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Modelling faecal coliform mortality in water hyacinths ponds

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Abstract

Removal of faecal coliforms was investigated in pilot-scale water hyacinths ponds. The investigation was conducted to evaluate the role of solar intensity, pH, dissolved oxygen, temperature, sedimentation, and attachment of faecal coliforms on *Eichhornia crassipes* on disappearance of bacteria in water hyacinths ponds. A mathematical model that used the plug flow philosophy and incorporating the aforementioned factors was developed to predict faecal coliform mortality rate. The proposed multifactor model satisfactorily predicted mortality rate of faecal coliforms in a pilot-scale water hyacinths ponds. After optimization of the parameters, mortality rate constant for pH (k_{pH}) was 0.001, mortality rate constant for DO (k_{DO}) was 0.0037 and solar intensity mortality rate constant k_s was 0.0102 cm^2/cal. The results also showed that the thickness of biofilm (L_f) was 2.5×10^{-4} m, and the effective surface area of water hyacinths roots per unit surface area of pond (R_s) was 10.4 m^2/m^2. The results further showed that environmental factors such as solar intensity and pH were the key factors when water hyacinths ponds have a large exposed surface area. However, attachment of bacteria to water hyacinths played a major role in ponds fully covered with water hyacinths. The inclusion of sedimentation parameters in the model improved model efficiency by only 3.2%. It was concluded that sedimentation is not a major factor governing faecal coliform disappearance in water hyacinths pond systems receiving pretreated wastewaters.

Keywords: Faecal coliforms; Mortality rate of bacteria; Water hyacinths; Ponds

1. Introduction

Water hyacinth, *Eichhornia crassipes,* is one of the rapidly growing and very productive photosynthetic plants in freshwater systems. This aquatic macrophyte is the eighth fastest growing plant on earth (Reddy and Sutton, 1984). Its explosive growth is considered unfavorably in natural water bodies such as Lake Victoria because it restricts navigation (Lockley and Turner, 1961) and imparts undesirable taste and odour to water (Reddy and DeBusk, 1991). *Eichhornia crassipes* is also considered a health hazard because it is associated with several pathogenic organisms and vectors of diseases such as schistosomiasis, filariasis, malaria and ancephalitis (Gopal, 1987; Reddy and DeBusk, 1991) because it concentrates the microorganisms around its roots and shoots (Spira et al., 1981; Muyodi, 2000). Accumulation of pathogens in water hyacinths found in freshwater is undesirable because water hyacinths remain as part of the water body. However, a similar accumulation in wastewater is desirable because effluent quality will improve.

The water hyacinths, *Eichhornia crassipes*, have been extensively used for improving wastewater effluents from waste stabilization ponds and septic tanks (Perdomo et al., 1998). The capacity of water hyacinth ponds to reduce organic matter is well documented (Cooper et al., 1996) and mathematical models have been developed to describe the kinetics of organic degradation in these ponds (Polprasert and Khatiwada, 1997). These systems have also been used for removal of nutrients (Imaoka and Teranishi, 1988) and heavy metals (Mugasha, 1995).

However, due to lack of sufficient design criteria, it is doubtful whether water hyacinths ponds can meet present effluent standards set by many authorities without bacterial disinfection, since it is known that the plant itself accumulates pathogens around its root zone by attachment (Reed

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et al., 1988; Gersberg et al., 1989). Literature has revealed that bacterial mortality in water hyacinth ponds depends on environmental and climatological factors. Various hypotheses and explanations have been tried to explain the causes of bacterial mortality, some of which are similar to those of waste stabilization ponds, and for that matter any comprehensive model should consider them. These include temperature (Marais, 1974), effect of pH (Parhad and Rao, 1974), depletion of nutrients (Gann et al., 1968), biocide excretion by plants (Gersberg et al., 1989), microbial antagonism (Polprasert et al., 1983), sedimentation (Auer and Niehaus, 1993), dissolved oxygen (Curtis et al., 1992), solar radiation (Calkins et al., 1976), adsorption under aerobic conditions (Ohgaki et al., 1986), and attachment of bacteria to plants (Muyodi, 2000). Polprasert et al. (1983) hypothesized that microbial antagonism may influence mortality of bacteria in ponds, but its influence was not evident in an earlier study (Mayo, 1995). Organic loading rates and retention time were also neglected due to the findings of Mayo and Gondwe (1989).

