UNIVERSITY OF ZIMBABWE

MODELLING OF FAECAL COLIFORM REMOVAL USING THE STELLA SOFTWARE. A CASE OF HORIZONTAL SUB-SURFACE FLOW CONSTRUCTED WETLAND IN TANZANIA

By
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DECLARATION

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person or material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgements has been made in the text"

Signature:………………. Name:…………………………. Date:……………………

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DEDICATION

I dedicate this thesis to the loving memory of my late Mother Mrs. Amina Malale and my Father Kassim Ibrahim Malale.

ABSTRACT

A number of studies have been conducted concerning wetlands systems in East Africa; most of which focused on the performance of constructed wetlands in the removal of TSS, Org-N, NH_3-N, NO_3^-, NO_2- and BOD_5. However, little attention has been given to the quantification of the contribution made by each process on the total removal of Faecal Coliform (FC). A research study was conducted to investigate the possibilities of optimising the FC Removal in Horizontal Sub-Surface Flow Constructed Wetland (HSSFCW) at University of Dar Es Salaam in Tanzania. The HSSFCW polishes the effluent from maturation ponds which form part of Waste Stabilization Pond (WSP). Modelling of FC by using STELLA program was the methodology used to achieve the main objective of this study. The modelling procedures that were considered in this study were the problem definition, conceptualisation, mathematical equations formulation, calibration, verification and sensitivity analysis. The validation was not considered because of data deficit in this study. The processes that were considered in the model were inflow, outflow, sedimentation, filtration, die-off of bacteria and growth. Also the study determined the best removal mechanism and parameter which was very sensitive to total removal of FC.

Grab sampling method was used for collecting samples from the inlet, middle section and outlet and were analysed for FC (Counts per 100ml), BOD_5 (mg/l), NH_3-N (mg/l), DO (mg/l) and pH. The temperature (^{0}C) and flow rate (m^3/d) were also determined for the samples that were collected between February and April 2007. Other input data included solar radiation (cal per m^2 per d) which was obtained from literature. All parameters mentioned above were used in the modelling processes.

The observed results were; FC: 1,163,636±268,675 (inlet), 884,636±344,564 (middle) and 45,909±19,373 (outlet). BOD_5: 141±35 (inlet), 119±25 (middle), and 68±11 (outlet). NH_3-N: 10.92±0.47 (inlet), 9.93±0.55 (middle), and 8.01±0.64 (outlet). DO: 5.91±0.23 (inlet), 5.76±0.20 (middle) and 5.59±0.26 (outlet). pH: 6.28±0.14 (inlet), 6.67±0.37 (middle) and 7.62±0.72 (outlet). However, the temperatures: 29.77±1.63 (inlet), 30.20±1.63 (middle), and 30.64±1.57 (outlet) and Flow rates: 1.7±0.003 (inlet), 1.42±0.100 (middle) and 1.05±0.106 (outlet). For the modelling results, the removal efficiency of FC on those processes was; die-off processed: 44.164%: 3,422,203±1,129,699: Sedimentation; 5.826%: 451,433±149,914: Outflow; 0.053%: 4,075±1,796 and filtration; 0.001%: 94±31. However, the growth and inflow processes were 47.836%: 3,706,710±1,285,500 and 5.593%: 473,347±403,928 respectively. The study established that calibrated results were lower than compared to observed results by 91%. From this result, it can be concluded that the model had optimised the FC reduction in HSSFCW. Also the study established that, the growth and inflow processes increased the FC within the system while the rest reduced. On sensitivity analysis, the study noted that solar radiation was very sensitive in decreasing the FC within the system. The study further established that pH was very sensitive in increasing the FC within the system while temperature, DO, BOD_5 and NH_3-N were sensitive within the relative ranges of ±10%. The optimal FC was observed at 0% of the relative change of temperature, DO, BOD_5 and NH_3-N in this model. Hence it can be concluded that solar radiation was the best parameter that reduced the FC concentration within the system. Therefore, it can be recommended that the model be used as tool for designing and managing the HSSFCW after being validated in order to optimise the effluents quality that is being discharged to the receiving water bodies.

ABBREVIATIONS

AWRA	American Water Resource Association
AVG	Average
BOD	Biochemical Oxygen Demand
BOD_5	Biochemical Oxygen Demand at 20^0C in 5 days
COD	Chemical Oxygen Demand
CW	Constructed Wetland
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
FC	Faecal Coliforms
FWR	Foundation for Water Research
FWS	Free Water Surface
HSSFCW	Horizontal Subsurface Flow Constructed Wetland
IWRM	Integrated Water Resources Management
NH_3-N	Ammoniacal-Nitrogen
ODEQ	Oklahoma Department of Environmental Quality
Q	Flow rate
S.D	Standard Deviation
SFS	Subsurface Flow System
SSF	Subsurface Flow
TSS	Total Suspended Solids
UDSM	University of Dar Es Salaam
WFP	Water for People
WHO	World Health Organisation
WSP	Waste Stabilization Pond

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CHAPTER ONE

INTRODUCTION

1.1 Background

Wetlands are transitional ecosystems that exist at the interface between aquatic and terrestrial systems (Carleton, 1997). They are comparatively shallow (typically less than 0.6m) bodies of slow-moving water in which dense stands of water-tolerant plants such as cattails, bulrushes, or reeds are grown (Polprasert, 2002). There are two types of wetlands, the natural wetlands and constructed wetlands, both of which play a role of treating polluted wastewater and especially polishing them from various secondary treatments. Constructed Wetlands (CW) are engineered systems that have been designed and constructed to utilise the natural process involving wetland vegetation, soil and their associated microbial assemblages to assist in treating wastewater. There are two types of Constructed Wetlands, Free Surface Constructed Wetland (FSCW) and Sub-Surface Flow Constructed Wetland (SSFCW). Now days the Constructed Wetlands are gaining popularity due to their economic and environmental sound attributes as the wastewater management option for treating wastewater and non-point source pollution (Senzia, *et al.,* 2002: Oketch, 2002).

There is a number of CW in East Africa. The CW in Uganda used to treat Municipal Wastewaters, while in Tanzania, used to treat Institutional Wastewaters. (Bojcevska, 2004; Kaseva, 2004). In these Constructed Wetlands, there are number of studies that were carried out concerning the performance of wetlands on the nitrogen removal, pathogens removal, Total Suspended Solids (TSS) removal, Biochemical Oxygen Demand (BOD) reduction, and Chemical Oxygen Demand (COD) reduction (Bojcevska *et* al., 2004; Kaseva, 2004; Kimwaga *et* al., 2003(a); Senzia *et al.,* 2002; Oketch *et* al., 2002), however, few studies have focused on the total removal and modelling of FC in Horizontal Sub-Surface Flow Constructed Wetland (HSSFCW).

FC are indicator organisms which cause waterborne diseases like cholera, typhoid and dysentery. The presence of FC is one of the major problems with drinking water supplies which primarily results from inadequate wastewater treatment in many developing countries. This study focused on the possibilities of optimising the FC reduction through modelling using the STELLA software. The modelling revealed the processes that contributed to the total removal of FC in HSSFCW. The model would be used as tool to protect the water bodies from the pollution especially on FC bacteria hence, to minimize or eliminate the outbreak diseases like cholera

The study was carried out on the HSSFCW system at Main Campus of University of Dar Es Salaam in Tanzania that receives effluents from Maturation Ponds which form part of a system of Waste Stabilization Ponds (WSP). The effluent from HSSFCW is discharged into a small river located nearby.

1.2 General objective of the study

The general objective of this study was to investigate possibilities of optimizing the FC removal in HSSFCW at Main Campus of University of Dar Es Salaam in Tanzania through modelling.

1.2.1 Specific objectives

- To review the literature on wetlands, their performance and modelling in general.
- To carry out data collection on the wastewater quality on FC, BOD_5, NH_3-N, pH, DO, and Temperature for the influent, middle and effluent wastewater from the HSSFCW and to measure the flow rate (Q).
- To carry out modelling procedures which are problem definition, conceptualization, mathematical equations, calibration, verification and sensitivity analysis.
- To determine the best process that contributes to total removal of FC in HSSFCW.

1.3 Scope of the study

The study focused on the ability of STELLA software to describe the mechanisms of Total FC removal at HSSFCW. The choice of software was based on its applicability in the modelling context especially of the water and wastewater quality aspects, user friendliness and availability. The study modelled only the FC bacteria. The parameters used in the model were FC bacteria, BOD_5, NH_3-N, DO, pH and temperature of wastewater. The measured flow rate was also used in the model. There were two reasons behind choosing the above parameters: Firstly, the parameters were used as food and nutrients for the FC bacteria. Secondly, there were the environmental conditions that favour the death and growth of Faecal Coliform bacteria in the HSSFCW.

The processes in the conceptual diagram were the inflow and growth processes which increase the FC concentration within the HSSFCW while outflow, sedimentation, filtration, and die-off processes were decreasing. The HSSFCW assumed to be attached growth biological reactor and then all the performances in them were described with first order plug-flow kinetics. In modelling procedures, the validation of the model was not considered in this model because of absence of a data set for validating the model.

CHAPTER TWO

LITERATURE REVIEW

2.1 Types of wetlands

2.1.1 Natural Wetlands

The Foundation for Water Research (FWR), (2005) defines wetlands as an umbrella name used to describe areas of land where water is the primaries factor controlling the environment and the associated plant and animal life. In his definition Cornel (2004) tried to explain more on the depth of water in the wetland. The author defines wetlands as inundated land with water depths typically less than 0.6m that support the growth of emergent plants such as cattail, bulrush, reeds and seeds.

Cornel (2004) explained some mechanisms that take place in the wetlands like filtration, which allows the suspended solids and other particles to be filtered. The filtration process in wetlands was done by the medium used, it could be gravel or other materials recommended for media in wetlands. Transfer of oxygen helped the micro organisms to use the oxygen in the degradation processes of organic matters and the presence of plants in the wetlands prevents light to penetrate in the wetlands so as to produce the algae bloom (Cornel, 2004).

Oketch (2002) reported that wetlands are referred to as kidneys and living mechanisms of the environment and are the most effective ways of cleansing polluted water.

Figure 1: A Natural Wetland (Source: FWR, 2005).

The natural wetlands usually occur when the water table is at or near the surface of the land or where the land is covered by shallow water either permanently, seasonally or at tide state (FWR, 2005).

In Tanzania, especial Dar es Salaam there is a number of natural wetlands for example; the wetlands located at Msimbazi, Tandale, Keko, Magomeni wards. These wetlands are surrounded by a number of residential buildings where most of the domestic wastewaters come from (Kimwaga *et al.,* 2003(a)).

2.1.2 Constructed Wetlands

Constructed Wetlands consist of gravel parked beds with water usually one meter deep or less, plants, animals, and micro organisms. These artificial wetlands rely on natural microbial, biological, physical and chemical processes to treat wastewaters. They typically have impervious clay or synthetic liners and engineered structures to control the flow direction, liquid detection times and water levels. Depending on the type of system, they may or may not contain an inert porous media such as rock, gravel or sand (ODEQ, 1999: Davis, 2003: Tayade, 2005).

According to Davis (2003), Constructed Wetlands can be used to improve the quality of point and non-point sources of water pollution, including storm water runoff, domestic wastewater, agricultural wastewater, and coal mine drainage. They can also be used to treat petroleum refinery wastes, compost and landfill leachates, fish pond discharges, and pre-treated industrial wastewaters, such as those from pulp and paper mills, textile mills, and seafood processing (Davis, 2003). In addition, FWR (2005) reported that Constructed Wetlands can be used for final polishing of wastewater which has already undergone treatment or they may be used as a complete and stand-alone system.

The Constructed Wetlands have a number of functions and value as reported by Davis (2003). They can improve water quality, they can used for flood storage and the desynchronization of storm rainfall and surface runoff, cycling of nutrients and other materials, habitat for fish- and wildlife, passive recreation, such as bird watching and photography, active recreation, such as hunting, education and research, aesthetics and landscape enhancement.

2.2 Classification of Constructed Wetlands

According to Cornel (2004) there are two types of constructed wetlands: Free Water Surface (FWS) and Sub-Surface Flow (SSF). The FWS wetlands are densely vegetated by a variety of plant species and typically have water depths less than 0.4m. Pre-treated wastewater is normally applied continuously to FWS constructed wetlands and treatment occurs as the water flows slowly through the stems and roots of the emergent vegetation and by settling.

The major disadvantages of FWS are; they required large tracts of land to obtain the complete purification of wastewater and operated in a restricted temperature range because of the sensitivity of the ecosystem and their attraction of unwanted animals like mosquitoes that can bring about malaria.

SSF wetlands consist of channels or trenches with relatively impermeable bottoms filled with sand or rock media to support emergent vegetation. The major disadvantage of these wetlands is the phenomena of clogging of the pores caused by accumulation of suspended solids present in wastewater. The vertical and horizontal sub-surface flows are the two types of SSF.

2.3 Advantages and disadvantages of constructed wetlands

Davis (2003) explained more on the advantages and disadvantages of CW. Advantages were that they can be less expensive to build than other treatment options, operation and maintenance expenses (energy and supplies) are low, the use local labour, they are able to tolerate fluctuations in flow, they facilitate water reuse and recycling. In addition; they provide habitats for many wetland organisms, they can be built to fit harmoniously into the landscape, and they provide numerous benefits in addition to water quality improvement, such as wildlife habitat and the aesthetic enhancement of open spaces. Bojcevska (2004) was not so much different from Davis (2003), him, explained in short, like constructed wetlands are low in construction, maintenance and operational costs, low energy requirements, capacity of recycling resource and/or generating resources and improved environmental and public health. While ODEQ (1999) reported that constructed wetlands are low cost technology, easy to maintain, they are attractive and can complement a home with lush attractive vegetation and/ or colourful flowers and can produce a high quality effluent.

However there are a number of limitations associated with the use of constructed wetlands. Davis (2003) highlighted the limitations as follows: They generally require larger land areas than do conventional wastewater treatment systems. The biological components are sensitive to toxic chemicals, such as ammonia and pesticides. Materials for constructing the wetlands might not be available (ODEQ, 1999).

2.4 Removal Mechanism in Constructed Wetlands

There are a number of mechanisms that are available to improve wastewater quality; these mechanisms, according to Davis (2003) include the settling of suspended particulate matter, filtration and chemical precipitation through contact of the water with the substrate and litter, chemical transformation, adsorption and ion exchange on the surfaces of plants, substrate, sediment, and litter, breakdown and transformation of pollutants by micro organisms and plants, uptake and transformation of nutrients by micro organisms and plants and predation and natural die-off of pathogens. These mechanisms occur in all types of wetlands.

2.5 Pollutants removal in Constructed Wetlands

Since the HSSFCW polish the effluents from Maturation Pond then the possible contaminants were bacteria, the algae bloom, and heavy metals like Zinc, Lead, Copper, and Iron and the organic matters, but this depends on the performance of the WSP in general. The sources of the pollutants are the wastewater from the University of Dar Es Salaam in Tanzania at the Main campus. The Main campus consists of residential buildings, offices and classes, restaurants and bars, and banks whereby the domestic, commercial and institutional wastewaters are generated, and the final discharge is the WSP and finally some to CW or direct to the environment (Kayombo *et al*., 2005).

2.5.1 Removal of Faecal coliform bacteria

FC bacteria are micro organisms found in the intestinal of humans and animals. Their presence in water indicates faecal pollution and the presence of potentially dangerous bacteria (Davis *et al*., 2003). The usual bacterial pathogens indicated include *Vibrio cholerae (V. cholerae),* which causes cholera; *Salmonellae*, which causes typhoid and paratyphoid; and *Shigella* species, which cause dysentery. Humans are the main source of human specific pathogens, with much higher levels of FC than other warm blooded animals (LaWare *et al*., 2005 and AWRA, 2006)

CW have high percentage removal of FC. The USA, EPA (1993), Tayade *et al*., (2005) and Senzia, *et al.,* (2002) showed the removal efficiency for CW of FC is between 82 and 99.9%. Although there is good removal efficiency in many cases it is not enough to routinely satisfy discharge requirements which often should be less than 1000FC counts/100ml according to Tanzania Standards or WHO guideline of less than 200FC counts /100ml (EPA, 1993).

2.5.2 Removal of Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) is a measure of the amount of oxygen consumed in the biological processes that breakdown organic matter in water. The greater the BOD, the greater the degree of pollution. According to Davis *et al*., (2003) the selected effluent discharge guidelines for BOD_5 to the receiving water bodies should be 25mg/l for European and 50mg/l for World Bank. The organic matter are the base pollutants present in municipal and industrial wastewater with a potential of causing deleterious effects to public health and the environment.

The removal efficiency of BOD_5 in the HSSFCW was reported as 69.43% (Kimwaga, *et al*., 2003), on the HSSFCW which received wastewater from primary facultative pond at University of Dar Es Salaam, Tanzania. For the one receives from maturation pond showed to have removal efficiency of 71.6%. (Senzia, *et al*., 2002). In Kenya, the removal efficiency of BOD_5 was reported to 99.1%. (Oketch, 2002).

2.5.3 Removal of Total Suspended Solids

Total Suspended Solids (TSS) is the total organics and inorganic particles that are not dissolved and are carried in flowing water. According to Davis *et* al., (2003) the selected effluent discharge guideline specifies that the level of TSS should be between 35-60mg/l for European and 50mg/l for World Bank guideline. The processes that can be removing the TSS are settling or sedimentation and filtration processes. The removal efficiency of TSS in HSSFCW was reported to be 69.53% (Kimwaga *et al*., 2003(a)).

2.5.4 Removal of Nitrogen

The main processes on nitrogen removal in constructed wetland are by nitrification and denitrification. The nitrification is the biological process where by toxic ammonia (NH_3) is converted to non toxic nitrate (NO_3^-) through the action of nitrifying bacteria. Three forms of nitrogen that can be directly toxic to aquatic organisms are NH_3, NO_2^- and NO_3^-. Though in general aquatic organisms are more sensitive to NH_3, with some species showing chronic impairment at a concentrations as low as 0.02 mg/l as NH_3-N. Below are the equations that expressed the nitrification process (Scott, 1995).

$$NH_4^+ + 1.5O_2 \xrightarrow{Nitrosomonas} 2H^+ + H_2O + NO_2^-$$

$$NO_2^- + 0.5O_2 \xrightarrow{Nitrobacter} NO_3^-$$

Denitrification is the removal of nitrogen in the form of nitrate by conversion of to nitrogen gas under anoxic (without oxygen) condition. Conversion of nitrate-nitrogen to a readily removable form can be accomplished by several genera of bacteria. Included in this list are *Achromobacter, Aerobacter, Alcaligenes, Bacillus, Brevibacterium, Flavobacterium, Lactobacillus, Micrococcus, Proteus, Pseudomonas, and Spirillum.* These bacteria are heterotrophy capable of dissimilatory nitrate reduction (Metcalf and Eddy, 1991).

The reactions for nitrate reduction were:

$$NO_3^- \longrightarrow NO_2^- \longrightarrow NO \longrightarrow N_2O \longrightarrow N_2$$

The last three compounds are gaseous products that can be released to the atmosphere (Metcalf and Eddy, 1991).

Other processes include ammonium sorption, and volatisation, distillatory nitrate biomass, sedimentation and filtration. Nitrification-denitrification process is a process where by bacteria transform nitrogen by using oxygen and carbon respectively. (Kimwaga *et al.,* 2003(b)). Most of the processes in the removal mechanisms in CW involve the micro organisms. For example, the aerobic and anaerobic bacteria involve in degradation of organic matter, while *Nitrosomonas and Nitrobacter* bacteria involved in nitrification and denitrification processes respectively. The participation of micro organisms in these processes, a die-off or growth of micro organisms may occur. Die-off process helps on the removal of micro organisms, while growth assists the degradation, nitrification, and denitrification processes. The reported removal efficiency of organic nitrogen was 70.3% (Senzia *et al.,* 2002).

2.5.5 Removal of Ammoniacal-Nitrogen (NH_3-N)

Biological components are sensitive to toxic chemicals such as ammonia and pesticides (ODEQ, 1999). According to Senzia, *et al*., (2002) reported that an increase of NH_3-N in the effluent of CW occurs when a preliminary treatment prior to the wetland to has high algae bloom. Decomposition of algae in CW produces additional NH_3-N which is not easily nitrified due to insufficient DO in Wetlands. The effluent discharge guidelines as specified by World Bank stipulated that the level of NH_3-N should be less than 10mg/l (Davis *et al*., 2003). Senzia *et al*., (2002) reported that the removal efficiency of NH_3-N was about 20% in HSSFCW that located at Main Campus at University of Dar Es Salaam in Tanzania.

2.6 Modelling in general

2.6.1 Significance of modeling

Mankind has always used models as a tool to solve problems as they give a simplified picture of reality. The model will never contain all features of the real system because it will be the real system itself, but it is important that the model contains the characteristics features that are essential in the context of the problem to be solved or described (JØrgensen and Bendoricchio, 2001).

Urbanization and technological development have had an increasing impact on the environment. Energy and pollutants are released into ecosystems, where they may cause more rapid growth of algae or bacteria; this may damage species, or alter the entire ecological structure. An ecosystem is extremely complex and so it is an overpowering task to predict the environmental effects that such emissions will have. Here that the model come into a picture (Jorgenson and Bendoricchio, 2001).

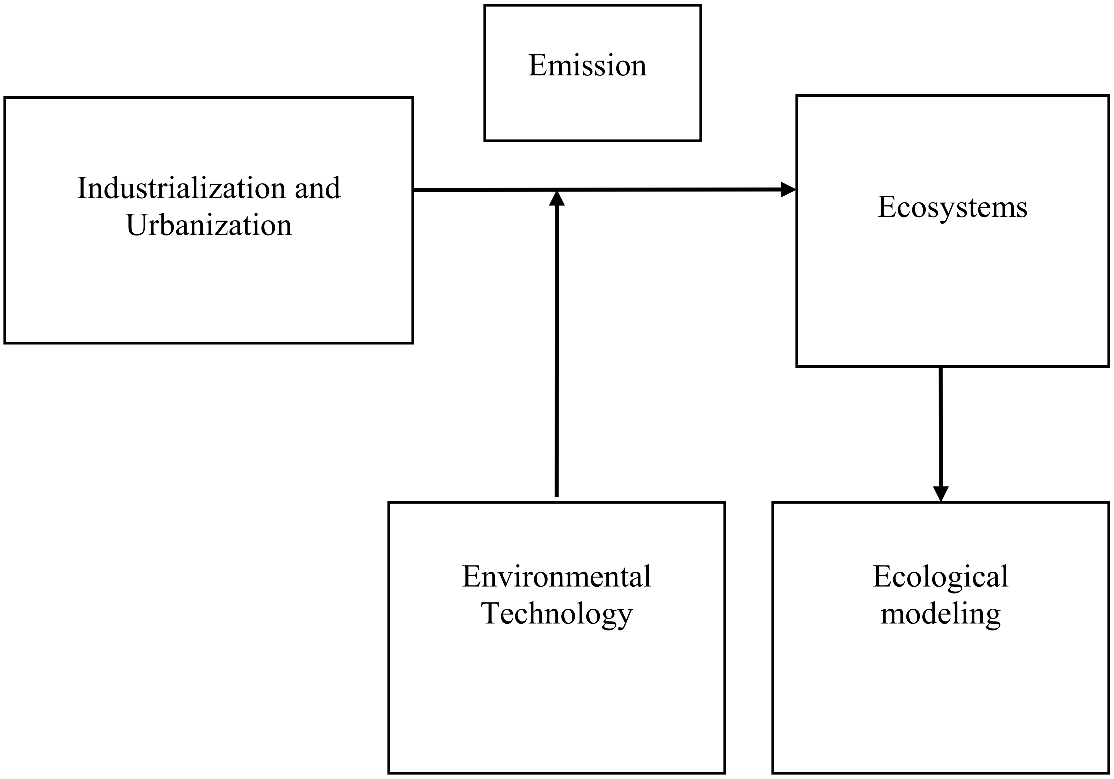

Figure 2: The relationship between environmental science, ecology, ecological modelling and environmental management and technology (Jorgenson and Bendoricchio, 2001).

