Cairo University

ENHANCING AGRICULTURE DRAINAGE WATER QUALITY TO IMPROVE WATER USE EFFICIENCY IN MIDDLE DELTA REGION

By

Emad Mohamed Mahmoud Khalil

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Irrigation and Hydraulics Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Under the Supervision of

Prof. Dr. Ahmed Wagdy Abdel Dayem

…………………………….

Professor of Hydrology
Irrigation and Hydraulics Department
Faculty of Engineering, Cairo University

Dr. Yasmin Mohamed Ali Nassar

…………………………….

Assistant Professor
Irrigation and Hydraulics Department
Faculty of Engineering, Some University

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Approved by the
Examining Committee

____
Prof. Dr. Ahmed Wagdy Abdel Dayem, Thesis Main Advisor

____
Prof. Dr. Ashraf Moheb Ghanem, Member

____
Prof. Dr. Maha Mohsen Tawfik. Deputy Chairperson, National Water research center.

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Abstract

The overall annual supply of water from conventional water resources in Egypt is approximately 59.2 BCM. However, 29% of this water is reused to meet the annual demand which is approximately 76.21 BCM, (Barnes J., 2012). Agricultural drainage reuse is one of the main areas where water is reused in Egypt. However, the constant increase in pollution loads to drain waters forms a major constraint under the drainage water reuse policy. Therefore, the main objective of this research is to enhance water quality in agriculture drains to be reused in irrigation purpose using low cost treatment technologies. This research presents a Decision Support Tool (DST) that help in proposing remedial solutions to decrease Biological Oxygen Demand (BOD) concentrations and salinity in drain waters. The water quality model and the DST have been applied to 21 drains in Kafr EL Sheikh Governorate.

The water quality model is mainly used to calculate the BOD concentrations along the drain. Different parameters are included during the calculations such as; cross sections of the drains, water velocity, discharge, population of the surrounding villages, distances between villages, effluent of sewage-waste from each village, biodegradability factor (k_t) of BOD, temperature (t), and measured BOD value at the beginning of the drain. The model assumes complete flow mixing at the point of sewage discharge and plug flow regime elsewhere.

The DST is designed to select the most suitable treatment technology; highest efficiency with least cost to reduce the BOD concentrations, to be utilized at each drain taking into account different site and technology parameters. The site specific parameters include, drain discharge, available space, and water table, while the technology specific parameters include, capital cost, operation and maintenance cost, and the removal efficiency.

Sensitivity analysis to different scenarios such as different stream cross section, temperature, discharge and removal efficiency and its effect on the selected treatment technologies have been also checked. The increases in temperature, stream cross section, and stream discharge have an effect on the BOD concentration and the selected treatment technologies through decision support system.

The research also checked through water quality field measurements the relation between Dissolved Oxygen (DO) concentration and BOD dilution, and the effect of increasing DO values on BOD bio-degradability.

After running the BOD model and the DST for the 21 drains, it was concluded that the source reduction of villages sewage using Anaerobic Baffled Reactor (ABR)with 65 % removal efficiency and cost per Kg/d BOD removed equal 6,596 EGP, is proposed to be used in 9 out of 21 drains because of its high reduction of organics, moderate capital and operating costs. Treating villages wastewater using Anaerobic Filter (AF) with 75 % removal efficiency and cost per Kg/d BOD removed equal 6,667 EGP was used in 6 drains, Up-flow Anaerobic Sludge Blanket (UASB) with 80 % removal efficiency and cost per Kg/d BOD removed equal 6,699 EGP was picked to treat the villages wastewater in 5 drains However, the In-stream wetland treatment with 50 % removal efficiency was selected in only one drain. On the contrary, by increasing the removal efficiency of the typical in-stream wetland to be 70% instead of 50 % through increasing air entrainment, and rerunning the DST, the modified in-stream wet-land was recommended to be used in 9 drains out of 21. This technology is a suitable remedial solution in terms of the required space, construction, and operational / maintenance cost. It is however worth noting the results of this DST are valid within the BOD concentrations of the studied agriculture drains. More heavily polluted drains might require other pollution reduction interventions.

