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TECHNICAL GUIDELINES FOR PROPER PLANNING, DESIGNING CONSTRUCTION AND SUSTAINABLE USE OF CONSTRUCTED WETLANDS TECHNOLOGY IN TANZANIA

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ABSTRACT

Constructed Wetland is the new technology which is advocated to be used in Tanzania for wastewater treatment onsite and offsite. The current wastewater treatment technologies used in the country are waste stabilization ponds, septic tank systems and pit latrines and therefore there are no guidelines for proper planning, designing construction and sustainable use of constructed wetlands technology. The technical guidelines at an entire project cycle will provide all stakeholders in Tanzania with an easy guidance for proper planning, designing, construction and sustainable use of constructed wetlands technology. It is hoped that the guidelines may serve as a useful resource for planners, designers and constructors as well as funding agencies hereby contributing to the continuous process of improving the environmental protection. In Tanzania, the need for technical guidance in the planning and implementation of constructed wetlands technology is become increasingly evident to the technology given the unsuccessful stories for some of the implemented constructed wetlands in some parts of the country. It is hoped that when these guidelines are properly followed and adhered to, it will yield a positive results in terms of proper planning, implementation and sustainable use of constructed wetlands technology. The methodologies used were documents review and interview.

Keywords: Constructed Wetlands, Wastewater, Technical

1. INTRODUCTION

Constructed wetlands (CWs) are planned systems designed and constructed to employ wetland vegetation to assist in treating wastewater in a more controlled environment than occurring in natural wetlands. Hammer (1989) defines CW as a designed, manmade complex of saturated substrate, emergent and submerged vegetation, animal life, and water that simulate natural wetlands for human uses and benefits. CW are "eco-friendly" alternatives for secondary and tertiary treatment of municipal and industrial wastewater. The pollutants removed by CW's

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include organic materials, suspended solids, nutrients, pathogens, heavy metals and other toxic or hazardous pollutants. Different types of CWs can effectively treat secondary or tertiary treated wastewaters. However, they should not be used to treat raw sewage and, in industrial situations, the wastes may need to be pre-treated so that the biological elements of the CW system can function effectively with the effluent. CW's are practical alternatives to conventional treatment of domestic sewage, industrial and agricultural wastes, storm water runoff, and acid mine drainage.

There is not even a single city or town in Tanzania with adequate sewage treatment facilities (Mohammed, 2002). Under normal circumstances, urban centres would be served by wastewater treatment plants and regulated septic disposal facilities, while peri urban areas would experience un-regulated waste dumping and burial. In Tanzania however, a very small portion of the urban centres is served with adequate wastewater treatment facilities. Coverage by sewerage services in major cities such as Dar es Salaam, Arusha and Mwanza is less than 15%, with an exception of Moshi at 40% (Mihayo and Njiru, 2005). About 60-70% of the urban population (Mato, 2002), in Tanzania, lives in unplanned peri-urban areas, relying mostly on pit latrines and septic tank soak away systems for sanitation. Major problems with pit latrines and septic tanks in Tanzania are leakages caused by poor construction, flooding of low lying areas, and lack of maintenance. Soak away pits fill up due to poor infiltration when built in clay soil areas. Possibility of conventional systems polluting drinking water sources is high due to close proximity to shallow water wells and surface water sources. Additionally, there is generally lack of adequate wastewater treatment due to lack of funds to install centralized wastewater treatment systems and lack of commitment among policy makers to seriously deal with the problem.

To tackle these problems, good solutions for improving sanitation systems in Tanzania have to be identified. A sustainable low cost solution for hygienic sanitation identified is engineered wetland systems, also known as Constructed Wetlands (CW). The use of constructed wetlands for domestic wastewater treatment in Tanzania has gained much popularity over the last fifteen years since the early pioneering works by Mwegoha (2002), Kimwaga (2003), Mbwette *et al*. (2001, 2005), Senzia (2003), Kiwanuka (2001), Kaseva (2002), Mutamba (2003), Katima (2005).

The long operational experience and research results have shown greater treatment efficiency, greater nutrient reclamation as compared to other natural biological treatment systems. These systems are low energy-consuming and use natural processes, in contrast to the complex conventional treatment systems that are high energy and high-maintenance demanding. Other advantages include: simplicity, low construction, operation, and maintenance costs, use renewable energy, use locally available materials and robustness. Although they have been found

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to be commonly used for treating domestic wastewaters, they can also be used for treating industrial wastewater, including water that contains agro-industrial wastes.

