Integrated Water Resources Management in the Lower Jordan Rift Valley

Sustainable Management of Available Water Resources with Innovative Technologies

Work package 3, Deliverable D 309

Optimized eco-technology systems

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Infobox

The works of the deliverable D 309: Optimized ecotechnology system designed specifically to achieve the nitrogen removal targets of the Jordanian Effluent Reuse Guidelines are summarized in the PhD thesis of MSc. Ghaida Abdallat (submitted in June 2015). The thesis had been supervised by Prof. Dr. Roland A. Müller, Environmental and Biotechnology Center, the Helmholtz Center for Environmental Research – UFZ, Leipzig.

So far the thesis is not yet published. Therefore only the title and the abstract of the thesis is represented as an overview.

Optimization of Nitrogen Removal in Various Vertical Flow Constructed Wetland Designs and Application of Treated Wastewater for Reuse in Irrigation in Jordan

A thesis submitted to the Faculty of Environmental Sciences and Process Engineering at the Brandenburg University of Technology Cottbus, Germany in partial fulfilment of the requirements for the award degree Doctor of Philosophy (Ph.D.) in Environmental Sciences

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Abstract

In arid countries, reclaimed water in irrigation is a widespread practice. Therefore, robust treatment designs are prerequisite to obtain effluent quality that conforms to the legal requirements and guidelines for reuse and health standards. Vertical flow constructed wetlands (VFCWs) are attractive decentralized treatment plants in many countries and communities. VFCWs are capable of providing adequate treatment for organic and solids removal, even though there are limitations on nutrient and pathogen removal. Within the context of the SMART project, various VFCW systems were investigated, in Germany and Jordan, to optimize nitrogen removal using sustainable and low cost options to guarantee the safe reuse and conform to the reuse standards in Jordan.

In Germany at Langenreichenbach research facility, two-stage VFCWs planted (*Phragmites australis*) and unplanted were evaluated and modified to compare the role of plants over two years. Generally, there was no significant role of plants on the treatment performance. Both systems showed high removal efficiency for TOC, BOD_5, and TSS over the study period. On the other hand, during the first year of the study, effluent TN concentrations ranged from 60 – 61 mg/L in both systems as a result of high effluent NO_3^--N concentrations (50 - 52 mg/L). In the second year, the systems were modified by adopting a saturated layer in the 1st stage to enhance denitrification. Average effluent TN concentrations were reduced to 45 mg /L in both systems. In addition, the operational modifications optimized the *E. coli* removal such that both systems achieved 4 log concentration reduction instead of 2 log concentration reduction during the first year of the study.

In Jordan at the Fuhais research facility, two VFCW systems were investigated considering category-A (TN: 45 mg/L and NO_3-N: 30 mg/L) in the Jordanian Standards (JS) for reuse in irrigation (JS 893/2006). Recirculating (ECO-1) and Multi-stage (ECO-2) VFCW designs have shown high removal efficiency of COD, TSS, and BOD_5 over three years of monitoring. ECO-1 is a modified VFCW system, combing simultaneous nitrification and denitrification by recycling portion of nitrified effluent (circulation ratio 3:1) into the recirculation tank. However, effluent TN and NO_3^--N concentrations were 55 and 44 mg/L, respectively, that the system conformed to the JS category-B (TN: 70 mg/L and NO_3^--N: 45 mg/L) during monitoring phase. Therefore, ECO-1 was modified by installing plastic media in the recirculation tank that attached growth increases the abundance and activity of microorganisms. TN concentration was reduced effectively of 40 mg/L, conforming to the JS category-A, whereas, NO_3^--N concentration was reduced to 37 mg/L, conforming to the JS category-B. However, over the study period, *E. coli* concentrations were not compatible with the JS (category-A: 100 MPN/100L and category-B: 1000 MPN/100L), but it was conformed to the JS category-C (more than 1000 MPN/100L).

ECO-2 consists of two unsaturated VFCWs in series; single-pass unplanted filter followed by planted filter (*Phragmites australis)*. *E. coli* removal was relatively high before operational modification that the effluent conformed to the JS category-B, achieving 4.4 log concentration reductions. The effluent TN and NO_3^--N concentrations did not conform to the JS of 77 and 76 mg/L, respectively, due to insufficiency of carbon source to promote denitrification (high BOD_5 removal in VFCW) during monitoring phase of the study. Thus, ECO-2 was modified adopting

raw wastewater step-feeding strategy that a specific volume of raw wastewater was mixed with 1st stage effluent in the mixing tank. TN and NO_3^--N concentrations were reduced to 52 and 50 mg/L, respectively; conforming to the JS category-B. Whereas, *E. coli* removal was influenced by *E. coli* ingress from raw step-feeding, achieving 3.5 log concentration reductions, conforming to the JS category-C.

The short-term impact of irrigation with different water quality and quantity was also investigated at the Fuhais research site. Soil physical, chemical, and biological properties in three parallel experimental reuse plots at Fuhais site were investigated. The plots were cultivated with lemon trees. The irrigation water was supplied via a subsurface irrigation system. Each plot received a water from a different source (tap water, ECO-1 and ECO-2 effluent). Moreover, each plot was divided into two sub-parts (A and B) whereby one plot received 11 mm/day of irrigation water and the other subplot received 6 mm/day. In the end of the experiment, using treated effluent and tap water showed the same trend of increased soli salinity (ECs). Significant difference in ECs, SAR, Mg^{+2}, Ca^{+2}, and Na^{+} were observed at 0 - 20 cm as a result of high evaporation and capillary rise that increased salts accumulation in the topsoil. However, using more water in subsurface irrigation system reduced the salts accumulation in sub soil layers due to continuous leaching. On the other hand, results showed no significant variation in soil physical properties (texture, structure, moisture, and infiltration rate) among reuse plots and subparts. In addition, results revealed an absence of total coliform, fecal coliform, and *E. coli* in the irrigated soils, indicating the effectiveness of using subsurface irrigation as a disinfection step for reuse.