Figure 2 represents the idea behind the introduction of ecological modelling as a management tool in around 1970. Today, environmental management is more complex and must apply environmental technology, cleaner production as alternative to the present technology and ecological engineering or ecotechnology. This later technology is applied to solving problems of non-point of diffuse pollution, mainly originating from agriculture. The important non-point pollution was barely acknowledged before around 1980. Further more the global environmental problems play a more important role today than they did twenty years ago.

2.6.2 Model classification

The models classified into three categories; biodemographic model where by its aim is to describe the number of individuals, species or classes of species. Bioenergetics model, describe the energy flows and biogeochemical consider the flow of material and the states variables which indicated a KG per unity volume or area (Jørgensen and Bendoricchio, 2001). Below is the table, which summarizes the model type and its measurements.

Table 1: Different types of models

Type of model	Measurements
Biodemographic	Number of species or individual
Bioenergetics	Energy
Biogeochemical	Mass or concentrations

2.6.3 Modelling elements

Model in the environmental sciences have five components which are forcing function or external variables, state variables, mathematical equations, parameters and universal constants (Jorgensen and Bendoricchio, 2001).

The forcing functions are the external factors that influence the state variables of an ecosystem. For example in eutrophication models the control functions are inputs of nutrients. There are two types of forcing functions; control and non control. The control forcing functions are the one influenced by human beings e.g. flow rate, while non-control are the one not influenced by human being, for example sunlight intensity, this factor can not be influenced by humans, it occurs naturally (JØrgensen and Bendoricchio, 2001).

State variables are that describe the state of an ecosystem. For example, bioaccumulation of toxic substances the state variable will be the organisms in the most important food chains and concentration of the toxic substance in the organisms (JØrgensen and Bendoricchio, 2001).

Mathematical equations are used to represent the biological, chemical and physical processes and describe the relationship between forcing functions and state variables (JØrgensen and Bendoricchio, 2001).

Parameters are the coefficients in the mathematical representation of processes while Universal constants are just normal constants like gas constant and atomic weights (JØrgensen and Bendoricchio, 2001).

2.6.4 Modelling procedures

Below are the modelling procedures according to JØrgensen and Bendoricchio (2001).

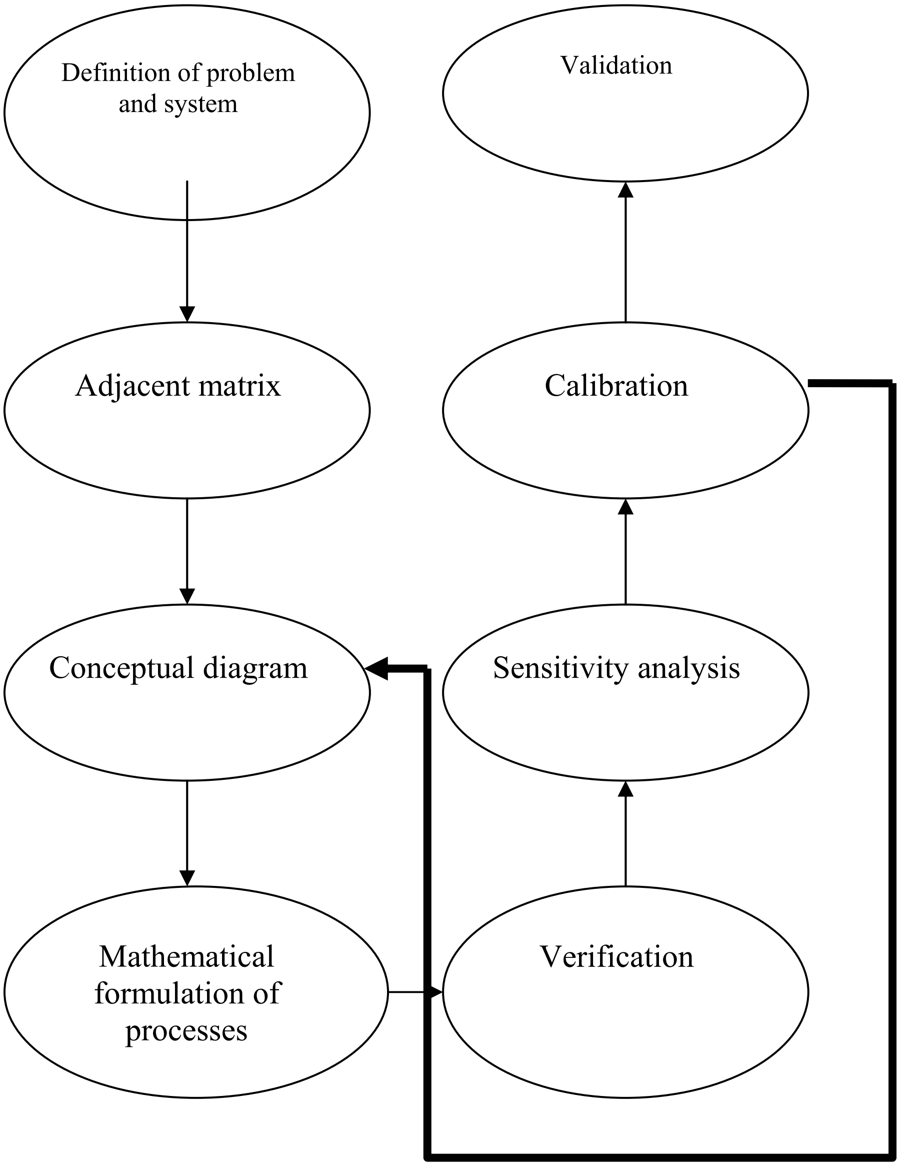

Figure 3: Modelling procedures (Jørgensen and Bendoricchio, 2001).

2.6.4.1 Definition of the problem

The problem to be solved has to be clearly defined. All the forcing functions selected are used to evaluate the extent to which they influence the state variables and the process of faecal coliform removal (Jørgensen and Bendoricchio, 2001). In this study the problem was to quantify each process that contributed on the total removal of FC hence to see the possibility on optimise the FC reduction in HSSFCW. The state variables in this study were FC, BOD_5 and NH_3-N while the forcing functions were DO, temperature, pH and flow rates. The state variables and forcing functions in this study were linked by the sub-model (mathematical equations) that presented in the removal mechanisms which include inflow, outflow, sedimentation, filtration, die-off and growth processes.

2.6.4.2 Conceptual diagram

Conceptual diagram is important stage on model development. This process comes after defining the problem clearly (JØrgensen and Bendoricchio, 2001). This is the stage at which the conceptualization of the model in the form of diagram is undertaken. It provides information on which the state variables, forcing functions and process equations are required in the model (Mashingia, 2006).

2.6.4.3 Mathematical equations formulation

This is the stage where different equations to describe processes are considered. Depending on the complexity of the processes, the equations can be of first order kinetics, Monod equations etc. Conservation of mass equations are developed for interactive physical and biological species reacting to environmental factors that affect the mechanisms (JØrgensen and Bendoricchio, 2001).

2.6.4.4 Verification

This is the test of the internal logic of the model. Typical questions in the verifications phase are: Does the model react as expected? Is the model stable in the long term? Does the model follow the law of mass conservation? Is the use of the units consistent? Verification is to some extent a subjective assessment of the behaviour of the model. To a large extent, the verification will go on during the use of the model before the calibration phase (JØrgensen and Bendoricchio, 2001). One of the techniques on verification is to disturb the input variables and study the behaviour of the output. If model is correct and the parameters are properly defined then the constants will remain constant regardless of the level of the input (Mashingia, 2006).

2.5.4.5 Calibration

This is an attempt to find the best accordance between computed and observed data by variation of some selected parameters. It may be carried out by trial and error or by use of software developed to find the parameters giving the best fit between observed and computed values (JØrgensen and Bendoricchio, 2001)

2.6.4.6 Validation

Validation must be distinguished from verification. It consists of an objective test of how well the model fit the data. This is done by running the model with a new set of data with physical parameters and forcing function to relate new condition. The model is revised each time until it is verifiably and consistently accurate. In contrast, the kinetic coefficients are kept fixed at the values derived the original calibration. When the new model is validated, it becomes an effective tool for the range of conditions defined by the original calibrated and validation data set (JØrgensen and Bendoricchio, 2001).

2.6.5 Modelling in Constructed Wetlands using STELLA Software

In Tanzania, there a number of modelling studies those have been carried out in the CW by using STELLA software. For example the study of TSS removal in a Coupled Dynamic and HSSFCW treating WSP effluents. This was the mathematical model developed to simulate the retention and removal of Total Suspended Solids (TSS) in the coupled Dynamic Roughing Filter (DRF) and HSSFCW treating effluents from WSP. The model was based on the deep – bed filtration models with an extension term that incorporates biological activities (biodegradation). The filtration and sedimentation processes were simulated by simple equations of first order kinetics, while biodegradation process was simulated by Monod's equation. The model was calibrated using the experimental data that were obtained from the experimental rigs constructed at the outlet of the facultative pond of WSP and was validated by data obtained from the experimental rigs placed after the maturation pond of WSP. The simulations of the model were performed using STELLA™ II software. From the model simulation, it was found that the sedimentation process was the major removal route of the TSS in the DRF accounting for 65% of the total removal followed by the filtration process (25%). However, the filtration process was the major route of removal of the TSS in the HSSFCW accounting for 75% removal followed by biodegradation, which accounted for 15% (Kayombo *et a*., 2005). From the results that presented on HSSFCW of this mathematical model, then filtration process was the main part to consider when designing the filtering bed. This would increase the removal efficiency of the system on removing the TSS.

The other modelling study which was done by using the STELLA soft ware was nitrogen removal from domestic wastewater by indigenous Macrophytes in HSSFCW in Tanzania. The overall objective was to develop a model for identifying the most suitable indigenous emergent macrophytes species of the six tested for wastewater treatment in HSSFCW in Tanzania, based on nitrogen removal. The main nitrogen removal mechanisms studied were plant uptake and denitrification (Kayombo *et al*., 2005) but nitrification and mineralization were also included in this model. It is assumed that ammonia and nitrate nitrogen removal from wetlands by macrophytes depended on the biomass of the roots. The model results showed that the higher reduction of NH_3-N was occurred at day 60 for the macrophytes by 1.6mg/l. From this study it can be concluded that the macrophytes plants reduced the NH_3-N concentration from the system.

The Transformation in HSSFCW planted with *Phragmatis Mauritianus* was one of the modelling studies which were carried out in Tanzania by using STELLA soft ware. The mathematical model that permits dynamic simulations of nitrogen interactions in HSSFCW that receiving effluents from primary facultative ponds. Nitrogen transformation processes considered in this model include nitrification, denitrification, plant uptake, decomposition and accretion of organic nitrogen. Volatilisation was not included because it only plays a negligible role in reducing nitrogen at the typically neutral pH levels found in sub-surface wetland systems. The research was conducted in the University of Dar Es Salaam pond system (Kayombo *et al.,* 2005). Four field-scale units of sub-surface flow constructed wetlands, with horizontal flow characteristics, were built to receive effluent from primary facultative ponds at the University of Dar Es Salaam waste stabilization pond system. The system is located at latitude 6_0 48' S and longitude 39_0 13' E. The area has monthly mean air temperatures between 23 – 28_o C. The primary facultative pond receives wastewater of largely domestic characteristics emanating from the campus. The quality of the water flowing to the constructed wetlands is highly dependent on the university's academic timetable. During the long vacation, the pond loading will be very low, compared to the time period the university is open, during which the wastewater flow rates change significantly (Kayombo *et al.,* 2005). The model includes mineralization, nitrification, denitrification, and plant uptake. Other processes are decaying/decomposition of plants, and accretion of organic nitrogen (Kayombo *et al.,* 2005). From the study it was established that nitrification/denitrification and plant uptake were the major removal mechanisms by 47.6% followed by accretion by 19.2% and denitrification by 15.02%. From this study it can be concluded that nitrification/denitrification and plant uptake were the processes when considering the deigning of SSF Constructed Wetlands.

Apart from the above studies, there was a modelling study conducted concerning heavy metals by using STELLA soft ware. The metals were lead (Pb), Copper (Cu) and Zinc (Zn). Heavy metals are used in large quantities in many industries. Wastewater from these industries naturally contains heavy metals and, if no legislation exists on this issue, heavy metals are discharged with the wastewater to the surrounding water bodies. Heavy metals are toxic to humans and all other living organisms, thereby being undesirable in the environment: Constructed wetlands can be a solution to preventing the pollution of lakes and streams from heavy metals.

CHAPTER THREE

STUDY AREA

3.1 Background information

The study was carried out at HSSFCW that is located at main campus of University of Dar Es Salaam, Tanzania. Its geographical location was latitude 6^0 48’ S and longitude 39^0 13’ E. The area has monthly mean maximum and minimum air temperatures of 28^0C and 23^0C, respectively. The effluents from HSSFCW are discharged to a small river located nearby the HSSFCW.

The main campus consists of a number of buildings which include staff houses, classes, banks, bar and restaurants, salon and water quality laboratories. The generated effluents from these buildings are discharged to the Waste Stabilization Pond (WSP) system that is located within the campus (Figure 4).

The main type of wastewaters that are disposed in WSP are a mixture of domestic and institutional wastewaters which are suspected to contains contaminants like pathogenic organisms, organic maters and heavy metals.

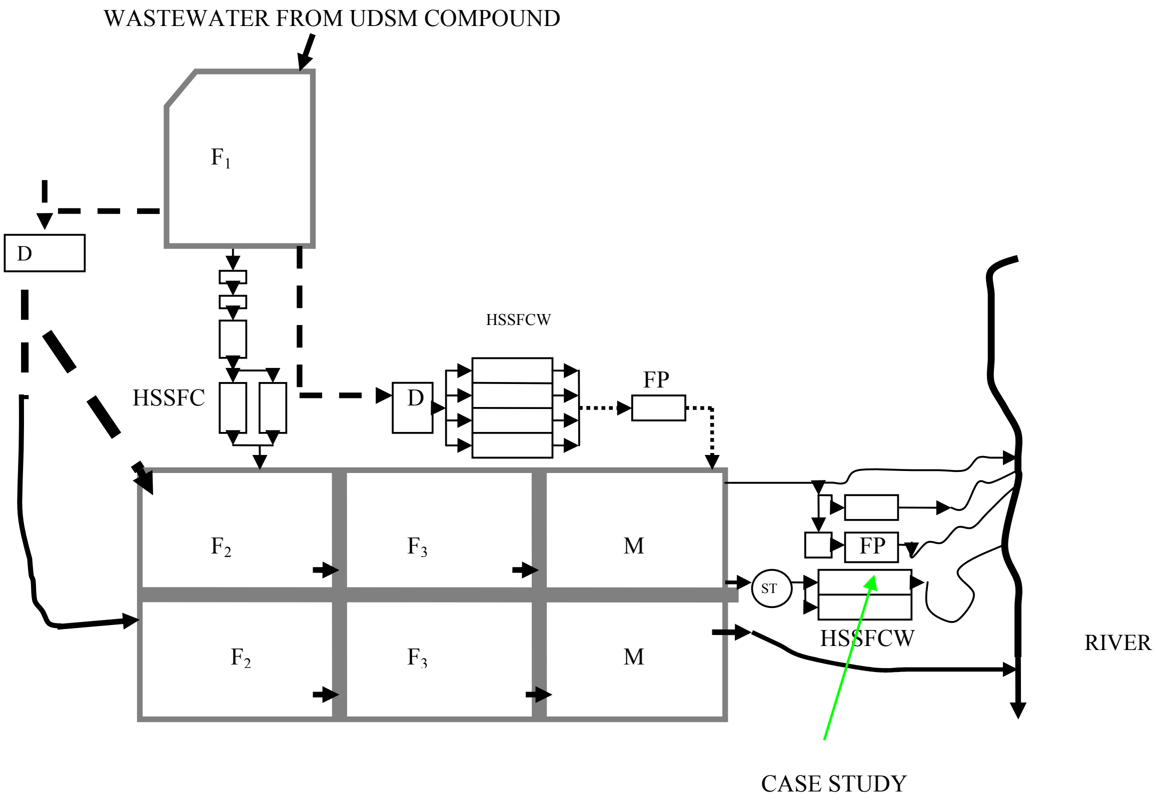

Figure 4: Schematic diagram of WSP and Constructed Wetlands UDSM.

Legend: F_1: Primary Facultative Pond, F_2: First Secondary Facultative Pond, F_3: Second Secondary Facultative Pond, M: Maturation Pond, FP: Fish Pond, HSSFCW: Horizontal Sub-Surface Flow Constructed Wetland, D: Distribution Chamber, and ST: Settling Tank.

The HSSFCW was polishing the effluents from the Maturation Pond which form part of the WSP. Therefore, it is suspected that the effluents from the HSSFCW to have few contaminants.

3.2 Operational and maintenance of HSSFCW

As presented in chapter two, clogging is main disadvantage of the HSSFCW, so the system was un-blocked so as to make the system operate in an efficient manner.

CHAPTER FOUR

MATERIALS AND METHODS

4.1 Data collection

4.1.1 Experimental set-up

The dimensions of HSSFCW were 6.9m length; 2.3m width 0.75m substrate depth and water depth of 0.6m. 80KG/ha/d and 10cm/d were the maximum Organic Loading Rate (OLR) and Hydraulic Loading Rate (HLR) respectively, while the design flow rate was 1.7m^3/d. The porosity of the system was 0.35 while the slope was about 1.2 (Senzia *et al.,* 2002).

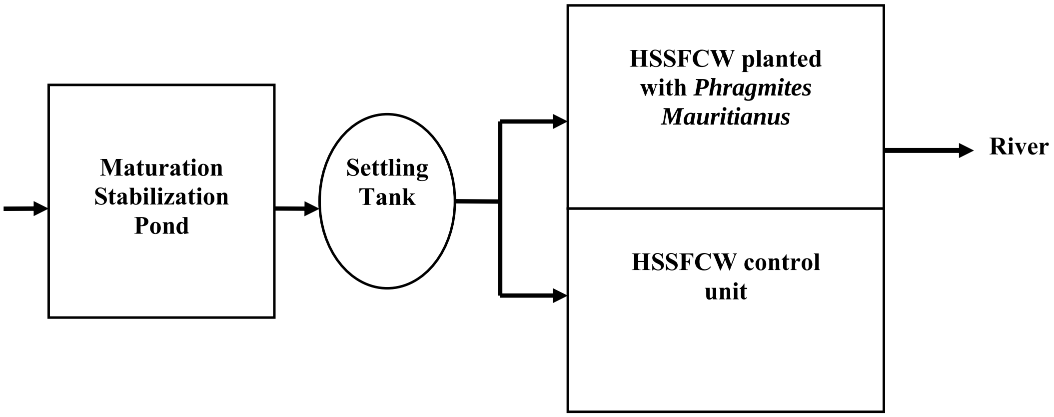

Figure 5: Layout of MSP, Settling Tank and HSSFCW.

Figure 6: The case study planted with *Phragmites Mauritianus*

3.1.2 Sampling

The sampling and analysis were carried out from February to April 2007 (Appendix 1). Grab samples were taken at the inlet, middle and outlet of the HSSFCW. The purpose of sampling at the mentioned sampling points was to know the efficiency of the system at those particular points. Figure 7 showed the inlet sampling point. The results obtained were used to model the FC removal. The intention of grab sampling was to know the concentration of the sample at a particular point and time. The method for sampling was manual. The collection of samples for microbiological examination was done using the plastic bottles that had been cleansed and rinsed carefully with distilled water. The bottles were full sampled and were closed tightly to prevent air (oxygen) from entering the bottles.

Figure 7: The sampling point at the inlet of the HSSFCW.

4.1.3 Analysis of Wastewater Parameters

Analysis was carried out by using the Standard Method of Water and Wastewater Examination by APHA (1992). The parameters that were measured were FC, NH_3-N, BOD_5, pH, DO, Temperature (T), and flow rate (Q). The purpose of choosing the above parameters was because they were suspected to have some effects on the total of FC removal.

4.1.3.1 Faecal Coliform bacteria.

The method used for FC test was the Pour Plate Method and the materials used were the M-FC agar base and Rhozoric Acid. The procedure for agar base preparation was 5.21g of M-FC agar base dissolved in 100ml of distilled water. One ml of Rhozoric acid was added to the mixture to make the agar base dissolve. The mixture was boiled and left to cool to 45^0C. For the FC analysis, One ml of the diluted sample was poured in a Petri dish and 5-10ml of the prepared MF-C media was added to the Petri dish. The mixture was incubated in an incubator at 45^0C for 48 hours. The FC was counted and the results were multiplied by 100 and the dilution factor. The dilution factors that were used in this study were ranging from 10^1 to 10^3.

4.1.3.2 Biochemical Oxygen Demand (BOD_5)

For BOD_5 measurement, the Sodium hydroxide (NaOH) pellets were used. The method used was $OxiTop^R$ measurement system. This is an automatic measurement with daily storage of measured values for more than 5 days. A 250ml sample was placed in the BOD bottle and NaOH pellets were put in cap of the BOD bottle then covered with the $OxiTop^R$ cap. The cap was set to read "00" before incubation. The bottle was then incubated in the incubator which was set at 20^0C. The purpose of NaOH was for regulating the pH for micro organism to degrade the organic matter. The readings were taken after 5 days.

4.1.3.3 Ammoniacal Nitrogen (NH_3-N)

For NH_3-N the NaOH solution, boric acid solution, mixed indicator which is the mixture of ethyl alcohol, methyl orange indicator, and methyl blue indicator and 0.2N of Sulphuric acid solution were used. Kjeltec System 1002 Distilling Unit was used for the distillation process. Part of the sample (50ml) was mixed with about 50ml of NaOH solution and the mixture was distilled in the distillation unit. NH_3-N was collected in the measuring flask which contained boric acid solution plus indicator. The purpose of boric acid solution was to absorb the NH_3-N during distillation process. The 50ml of distilled sample was then titrated with 0.02N Sulphuric Acid (H_2SO_4) and the mixed indicator was used as the indicator. The colour changed from yellowish to purple at the end point. The volume of the titrant was recorded and the calculation of NH_3-N concentration was made by using the formula which was adopted from WRED (1998).

$$NH_3\text{-}N\ (mg/l) = \frac{V_t * 280}{V_S} \qquad \text{..........} \textbf{Equation 1}$$

Where:

V_t is the volume of the tirant

V_s is the volume of the sample

Considering one of the experiment that was done in water quality laboratory on 1st February 2007, the following were obtained.

V_t = 1.8ml

V_s = 50ml

Then from the formula above the value of NH_3-N in mg/l were 10.08. For more calculations of the NH_3-N refer on Appendix 1.