The primary objective of this work was to formulate a multifactor mathematical model for the mortality of faecal coliforms in water hyacinth ponds in tropical climates. Faecal coliforms were selected as test organisms because they are numerous in wastewater and they are easily tested for. Their presence in water is taken as an indication that pathogenic organisms may also be present because coliform organisms are present in intestinal tract of human beings. Conversely, their absence is taken as an indication that water is free from pathogenic microorganisms. Therefore removal of faecal coliforms in water hyacinths ponds will give an indication of potential of this system for removal of pathogenic bacteria.

2. Materials and methods

2.1. Description of the pilot water hyacinth pond system

The pilot water hyacinths pond is located at Longitude 39°13′E and Latitude 6°48′S approximately, close to mean sea level with a mean monthly temperature range of 23 °C to 28 °C. This pond had a hydraulic retention time of 10 days and a flow rate of 1 m^3/day, which was discharged from the University of Dar es Salaam primary facultative pond. The influent wastewater is predominantly domestic in nature.

Fig. 1 depicts the layout of the system. Wastewater was directed to the water hyacinths pond by a 75 mm HDPE pipe fixed with a gate valve to control flow rate. A constant head of wastewater was maintained in a chamber upstream of the pond unit. Flushing out of sediments in case of blockage in the chamber was done through a 50 mm pipe. Wastewater was evenly distributed in the water hyacinth unit through an inlet gutter from a 12 mm diameter influent pipe.

Effluent sampling of wastewater was conducted through an outlet pipe connected to a vertically placed 38 mm pipe that maintained a water column of 0.9 m in the pond unit. Outlet washout next to outlet pipe was put in place during construction for purposes of flashing out sediments in case of blockage. Side sampling was done from globe gate valves installed on the sides.

2.2. Sampling and analysis

To assess the mortality of faecal coliforms in water hyacinth ponds, the water hyacinth biomass was planted after construction. Water hyacinth biomass multiplied at a rate of 0.23 m^2/day. The wetland area covered by the water hyacinth per unit time of growth was obtained with the aid of a quadrant's technique. Grab samples were collected from the influent and effluent of the unit between 9:00 am and 10:00 am for every day of sampling and examination of samples was done immediately. A number of researchers have used this sampling technique, especially for wastewater analysis (Mayo, 1989; Cooper et al., 1996) and they have yielded reliable results.

Dissolved oxygen (DO), pH and temperature were measured *in-situ*. Temperature and pH of the samples were measured using a pH meter (Metrohm, model 704) equipped with a thermometer. DO of the samples was measured using a DO meter (YSI Incorporated, model 50B).

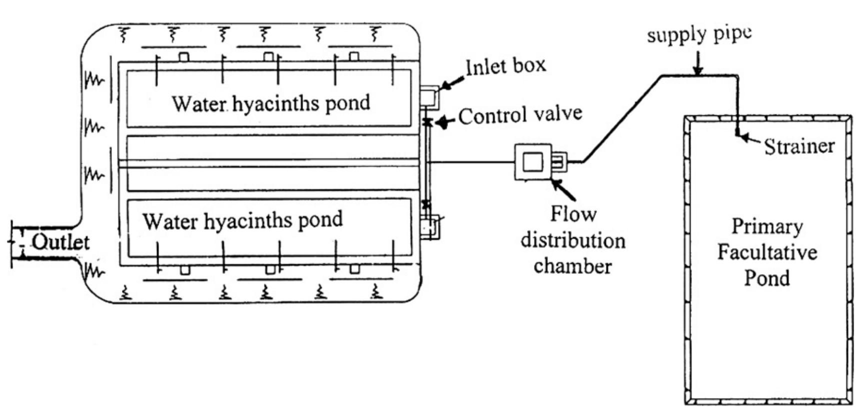

Fig. 1. Layout of experimental water hyacinths ponds.