Another potential advantage of using sub-surface flow constructed wetlands is that they do not allow mosquitoes to breed. Also, the systems can be designed in clay soils by which septic tank systems cannot fit, they can be designed in areas with high water table because the maximum depth below the ground surface is 0.6 m, they can fit for decentralized wastewater treatment as it can be designed in small, medium and large scales.

Developing these guidelines follows the introduction of economic development frameworks in Tanzania such as sustainable Development Goals, MKAKATI WA KUKUZA UCHUMI NA KUPUNGUZA UMASIKINI TANZANIA - Strategy for raising economy and reducing poverty in Tanzania (MKUKUTA. These guidelines will provide a platform for sustainable use of constructed wetlands technology hence improving sanitation delivery services in areas without access to conventional sanitation systems.

The overall objective is to provide technical guideline in order to increase access, affordability, and sustainability of constructed wetland technology in urban, peri-urban and rural area of Tanzania. The specific objectives includes: To provide guidance and a framework for proper design of constructed wetlands; To provide guidance and a framework for proper construction of constructed wetlands and To provide guidance and a framework for proper operation and maintenance of constructed Wetlands.

2. MATERIAL AND METHODS

The methodologies used were documents review and interview. Relevant research reports on constructed wetland technologies and wastewater management in Tanzania were reviewed. Different researchers who researched on constructed wetland technologies in Tanzania were interviewed.

3. TECHNICAL GUIDELINES IN PLANNING, DESIGN, CONSTRUCTION AND IMPLEMENTATION PHASES

3.1 Planning phase

A conceptual planning of a CW system is essential. It should be a very primary step with the aim of evaluation, analyzing and defining objectives for the system in relation to the exiting situation on the ground and available resources. As such, planning phase should successful accomplish the following:

i. Define treatment objectives by carrying out preliminary analysis for the need of a CW system.
ii. Identify and investigate the land available for establishing a CW system. Potential challenges might be associated with areas with high water table, rocky land, low land areas (the danger of stormwater runoff) and instable land. In the presence of this type of land, a systematic intervention should be developed in the first place.
iii. Understand and analyze the existing topography, soil type and permeability
iv. Estimate the total amount of wastewater to be treated. In the presence of wastewater measure the quantity generated. In the absence of wastewater, use standard per capital water consumption and wastewater generation as recommended by local regulatory authorities
v. Characterize the quality of wastewater by analyzing critical parameters including biological Oxygen Demand (BOD_5), Total Suspended Solids (TSS), Ammonia Nitrogen (NH_3-N), Nitrate Nitrogen (NO_3 - N), Fecal Coliforms (FC) and Total Phosphorus (TP). Other parameters are Chemical Oxygen Demand (COD), water and ambient temperature, pH and heavy metals. In the presence of wastewater, carry out laboratory analysis and make use of available analysis records. In the absence of wastewater, use standard per capital pollutant concentration as recommended by local regulatory authorities
vi. Survey and document existing wetland plants, substrates, construction and bed lining materials. Make multiple analyses and decide the appropriate materials.
vii. Identify and inspect existing pre-treatment system such as grit chambers, bar screens, septic tanks and waste stabilization ponds. In the absence of pre-treatment facilities, analyze for potential alternatives
viii. Identify the potential for reuse of treated wastewater
ix. Prepare baseline report which should be used as reference during the design, construction as well as operation and maintenance phases of the project

3.2 Design phase

This is a very crucial step in the life cycle of a wetland system. Since available land is frequently a limiting factor, determination of the land size required to reach treatment goals should be the key activity of the design process. However, globally, there is no optimal design of constructed wetlands for various applications despite a large amount of research and published information. Nevertheless, designers should consider the following guidelines for creating functional CW system:

i. Re-define treatment objectives based on the collected baseline information especially results of wastewater characterization.

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ii. Decide on the type of CW to be established. Two types are common in Tanzania: Surface Flow (SF) and Horizontal Subsurface Flow (HSSF) constructed wetlands. HSSFCW are most appropriate because there is no direct contact between the water column and the atmosphere, there is no opportunity for vermin to breed, and the system is safer from a public health perspective. However, the influencing factors are *treatment goals, land availability, local climate, cost implications and social acceptability of the receiving community*

iii. Choose appropriate design method. The common methods include (1) historical data method which base on empirical data collected from pilot scale and fully operational treatment wetlands (2) areal and volumetric loading which take into account the relationships between the volume of water or mass of pollutant to the surface area of the wetland (3) attached growth models whereby CW are considered as attached growth microbial reactors. Attached growth models and specifically Plug Flow approach provides a more appropriate description of a flow pattern is SSFCW. Besides, advanced studies in Tanzania entails that the performance of the systems has been found to be more influenced by hydrodynamics in CW system especially in tropical areas; hence it is advised to enhance mass transfer effects by controlling the velocity of flow in the CW system.