4.1.3.4 Dissolved Oxygen (DO).

The method used for DO test was by using the DO meter Model 50B. The sample was put in a beaker and a probe was inserted into it. Readings of the sample were taken when they were stable.

4.1.3.5 pH and Temperature

Temperature and pH of the wastewater were measured by using the 8424 microcomputer pH meter. The sample was also poured in the beaker and the probe inserted into it. Readings were then taken when they where stable.

4.1.3.6 Flow rate

The inflow was maintained at 1.7m^3/d (19.7ml/sec) so as to meet the design flow rate of the HSSFCW. A Beaker of 250ml and stop watch were used to measure the flow rate of the inflow, middle and outflow. Records on effluent volume in millilitres were taken for every 10 seconds. Results were then converted to m^3/d.

Table 2: Flow rates calculation

Sampling Date	**Inlet (ml/sec)**	**Middle (ml/sec)**	**Outlet (ml/sec)**	**Inlet (m^3/d)**	**Middle (m^3/d)**	**Outlet (m^3/d)**
1-Feb-07	19.73	18.55	13.87	1.70	1.60	1.20
6-Feb-07	19.72	18.56	13.84	1.70	1.60	1.20
8-Feb-07	19.64	15.09	10.42	1.70	1.30	0.90
12-Feb-07	19.63	13.88	9.25	1.70	1.20	0.80
14-Feb-07	19.65	16.25	11.54	1.70	1.40	1.00
19-Feb-07	19.71	15.08	11.45	1.70	1.30	0.99
21-Feb-07	19.73	15.09	10.42	1.70	1.30	0.90
26-Feb-07	19.64	15.09	11.45	1.70	1.30	0.99
28-Feb-07	19.72	16.21	11.53	1.70	1.40	1.00
5-Mar-07	19.69	17.41	12.73	1.70	1.50	1.10
7-Mar-07	19.71	17.37	13.84	1.70	1.50	1.20
12-Mar-07	19.65	16.21	11.52	1.70	1.40	1.00
14-Mar-07	19.67	16.26	12.71	1.70	1.40	1.10
19-Mar-07	19.66	16.23	11.57	1.70	1.40	1.00
21-Mar-07	19.71	17.36	12.73	1.70	1.50	1.10
26-Mar-07	19.69	17.35	12.73	1.70	1.50	1.10
28-Mar-07	19.69	17.36	13.84	1.70	1.50	1.20
2-Apr-07	19.67	16.24	11.58	1.70	1.40	1.00
4-Apr-07	19.68	17.34	12.72	1.70	1.50	1.10
11-Apr-07	19.67	16.24	12.72	1.70	1.40	1.10
16-Apr-07	19.65	16.22	11.53	1.70	1.40	1.00
18-Apr-07	19.67	16.24	12.71	1.70	1.40	1.10
Minimum	19.63	13.88	9.25	1.70	1.20	0.80
Maximum	19.73	18.56	13.87	1.70	1.60	1.20
Average	19.68	16.44	12.12	1.70	1.42	1.05
S.D	0.03	1.16	1.22	0.003	0.10	0.11

4.2 Modelling Approach

4.2.1 Modelling procedures diagram

In this study the modelling procedure was presented in the diagram below. Description of each step is presented in chapter two. The validation was not included due to deficit of the data. It needs a set of different data collected at a different time from the one used in calibration.

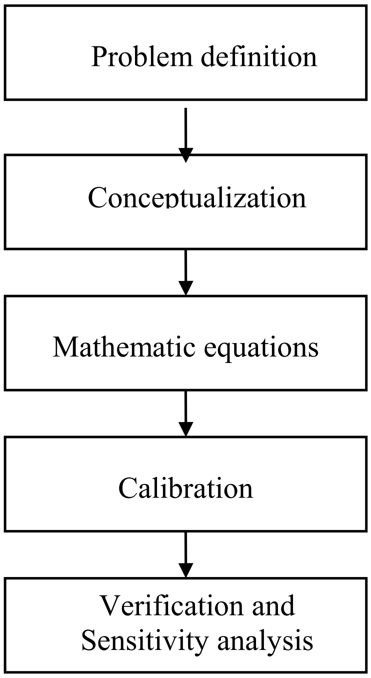

Figure 8: Flow diagram of modelling procedures that were considered in the study

4.2.2 Conceptual diagram

In this study, processes that contributed to the total FC removal are inflow, outflow, sedimentation, filtration, and natural dying processes (refer figure 9). Sedimentation is the separation from water, by gravitation settling, of suspended particles that are heavier than water (Metcalf and Eddy, 1991). Filtration was used extensively for achieving supplemental removal of suspended solids including particulate BOD from wastewater effluents of biological and chemical treatment processes (Metcalf and Eddy, 1991). The growth process was considered because within the system there was growth of micro organisms which occurred due to supply of nutrients. The death process might be due to un-favourable environmental conditions including UV from sunlight and temperatures unfavourable for cell reproduction (Polprasert, 2002).

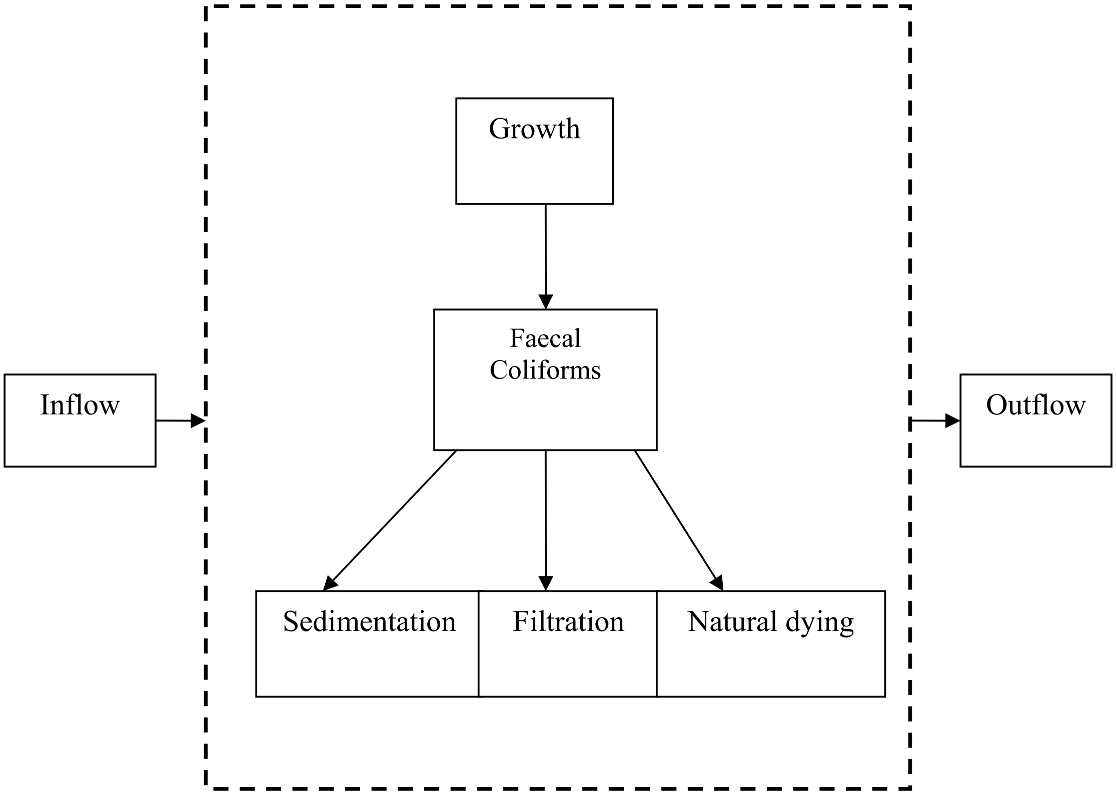

Figure 9: The conceptual diagram for Faecal Coliforms Removal

The area enclosed with a dash line represents the inner part of HSSFCW.

4.3 Mathematical equations

The mathematical equations in this study were adopted from the ones reported by Kimwaga *et al*. (2003), Scott (1995) and Metcalf and Eddy (1991) basing on the processes that took place during the total removal of FC in HSSFCW.

4.3.1 Inflow equation

$$FC_{ip} = \frac{Q_{in} \times FC_{in}}{V_{cw}} \qquad \text{...}\textbf{Equation 2}$$

Where:

FC_{ip} is FC concentration in the inflow process (Counts per 100ml per day)

Q_{in} is the design flow rate (m^3/d)

FC_{in} is the concentration of FC (Counts per 100ml)

V_{cw} is the volume of constructed wetland (m^3)

4.3.2 Outflow equation

$$FC_{op} = \frac{Q_o \times FC_o}{V_{cw}} \qquad \text{..........Equation 3}$$

Where:

FC_{op} is FC concentration in the out-flow process (Counts per 100ml per day)

Q_o is the design flow rate (m^3/d)

FC_o is the concentration of faecal coliform (counts per 100ml)

V_{cw} ls the volume of constructed wetland (m^3)

4.3.3 Sedimentation equation

$$FC_{sd} = \frac{FC_{md} \times S_r}{H} \qquad \text{..........Equation 4}$$

Where:

FC_{sd} is the FC concentration in the sedimentation process (Counts per 100ml per day)

FC_{md} is the concentration of faecal coliform at the middle (Counts per 100ml)

S_r is sedimentation rate or settling velocity (m/d)

H is the effective depth of the wetland (m)

The table below showed the various values of settling velocities of the suspended solids in the sedimentation basin. In this study, it was assumed that the micro organisms settled with the suspended solids. Also it was assumed that HSSFCW acted as a settling basin. Because it is a secondary treatment, then the settling velocity was assumed to be 0.086m/d in this study.

Table 3: Settling velocities of suspended solids in primary and secondary effluents

Settling velocity				**Percentage of total**	
Ft/s	Cm/s	m/s	m/d	Primary	Secondary
3.3×10^{-4}	10^{-2}	10^{-4}	8.64	20	16
3.3×10^{-5}	10^{-3}	10^{-5}	0.864	30	34
$< 3.3 \times 10^{-6}$	$< 10^{-4}$	$< 10^{-6}$	< 0.0864	50	50

(Metcalf and Eddy, 1991).

4.3.4 Filtration equation

$$FC_f = \frac{FC_{md} \times f \times a \times b}{V_{cw}}$$ ……………………………………………………………**Equation 5**

Where:

FC_f is the FC concentration in the filtration processes (Counts per 100ml per day)

f is the filtration rate (m/d)

a And b are constants in m

4.3.5 Die-off equations

The death rate is usually a function of the viable population and environmental characteristics (Metcalf and Eddy, 1991). Also, Metcalf and Eddy (1991) outlined that the rate of disappearance of pathogenic bacteria and viruses due to die-off approximately follows first order kinetics.

$$r_B = -k_B \times C_B$$ ……………………………………………………………**Equation 6**

Where:

r_B is rate of bacteria die-off per unit time per unit volume of water (Count/L^3.T)

C_B is bacteria concentration (Count/L^3) and k_B is die-off constant (T^{-1})

The k_B can be compared with the overall decay coefficient which presented by Kimwaga (2003).

$$r_z = r_t + r_i + r_f$$ ……………………………………………………………**Equation 7**

Where:

r_z is the overall removal rate coefficient (per day)

r_t is the removal rate coefficient due to temperature (per day)

r_i is the removal rate coefficient due to solar radiation (per day)

r_f is the removal rate coefficient due to combine effects of adsorption, filtration and sedimentation.

$$r_t = r_{20} \times \phi_T^{(t-20)}$$ ……………………………………………………………**Equation 8**

(Arrhenius-van't Hoff equation)

Where:

r_{20} is the removal rate at 20^0C (per day)

t is the water temperature ^{0}C

ϕ_T is the temperature coefficient

$$r_i = \phi \times I_{avg}$$

Equation 9

Where:

ϕ is the light mortality coefficient (m^2 per cal)

I_{avg} is an average solar radiation (cal per m^2 per day)

$$r_f = \frac{4}{\Pi} n\alpha u \frac{(1-\theta)}{d}$$

……………………………………………………………………**Equation 10**

Where:

n is single collector removal rate coefficient

α is the sticking efficiency

µ is velocity of flow (m per day)

d is the porous media grain diameter (m)

θ is the porosity of the bed

Note: The calculation of single collector removal rate coefficient (n) was shown in the Appendix II and for the sticking efficiency α the value showed in the table of parameter used in the model.

$$FC_d = r_z * FC_{md}$$

……………………………………………………………………….**Equation 11**

Where:

FC_d is the FC concentration in the death process (FC counts/100ml.d)

r_z is the overall removal rate coefficient (per day)

FC_{md} is the FC at the middle (FC counts/100ml)

4.3.6 Growth rate equation

$$\mu = \mu_{\max} \frac{S}{k_s + S}$$

……………………………………………………………………….**Equation 12**

Where:

μ is specific growth rate, (time^{-1})

$\mu_{\max}$ is the maximum specific growth rate (time^{-1})

S is the concentration of growth-limiting substrate in solution (mass/unit volume)

K_s is half-velocity constant (mass per unit volume).

If bacteria growth depends on more than one substrate e.g. oxygen and ammonia ion then the equation would be as follows.

$$\mu = \mu_{\max}\left[\frac{S_o}{k_o + S_o}\right] * \left[\frac{S_{NH}}{k_{NH} + S_{NH}}\right] * \ldots \quad \text{……………………………………………}\textbf{Equation 13}$$

Where:

μ is specific growth rate, (hr^{-1})

$\mu_{\max}$ is the maximum specific growth rate (hr^{-1})

S_o is O_2 concentration (mg/l O_2)

K_o is O_2 half-saturation constant (mg/l O_2)

S_{NH} is NH_4^- ammonia ion concentration (mg/l N)

K_{NH} is ammonia ion half-saturation constant (mg/l N)

$$FC_g = \mu * FC_{md} \quad \text{…………………………………………………………………}\textbf{Equation 14}$$

Where:

FC_g is the FC concentration in the growth process (Counts/100ml.d)

μ is specific growth rate, (d^{-1})

FC_{md} is the FC at the middle (Counts/100ml)

All the equations presented above were used in the FC model. The quantification of the FC concentration was done by using STELLA soft ware.

4.4 Model calibration

Calibration is the tuning of the model to fit the observed values. This involved varying the model parameters to obtain an optimal agreement between model calculations and the observed values and this was done based on adjusting the kinetic parameters. The major kinetic coefficients that were used in this study in model calibration were the Half Saturation Constants of BOD, DO, NH_3-N and pH. The light mortality constant, temperature coefficient, sedimentation rate and filtration rate were also used in calibration of the model.

4.5 Model verification and sensitivity analysis

Model verification was done by varying the input parameters and observing the variations in the output. The inputs that were varied were the average solar radiation, NH_3-N, BOD_5, and DO, pH, BOD_5 and temperatures. The output that was observed was the simulated FC within the system. The verification was done by varying one parameter at a time (i.e. on varying average solar radiation while keeping the rest of the parameters constant). For the sensitivity analysis, the objective was to see how much the output changed with the inputs. This was carried out by varying the inputs with a relative change of ± 10% of the inputs. The sensitivity made it possible to distinguish between high-leverage variables, whose values have a significant behaviour and low-leverage variables, whose values have minimal impact on the system (Jørgensen and Bendoricchio, 2001).

CHAPTER FIVE

RESULTS AND DISCUSSIONS

5.1 Observed results

5.1.1 Removal of Faecal Coliform Bacteria

The values of FC Counts per 100ml in HSSFCW at the inlet was 1,163,636 ± 268,675, middle section was 884,909 ± 344,564 and outlet was 45,909 ± 19,373, however the removal efficiency was 96 ± 0.9%. Upon comparing the observed results with the Tanzanian Standard which stated that FC should be less than 1000 Counts per 100ml, all of the results at the inlet, middle and outlet were found to above it (1000 Counts per 100ml). But the removal efficiency of the system was very high at 96%. It can be concluded that there is a need to improve the WSP as well as HSSFCW systems so as their discharge can meet the recommended standards before disposing to the environment.

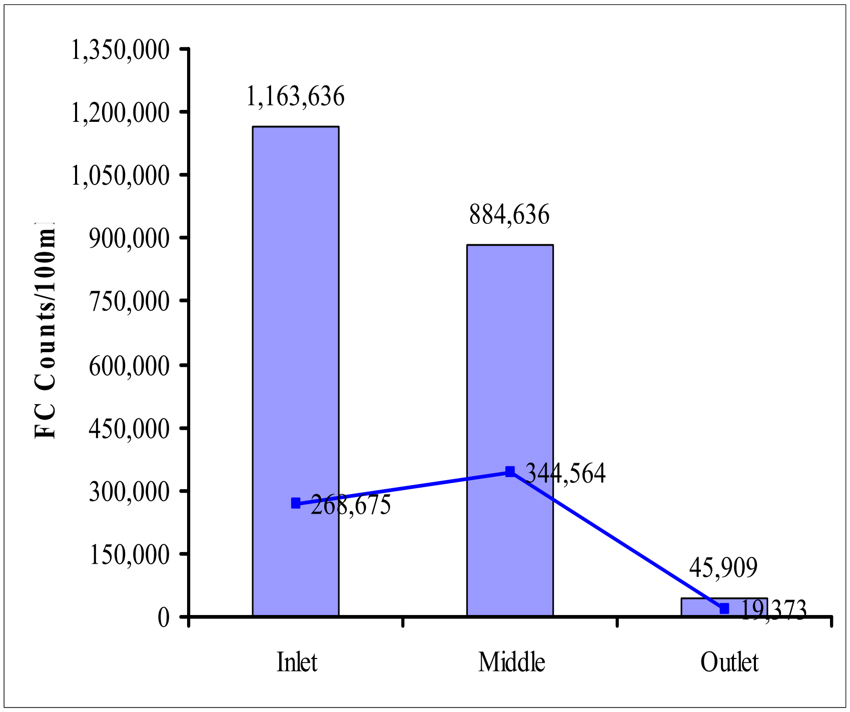

Figure 10: Averages and Standard Deviations values of FC in HSSFCW.

In figure 10 above, the inlet has higher FC concentration as compared to middle section and outlet. The trend of FC concentration from the inlet to the outlet showed a decrease across the system hence it could be concluded that there was a treatment that was taking place within the system. The treatment was, however, not effective because the effluents were much higher as compared to the Tanzanian standard (figure 10).

The main source of coliform bacteria is the intestinal track of man which contains countless rod shaped bacteria. Each person discharges from 100 to 400 billion coliform organisms per day, in addition to other kind of bacteria. Thus, the presence of coliform organisms is taken as indication that pathogenic organisms might be present, and the absence of coliform organisms is taken as an indication that water is free from disease producing organisms (Metcalf and Eddy, 1991). In this study, The outlet of HSSFCW showed that FC bacteria above the Tanzanian Standards were discharged to the stream located nearby. The FC bacteria are part of coliforms bacteria; their presence in water indicates bacteria contamination by disease causing micro organisms (Metcalf and Eddy, 1991: Davis and Hirji, 2003).

5.1.2 Removal of Biochemical Oxygen Demand

The BOD_5 in mg/l at the inlet was 141±35, middle section was 119 ± 25 and outlet 68±11, and however, the removal efficiency of HSSFCW in BOD_5 was 51±5%. Although the efficiency of HSSFCW was good, the BOD_5 was still above the WB guideline (Appendix 1).

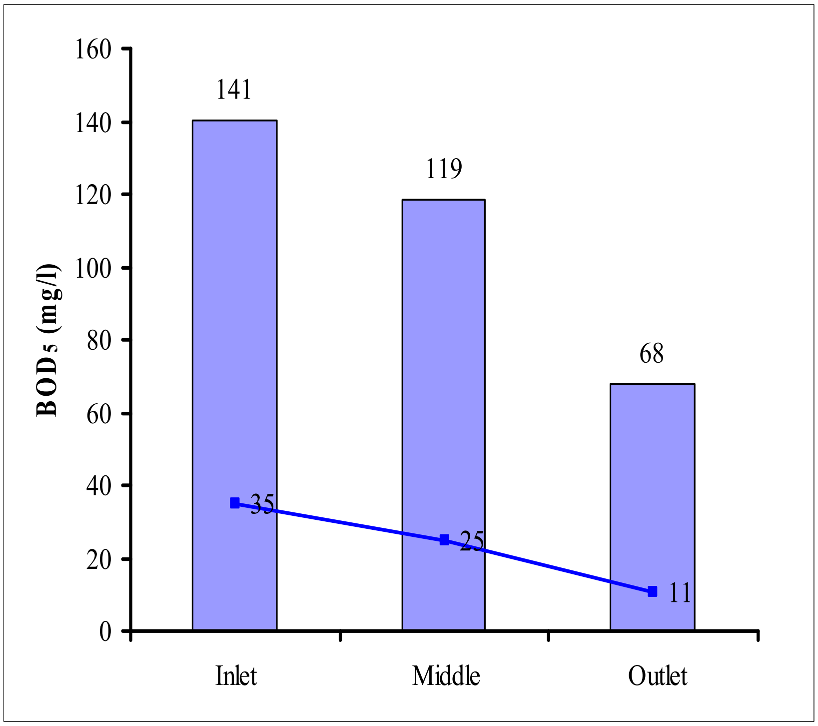

Figure 11: Averages and Standard Deviations values of BOD_5 in HSSFCW.

Figure 11 showed that the values of BOD_5 were decreasing across the system. The decrease of BOD_5 was due to the presence of degradable micro organisms which are used to degrade the organic matter present in wastewaters. The removal of carbonaceous BOD, the coagulation of non-settleable colloidal solids and stabilization of organic matter are accomplished biologically using a variety of micro organisms, principally bacteria (Metcalf and Eddy, 1991). In the degradation process, micro organisms consume oxygen, as a result of DO depletion across the system (i.e. inlet, middle section and outlet). The decrease of DO within the aerobic system affects the micro organisms. This might result in poor performance of the system when treating ammonia group (NO_3^-, NO_2^-, Org-N and NH_3-N) as well as the other organic matter. In this case, the HSSFCW would be a point source of pollution to the stream.

5.1.3 Removal of Ammoniacal-Nitrogen

The NH_3-N in mg/l at the inlet was 10.92±0.47, middle section was 9.93±0.55 and outlet was 8.01 ± 0.64, however, the removal efficiency of HSSFCW on removing NH_3-N was 27 ± 3.3%. The results were found to be within the WB guideline (Appendix 1).

