment services and population growth. Although treated effluent reuse plans have been executed since 1986, there are still no definite strategies for the utilization of biosolids for beneficial uses.

Generated quantities of bio-solids from 12 mechanical wastewater treatment plants (MWTPs) were estimated at about  $1000 \text{ m}^3/\text{day}$  in 2002, while about  $250,000 \text{ m}^3$  of biosolids are accumulated in the anaerobic lagoons of 5 plants utilizing natural treatment system (Wastewater Stabilization Ponds WSPs) after their many years of operation. Bio-solids generated at MWTPs are usually thickened, dewatered using drying beds, then disposed of at adjacent dumping sites and landfills, while anaerobic lagoons at WSPs are occasionally de-sludged (for operational purposes) and bio-solids are inadequately stored in nearby areas. In other words, none of these bio-solids are beneficially reused or recycled. Obviously, the current temporary practice cannot be continued. Adverse impacts include potential operational problems such as leachate management (especially in rainy seasons) and gas hazards. Land application is currently the most widely employed reuse option in many countries.

Jordanian regulations for the reuse of bio-solids in agriculture, issued in 1996, have not yet been enforced. It is believed that these regulations need to be refined as they do not take into consideration the dynamic variations in the field (where temperature fluctuations, sunshine hours and rainfall intensities vary widely) when specifying time requirements for sludge to stay in the drying beds in order to be safely reused.

We agreed that the Royal Scientific Society (RSS) of Jordan will collaborate with the University of Arizona to carry out the research project that will focus on development of the stress unit concept to quantify and predict the reduction and inactivation of micro-organisms

in bio-solids for eventual agricultural land application. The specific research justifications and activities include:

- (i) Drying beds are a widely used method of sludge dewatering with significant merits such as low cost and low maintenance. The inexpensive decanting type of drying bed is particularly advantageous under hot and dry weather conditions such as arid and semi-arid Jordan and Arizona. However, both nations face a challenge in quantifying and characterizing the microbial consortia present in the biosolids, particularly to determine the amounts of multiple microbial species and whether pathogens are active or inactive due to exposure to high temperature and low environmental water content.
- (ii) It is essential to develop a model to quantify and predict the reduction and inactivation of microorganisms in biosolids for eventual land use application in arid and semi-arid lands. Information on the conceptual model encountered in the field must be provided by heat and moisture sensors used in the biosolids drying beds to aid in the development of predictive models for indicator and pathogen survival. Since enteric pathogen survival is primarily dependent upon temperature and moisture, this data must be used to develop a model of pathogen survival (die-off) under Jordanian and Arizonan conditions. The primary objective of this project is to provide guidelines to minimize health risks caused by biosolids use.

To achieve our goal, we agreed to submit a completed proposal to the RADAC. If funded, researchers in Arizona would provide technical assistance to set up a data acquisition system at the Wadi Mousa WWTP site. The system would include a weather station, a data logger, thermocouple wires, communication device (RF radio or cell phone unit), 10 watt solar panel & mounting bracket, pyranometer, 10 foot tripod stand with grounding wire, water content reflectometry, and anemometer.

Based on the existing website available through the University of Arizona (<http://ag.arizona.edu/research/cchoi/bsg/BSG/>), we chose to collaboratively develop a common website to share the remotely monitored real-time data. Dr. Hayek and Mr. Suleiman were confident that the computer technical staff at the RSS could greatly contribute to the website development using Java. They also showed interest in sending research staff members to Arizona for long-term training through this grant.

We were able to see Petra after our work on the second day in Wadi Mousa. Mr. Farajat Radwan from PA Consulting volunteered to guide us. He was trained as an irrigation engineer at the University of Jordan, but he was born and raised in the region and previously worked as a tour guide at Petra for many years. The entrance of the ancient city, the Siq, and the city itself were spectacular. The carved city was unbelievably well preserved after more than 2000 years. After spending three hours in relatively quiet Petra, we understood the archeological significance of the area and the importance of environmental protection in the area. We have no doubt that the days for a serene and contemplative visit are numbered. Indeed, we found many hotels were closed during our visit. As the regional geopolitical situation improves, Petra will once again be one of the prime tourist attractions in the Middle East.

The following day (Saturday), Dr. Hayek, Mr. Suleiman and I reviewed and revised the collaborative research plan and the corresponding budget in the morning. After the morning session, we headed for Amman.

#### 4. Amman

On Sunday, Dr. Tamimi, Dr. Waller, and I gave a seminar to the RSS and University of Jordan people in an RSS seminar room. There were about ten attendees, and two of those were planning to visit Tucson this fall. The Badia people could not make it due to scheduling problems and miscommunication stemming from our delayed arrival due to the British Airlines strike. Dr. Tamimi focused on the overview of the RADAC proposal application procedure. My presentation focused on the ongoing biosolids research. Dr. Hayek and Mr. Suleiman were interested in the current data acquisition setup at the Avra Valley WWTP near Tucson and the preliminary data. I also went through the slides relevant to subsurface drip irrigation and wastewater reuse. Dr. Waller presented various issues about irrigation and remote sensing in arid and semi-arid lands. In the evening, we were able to visit a Roman theatre and citadel downtown, the remains of the Roman city of Philadelphia. We also explored nearby marketplaces.

On Monday, we visited the RSS Environmental Research Center labs in the morning. The labs were well-organized. Detailed observations about these laboratories were noted in Ms. Dima Kayed's report. Dr. Hayek indicated that many instruments were donated by Japanese companies. He also indicated ongoing collaborative work with Canadian and EU partners. After the lab tour, we met with the RSS Director, Dr. Said Alloush. He told us the history of the RSS and his vision for the agency.

In the afternoon, we visited the U.S. Embassy in Amman and met with Amal Hijaji (USAID Water Resources and Environment Office). She wanted to learn our opinions regarding the current progress in Aqaba and Wadi Mousa. She was very knowledgeable about ongoing wastewater-related activities in Jordan. She genuinely hoped that we would develop a healthy relationship with Jordanian researchers. It was apparent that she had squeezed the meeting with us into her busy schedule that day because she wanted to discuss our experience in Jordan and our future plans. After the meeting, we came back to the RSS and visited Dr. Mohammad Shahbaz, Program Director at The Higher Council for Science and Technology.

Dr. Shahbaz stated his vision for Jordanian water use (particularly groundwater) and research needs in conjunction with his recent research efforts. His concern was the rapid depletion of aquifers. It appeared he had made a concerted effort to map out a policy for a sustainable water use in Jordan's northeastern desert.

#### 5. Final Comments

Water is the most important resource in Jordan. The water supply and wastewater treatment plants are very important infrastructures for Jordanians. I was glad to hear that additional wastewater plants are to be constructed in Aqaba and Amman in collaboration with the USAID. However, 85 % of the wastewater is currently treated using stabilization ponds, which are similar to the ones we observed in Aqaba. Many people felt that a comprehensive sludge production and reuse program needs to be carried out in Jordan. The RSS ERC laboratories can play a major role in biosolids characterization and analysis in the near future. As Ms. Dima Kayed pointed out in her report, NCARTT can play a prominent role in the safe land application of biosolids in collaboration with the RSS ERC. Dr. Ian Pepper, NSF WQC Director at the University of Arizona, can serve as an important consultant in dissemination of knowledge in the land application of biosolids. Dr. Charles Gerba, Professor and Director of Environmental Microbiology Laboratory at the University of Arizona, can train the RSS staff for microbial analysis of biosolids. Both Drs. Pepper and Gerba will participate in the RADAC proposal development.