PLANNING OF CROP IRRIGATION WITH TREATED WASTEWATER USING GEOGRAPHIC INFORMATION SYSTEM - THE CASE OF SANA'A WASTEWATER TREATMENT PLANT

GAWAHER AL- MAHNASH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Partial Fulfilment of the Requirement for the Degree of Master of Science

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DEDICATION

To my Mother,

Father,

elder Brother,

and all of Family members

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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By

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September 2004

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Faculty: Engineering

There is water scarcity problem in arid and semiarid areas like the Sana'a basin, eventhough the cities produce a large amount of wastewater. Therefore, reuse of treated wastewater in irrigation is warranted. However, the sewerage system covers only 20 percent of the city of Sana'a. The flow to the Sana'a Wastewater Treatment Plant (WWTP) is estimated to be 50,000 m^3/day by the year 2005. This is the available amount for irrigation use.

The main objective of this study was to determine the possible reuse of treated wastewater for irrigation and the extent of the agricultural area that could be irrigated with the treated wastewater. A Geographical Information System facility was then used to select suitable crops and determine the irrigation water requirement.

In spite of the low treatment efficiency of the Sana'a WWTP, especially the microbiological test result, reuse of this water in irrigation has less environmental problems compared to other means of wastewater disposal. Moreover, wastewater is

a renewable source of water and provides nutrients for crops and organic matter for soil conditioning.

The soil map was prepared by a consultant within the Sana'a Basin Water Management Project. The soil map was used as the base map layer of this work and the crops to be grown were grouped into three types of crops: deep rooted; shallow rooted; and tree. The soil characteristics such as salinity, texture and the crop suitability were keyed into text tables and joined to the attribute table of the soil map to produce the crop blocks map. From soil units data and command percolation factors of the soils, the map of texture percolation factor was created. The soil texture map was overlaid with the crop blocks map to calculate the percolation losses of every block. The crop water requirement for every block was calculated per month while considering the crop coefficient, kc, for different growth stages throughout the year. The peak water requirement was in May. The total irrigation water requirement was calculated by aggregating the percolation water losses, the peak crop water requirement and the leaching requirement. The total water requirement was found to be 13,058,855 m^3/month, which was equal to 5,595 m^3/month/ha. The minimum possible irrigated area using wastewater of this project was 268 ha, depending on the irrigation schedule and operation system of the lagoon storage/balance.

An irrigation system was designed for a 30 ha area. The nearest area to the water source was chosen, and a sprinkler irrigation system was suggested to avoid losses due to the scarcity of water in the study area. AutoCAD was used to draw the layout of the irrigated blocks and distribute the sprinklers. This layout was exported to

ArcView GIS to show the irrigated area by making a buffering of the sprinklers wetted diameter. An irrigation schedule was suggested as an economic system design with appropriate quantity of water use.

This study recommends connecting the rest (80 percent) of the city of Sana'a to the trunk sewerage system to convey the wastewater to the WWTP for treatment and reuse for irrigation purposes. And the treatment process in the WWTP should give more emphasis to the chlorination and disinfection process and control of the trace element inlet to the WWTP or its removal as a primary treatment of the WWTP. Other wastewater treatment plants should be established at appropriate locations around the city for a satisfactory effluent quality.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

PERANCANGAN PENGAIRAN TANAMAN DARIPADA KUMBAHAN AIR YANG DIRAWAT MENGGUNAKAN GEOGRAPHIC INFORMATION SYSTEM – KAJIAN KES DI LOJI RAWATAN KUMBAHAN SANA'A

Oleh

GAWAHER AL-MAHNASH

September 2004

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Terdapat masalah air yang kritikal di kawasan kering dan separa kering seperti di lembangan Sana'a Walau bagaimanapun bandar ini mengeluarkan air kumbahan dalam kuantiti yang banyak. Oleh itu, penggunaan semula air kumbahan yang telah dirawat di dalam pengairan adalah satu keperluan. Walau bagaimanapun, sistem saluran najis hanya meliputi 20 peratus daripada Bandar Sana'a. Pengaliran kepada Loji Rawatan Kumbahan Air (WWTP) dianggarkan sebanyak 50,000 m^3/hari atau 1,500,000 m^3/bulan.