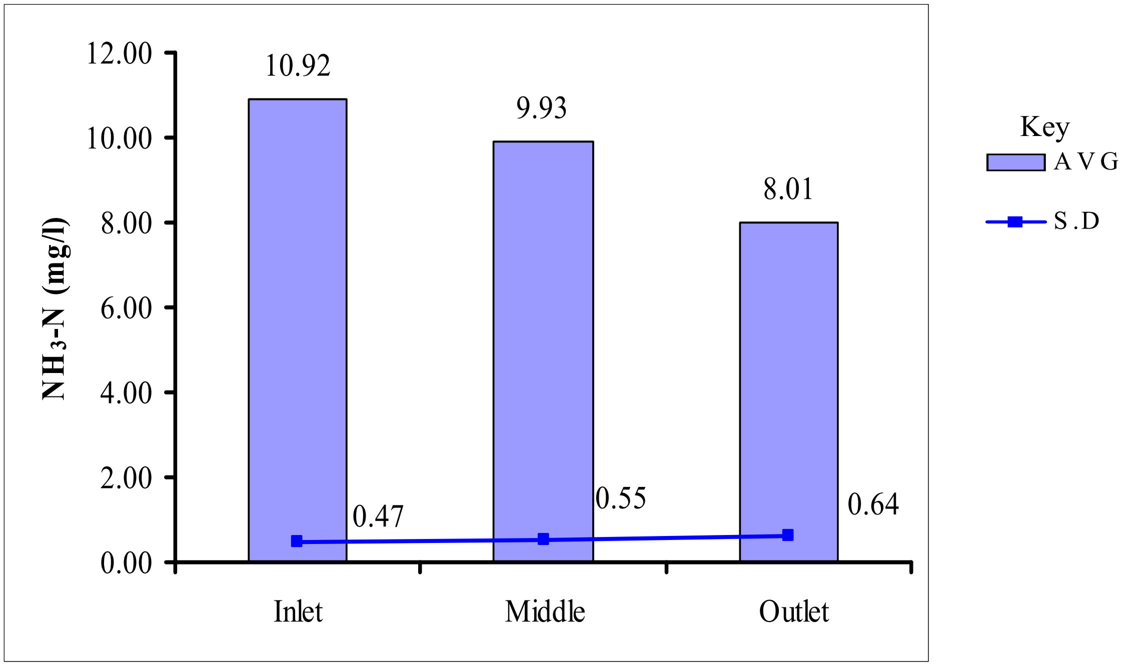

Figure 12: Averages and Standard Deviations values of NH_3-N in HSSFCW.

Figure 12, the values of NH_3-N showed to decrease across the system. The decrease of Ammoniacal nitrogen might be due to chemical processes which were taking place within the system. These chemical processes might be the nitrification process, the conversion of Ammoniacal nitrogen to nitrate due the presence of *Nitrosomonas* and *Nitrobactor* bacteria (Metcalf and Eddy, 1991).

5.1.4 DO, temperature, pH and flow rates

The DO values in mg/l at the inlet were 5.91±0.23, middle section was 5.76±0.20 and outlet was 5.59±0.26. The temperature in °C at the inlet was 29.77±1.63, middle section was 30.20±1.63 and outlet was 30.64±1.57. The pH values at the inlet were 6.28±0.14, middle section was 6.67±0.37 and outlet was 7.62±0.72. Flow rate in m^3/d at the inlet was 1.7±0.003, middle section was 1.42±0.106 and outlet was 1.05±0.106. All the presented values are within the WB guideline (Appendix 1).

The average values of DO and flow rates decreased while the temperature and pH values were increased across the system. These results were similar to the one reported by Metcalf and Eddy, (1991) and Kaseva, (2004).

The decrease of DO and increase of temperature were due to biological and chemical activities taking place within the system. The biological activity within the system might have been the consumption of oxygen by micro organisms when degrading the organic mater, or the oxygen consumed by bacteria in the growth process. The chemical activity could have been as a result of the nitrification process. The increase of pH might be due to chemical process (nitrification) or the materials used for construction of HSSFCW (limestone). This result was similar to the one presented by Kaseva (2004). The decrease of flow rate was might have been due to evatransporation by the plants during photosynthesis.

5.2 Relationship between FC and other parameters

5.2.1 Relationship between FC and BOD$_5$

The FC bacteria showed considerable dependence on BOD$_5$ as shown in figure 13. According to Metcalf and Eddy (1991) the BOD$_5$ is used as a food to micro organisms, and it can thus be concluded that the rise and fall of the FC bacteria was due to availability of food and nutrients within the system.

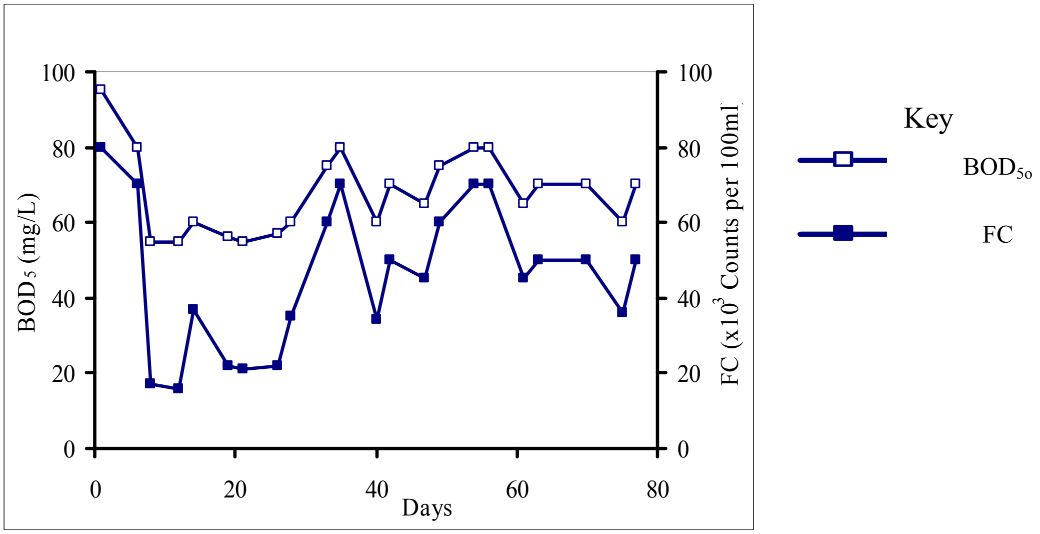

Figure 13: The relationship between FC and BOD$_5$

5.2.2 Relationship between FC and DO

Oxygen in wetland systems is important for heterotrophic bacterial oxidation and growth (Mashingia, 2006). It is required for the respiration of aerobic micro organisms as well as all other aerobic life forms (Metcalf and Eddy, 1991). Oxygen is an essential component for many wetland pollutant removal processes, especially nitrification, decomposition or organic matter and other biological mediated processes. It enters wetlands via water inflow or by diffusion on the water surface when the surface is turbulent. Oxygen is produced photo-synthetically by algae. Plants also release oxygen in the water by root exudation into the root zone of the sediments (Mashingia, 2006).

In figure 14, the FC bacteria was found to depend on DO for the growth process. There was a direct relationship between FC and DO; FC bacteria increased with increasing DO and vice versa; refer on the first 5 days figure 14.

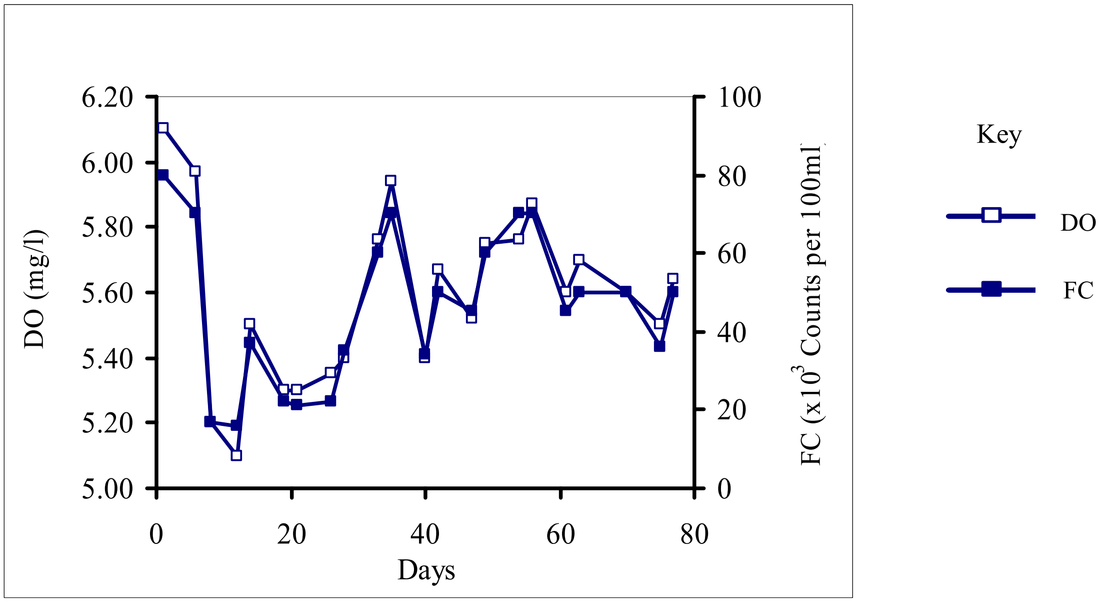

Figure 14: The relationship between FC and DO

5.2.3 Relationship between FC and NH_3-N

Ammoniacal nitrogen exists in aqueous solution as either the ammonium ion or ammonia gas, depending on the pH of the solution.

$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$

At pH above 7, the equilibrium is shifted to the left, at the pH below 7, the ammonium ion is predominant. Looking at the pH values at the outflow (Appendix 1), they were mostly are above 7. It was concluded that ammonia gas is predominant within the system. Ammonia gas is toxic to micro organisms according to Metcalf and Eddy (1991).

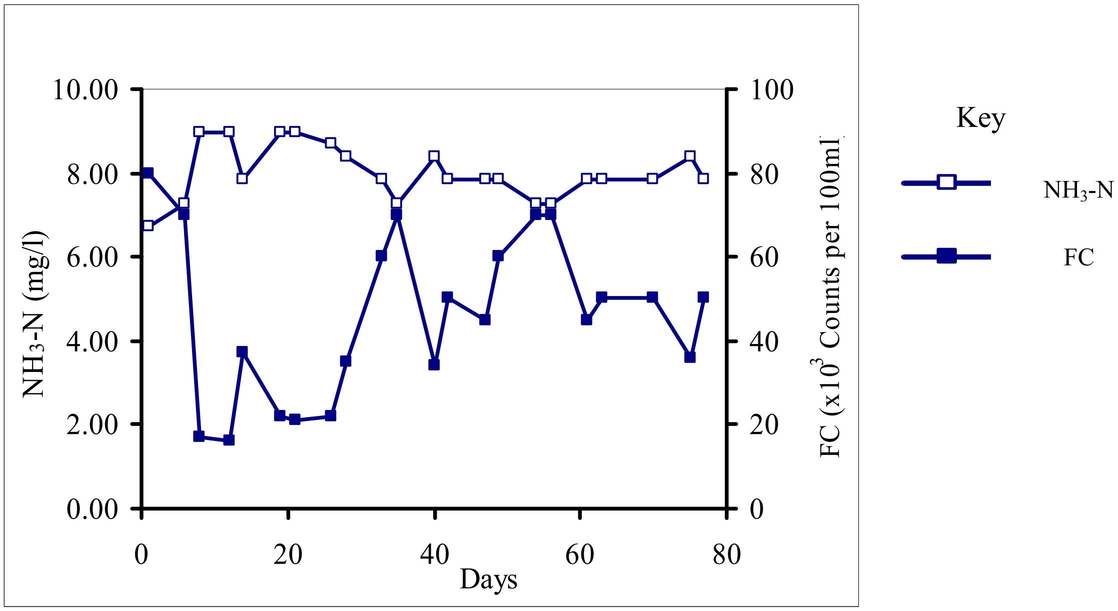

Figure 15: The relationship between FC and NH_3-N

From the toxicity of NH_3-N, the FC bacteria graph behaved to be opposite direction with NH_3-N graph (figure 15).this relationship proved that NH_3-N is a toxic to micro organisms as presented by Metcalf and Eddy (1991).

5.2.4 Relationship between FC and pH values

In the figure 16 the trend of FC graph with time followed the trend of pH values with time. On the first 5 days, the FC bacteria and the pH values showed to decrease while on the 15th day the values were increased this means that FC bacteria were dependence on the pH values.

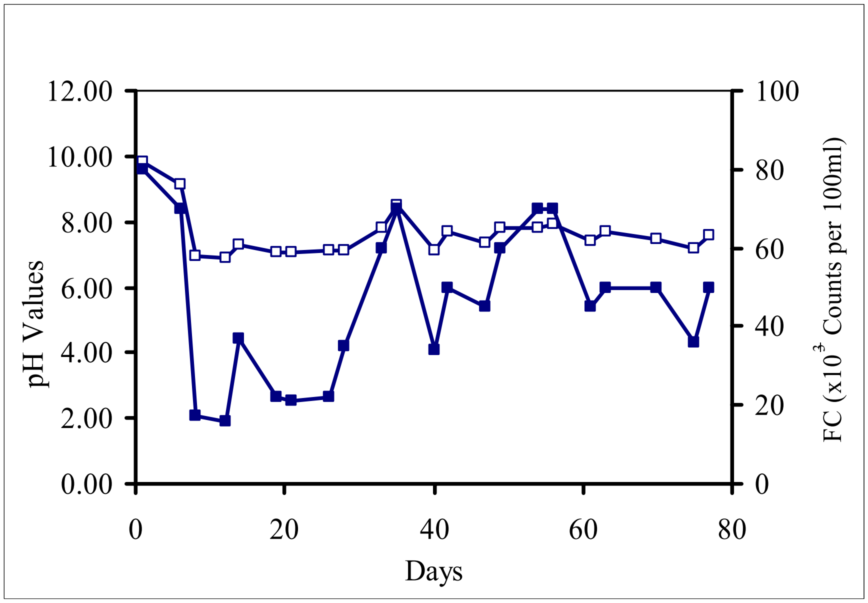

Figure 16: The relationship between FC and pH values

5.2.5 Relationship between FC and Temperature values

The FC graph showed to follow the trend of temperature; this means FC bacteria are dependent to temperature.

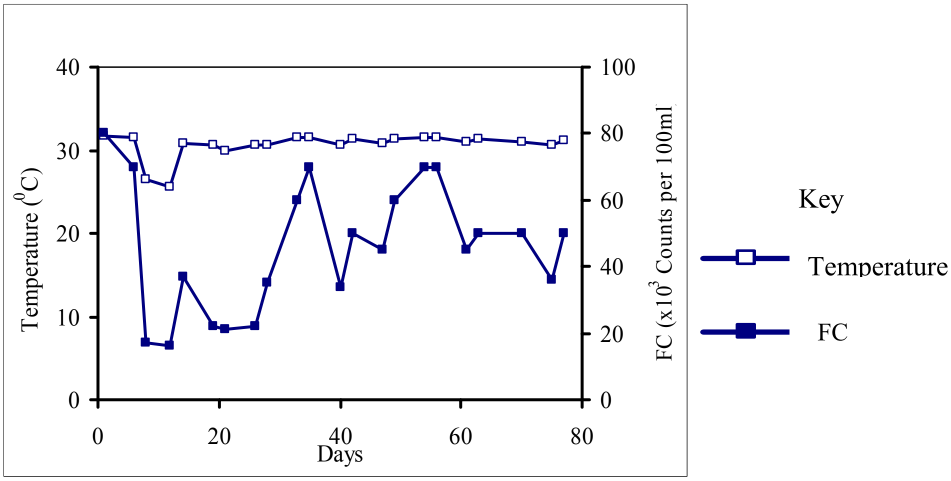

Figure 17: The relationship between FC and Temperature

5.3 Model results and discussions

5.3.1 Model simulation

The forcing functions in this study were DO, Temperature, pH and flow rates while the state variables were BOD$_5$, NH$_3$-N, and FC bacteria. The definitions of forcing function and state variable were explained modelling elements in chapter two. The mathematical equations used mostly were adopted from Kimwaga *at al.,* (2003), Metcalf and Eddy, (1991) and Scott (1995).

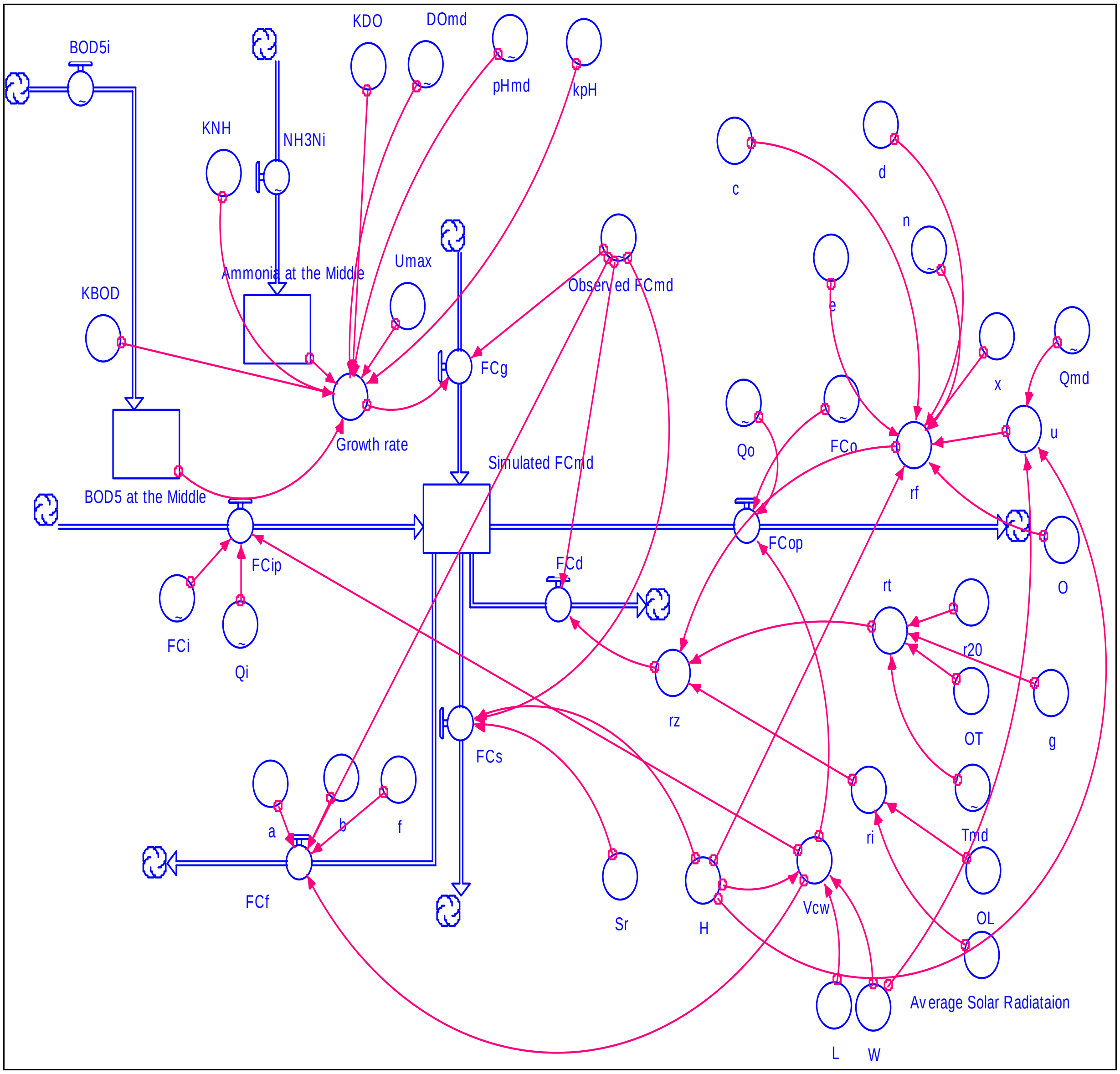

Figure 18: STELLA diagram of Faecal Coliform Removal in HSSFCW

The parameters and constants are presented in appendix 2.

The calibration results showed that simulated Faecal Coliform followed the trend of observed Faecal Coliform; this tells that the developed model was successively ran (Figure 18).

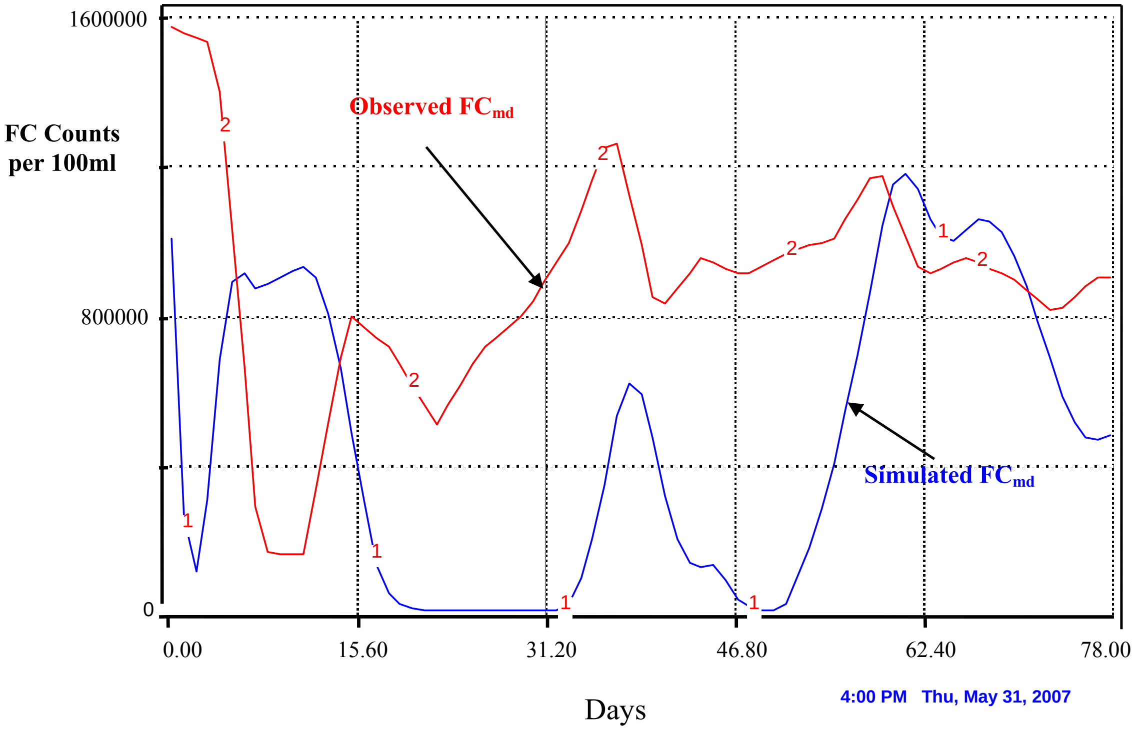

Figure 19: The simulated and observed results of FC removal in HSSFCW

From figure 19, the simulated FC was lagging behind as compared to the observed results but it following the trend of the observed values. Table 4 presented the calibrated values that obtained after calibration. After calibration most of the constants used in the model was changed as compared to the one obtained from the literature review. (Table 4)

Table 4: Calibrated values of the Simulated FC model

Symbols	Units	Literature	Calibrated
k_{BOD}	mg/l	60	80
k_{NH}	mg/l	1	0.09
k_{DO}	mg/l	1.3	1.18019
k_{pH}		220	30
μ_{max}	d^{-1}	0.768	0.768
μ (or gr)	d^{-1}		4.3
f	m/d	1	0.009
s_r	m/d	0.0864	0.3899
Φ (or OL)	m^2/cal	0.035	0.02
I_{avg}	cal/m^2.d	200	200
r_i	d^{-1}		4
Φ_T (or OT)	No.	1.04	0.0009
r_{20}	d^{-1}	0.05-1.14	1.14
r_t	d^{-1}		2.90E-33
r_f	d^{-1}		0.00022
r_z	d^{-1}		4

5.4.2 Removal mechanisms

5.4.2.1 Die-off process

It was observed that die-off process was the major removal mechanism about 3,422,203±1,129,699 FC Counts per 100ml per day. The reasons behind were due to unfavourable environmental conditions to micro organisms which were temperature and solar radiations. The solar radiations had 99.99% effects to the death of FC bacteria followed by the combined effects; adsorption, filtration and sedimentation which, was 0.01%. The temperature showed to have 0.00% effects to the death of FC bacteria. The overall removal rate coefficient of FC was 4 per day.