It was also concluded that drains with discharges greater than 5 m^3/sec are less affected with BOD effluents from villages with population up to 60,000 inhabitants.

Moreover, to decrease the salinity in drain waters, the study recommends using halophytes in the farm-land surrounding drains with salinity values (EC) more than 6 ds/m, and using tolerant crops in the farm-land surrounding drains with (EC) values between (3-6) ds/m.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Egypt is among those countries that face several water challenges, as the annual share per capita of renewable water resources (mainly provided by the Nile) is dramatically reduced from more than 2500 cubic meters at the year 1950 to less than 700 cubic meters at the year 2013, and is expected to fall to about 600 m3/cap/yr by the year 2025 according to the National Water Resources Plan (NWRP, 2005). That happened because the population has been growing in the last 25 years from 38 million in 1977 to 86 million in 2013 and is expected to reach about 120 million capita in 2025 with approximately 2% annual growth rate.

The Ministry of Water Resources and Irrigation (MWRI) is the official authority in charge of development, allocation and distribution of all conventional and non-conventional water resources of the country. Since 2002, MWRI started to formulate the National Water Resources Plan (NWRP) based on a strategy called “Facing the Challenge” (FtC) (NWRP, 2005). Facing the challenge strategy included measures to develop additional resources, make better use of existing resources, and measures in the field of water quality and environmental protection.

The plan has three major pillars; (i) Increasing water use efficiency; (ii) Water quality protection and; and (iii) Pollution control and water supply augmentation.

Conventional water resources in Egypt are limited to the Nile River; groundwater in the deserts and Sinai, and precipitation (Rainfall) along the Northern coast, and non-conventional water resources include renewable groundwater aquifers in the Nile valley and Delta, agricultural drainage water, and treated wastewater.

Zhu et al. (1998) concluded that non-conventional water resources especially agricultural drainage water is considered relatively a cheap source since it does not require much infrastructure – just pumps to lift the drainage water from drains back to the irrigation network – for example, desalinating seawater costs almost one US dollar per cubic meter, whereas one cubic meter of recycled drainage water costs few cents. A main concern when considering drainage water reuse is whether the drainage water quality is within the allowable limits for irrigation uses as outlined by the water quality standards and laws. Thus more attention needs to be directed to improve drainage water quality (Biswas, A.1988) and (El Sayed, A. 1997).

Dispose sewage waste directly to the drains without treatment leads to deterioration of drainage water quality, and pollution of water courses by wastewater which causing health and environmental risks and effect on the reuse of drainage water plans (Peter, K. et al., 2005).

Because of this, the research focus on finding a suitable method to improve drainage water quality and reuse this water in irrigation purpose through development of a model that can calculate the Biological Oxygen Demand (BOD) concentration, along agricultural drains, and propose the appropriate remedial solutions or technologies that can be managed by the local people, cost effective, and environmentally sound.

Decentralized treatment technologies have been developed particularly over the last two decades, and it may be capable to reduce the treatment cost and the complexity of operation without sacrificing the degree of pollution control.

1.2 PROBLEM STATEMENT

There is a severe shortage in irrigation water supply in the Northern Delta governorates especially in the tail end of irrigation canals, and it is proposed to substitute shortage in fresh water supply by the available agriculture drainage water.

Poor drainage water quality is increasingly becoming a constraint for the drainage water reuse policy causing deterioration of soil and crop yield. In addition farmers are subjected to health hazards and effect on the future expansion plans for cultivated areas.

Domestic wastewater is discharged directly to drainage canals without any treatment and nowadays many of open drains are carrying a mixture of agricultural drainage water, domestic, industrial wastewater, and solid waste debris. Increasing pollution loads in some drains reduce the capabilities to reuse their water in irrigation. A fact sheet prepared by Drainage Research Institute (DRI, 2005) showed that increasing the pollution of agriculture drains forced MWRI to close some re-use pump stations to avoid contamination of irrigation canal where reuse is practiced.