Objektif utama kajian ini adalah untuk memastikan kemungkinan penggunaan semula kumbahan air yang telah dirawat bagi pengairan dan keluasan kawasan ladang yang boleh menggunakan air kumbahan yang telah dirawat. Aplikasisistem maklumat geografi (GIS) telah digunakan untuk memilih tanaman yang sesuai dan mengenalpasti kadar air untuk keperluan pengairan.

Berasaskan keputusan ujian mikrobiologi, kecekapan rawatan WWTP Sana'a adalah rendah. Oleh itu, penggunaan semula air dalam pengairan akan mengurangkan

masalah persekitaran berbanding kaedah pembuangan air kumbahan yang lain. Selain itu, sumber air kumbahan yang diperbaharui akan memberikan khasiat kepada tanaman dan menjadikan tanah bersifat lebih organik.

Peta tanah telah disediakan oleh Perunding HYDRO SULT dan Projek Pengurusan Air Lembangan Sana'a. Peta tanah tersebut merupakan peta dasar bagi kajian ini dan tanaman dibahagi kepada tiga kumpulan.iaitu berakar panjang,berakar cetekdan jenis pokok Sifat-sifat tanah seperti paras kandungan garam, struktur tanah dan kesesuaian tanah untuk tiga jenis tanaman telah dimasukkan ke dalam jadual dan digabungkan dengan butiran jadual di dalam peta tanah untuk menghasilkan peta blok tanaman. Daripada data keadaan unit tekstur tanah dan faktor keresapan tekstur tanah, peta tekstur keresapan telah dihasilkan. Peta keresapan ini telah ditindihkan dengan peta blok tanaman bagi pengiraan kehilangan air secara serapan untuk setiap blok. Keperluan air bagi setiap blok telah dikira bagi setiap bulan dan pekali tanaman (kc) untuk setiap peringkat tumbesaran telah diambilkira bagi sepanjang tahun. Kadar tertinggi adalah dalam bulan Mei. Jumlah keperluan air bagi pengairan telah dikira dengan membahagikan kehilangan air secara serapan, kadar tertinggi keperluan air untuk tanaman dan keperluan larutlesap. Jumlah air yang diperlukan adalah 13,058,855 m^3/sebulan iaitu bersamaan 5,595m^3/sebulan/ha.

Kawasan pengairan yang berkemungkinan menggunakan kumbahan air bagi projek ini adalah 268 ha. Jumlah ini bergantung kepada jadual pengairan dan sistem operasi bagi simpanan lagun air. Sistem pengairan telah direka bentuk untuk kawasan seluas 30 ha. Kawasan yang paling dekat kepada punca air telah ditentukan. Sistem pengairan secara pemercik telah dicadangkan untuk mengelakkan kehilangan yang

berpunca daripada kekurangan air dalam kawasan kajian ini. AutoCAD telah digunakan untuk melukis lakaran blok-blok kawasan yang diperlukan untuk pengairan dan juga pembahagian pemercik. Lakaran ini kemudiannya dihantar kepada GIS ArcView untuk menunjukkan kawasan pengairan yang telah dibekalkan air dengan membina penampan garispusat pembasahan pemercik. Jadual pengairan dicadangkan sebagai satu sistem rekabentuk yang ekonomik dengan jumlah kuantiti penggunaan air yang mencukupi.

Kajian ini mencadangkan agar menghubungkan 80% lagi daripada bandar Sana'a kepada sistem saluran najis untuk memindahkan air kumbahan ke WWTP untuk tujuan rawatan dan digunakan semula untuk pengairan. Proses rawatan di WWTP pula perlu lebih menekankan kepada proses pengklorinan dan pembasmian kuman serta mengawal elemen bendasing saluran air masuk ke WWTP atau memindahkannya sebagai perawatan utama WWTP. Lebih banyak WWTP perlu dibina di kawasan yang sesuai di sekitar bandar untuk mendapatkan sumber pengairan air kumbahan yang berkualiti dan memuaskan.

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I certify that an Examination Committee met on 20 September 2004 to conduct the final examination of Gawaher Al-Mahnash on this MSc thesis entitled "Planning of crop irrigation with treated wastewater using GIS in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree Regulation 1981. The Committee records that the candidate be awarded the relevant degree. Members of the Eexamination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

_____

GAWAHER MUTHANNA

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