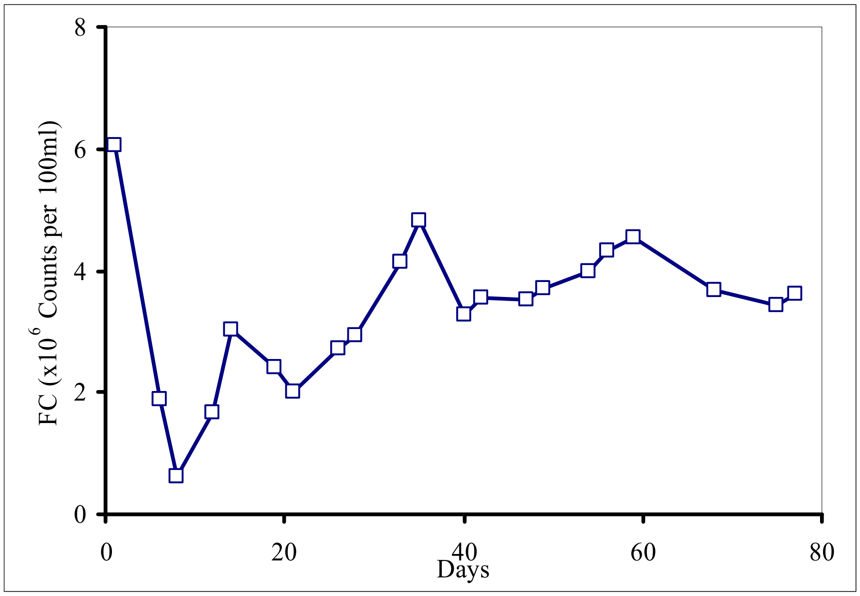

Figure 20: The FC removal in die-off process

5.4.2.2 Sedimentation process

The second process that contributed much in the removal of FC was the sedimentation with 451,433±149,914 FC Counts per 100ml per day. The FC in sedimentation process was suspected due to the settling organic matters which suspected to settle with the FC bacteria. This process was governed by the sedimentation rate in the HSSFCW.

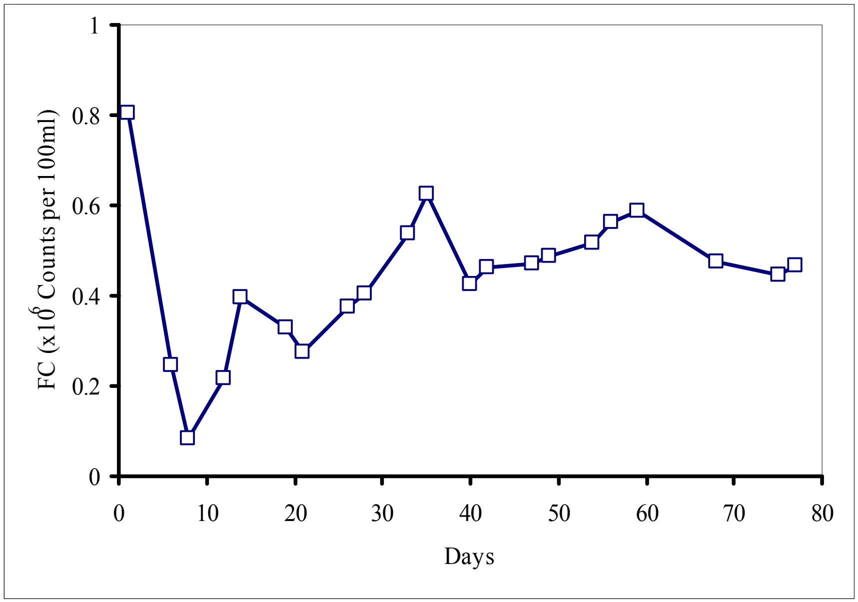

Figure 21: The FC removal in sedimentation process

5.4.2.3 Filtration process

In this process there were 94±31 FC counts per 100ml per day. It was suspected that the suspended solids in the wastewater that are filtered within the system contained some faecal coliform bacteria. Since, the water was from Maturation Stabilization Pond then had few suspended matter. Most of the suspended solids were remained in the Primary Facultative pond of WSP.

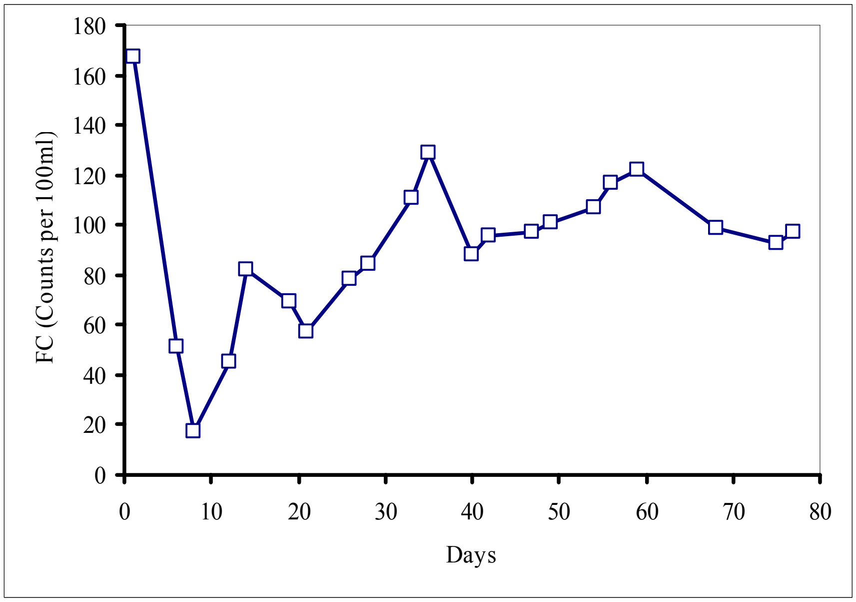

Figure 22: The FC in filtration process

5.4.2.4 Outflow process

The FC values in the outflow process was 4,075±1,796 Counts per 100ml per day. This concentration of FC is the one which is discharged to the stream located nearby the HSSFCW. If this value compared with the observed value which was 45,909±19,373 Counts per 100ml, the simulated value of FC at the outlet were much lower than the observed values, hence the model helped to optimise the decrease of FC concentration at the outlet.

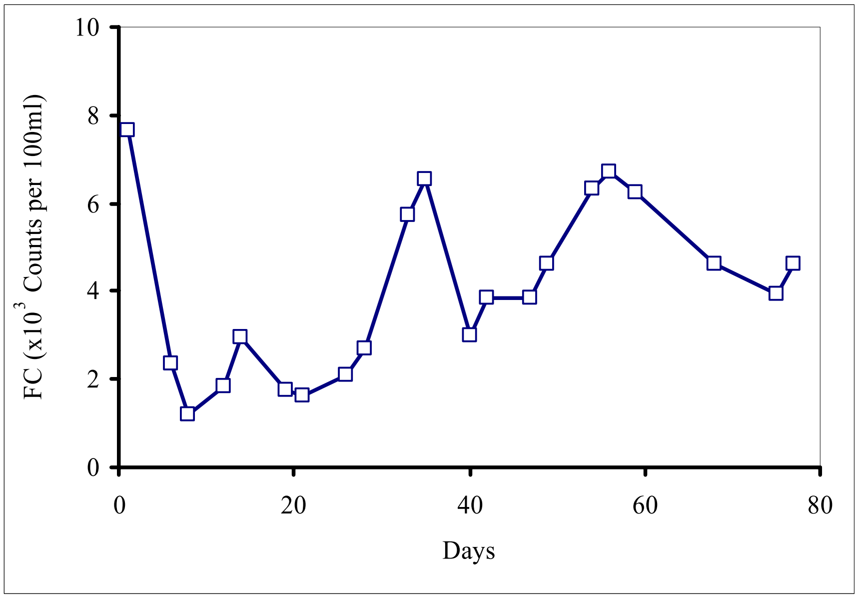

Figure 23: The FC removal in outflow process

5.4.2.5 Inflow and Growth processes

On top of all the processes presented figures above, there were the inflow and growth processes (figure 24 and 25). These processes increased the FC concentration within the system. It was observed that the growth process had 3,706,710±1,285,500 and inflow process had 164,343 ±32,935 FC Counts per 100ml per day.

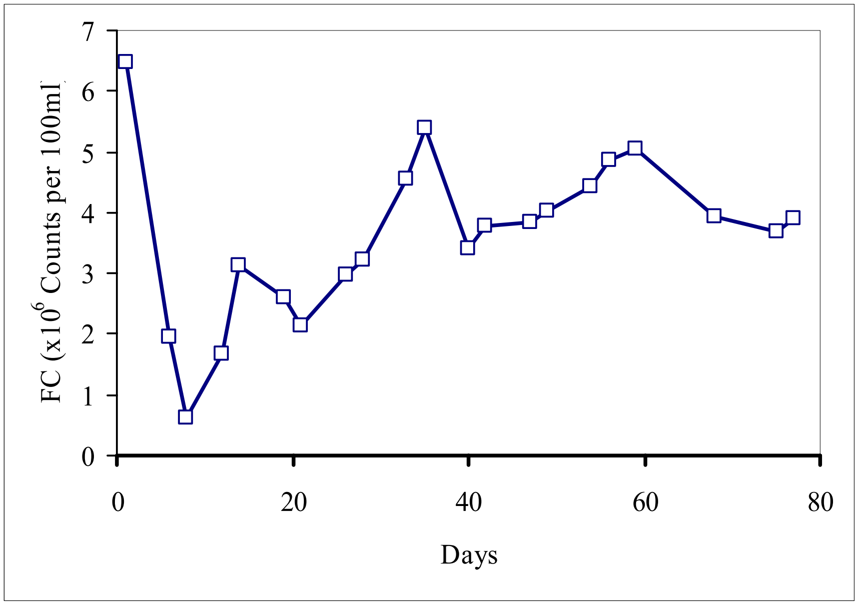

Figure 24: The FC increase in the growth process

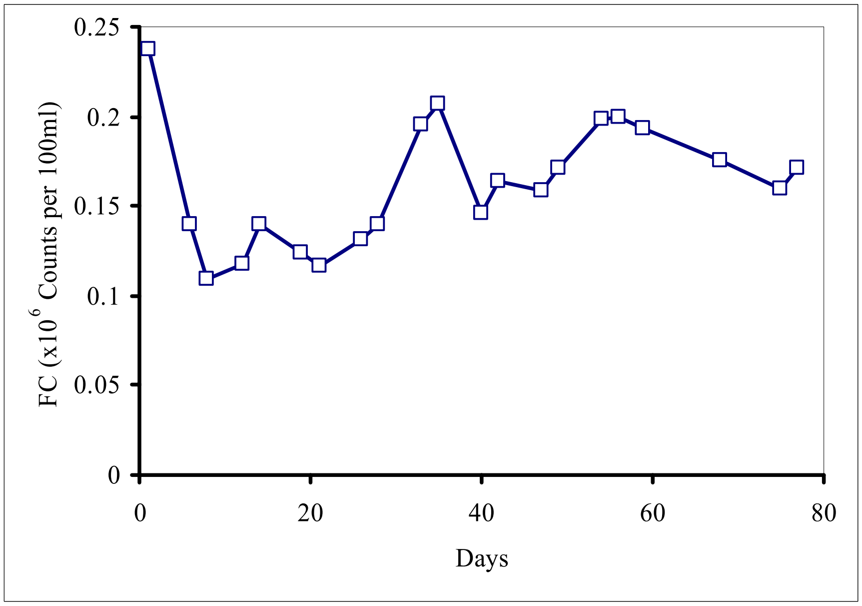

Figure 25: The FC removal in the inflow process

5.4.3 Verification and Sensitivity analysis results

5.4.3.1 Solar radiation

From figure 26 solar radiations showed to have an effect of decreasing the FC in the simulated model. As the solar radiation increases there is a decrease of simulated FC within the system. At a range of -10% to 0% of the relative change, the simulated FC were decreasing at great rate and from 0% to 10% of the relative change, the simulated FC were approached 0%.

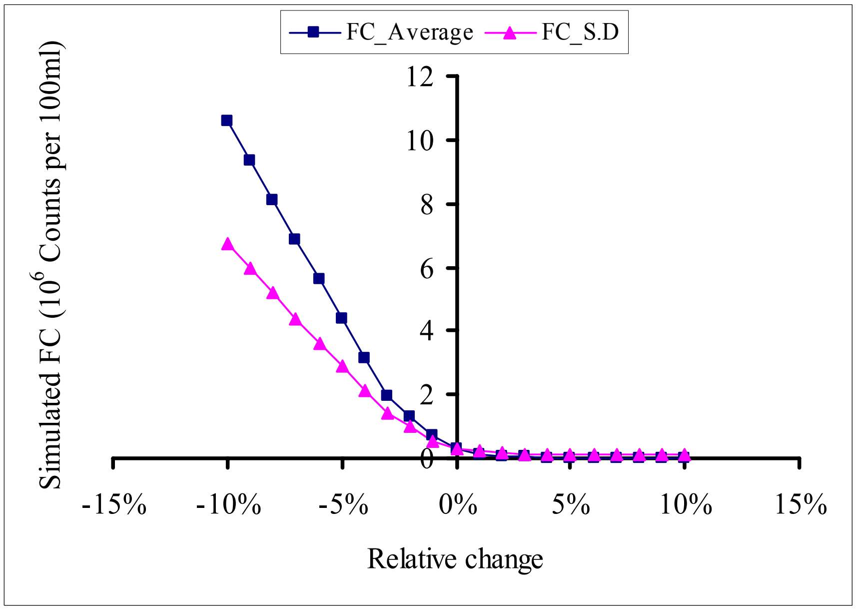

Figure 26: The solar radiation sensitivity to simulated FC

5.4.3.2 Biochemical Oxygen Demand (BOD$_5$)

The bigger change of the input (BOD$_5$) showed to have a small change on the output (simulated FC); hence the BOD$_5$ was not sensitive to the simulated FC (figure 27).

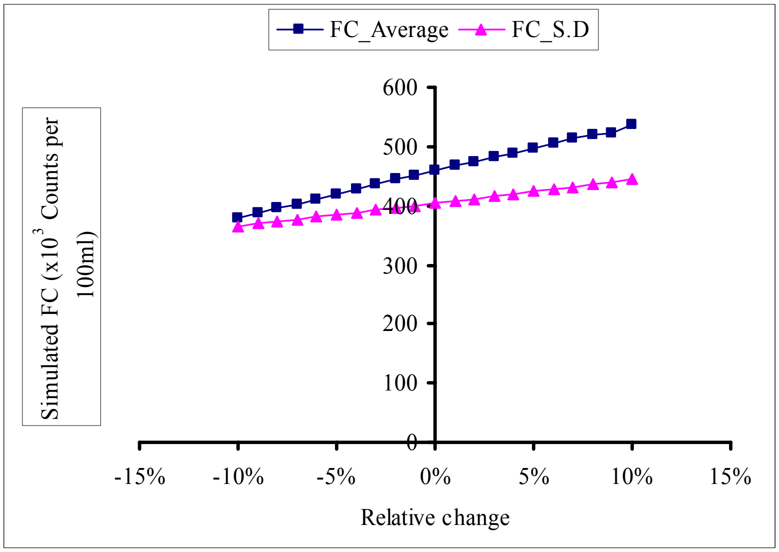

Figure 27: The solar radiation sensitivity to simulated FC

5.4.3.3 Dissolved Oxygen (DO)

The small change of the input values showed to have a big change in the output value.

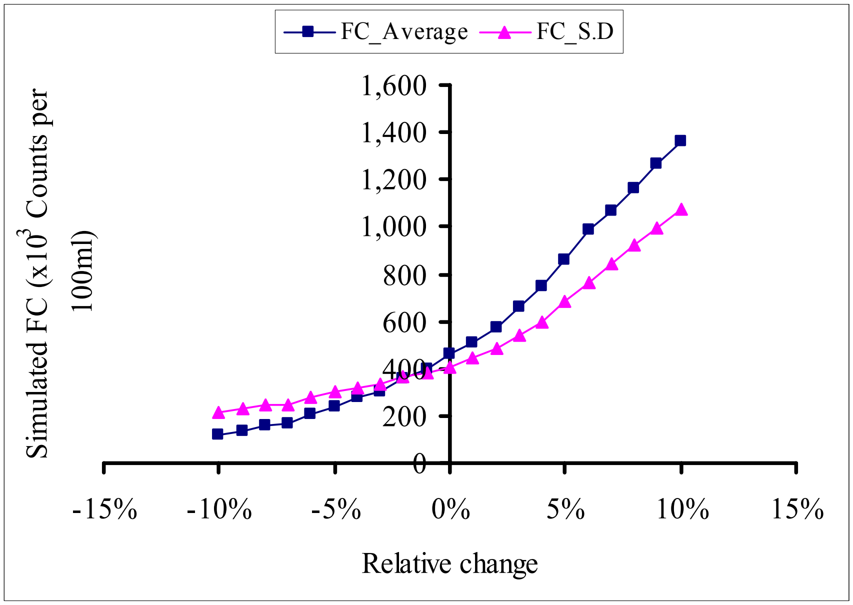

Figure 28: The DO sensitivity to simulated FC

Hence, the DO was very sensitive to FC on the increasing effect.

5.4.3.4 pH Values

When the relative change of the input was between -10% and 0%, there was a greater effect on decreasing the output value. But when the relative change of the input was between 0% and 10%, then there was the greater effect on increasing the output value (figure 29)

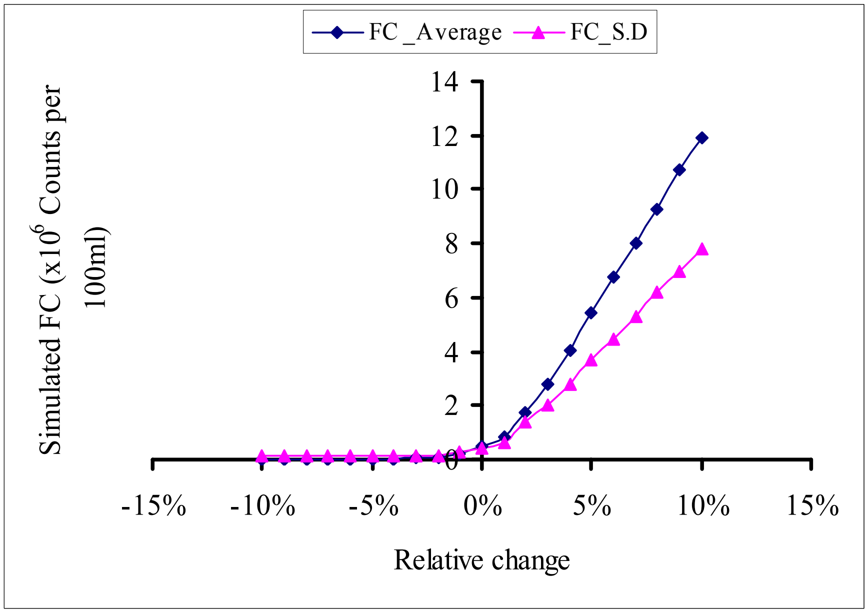

Figure 29: the pH sensitivity to simulated FC

5.4.3.5 Ammoniacal-Nitrogen (NH_3-N)

From the figure 30 showed that the effect of the input to the output was very small. The bigger change of the input gave the very smaller change of the output. Then, it can be concluded that the NH_3-N had no much effect to the simulated FC in this model.

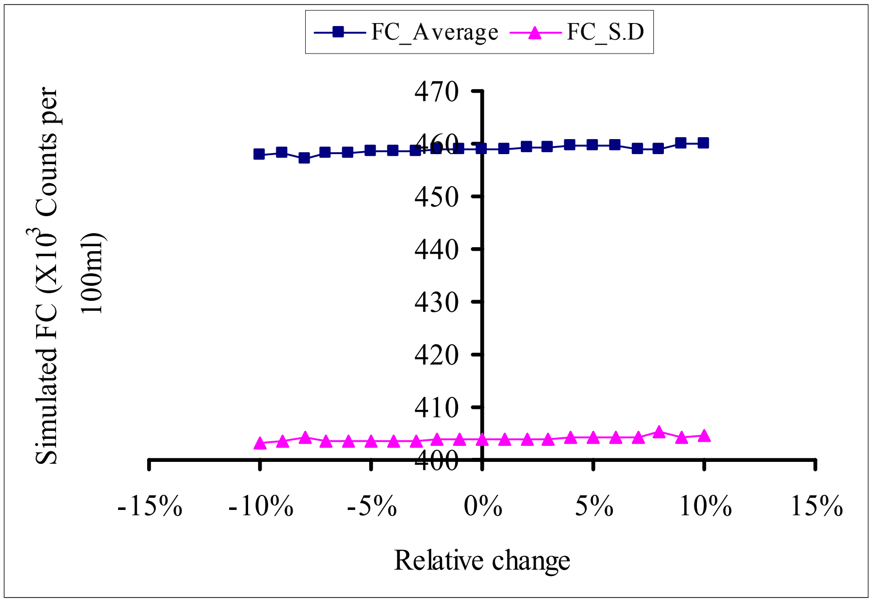

Figure 30: The NH_3-N Sensitivity to Simulated FC

5.4.3.6 Temperature

From figure 31 showed that the effect of the input to the output was very small. The bigger change of the input gave the very smaller change of the output. Then, it can be concluded that the temperature had small effect to the simulated FC in this model.

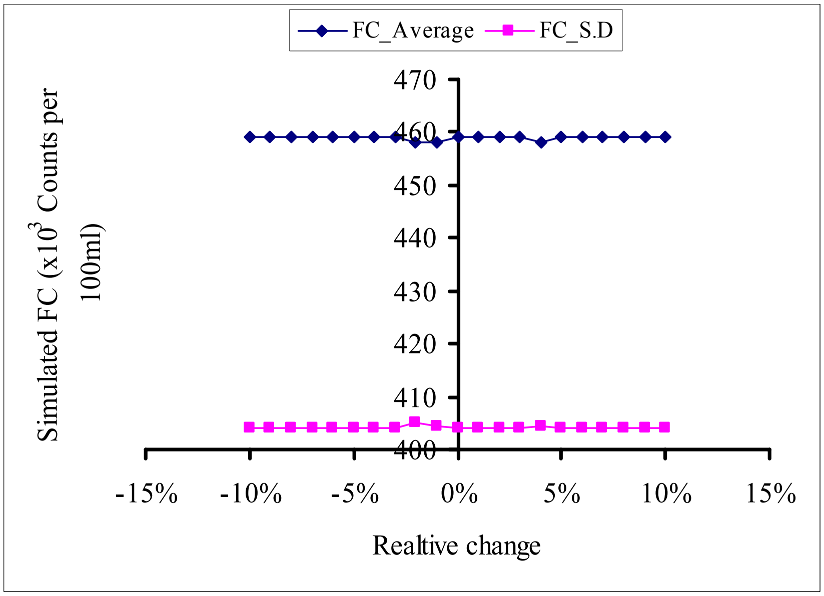

Figure 31: The Temperature Sensitivity to Simulated FC

From the above facts (from figure 26 to 31) it can be concluded that, solar radiation had the greater effect on decreasing the FC bacteria within the system while pH, DO and BOD_5 had the increase effect. The temperature and NH_3-N, have got small effect on the FC bacteria. Then on designing the HSSFCW for removing FC bacteria solar radiation should be considered much in this model.