iv. Determine the size and configuration of the CW system

v. Ensure structural stability of embankment walls and other civil structures

vi. Keep the design simple. Complex technological approaches often invite failure.

vii. Design for minimal maintenance

viii. Design the system to use natural energies, such as gravity flow.

ix. Design for the extremes of weather and climate, not the average. Storms, floods, and droughts are to be expected and planned for, not feared.

x. Design the wetland with the landscape, not against it. Integrate the design with the natural topography of the site.

xi. Avoid over-engineering the design with rectangular basins, rigid structures and channels, and regular morphology. Mimic natural systems.

xii. Give the system enough retention time. Wetlands do not necessarily become functional overnight and several years may elapse before performance reaches optimal levels.

xiii. Prepare design report incorporating assumptions made, design criteria, key design provisions and specifications, bills of quantities and engineering drawings. The engineering drawings should include layouts drawings, plan views, details drawings and typical sections.

3.3 Construction phase

A CW is an engineered system designed and built to treat wastewater and satisfy other multiple objectives. As such, standard engineering techniques, approaches and procedures should be used during the construction phase. As a guideline, the following should be taken into account:

i. Review siting investigations thereby considering size and configuration of the designed CW, physical characteristics of the site and regulatory requirements. Then develop an appropriate construction plan.
ii. Select and engage qualified and registered civil engineering contractor for construction activities as required by local regulations.
iii. Construct in accordance with best engineering practices, specifications and provided engineering drawings. Many contractors who are experienced with other kinds of construction may have had little experience in building CW systems. Close supervision form qualified and registered experts, construction plans, specifications, and detailed engineering drawings should portray the desired work.
iv. During physical construction of the system, closely observe and monitor earth works (excavation and surface trimmings), levels (inlet, bed and outlet) and quality of construction materials.
v. Before packing the substrates, CW should be flooded to design depth and tested for leakage and water control structures to ensure that they are operating properly and check that water levels and flow distributions meet expectations.
vi. Closely observe and monitor the packing of substrates into the inlet, treatment and outlet zones of the CW. Items of interest are the type, size and cleanliness of the substrates which should comply with specifications and engineering drawings.
vii. The contractor should ensure that building works comply with all safety requirements to protect the workers and members of the public from construction based hazards.
viii. Initiate and implement the defects liability plan thereby undertaking periodic inspections, identify work defects and control corrective actions
ix. Prepare and provide operation and maintenance manuals to users for effective functionality of the CW system
x. Prepare and facilitate operation and maintenance training to prospective users of CW to ensure proper use and running of the system
xi. Prepare final construction completion report which document every built components and its specifications including updated engineering drawings

3.4 Implementation phase (operation, maintenance and monitoring

Like any other engineering wastewater treatment facility, CW require regular maintenance and monitoring to ensure it remains functional and in a 'healthy' condition. With the help of standard operation and maintenance manual, a plan should be prepared to reflect specific system characteristics. The plan should provide a schedule for routine cleaning of wastewater distribution systems, inspection of various components, maintenance of structures, caring vegetation, control of vectors and pests and system monitoring. As such, the operation and maintenance plan should:

i. Specify individuals responsible for performing and paying for maintenance
ii. Fence the CW system to avoid illegal intrusion of unauthorized personnel and livestock
iii. Inspect and clean inlet and outlet structures, pipes, water control structures and drainage systems on a regular basis and immediately after any unusual flow event
iv. Inspect and repair damaged embankments and structures
v. Ensure the system is operating with acceptable range of water levels as per design provisions
vi. Check flow and water levels regularly to ensure that water is moving through all parts of the wetland; that buildup of debris is not blocking and clogging the flow paths; and that stagnant areas are not developing. It should be kept in mind that stagnant water decreases pollutants removal and increases the likelihood of mosquitoes and unsightly conditions
vii. Inspect vegetation regularly thereby removing invasive species (weeding), pruning and harvesting. Macrophytes can be harvested once per year and can be cut at 10 - 30 cm above the surface of substrate and the harvested vegetation should not be dumped along the wetland bed.
viii. Monitor the performance efficiency of the system by analyzing influent to and effluent from the CW. It is advised to analyse wastewater for faecal coliforms, nitrate, BOD, ammonia, pH, total suspended solids (TSS) and total phosphates. Analysis should be done at least twice per year.

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