5.4.4 Application of the FC Model

Basing on the facts from literature review, this model would be used as a management tool after being validated and produce the good results.

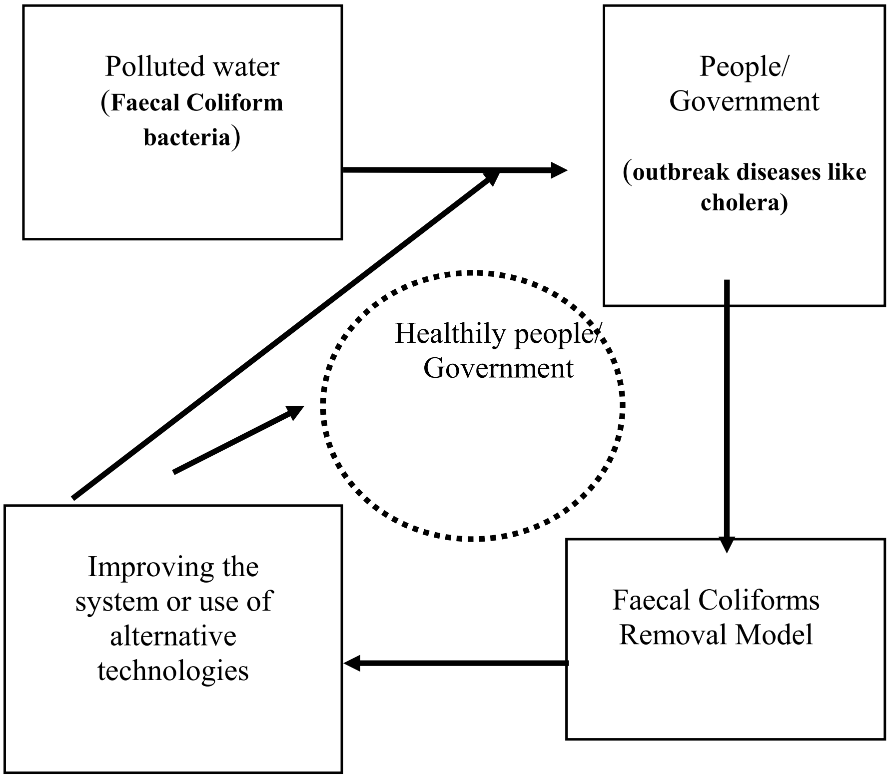

Figure 32: The relationship between water pollution, effects to people or Government, ecological modelling, environmental management and technology and the improvement to people or government.

Figure 32 above attempts to outline the effect of pollution to the people or to the government concerned. Results from the study showed that the effluents from the HSSFCW that goes to the river located nearby HSSFCW contained with FC values which are even above the Tanzania standard (1000 FC counts/100ml). If water is contaminated with *E. Coli*, then people living nearby the HSSFCW are likely to get cholera which is one of the fatal waterborne diseases. Every year Tanzania experiences cholera outbreak which forces the government to spend a lot of money on treatment rather than investing in preventive measures. The amount of money that was spent during cholera outbreak could be used for the alternative development initiatives.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- The developed model was a success since it demonstrated its effectiveness in optimising the FC removal in HSSFCW by 91% that means the FC was reduced from 45,909±19,373 Counts per 100ml of the observed results to 4,075±1,796 FC Counts per 100ml of the simulated results at the outlet section.

- The die-off process was the best removal mechanism as compared to the rest of the processes and solar radiation was very sensitive parameter on decreasing of FC within the system.

6.2 Recommendation

- From the above conclusions then it recommended that the developed model could be used as a design tool of the HSSFCW as well as a management tool for the environment. This would improve the effluent quality of HSSFCW especially on FC removal so as to protect the environment and receiving water bodies.

- On designing the HSSFCW the solar radiations were supposed to be considered in the tropical countries.

6.3 Recommendation for further work

In order for the model to be applicable the validation part should be carried out. This procedure needs either the same data set from the same Horizontal Sub-Surface Flow Constructed Wetland (HSSFCW) but in a different period of the data set used in calibrations or the same data set from the different HSSFCW at any period.

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APPENDICES

Appendix A: Wastewater characterises in HSSFCW

Table A-1: The FC (Counts per 100ml) and BOD$_5$ (mg/l)

S.Date	FC In	FC M	FC Out	R.E	BOD$_5$ In	BOD$_5$ M	BOD$_5$ Out	R.E
1-Feb-07	1,700,000	1,570,000	80,000	95%	251	185	95	62%
6-Feb-07	1,600,000	1,520,000	70,000	96%	210	175	80	62%
8-Feb-07	800,000	160,000	17,000	98%	100	90	55	45%
12-Feb-07	700,000	152,000	16,000	98%	90	85	55	39%
14-Feb-07	1,000,000	800,000	37,000	96%	135	110	60	56%
19-Feb-07	900,000	700,000	22,000	98%	115	100	56	51%
21-Feb-07	800,000	500,000	21,000	97%	105	90	55	48%
26-Feb-07	900,000	700,000	22,000	98%	115	100	57	50%
28-Feb-07	1,000,000	800,000	35,000	97%	125	105	60	52%
5-Mar-07	1,350,000	990,000	60,000	96%	150	125	75	50%
7-Mar-07	1,500,000	1,300,000	70,000	95%	165	140	80	52%
12-Mar-07	1,000,000	800,000	34,000	97%	120	100	60	50%
14-Mar-07	1,250,000	950,000	50,000	96%	140	117	70	50%
19-Mar-07	1,100,000	900,000	45,000	96%	135	110	65	52%
21-Mar-07	1,300,000	970,000	60,000	95%	145	125	75	48%
26-Mar-07	1,400,000	1,000,000	70,000	95%	150	130	80	47%
28-Mar-07	1,400,000	1,200,000	70,000	95%	155	140	80	48%
2-Apr-07	1,200,000	900,000	45,000	96%	135	115	65	52%
4-Apr-07	1,300,000	950,000	50,000	96%	145	125	70	52%
11-Apr-07	1,200,000	900,000	50,000	96%	135	115	70	48%
16-Apr-07	1,000,000	800,000	36,000	96%	134	110	60	55%
18-Apr-07	1,200,000	900,000	50,000	96%	136	115	70	49%
Minimum	700,000	152,000	16,000	95%	90	85	55	39%
Maximum	1,700,000	1,570,000	80,000	98%	251	185	95	62%
Average	1,163,636	884,636	45,909	96%	141	119	68	51%

Appendix A

Table A-2: The NH$_3$-N (mg/l) and pH values

S.Date	**NH_3-N In**	**NH_3-N M**	**NH_3-N**	**R.E**	**pH In**	**pH M**	**pH Out**
1-Feb-07	10.08	8.12	6.72	33%	6.63	7.70	9.81
6-Feb-07	10.08	9.52	7.28	28%	6.50	7.66	9.14
8-Feb-07	11.76	10.64	8.96	24%	6.00	6.37	6.93
12-Feb-07	11.76	10.65	8.96	24%	6.00	6.30	6.90
14-Feb-07	11.20	10.08	7.84	30%	6.25	6.50	7.27
19-Feb-07	11.48	10.36	8.96	22%	6.19	6.40	7.04
21-Feb-07	11.48	10.64	8.96	22%	6.10	6.40	7.04
26-Feb-07	11.20	10.08	8.68	23%	6.20	6.40	7.10
28-Feb-07	11.20	10.08	8.40	25%	6.21	6.43	7.12
5-Mar-07	10.64	9.52	7.84	26%	6.35	6.77	7.80
7-Mar-07	10.64	9.52	7.28	32%	6.40	6.90	8.50
12-Mar-07	11.20	10.08	8.40	25%	6.20	6.40	7.10
14-Mar-07	10.64	10.08	7.84	26%	6.30	6.70	7.70
19-Mar-07	11.20	10.08	7.84	30%	6.30	6.50	7.34
21-Mar-07	10.64	9.52	7.84	26%	6.30	6.75	7.80
26-Mar-07	10.64	9.52	7.28	32%	6.39	6.82	7.80
28-Mar-07	10.64	9.52	7.28	32%	6.40	6.90	7.90
2-Apr-07	10.64	10.08	7.84	26%	6.30	6.50	7.40
4-Apr-07	10.64	10.08	7.84	26%	6.30	6.70	7.72
11-Apr-07	10.64	10.08	7.84	26%	6.30	6.53	7.44
16-Apr-07	11.20	10.08	8.40	25%	6.21	6.46	7.20
18-Apr-07	10.64	10.08	7.84	26%	6.30	6.65	7.60
Minimum	10.08	8.12	6.72	22%	6.00	6.30	6.90
Maximum	11.76	10.65	8.96	33%	6.63	7.70	9.81
Average	10.92	9.93	8.01	27%	6.28	6.67	7.62
S.D	0.47	0.55	0.64	3.29%	0.14	0.37	0.72

Appendix A

Table A-3: DO (mg/l), Temperature (^{0}C) and Flow rate (m^3/d)

S.Date	DO In	DO M	DO Out	Tww In	Tww M	Tww	Q In	Q M	Q Out
1-Feb-07	6.70	6.20	6.10	31.30	31.50	31.80	1.70	1.60	1.20
6-Feb-07	6.19	6.18	5.97	31.30	31.50	31.60	1.70	1.60	1.20
8-Feb-07	5.70	5.55	5.20	25.80	25.90	26.40	1.70	1.30	0.90
12-Feb-07	5.60	5.50	5.10	24.50	24.90	25.60	1.70	1.20	0.80
14-Feb-07	5.80	5.70	5.50	30.00	30.30	30.80	1.70	1.40	1.00
19-Feb-07	5.70	5.60	5.30	29.00	30.00	30.60	1.70	1.30	0.99
21-Feb-07	5.70	5.57	5.30	29.00	29.90	30.00	1.70	1.30	0.90
26-Feb-07	5.73	5.60	5.35	29.70	30.00	30.60	1.70	1.30	0.99
28-Feb-07	5.80	5.66	5.40	30.00	30.30	30.70	1.70	1.40	1.00
5-Mar-07	6.00	5.80	5.76	30.70	31.10	31.50	1.70	1.50	1.10
7-Mar-07	6.14	6.13	5.94	31.00	31.20	31.60	1.70	1.50	1.20
12-Mar-07	5.80	5.60	5.40	29.80	30.20	30.60	1.70	1.40	1.00
14-Mar-07	5.90	5.80	5.67	30.10	30.90	31.40	1.70	1.40	1.10
19-Mar-07	5.80	5.70	5.52	30.00	30.40	30.90	1.70	1.40	1.00
21-Mar-07	5.90	5.80	5.75	30.20	31.00	31.40	1.70	1.50	1.10
26-Mar-07	6.00	5.87	5.76	31.00	31.20	31.60	1.70	1.50	1.10
28-Mar-07	6.10	5.89	5.87	31.00	31.20	31.60	1.70	1.50	1.20
2-Apr-07	5.90	5.70	5.60	30.10	30.50	31.00	1.70	1.40	1.00
4-Apr-07	5.90	5.80	5.70	30.20	30.90	31.40	1.70	1.50	1.10
11-Apr-07	5.90	5.70	5.60	30.10	30.50	31.00	1.70	1.40	1.10
16-Apr-07	5.80	5.66	5.50	30.00	30.30	30.70	1.70	1.40	1.00
18-Apr-07	5.90	5.78	5.64	30.10	30.70	31.20	1.70	1.40	1.10
Minimum	5.60	5.50	5.10	24.50	24.90	25.60	1.70	1.20	0.80
Maximum	6.70	6.20	6.10	31.30	31.50	31.80	1.70	1.60	1.20
Average	5.91	5.76	5.59	29.77	30.20	30.64	1.70	1.42	1.05
S.D	0.23	0.20	0.26	1.63	1.63	1.57	0.003	0.100	0.106

Table A-4: Average values of measured parameters in HSSFCW

Parameter	Unit	Inlet	Middle section	Outlet	Standard/Guideline
FC	Counts/100ml	1,163,636±268,675	884,636±344,564	45,906±19,373	1000, 100*, 200**
BOD_5	mg/l	141±35	119±25	68±11	50*
NH_3-N	mg/l	10.91±0.47	9.93±0.55	8.01±0.64	10*
DO	mg/l	5.91±0.23	5.76±0.20	5.59±0.26	4-7*
pH		6.28±0.14	6.67±0.37	7.62±0.72	6-9*
Temperature	^{0}C	29.77±1.63	30.20±1.63	30.64±1.57	< 3*
Flow rates	m^3/d	1.7±0.003	1.42±0.100	1.05±0.106	

* WB Guideline: ** WHO Guideline

The standard and guidelines were for discharging the effluents to the receiving water bodies.

Appendix B: Model Calibrations and Sensitivity analysis

Table B-1: Parameters used in the model

Symbols	Units	Values	Source	Descriptions
$BOD5_{in}$	mg/l	Collected data	Study	Inflow Biochemical Oxygen Demand at 20^0C in 5 days
k_{BOD}	mg/l	60	(Metcalf and Eddy, 1991)	Half-saturation constant of BOD
NH_3-Nin	mg/l	Collected data	Study	Inflow Ammonia-Nitrogen
k_{NH}	mg/l	1	(Kayombo *et al.,* 2005)	Half-saturation constant of ammonia
DO_{md}	mg/l	Collected data	Study	Dissolved Oxygen at the middle
k_{DO}	mg/l	1.3	(Kayombo *et al.,* 2005)	Half-satuation constant of DO
pH_{md}		Collected data	Study	pH values at the middle
k_{pH}		220	(Kayombo et al., 2005)	Half-saturation constant for pH
μ (or gr)	d^{-1}	Calculated	(Metcalf and Eddy, 1991)	Specific Growth rate
FC_g	FC counts/100 ml.d	Calculated	(Metcalf and Eddy, 1991)	Faecal Coliform in growing process
FC_i	FC counts/100 ml	Calculated	Study	Inflow Faecal coliform
Q_i	m^3/d	Collected data	Study	Inflow rate
V_{cw}	m^3	Calculated	(Senzia *et al.,* 2002)	Volume of HSSFCW
μ_{max}	d^{-1}	0.768	(Scott, 1995)	Max specific growth rate
L	m	6.9	(Senzia *et al.,* 2002)	Length of HSSFCW
w	m	2.3	(Senzia *et al.,* 2002)	Width of HSSFCW
H	m	0.75	(Senzia *et al.,* 2002)	Substrate depth of HSSFCW
FC_{ip}	FC counts/100 ml.d	Calculated	(Kimwaga *et al.,* 2003)	Faecal coliform in the inflow process
a	m	0.15	(Kimwaga *et al.,* 2003)	Constant
b	m	0.95	(Kimwaga *et al.,* 2003)	Constant
f	m/d	1	(Kimwaga *et al.,* 2003)	Filtration rate
FC_{md}	FC counts/100 ml	Collected data	Study	Faecal coliform at the middle
FC_f	FC counts/100 ml.d	Calculated	(Kimwaga *et al.,* 2003)	Faecal coliform in filtration process
s_r	m/d	0.0864	(Metcalf and Eddy, 1991)	sedimentation rate
FC_{sd}	FC counts/100 ml	Calculated	(Kimwaga *et al.,* 2003)	Faecal coliform in the sedimentation process
Φ (or OL)	m^2/cal	0.035	(Metcalf and Eddy, 1991)	Light mortality coefficient
I_{avg}	$cal/m^2.d$	200	(Kayombo *et al.,* 2005)	Average solar radiation
r_i	d^{-1}	Calculated	(Kimwaga *et al.,* 2003)	Removal rate coefficient due to solar radiation

Appendix B
Table B-1 continued.

Symbols	Units	Values	Source	Descriptions
T	^0C	Collected data	Study	Temperature of the wastewater
Φ_T (or OT)	No.	1.04	(Kayombo *et al.,* 2005)	Temperature coefficient
r_{20}	d^{-1}	0.05-1.14	(Kayombo *et al.,* 2005)	Removal rate at 20^0C
r_t	d^{-1}	Calculated	(Kimwaga *et al.,* 2003)	Removal rate coefficient due to temperature
n	No.	Calculated	(Kimwaga et al., 2003)	Single collector removal rate coefficient
α (or x)	No.	$2.4 * 10^{-3}$	(Li Cheng, *et al.,* 2006)	Sticking efficiency
u	m/d	Calculated	(Metcalf and Eddy, 1991)	Velocity of flow
ϴ (or O)	No.	0.35	(Senzia *et al.,* 2002)	Porosity of the bed
r_f	d^{-1}	Calculated	(Kimwaga *et al.,* 2003)	Removal rate coeeficient due to combined effects of adsorption, filtration and sedimentation
r_z	d^{-1}	Calculated	(Kimwaga *et al.,* 2003)	Overall removal rate coefficient
FC_d	FC counts/100ml.d	Calculated	(Kimwaga *et al.,* 2003)	Faecal coliform due to natural die-off process
Q_o	m^3/d	Collected data	Study	Out flow rate
FCo	FC counts /100ml	Collected data	Study	Out flow faecal coliform
FC_{op}	FC counts/100ml.d	Calculated	(Kimwaga *et al.,* 2003)	Faecal coliform in the outflow process

Appendix B

$$\eta = 0.9A_s^{1/3}\left[\frac{K_B T}{\mu d_c d_p u}\right]^{1/3} + \frac{2}{3}A_s\left[\frac{d_p}{d_c}\right]^2 + \frac{\left[\rho_p - \rho\right] g d_p^{\ 2}}{18\mu u}$$

Table B-2: Calculation of Single Coefficient Efficiency

S.Date	K_B (J/K)	T_{in} (^{0}C)	T_{out} (^{0}C)	T_{in} (K)	T_{out} (K)	μ (N.s/m^2)	Q_{md} (m^3/d)	X-Area (m^2)
1-Feb-07	3.805E-24	31.30	31.80	304	305	798	1.60	1.725
6-Feb-07	3.805E-24	31.30	31.60	304	305	798	1.60	1.725
8-Feb-07	3.805E-24	25.80	26.40	299	299	798	1.30	1.725
12-Feb-07	3.805E-24	24.50	25.60	298	299	798	1.20	1.725
14-Feb-07	3.805E-24	30.00	30.80	303	304	798	1.40	1.725
19-Feb-07	3.805E-24	29.00	30.60	302	304	798	1.30	1.725
21-Feb-07	3.805E-24	29.00	30.00	302	303	798	1.30	1.725
26-Feb-07	3.805E-24	29.70	30.60	303	304	798	1.30	1.725
28-Feb-07	3.805E-24	30.00	30.70	303	304	798	1.40	1.725
5-Mar-07	3.805E-24	30.70	31.50	304	305	798	1.50	1.725
7-Mar-07	3.805E-24	31.00	31.60	304	305	798	1.50	1.725
12-Mar-07	3.805E-24	29.80	30.60	303	304	798	1.40	1.725
14-Mar-07	3.805E-24	30.10	31.40	303	304	798	1.40	1.725
19-Mar-07	3.805E-24	30.00	30.90	303	304	798	1.40	1.725
21-Mar-07	3.805E-24	30.20	31.40	303	304	798	1.50	1.725
26-Mar-07	3.805E-24	31.00	31.60	304	305	798	1.50	1.725
28-Mar-07	3.805E-24	31.00	31.60	304	305	798	1.50	1.725
2-Apr-07	3.805E-24	30.10	31.00	303	304	798	1.40	1.725
4-Apr-07	3.805E-24	30.20	31.40	303	304	798	1.50	1.725
11-Apr-07	3.805E-24	30.10	31.00	303	304	798	1.40	1.725
16-Apr-07	3.805E-24	30.00	30.70	303	304	798	1.40	1.725
18-Apr-07	3.805E-24	30.10	31.20	273	304	798	1.40	1.725

Appendix B

Table B-2 continued.

u (m/s)	dc (m)	dp (µm)	ρ_p (Kg/m^3)	ρ_{ww} (Kg/m^3)	g (m/s^2)	Θ	(1-Θ)^(1/3)	A_s
u (m/s)	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000108	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000108	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000087	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000080	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000094	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000087	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000087	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000087	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000094	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000101	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000101	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000094	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000094	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000094	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000101	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000101	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000101	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000094	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000101	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000094	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15
0.0000094	0.025	0.000015	1009	995.7	9.81	0.35	0.65	7.15

Table B-2 Continued.

n_{Din}	n_{Dout}	n_{Iin}	n_{Iout}	n_{Gin}	n_{Gout}	n_{in}	n_{out}	n
7.99487E-05	9.287E-26	1.72E-06	1.71611E-06	1.901E-07	1.90052E-07	8.1855E-05	1.906E-06	0.977
7.98626E-05	9.265E-26	1.72E-06	1.71611E-06	1.899E-07	1.8995E-07	8.1769E-05	1.906E-06	0.977
0.000118631	1.354E-25	1.72E-06	1.71611E-06	2.336E-07	2.33629E-07	0.00012058	1.95E-06	0.984
0.000139606	1.592E-25	1.72E-06	1.71611E-06	2.54E-07	2.53996E-07	0.00014158	1.97E-06	0.986
0.000103737	1.202E-25	1.72E-06	1.71611E-06	2.17E-07	2.16952E-07	0.00010567	1.933E-06	0.982
0.000120061	1.394E-25	1.72E-06	1.71611E-06	2.338E-07	2.33784E-07	0.00012201	1.95E-06	0.984
0.000119902	1.387E-25	1.72E-06	1.71611E-06	2.336E-07	2.33629E-07	0.00012185	1.95E-06	0.984
0.00012018	1.392E-25	1.72E-06	1.71611E-06	2.336E-07	2.33629E-07	0.00012213	1.95E-06	0.984
0.000104249	1.207E-25	1.72E-06	1.71611E-06	2.175E-07	2.17487E-07	0.00010618	1.934E-06	0.982
9.05825E-05	1.052E-25	1.72E-06	1.71611E-06	2.025E-07	2.02497E-07	9.2501E-05	1.919E-06	0.979
9.10901E-05	1.058E-25	1.72E-06	1.71611E-06	2.03E-07	2.02963E-07	9.3009E-05	1.919E-06	0.979
0.000104181	1.207E-25	1.72E-06	1.71611E-06	2.175E-07	2.17487E-07	0.00010611	1.934E-06	0.982
0.000103644	1.206E-25	1.72E-06	1.71611E-06	2.168E-07	2.16818E-07	0.00010558	1.933E-06	0.982
0.000103993	1.206E-25	1.72E-06	1.71611E-06	2.172E-07	2.17219E-07	0.00010593	1.933E-06	0.982
9.09551E-05	1.058E-25	1.72E-06	1.71611E-06	2.031E-07	2.0308E-07	9.2874E-05	1.919E-06	0.979
9.13002E-05	1.06E-25	1.72E-06	1.71611E-06	2.032E-07	2.03197E-07	9.322E-05	1.919E-06	0.979
9.11951E-05	1.059E-25	1.72E-06	1.71611E-06	2.031E-07	2.0308E-07	9.3114E-05	1.919E-06	0.979
0.000103899	1.205E-25	1.72E-06	1.71611E-06	2.171E-07	2.17086E-07	0.00010583	1.933E-06	0.982
9.1165E-05	1.06E-25	1.72E-06	1.71611E-06	2.033E-07	2.03314E-07	9.3084E-05	1.919E-06	0.979
0.000103899	1.205E-25	1.72E-06	1.71611E-06	2.171E-07	2.17086E-07	0.00010583	1.933E-06	0.982
0.000104121	1.206E-25	1.72E-06	1.71611E-06	2.174E-07	2.17353E-07	0.00010605	1.933E-06	0.982
0.000104105	1.207E-25	1.72E-06	1.71611E-06	2.171E-07	2.17086E-07	0.00010604	1.933E-06	0.982

Appendix B

Stella Mathematical Equations for FC Model

Ammonia_at_the_Middle(t) = Ammonia_at_the_Middle(t - dt) + (NH3Ni) * dt
INIT Ammonia_at_the_Middle = 10
DOCUMENT: Ammonia-Nitrogen at the middle section (mg/l)
NH3Ni = GRAPH(TIME)
(0.00, 10.1), (3.67, 10.1), (7.33, 11.8), (11.0, 11.8), (14.7, 11.2), (18.3, 11.5), (22.0, 11.5), (25.7, 11.2), (29.3, 11.2), (33.0, 10.6), (36.7, 10.6), (40.3, 11.2), (44.0, 10.6), (47.7, 11.2), (51.3, 10.6), (55.0, 10.6), (58.7, 10.6), (62.3, 10.6), (66.0, 10.6), (69.7, 10.6), (73.3, 11.2), (77.0, 10.6)
DOCUMENT: In-flow Ammoniacal Nitrogen (mg/d)
BOD5_at_the_Middle(t) = BOD5_at_the_Middle(t - dt) + (BOD5i) * dt
INIT BOD5_at_the_Middle = 10
DOCUMENT: Stock of BOD
BOD5i = GRAPH(Time)
(0.00, 251), (3.67, 210), (7.33, 100), (11.0, 90.0), (14.7, 135), (18.3, 115), (22.0, 105), (25.7, 115), (29.3, 125), (33.0, 150), (36.7, 165), (40.3, 120), (44.0, 140), (47.7, 135), (51.3, 145), (55.0, 150), (58.7, 155), (62.3, 135), (66.0, 145), (69.7, 135), (73.3, 134), (77.0, 136)
DOCUMENT: In-flow BOD5 (mg/d)
Simulated_FCmd(t) = Simulated_FCmd(t - dt) + (FCg + FCip - FCf - FCs - FCop - FCd) * dt
INIT Simulated_FCmd = 1000000
DOCUMENT: Population of faecal coliform at the middle section (FC Counts per 100ml/day)
FCg = Growth_rate*Observed_FCmd
DOCUMENT: Faecal coliform in growth process (FC counts per 100ml per day)
FCip = Qi*FCi/Vcw
DOCUMENT: Faecal coliform in the inflow process (FC Counts per 100ml per day)
FCf = (Observed_FCmd*f*a*b)/Vcw
DOCUMENT: FC in filtration process (FC Counts per 100ml per day)
FCs = Observed_FCmd*Sr/H
DOCUMENT: Faecal coliform in sedimentation process (FC Counts per 100ml per day)
FCop = (Qo*FCo)/Vcw
DOCUMENT: Faecal coliform in the outflow process (FC Counts per 100ml per day)
FCd = Observed_FCmd*rz
DOCUMENT: Faecal coliform due to natural die-off process (FC Counts per 100ml per day)
a = 0.15
DOCUMENT: Constant (m)
Average_Solar_Radiataion = 200
DOCUMENT: Average solar radiation (cal per m2 per d)
b = 0.95
DOCUMENT: Constant (m)
c = 4
DOCUMENT: 4 (Unit less)
d = 3
DOCUMENT: 3 (unit less)

Appendix B
Stella Mathematical Equations for FC Model Continued.

e = 1
DOCUMENT: 1 (Unit less)
f = 0.009
DOCUMENT: Filtration rate (m/d)
g = 20
DOCUMENT: 20 degree of centigrade

Growth_rate = Umax*(Ammonia_at_the_Middle/ (KNH+Ammonia_at_the_Middle))*(BOD5_at_the_Middle/ (KBOD+BOD5_at_the_Middle))*(DOmd/ (KDO+DOmd))*(pHmd/kpH+pHmd)
H = 0.75
DOCUMENT: Substrate depth (m)
KBOD = 80
DOCUMENT: Half-Saturation Constant of BOD (mg/l)
KDO = 1.18019
DOCUMENT: Half-saturation Constant of Dissolved Oxygen (DO) (mg/l)
KNH = 0.09
DOCUMENT: Half-Saturation Constant of Nitrogen (Ammonia) (mg/l)
kpH = 30
DOCUMENT: Half-saturation constant of pH (Unit less)
L = 6.9
DOCUMENT: Length of the Horizontal Sub-surface Flow Constructed Wetland (m)
O = 0.35
DOCUMENT: Porosity of the bed (Unit less)
OL = 0.019999981
DOCUMENT: Light mortality coefficient (m2 per cal)
OT = 0.0009
DOCUMENT: Temperature coefficient (unit less)
r20 = 1.14
DOCUMENT: Removal rate coefficient at 20 degrees celcus
rf = (c/d)*n*x*u*((e-O)/H)
DOCUMENT: Removal rate due to combined effects of adsorption, filtration and sedimentation (Per day)
ri = OL*Average_Solar_Radiataion
DOCUMENT: Removal rate coefficient due to solar radiation (per day)
rt = r20*OT^(Tmd-g)
DOCUMENT: Removal rate coefficient due to temperature (per day)
rz = ri+rt+rf
DOCUMENT: Overall removal rate coefficient (per day)
Sr = 0.3899
DOCUMENT: Sedimentation rate (m/d)
u = Qmd/ (H*W)
DOCUMENT: Velocity of flow (m/d)
Umax = 0.768
DOCUMENT: Maximum specific growth rate (Per day)
Vcw = H*L*W
DOCUMENT: Volume of Horizontal Sub-surface Flow Constructed Wetland (m3)

Appendix B
Stella Mathematical Equations for FC Model Continued.

W = 2.3
DOCUMENT: Width of Horizontal Sub-surface Flow Constructed Wetland (m)
x = 2.4*10^-4
DOCUMENT: Sticking efficiency (Unit less)
DOmd = GRAPH(TIME)
(0.00, 6.20), (3.67, 6.18), (7.33, 5.55), (11.0, 5.50), (14.7, 5.70), (18.3, 5.60), (22.0, 5.57), (25.7, 5.60), (29.3, 5.66), (33.0, 5.80), (36.7, 6.13), (40.3, 5.60), (44.0, 5.80), (47.7, 5.70), (51.3, 5.80), (55.0, 5.87), (58.7, 5.89), (62.3, 5.70), (66.0, 5.80), (69.7, 5.70), (73.3, 5.66), (77.0, 5.78)
DOCUMENT: Dissolved Oxygen (DO) at the middle section (mg/l)
FCi = GRAPH(TIME)
(0.00, 1.7e+006), (3.67, 1.6e+006), (7.33, 800000), (11.0, 700000), (14.7, 1e+006), (18.3, 900000), (22.0, 800000), (25.7, 900000), (29.3, 1e+006), (33.0, 1.4e+006), (36.7, 1.5e+006), (40.3, 1e+006), (44.0, 1.3e+006), (47.7, 1.1e+006), (51.3, 1.3e+006), (55.0, 1.4e+006), (58.7, 1.4e+006), (62.3, 1.2e+006), (66.0, 1.3e+006), (69.7, 1.2e+006), (73.3, 1e+006), (77.0, 1.2e+006)
DOCUMENT: Inflow Faecal coliform (FC counts per 100ml)
FCo = GRAPH(TIME)
(0.00, 80000), (3.67, 70000), (7.33, 17000), (11.0, 16000), (14.7, 37000), (18.3, 22000), (22.0, 21000), (25.7, 22000), (29.3, 35000), (33.0, 60000), (36.7, 70000), (40.3, 34000), (44.0, 50000), (47.7, 45000), (51.3, 60000), (55.0, 70000), (58.7, 70000), (62.3, 45000), (66.0, 50000), (69.7, 50000), (73.3, 36000), (77.0, 50000)
DOCUMENT: Faecal coliform in the outflow (FC counts per 100ml)
n = GRAPH(Time)
(0.00, 0.977), (3.67, 0.977), (7.33, 0.984), (11.0, 0.986), (14.7, 0.982), (18.3, 0.984), (22.0, 0.984), (25.7, 0.984), (29.3, 0.982), (33.0, 0.979), (36.7, 0.979), (40.3, 0.982), (44.0, 0.982), (47.7, 0.982), (51.3, 0.979), (55.0, 0.979), (58.7, 0.979), (62.3, 0.982), (66.0, 0.979), (69.7, 0.982), (73.3, 0.982), (77.0, 0.982)
DOCUMENT: Single collector removal rate coefficient (Unit less)
Observed_FCmd = GRAPH(TIME)
(0.00, 1.6e+006), (3.67, 1.5e+006), (7.33, 160000), (11.0, 152000), (14.7, 800000), (18.3, 700000), (22.0, 500000), (25.7, 700000), (29.3, 800000), (33.0, 990000), (36.7, 1.3e+006), (40.3, 800000), (44.0, 950000), (47.7, 900000), (51.3, 970000), (55.0, 1e+006), (58.7, 1.2e+006), (62.3, 900000), (66.0, 950000), (69.7, 900000), (73.3, 800000), (77.0, 900000)
DOCUMENT: Faecal coliform at the middle section (FC counts/100ml)
pHmd = GRAPH(TIME)
(0.00, 7.70), (3.67, 7.66), (7.33, 6.37), (11.0, 6.30), (14.7, 6.50), (18.3, 6.40), (22.0, 6.40), (25.7, 6.40), (29.3, 6.43), (33.0, 6.77), (36.7, 6.90), (40.3, 6.40), (44.0, 6.70), (47.7, 6.50), (51.3, 6.75), (55.0, 6.82), (58.7, 6.90), (62.3, 6.50), (66.0, 6.70), (69.7, 6.53), (73.3, 6.46), (77.0, 6.65)
DOCUMENT: pH at the middle section (Unit less)
Qi = GRAPH (TIME)
(0.00, 1.70), (3.67, 1.70), (7.33, 1.70), (11.0, 1.70), (14.7, 1.70), (18.3, 1.70), (22.0, 1.70), (25.7, 1.70), (29.3, 1.70), (33.0, 1.70), (36.7, 1.70), (40.3, 1.70), (44.0, 1.70), (47.7, 1.70), (51.3, 1.70), (55.0, 1.70), (58.7, 1.70), (62.3, 1.70), (66.0, 1.70), (69.7, 1.70), (73.3, 1.70), (77.0, 1.70)

Appendix B
Stella Mathematical Equations for FC Model Continued.

DOCUMENT: Inflow rate (m3/d)
Qmd = GRAPH (Time)
(0.00, 1.60), (3.67, 1.60), (7.33, 1.30), (11.0, 1.20), (14.7, 1.40), (18.3, 1.30), (22.0, 1.30), (25.7, 1.30), (29.3, 1.40), (33.0, 1.50), (36.7, 1.50), (40.3, 1.40), (44.0, 1.40), (47.7, 1.40), (51.3, 1.50), (55.0, 1.50), (58.7, 1.50), (62.3, 1.40), (66.0, 1.50), (69.7, 1.40), (73.3, 1.40), (77.0, 1.40)

DOCUMENT: flow rate at the middle (m3/d)
Qo = GRAPH (TIME)
(0.00, 1.20), (3.67, 1.20), (7.33, 0.9), (11.0, 0.8), (14.7, 1.00), (18.3, 0.99), (22.0, 0.9), (25.7, 0.99), (29.3, 1.00), (33.0, 1.10), (36.7, 1.20), (40.3, 1.00), (44.0, 1.10), (47.7, 1.00), (51.3, 1.10), (55.0, 1.10), (58.7, 1.20), (62.3, 1.00), (66.0, 1.10), (69.7, 1.10), (73.3, 1.00), (77.0, 1.10)
DOCUMENT: Out flow rate (m3/d)

Tmd = GRAPH (TIME)
(0.00, 31.5), (3.67, 31.5), (7.33, 25.9), (11.0, 24.9), (14.7, 30.3), (18.3, 30.0), (22.0, 29.9), (25.7, 30.0), (29.3, 30.3), (33.0, 31.1), (36.7, 31.2), (40.3, 30.2), (44.0, 30.9), (47.7, 30.4), (51.3, 31.0), (55.0, 31.2), (58.7, 31.2), (62.3, 30.5), (66.0, 30.9), (69.7, 30.5), (73.3, 30.3), (77.0, 30.7)
DOCUMENT: Temperature at the middle section (degree celcus)

Appendix B

Table B-3: FC in the processes (Counts/100ml/d)

Days	Simulated FC	FC_Inflow	FC_Growth	FC_Sedimentation	FC_Filtration	FC_Die-off	FC-Outflow
0	1,000,000	240,858	4,484,023	812,646	168	4,654,139	7,928.05
1	250,000	236,963	6,478,267	805,557	167	6,044,346	7,653.09
2	107,507	233,068	6,906,286	798,468	165	6,144,017	7,378.13
3	296,833	227,658	6,952,594	781,060	162	6,010,068	7,012.59
4	678,783	202,555	5,485,605	629,511	130	4,843,924	5,519.22
5	887,857	171,393	3,648,339	436,688	91	3,360,189	3,845.71
6	906,775	140,230	1,942,219	243,865	51	1,876,464	2,370.92
7	866,475	115,127	713,752	93,639	19	720,521	1,341.32
8	879,834	109,717	620,879	81,855	17	629,849	1,216.84
9	897,492	105,822	611,997	80,721	17	621,121	1,159.35
10	912,292	101,927	602,874	79,587	16	612,393	1,103.11
11	923,994	105,822	952,778	124,957	26	961,500	1,313.29
12	894,797	117,508	1,673,719	216,832	45	1,668,447	1,824.05
13	798,876	129,194	2,412,536	308,706	64	2,375,396	2,387.30
14	654,052	140,014	3,119,610	394,689	82	3,037,012	2,946.86
15	478,947	139,581	3,194,812	404,078	84	3,109,257	2,815.84
16	297,105	135,686	3,072,742	389,900	81	2,988,078	2,466.16
17	125,008	131,790	2,950,634	375,722	78	2,782,637	2,118.35
18	46,878	127,895	2,807,054	358,393	74	2,603,947	1,834.00
19	17,579	124,000	2,592,889	330,824	69	2,395,232	1,751.28
20	6,592	120,105	2,372,628	302,468	63	2,192,637	1,685.11
21	2,472	116,209	2,151,772	274,112	57	1,993,738	1,620.05
22	927	116,209	2,153,756	274,112	57	1,994,757	1,620.05
23	348	120,105	2,379,210	302,468	63	2,195,317	1,685.11
24	130	124,000	2,605,070	330,824	69	2,396,507	1,751.28
25	49	127,895	2,825,349	358,393	74	2,592,976	1,831.48
26	18	131,790	2,968,487	375,722	78	2,722,408	2,080.45
27	7	135,686	3,088,234	389,900	81	2,831,560	2,382.55
28	3	139,581	3,208,452	404,078	84	2,941,187	2,686.28
29	1	145,640	3,362,163	421,092	87	3,083,554	3,070.14
30	0	158,733	3,626,839	447,322	93	3,334,433	3,725.00
31	0	172,366	3,906,724	474,260	98	3,600,302	4,430.11
32	0	186,000	4,193,706	501,199	104	3,853,694	5,166.46
33	19,543	195,738	4,544,264	536,644	111	4,129,331	5,741.90
34	87,717	201,581	4,957,664	580,597	120	4,467,532	6,143.93
35	192,569	207,424	5,377,031	624,549	129	4,805,734	6,558.45
36	340,054	211,860	5,736,931	662,121	137	5,094,841	6,889.19
37	524,856	198,010	5,258,188	616,751	128	4,745,726	6,000.13
38	612,450	178,534	4,544,087	545,860	113	4,200,236	4,809.46

Appendix B

Table B-3 Continued.

Days	Simulated FC	FC_Inflow	FC_Growth	FC_Sedimentation	C_Filtratio	FC_Die-off	FC-Outflow
39	584,052	159,057	3,858,211	474,969	98	3,654,747	3,708.78
40	467,798	146,073	3,392,104	424,558	88	3,266,844	3,011.57
41	311,473	154,188	3,565,223	440,705	91	3,391,093	3,389.59
42	195,605	163,927	3,791,773	461,972	96	3,554,738	3,867.44
43	130,630	173,665	4,023,430	483,240	100	3,718,384	4,365.29
44	121,637	175,612	4,093,552	490,329	102	3,772,932	4,501.62
45	122,936	169,770	3,999,371	483,240	100	3,718,384	4,267.28
46	86,086	163,927	3,906,163	476,151	99	3,642,335	4,039.19
47	33,552	158,841	3,825,949	470,007	97	3,531,802	3,854.38
48	12,582	163,602	3,903,128	476,151	99	3,594,184	4,160.35
49	4,718	171,393	4,030,191	486,075	101	3,713,724	4,632.16
50	1,769	179,183	4,159,163	496,000	103	3,816,083	5,122.72
51	22,807	186,108	4,272,177	504,665	105	3,883,256	5,572.60
52	87,495	190,220	4,328,228	509,233	106	3,918,409	5,839.11
53	172,356	194,115	4,380,083	513,486	106	3,951,139	6,091.16
54	275,732	198,010	4,432,176	517,740	107	3,983,868	6,343.21
55	397,859	199,958	4,588,127	534,045	111	4,109,330	6,549.43
56	535,910	199,958	4,848,923	562,401	117	4,327,524	6,709.82
57	688,040	199,958	5,111,432	590,758	122	4,545,719	6,870.21
58	855,961	199,525	5,335,336	615,176	128	4,733,608	6,966.27
59	1,034,944	193,466	5,039,581	588,395	122	4,527,532	6,241.48
60	1,145,701	185,675	4,594,310	545,860	113	4,200,236	5,316.61
61	1,174,160	177,885	4,161,701	503,325	104	3,872,941	4,454.23
62	1,132,921	172,691	3,854,356	471,818	98	3,630,501	3,873.24
63	1,053,677	175,937	3,920,097	476,151	99	3,663,840	4,039.19
64	1,005,583	179,832	4,015,343	483,240	100	3,718,392	4,267.28
65	994,758	183,728	4,111,702	490,329	102	3,772,944	4,501.62
66	1,022,312	183,728	4,114,786	490,329	102	3,772,944	4,620.88
67	1,052,829	179,832	4,024,442	483,240	100	3,718,392	4,620.88
68	1,050,751	175,937	3,934,991	476,151	99	3,663,840	4,620.88
69	1,016,969	171,825	3,844,200	468,668	97	3,606,257	4,595.07
70	953,378	164,900	3,725,231	456,065	95	3,509,281	4,238.15
71	873,830	157,110	3,598,060	441,887	92	3,400,185	3,794.05
72	783,043	149,319	3,471,609	427,708	89	3,291,088	3,367.44
73	681,718	144,991	3,406,160	419,832	87	3,230,478	3,137.57
74	579,335	151,916	3,538,023	432,435	90	3,327,453	3,507.70
75	505,789	159,707	3,687,044	446,613	93	3,436,550	3,940.14
76	465,343	167,497	3,838,183	460,791	96	3,545,647	4,390.08
77	460,100	171,393	3,914,647	467,880	97	3,600,196	4,620.88
Final	473,347						
Average	459,038	164,343	3,706,710	451,433	94	3,422,203	4,075

Appendix B

Table B-3: Removal rate coefficients (per day)

Days	r_Combined effect	r_Solar radiation	r_Temperature	r_Overll
0	2.51E-04	3.999996	1.07E-35	4.000248
1	2.51E-04	3.999996	1.07E-35	4.000248
2	2.51E-04	3.999996	1.07E-35	4.000248
3	2.51E-04	3.999996	1.07E-35	4.000248
4	2.47E-04	3.999996	3.81E-34	4.000243
5	2.35E-04	3.999996	1.71E-29	4.000231
6	2.22E-04	3.999996	7.67E-25	4.000219
7	2.10E-04	3.999996	3.44E-20	4.000206
8	2.03E-04	3.999996	4.37E-18	4.000199
9	1.99E-04	3.999996	2.96E-17	4.000195
10	1.94E-04	3.999996	2.00E-16	4.000191
11	1.90E-04	3.999996	1.36E-15	4.000186
12	1.99E-04	3.999996	4.44E-20	4.000195
13	2.07E-04	3.999996	1.45E-24	4.000203
14	2.15E-04	3.999996	4.74E-29	4.000212
15	2.20E-04	3.999996	5.87E-32	4.000216
16	2.15E-04	3.999996	1.04E-31	4.000212
17	2.11E-04	3.999996	1.85E-31	4.000207
18	2.07E-04	3.999996	3.28E-31	4.000203
19	2.06E-04	3.999996	4.52E-31	4.000202
20	2.06E-04	3.999996	5.47E-31	4.000202
21	2.06E-04	3.999996	6.62E-31	4.000202
22	2.06E-04	3.999996	8.02E-31	4.000202
23	2.06E-04	3.999996	6.62E-31	4.000202
24	2.06E-04	3.999996	5.47E-31	4.000202
25	2.06E-04	3.999996	4.52E-31	4.000202
26	2.07E-04	3.999996	3.28E-31	4.000203
27	2.11E-04	3.999996	1.85E-31	4.000207
28	2.15E-04	3.999996	1.04E-31	4.000212
29	2.20E-04	3.999996	5.87E-32	4.000216
30	2.24E-04	3.999996	1.75E-32	4.00022
31	2.28E-04	3.999996	3.78E-33	4.000224
32	2.32E-04	3.999996	8.19E-34	4.000228
33	2.36E-04	3.999996	1.77E-34	4.000232
34	2.36E-04	3.999996	1.47E-34	4.000232
35	2.36E-04	3.999996	1.21E-34	4.000232
36	2.36E-04	3.999996	1.00E-34	4.000232
37	2.35E-04	3.999996	1.66E-34	4.000231
38	2.31E-04	3.999996	1.13E-33	4.000227
39	2.27E-04	3.999996	7.63E-33	4.000223
40	2.22E-04	3.999996	5.17E-32	4.000219
41	0.000221031	3.999996	4.00439E-32	4.000217
42	0.000221031	3.999996	1.04972E-32	4.000217
43	0.000221031	3.999996	2.75176E-33	4.000217
44	0.000221031	3.999996	7.21354E-34	4.000217
45	0.000221031	3.999996	1.87706E-33	4.000217
46	0.000221031	3.999996	4.88438E-33	4.000217
47	0.000221031	3.999996	1.27098E-32	4.000217
48	0.000222404	3.999996	1.64019E-32	4.000219
49	0.00022652	3.999996	5.20593E-33	4.000223

Appendix B

Table B-4 continued.

Days	r_Combined effect	r_Solar radiation	r_Temperature	r_Overll
50	0.000230628	3.999996	1.65235E-33	4.000227
51	0.00023473	3.999996	5.24451E-34	4.000231
52	0.000236095	3.999996	2.77216E-34	4.000232
53	0.000236095	3.999996	1.89097E-34	4.000232
54	0.000236095	3.999996	1.28989E-34	4.000232
55	0.000236095	3.999996	8.79875E-35	4.000232
56	0.000236095	3.999996	8.79875E-35	4.000232
57	0.000236095	3.999996	8.79875E-35	4.000232
58	0.000236095	3.999996	8.79875E-35	4.000232
59	0.00023473	3.999996	1.37481E-34	4.000231
60	0.000230628	3.999996	5.24451E-34	4.000227
61	0.00022652	3.999996	2.00063E-33	4.000223
62	0.000222404	3.999996	7.63186E-33	4.000219
63	0.000223777	3.999996	7.16047E-33	4.00022
64	0.00022789	3.999996	3.33179E-33	4.000224
65	0.000231996	3.999996	1.55029E-33	4.000228
66	0.000236095	3.999996	7.21354E-34	4.000232
67	0.000231996	3.999996	1.55029E-33	4.000228
68	0.00022789	3.999996	3.33179E-33	4.000224
69	0.000223777	3.999996	7.16047E-33	4.00022
70	0.000221031	3.999996	1.35466E-32	4.000217
71	0.000221031	3.999996	1.98592E-32	4.000217
72	0.000221031	3.999996	2.91134E-32	4.000217
73	0.000221031	3.999996	4.26801E-32	4.000217
74	0.000221031	3.999996	2.91134E-32	4.000217
75	0.000221031	3.999996	1.35466E-32	4.000217
76	0.000221031	3.999996	6.30325E-33	4.000217
77	0.000221031	3.999996	2.93292E-33	4.000217
Final	0.000221031	3.999996	2.93292E-33	4.000217
Sum	0.017415666	311.999688	1.59187E-15	312.01712
Percent	5.58164E-05	0.999944141	5.10188E-18	1
Average	0.000223278	3.999996	2.04086E-17	4.0002194
S.D	1.34721E-05	5.36356E-15	1.55045E-16	1.348E-05

Appendix B

Table B-5: The sensitivity of solar radiations (FC Counts per 100ml)

Days	-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%	-1%
0	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
1	310,996	300,620	290,244	279,869	269,493	259,117	250,000	250,000	250,000	250,000
2	634,101	561,743	489,386	423,848	363,596	303,343	244,140	192,534	143,489	117,792
3	1,437,790	1,303,996	1,170,202	1,043,228	921,540	799,851	679,211	566,169	455,687	368,554
4	2,420,709	2,226,818	2,032,927	1,845,856	1,664,071	1,482,285	1,301,548	1,128,409	957,830	810,601
5	3,114,146	2,871,819	2,629,492	2,393,985	2,163,763	1,933,541	1,704,368	1,482,792	1,263,778	1,068,112
6	3,469,064	3,193,137	2,917,210	2,648,103	2,384,281	2,120,459	1,857,686	1,602,510	1,349,896	1,120,630
7	3,616,400	3,321,709	3,027,019	2,739,148	2,456,563	2,173,977	1,892,440	1,618,501	1,347,123	1,099,093
8	3,702,225	3,400,330	3,098,434	2,803,359	2,513,568	2,223,778	1,935,036	1,653,892	1,375,309	1,120,075
9	3,785,042	3,476,848	3,168,654	2,867,281	2,571,192	2,275,103	1,980,064	1,692,622	1,407,740	1,146,208
10	3,865,950	3,551,545	3,237,140	2,929,556	2,627,256	2,324,957	2,023,706	1,730,053	1,438,961	1,171,217
11	3,944,662	3,624,134	3,303,606	2,989,897	2,681,474	2,373,051	2,065,677	1,765,900	1,468,684	1,194,817
12	4,015,922	3,685,779	3,355,636	3,032,314	2,714,276	2,396,238	2,079,249	1,769,858	1,463,028	1,179,546
13	4,075,542	3,728,716	3,381,890	3,041,883	2,707,162	2,372,441	2,038,768	1,712,694	1,389,180	1,089,014
14	4,124,797	3,754,218	3,383,639	3,019,880	2,661,406	2,302,932	1,945,507	1,595,679	1,248,412	924,494
15	4,166,996	3,766,049	3,365,101	2,970,974	2,582,131	2,193,289	1,805,495	1,425,299	1,047,664	693,378
16	4,230,933	3,798,894	3,366,856	2,941,637	2,521,704	2,101,771	1,682,886	1,271,599	862,873	477,496
17	4,322,822	3,860,783	3,398,745	2,943,527	2,493,593	2,043,660	1,594,775	1,153,489	714,763	299,385
18	4,439,862	3,948,915	3,457,967	2,973,840	2,494,998	2,016,155	1,538,362	1,068,166	600,531	156,244
19	4,571,741	4,053,218	3,534,695	3,022,992	2,516,574	2,010,156	1,504,786	1,007,015	511,804	59,829
20	4,692,649	4,148,672	3,604,694	3,067,536	2,535,664	2,003,791	1,472,967	949,741	429,076	22,436
21	4,801,748	4,234,497	3,667,247	3,106,817	2,551,671	1,996,526	1,442,430	895,931	351,993	8,413
22	4,900,315	4,311,974	3,723,633	3,142,112	2,565,875	1,989,639	1,414,452	846,862	281,833	3,155
23	4,996,204	4,386,772	3,777,340	3,174,728	2,577,401	1,980,073	1,383,795	795,115	208,995	1,183
24	5,096,640	4,463,936	3,831,231	3,205,346	2,584,746	1,964,146	1,344,595	732,642	123,249	444
25	5,202,028	4,543,869	3,885,709	3,234,370	2,588,316	1,942,261	1,297,256	659,848	47,518	166
26	5,312,810	4,627,074	3,941,339	3,262,424	2,588,794	1,915,164	1,242,583	577,599	17,819	62
27	5,430,068	4,715,424	4,000,780	3,292,956	2,590,417	1,887,878	1,186,387	492,495	6,682	23
28	5,554,233	4,809,589	4,064,945	3,327,121	2,594,582	1,862,043	1,130,553	406,660	2,506	9
29	5,685,478	4,909,743	4,134,008	3,365,093	2,601,463	1,837,833	1,075,252	320,269	940	3
30	5,827,513	5,019,378	4,211,243	3,409,928	2,613,898	1,817,868	1,022,887	235,503	352	1
31	5,992,524	5,149,971	4,307,418	3,471,684	2,641,236	1,810,788	981,389	159,587	132	0
32	6,182,603	5,303,559	4,424,515	3,552,291	2,685,352	1,818,413	952,522	94,230	50	0
33	6,398,958	5,481,350	4,563,743	3,652,955	2,747,453	1,841,950	937,496	41,757	19	0
34	6,671,868	5,712,969	4,754,071	3,801,992	2,855,199	1,908,405	962,661	26,556	7	0
35	7,039,106	6,035,535	5,031,964	4,035,212	3,043,746	2,052,280	1,061,863	81,085	14,172	213
36	7,513,113	6,461,488	5,409,862	4,365,056	3,325,536	2,286,015	1,247,543	218,711	103,743	41,730
37	8,096,348	6,993,777	5,891,206	4,795,455	3,704,989	2,614,523	1,525,106	445,328	279,415	166,456
38	8,667,385	7,517,359	6,367,334	5,224,128	4,086,207	2,948,287	1,811,415	684,183	470,815	310,402
39	9,184,066	7,992,040	6,800,014	5,614,809	4,434,888	3,254,968	2,076,096	906,864	651,496	449,083
40	9,643,263	8,414,692	7,186,121	5,964,370	4,747,904	3,531,439	2,316,022	1,110,244	818,331	579,372
41	10,046,710	8,785,472	7,524,235	6,269,817	5,020,685	3,771,552	2,523,468	1,285,024	960,444	688,819
42	10,404,149	9,109,002	7,813,855	6,525,529	5,242,487	3,959,446	2,677,453	1,405,100	1,046,611	741,076
43	10,709,847	9,379,155	8,048,463	6,724,591	5,406,004	4,087,417	2,769,879	1,461,980	1,067,946	726,866
44	10,956,825	9,588,951	8,221,077	6,860,023	5,504,254	4,148,486	2,793,766	1,448,685	1,017,469	639,207
45	11,193,079	9,787,478	8,381,877	6,983,096	5,589,600	4,196,104	2,803,657	1,420,849	951,906	535,917
46	11,470,260	10,027,477	8,584,694	7,148,731	5,718,054	4,287,376	2,857,747	1,437,758	931,632	478,462
47	11,786,830	10,307,411	8,827,992	7,355,393	5,888,079	4,420,764	2,954,499	1,497,874	955,112	465,305

Appendix B

Table B-5 continued.

	-10%	**-9%**	**-8%**	**-7%**	**-6%**	**-5%**	**-4%**	**-3%**	**-2%**	**-1%**
48	12,138,332	10,622,749	9,107,166	7,598,404	6,094,926	4,591,448	3,089,019	1,596,230	1,017,305	491,334
49	12,485,217	10,932,998	9,380,779	7,835,380	6,295,266	4,755,152	3,216,086	1,686,661	1,071,099	508,493
50	12,814,440	11,224,821	9,635,202	8,052,403	6,474,889	4,897,375	3,320,910	1,754,084	1,101,123	501,116
51	13,124,685	11,496,902	9,869,119	8,248,157	6,632,479	5,016,801	3,402,172	1,797,183	1,106,058	467,888
52	13,430,664	11,764,051	10,097,438	8,437,645	6,783,137	5,128,629	3,475,170	1,831,351	1,101,395	424,395
53	13,784,193	12,078,398	10,372,603	8,673,629	6,979,939	5,286,249	3,593,608	1,910,607	1,141,470	425,287
54	14,190,045	12,444,741	10,699,438	8,960,954	7,227,755	5,494,556	3,762,406	2,039,896	1,231,250	475,558
55	14,649,031	12,863,891	11,078,751	9,300,431	7,527,395	5,754,360	3,982,374	2,220,028	1,371,545	576,017
56	15,131,569	13,305,338	11,479,107	9,659,696	7,845,570	6,031,444	4,218,367	2,414,929	1,525,356	688,737
57	15,605,935	13,736,432	11,866,928	10,004,244	8,146,846	6,289,447	4,433,097	2,586,387	1,653,541	773,650
58	16,069,725	14,154,767	12,239,808	10,331,670	8,428,817	6,525,964	4,624,160	2,731,995	1,753,694	828,349
59	16,522,906	14,560,615	12,598,323	10,642,852	8,692,665	6,742,479	4,793,341	2,853,843	1,828,209	855,530
60	16,992,705	14,985,141	12,977,576	10,976,832	8,981,373	6,985,914	4,991,504	3,006,733	1,935,826	917,875
61	17,481,463	15,431,898	13,382,334	11,339,590	9,302,131	7,264,672	5,228,262	3,201,491	2,088,585	1,028,633
62	17,981,627	15,893,335	13,805,044	11,723,573	9,647,386	7,571,200	5,496,063	3,430,565	2,278,931	1,180,252
63	18,474,253	16,349,659	14,225,064	12,107,290	9,994,801	7,882,311	5,770,871	3,669,070	2,481,133	1,346,151
64	18,917,270	16,756,039	14,594,809	12,440,398	10,291,272	8,142,147	5,994,070	3,855,633	2,631,059	1,459,441
65	19,305,712	17,107,299	14,908,887	12,717,294	10,530,987	8,344,680	6,159,421	3,983,802	2,722,047	1,513,247
66	19,637,586	17,401,446	15,165,307	12,935,987	10,711,952	8,487,918	6,264,932	4,051,586	2,752,103	1,505,576
67	19,953,136	17,679,270	15,405,403	13,138,356	10,876,594	8,614,832	6,354,119	4,103,046	2,765,836	1,481,581
68	20,293,278	17,982,229	15,671,180	13,366,952	11,068,008	8,769,064	6,471,169	4,182,914	2,808,523	1,487,087
69	20,657,021	18,309,336	15,961,651	13,620,786	11,285,206	8,949,626	6,615,095	4,290,204	2,879,176	1,521,103
70	21,039,847	18,656,101	16,272,355	13,895,430	11,523,789	9,152,148	6,781,557	4,420,605	2,973,517	1,579,383
71	21,395,469	18,976,632	16,557,796	14,145,779	11,739,048	9,332,316	6,926,634	4,530,591	3,048,412	1,619,188
72	21,711,199	19,258,362	16,805,526	14,359,509	11,918,778	9,478,046	7,038,364	4,608,321	3,092,142	1,628,918
73	21,988,714	19,502,969	17,017,223	14,538,297	12,064,657	9,591,016	7,118,425	4,655,473	3,106,385	1,610,252
74	22,244,753	19,726,704	17,208,656	14,697,427	12,191,484	9,685,540	7,180,646	4,685,391	3,104,000	1,575,564
75	22,529,801	19,978,479	17,427,158	14,882,657	12,343,441	9,804,225	7,266,057	4,737,530	3,122,866	1,561,157
76	22,849,027	20,263,342	17,677,657	15,098,792	12,525,212	9,951,633	7,379,102	4,816,211	3,167,183	1,571,111
77	23,203,830	20,582,691	17,961,551	15,347,232	12,738,198	10,129,163	7,521,178	4,922,832	3,238,350	1,606,824
Final	23,577,076	20,919,937	18,262,798	15,612,478	12,967,444	10,322,410	7,678,424	5,044,079	3,323,597	1,656,070
AVG	10,568,188	9,323,980	8,079,773	6,842,213	5,609,805	4,377,396	3,146,026	1,923,354	1,271,629	709,760
S.D	6,735,694	5,955,073	5,176,428	4,401,053	3,630,814	2,869,498	2,126,720	1,432,194	995,899	555,030

Appendix B

Table B-5 continued.

Solar Radiation	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
200	200	202	204	206	208	210	212	214	216	218	220
Days											
0	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
1	250000	250000	250000	250000	250000	250000	250000	250000	250000	250000	250000
2	107507	97223	93750	93750	93750	93750	93750	93750	93750	93750	93750
3	296833	225112	161807	110656	59504	41565	35156	35156	35156	35156	35156
4	678783	546965	423563	312315	201066	123030	58356	14609	13184	13184	13184
5	887857	707603	535765	376080	216395	94111	24410	5478	4944	4944	4944
6	906775	692921	487483	294198	108428	35291	9154	2054	1854	1854	1854
7	866475	633857	409656	197607	40661	13234	3433	770	695	695	695
8	880252	640429	409023	189769	29696	4963	1287	289	261	261	261
9	900087	653966	416261	190710	24338	1861	483	108	98	98	98
10	918886	666554	422638	190876	18294	698	181	41	37	37	37
11	936362	677906	427867	189981	11275	262	68	15	14	14	14
12	911476	643406	383752	136252	4382	98	25	6	5	5	5
13	804261	519507	243170	52367	1643	37	10	2	2	2	2
14	615988	307482	93472	19637	616	14	4	1	1	1	1
15	354503	117463	35052	7364	231	5	1	0	0	0	0
16	136568	44049	13144	2762	87	2	1	0	0	0	0
17	51213	16518	4929	1036	33	1	0	0	0	0	0
18	19205	6194	1848	388	12	0	0	0	0	0	0
19	7202	2323	693	146	5	0	0	0	0	0	0
20	2701	871	260	55	2	0	0	0	0	0	0
21	1013	327	97	20	1	0	0	0	0	0	0
22	380	123	37	8	0	0	0	0	0	0	0
23	142	46	14	3	0	0	0	0	0	0	0
24	53	17	5	1	0	0	0	0	0	0	0
25	20	6	2	0	0	0	0	0	0	0	0
26	8	2	1	0	0	0	0	0	0	0	0
27	3	1	0	0	0	0	0	0	0	0	0
28	1	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0
36	5681	0	0	0	0	0	0	0	0	0	0
37	79462	25445	0	0	0	0	0	0	0	0	0
38	175953	74482	2437	0	0	0	0	0	0	0	0
39	272634	129164	15118	0	0	0	0	0	0	0	0
40	366378	186362	35771	0	0	0	0	0	0	0	0
41	443158	230475	47218	0	0	0	0	0	0	0	0
42	461506	214915	19003	0	0	0	0	0	0	0	0
43	411751	129613	7126	0	0	0	0	0	0	0	0
44	286910	48902	2672	0	0	0	0	0	0	0	0
45	145893	0	1002	0	0	0	0	0	0	0	0
46	57184	0	376	0	0	0	0	0	0	0	0
47	21444	0	141	0	0	0	0	0	0	0	0

Appendix B

Table B-5 continued.

Days	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
48	12,382	0	53	0	0	0	0	0	0	0	0
49	4,857	0	20	0	0	0	0	0	0	0	0
50	1,821	0	7	0	0	0	0	0	0	0	0
51	683	0	3	0	0	0	0	0	0	0	0
52	256	0	1	0	0	0	0	0	0	0	0
53	96	0	0	0	0	0	0	0	0	0	0
54	13,158	0	0	0	0	0	0	0	0	0	0
55	73,781	21,472	971	0	0	0	0	0	0	0	0
56	145,410	52,010	647	0	0	0	0	0	0	0	0
57	187,050	50,378	243	0	0	0	0	0	0	0	0
58	196,294	21,471	91	0	0	0	0	0	0	0	0
59	176,142	8,051	34	0	0	0	0	0	0	0	0
60	193,214	3,445	13	0	0	0	0	0	0	0	0
61	261,973	30,204	1,897	0	0	0	0	0	0	0	0
62	374,864	104,368	37,335	3,531	0	0	0	0	0	0	0
63	504,461	197,661	94,325	24,218	0	0	0	0	0	0	0
64	581,114	237,679	97,706	9,962	0	0	0	0	0	0	0
65	597,738	217,121	48,118	3,736	0	0	0	0	0	0	0
66	552,340	133,996	18,044	1,401	0	0	0	0	0	0	0
67	490,618	51,037	6,767	525	0	0	0	0	0	0	0
68	458,942	19,139	2,537	197	0	0	0	0	0	0	0
69	456,322	7,177	952	74	0	0	0	0	0	0	0
70	478,541	2,691	357	28	0	0	0	0	0	0	0
71	483,255	1,009	134	10	0	0	0	0	0	0	0
72	458,985	378	50	4	0	0	0	0	0	0	0
73	407,410	142	19	1	0	0	0	0	0	0	0
74	340,419	53	7	1	0	0	0	0	0	0	0
75	292,740	20	3	0	0	0	0	0	0	0	0
76	268,330	7	1	0	0	0	0	0	0	0	0
77	268,588	3	0	0	0	0	0	0	0	0	0
Final	281,834	1	0	0	0	0	0	0	0	0	0
AVG	288,938	134,807	79,183	46,325	26,081	20,999	18,688	17,750	17,722	17,722	17,722
S.D	305,532	234,779	177,033	136,932	120,767	117,505	116,701	116,639	116,641	116,641	116,641

Appendix B

Table B-6: The sensitivity of Temperature (FC Counts per 100ml)

Days	-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%	-1%
0	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
1	250000	250000	250000	250000	250000	250000	250000	250000	250000	250000
2	107507	107507	107507	107507	107507	107507	107507	107507	107507	107507
3	296833	296833	296833	296833	296833	296833	296833	296833	296833	296833
4	678783	678783	678783	678783	678783	678783	678783	678783	678783	678783
5	887857	887857	887857	887857	887857	887857	887857	887857	887857	887857
6	906775	906775	906775	906775	906775	906775	906775	906775	906775	906775
7	866475	866475	866475	866475	866475	866475	866475	866475	866475	866475
8	879834	879834	879834	879834	879834	879834	879834	879834	879834	879834
9	897492	897492	897492	897492	897492	897492	897492	897492	897492	897492
10	912292	912292	912292	912292	912292	912292	912292	912292	912292	912292
11	923994	923994	923994	923994	923994	923994	923994	923994	923994	923994
12	894797	894797	894797	894797	894797	894797	894797	894797	894797	894797
13	798876	798876	798876	798876	798876	798876	798876	798876	798876	798876
14	654052	654052	654052	654052	654052	654052	654052	654052	654052	654052
15	478947	478947	478947	478947	478947	478947	478947	478947	478947	478947
16	297105	297105	297105	297105	297105	297105	297105	297105	297105	297105
17	125008	125008	125008	125008	125008	125008	125008	125008	125008	125008
18	46878	46878	46878	46878	46878	46878	46878	46878	0	46878
19	17579	17579	17579	17579	17579	17579	17579	17579	0	17579
20	6592	6592	6592	6592	6592	6592	6592	6592	0	6592
21	2472	2472	2472	2472	2472	2472	2472	2472	0	2472
22	927	927	927	927	927	927	927	927	0	927
23	348	348	348	348	348	348	348	348	0	348
24	130	130	130	130	130	130	130	130	0	130
25	49	49	49	49	49	49	49	49	0	49
26	18	18	18	18	18	18	18	18	0	18
27	7	7	7	7	7	7	7	7	0	7
28	3	3	3	3	3	3	3	3	0	3
29	1	1	1	1	1	1	1	1	0	1
30	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0
33	19543	19543	19543	19543	19543	19543	19543	19543	19543	19543
34	87717	87717	87717	87717	87717	87717	87717	87717	87717	87717
35	192569	192569	192569	192569	192569	192569	192569	192569	192569	192569
36	340054	340054	340054	340054	340054	340054	340054	340054	340054	340054
37	524856	524856	524856	524856	524856	524856	524856	524856	524856	524856
38	612450	612450	612450	612450	612450	612450	612450	612450	612450	612450
39	584052	584052	584052	584052	584052	584052	584052	584052	584052	584052
40	467798	467798	467798	467798	467798	467798	467798	467798	467798	467798
41	311473	311473	311473	311473	311473	311473	311473	311473	311473	311473
42	195605	195605	195605	195605	195605	195605	195605	195605	195605	195605
43	130630	130630	130630	130630	130630	130630	130630	130630	130630	130630
44	121637	121637	121637	121637	121637	121637	121637	121637	121636	121637
45	122936	122936	122936	122936	122936	122936	122936	122936	122936	122936
46	86086	86086	86086	86086	86086	86086	86086	86086	86086	50476
47	33552	33552	33552	33552	33552	33552	33552	33552	33552	18929

Appendix B

Table B-6 continued.

Days	-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%	-1%
48	12,582	12,582	12,582	12,582	12,582	12,582	12,582	12,582	12,582	7,098
49	4,718	4,718	4,718	4,718	4,718	4,718	4,718	4,718	4,718	2,662
50	1,769	1,769	1,769	1,769	1,769	1,769	1,769	1,769	1,769	998
51	22,807	22,807	22,807	22,807	22,807	22,807	22,807	22,807	22,807	22,164
52	87,495	87,495	87,495	87,495	87,495	87,495	87,495	87,495	87,495	86,852
53	172,356	172,356	172,356	172,356	172,356	172,356	172,356	172,356	172,356	171,713
54	275,732	275,732	275,732	275,732	275,732	275,732	275,732	275,732	275,732	275,089
55	397,859	397,859	397,859	397,859	397,859	397,859	397,859	397,859	397,859	397,217
56	535,910	535,910	535,910	535,910	535,910	535,910	535,910	535,910	535,910	535,268
57	688,040	688,040	688,040	688,040	688,040	688,040	688,040	688,040	688,040	687,397
58	855,961	855,961	855,961	855,961	855,961	855,961	855,961	855,961	855,961	855,318
59	1,034,944	1,034,944	1,034,944	1,034,944	1,034,944	1,034,944	1,034,944	1,034,944	1,034,944	1,034,302
60	1,145,701	1,145,701	1,145,701	1,145,701	1,145,701	1,145,701	1,145,701	1,145,701	1,145,701	1,145,058
61	1,174,160	1,174,160	1,174,160	1,174,160	1,174,160	1,174,160	1,174,160	1,174,160	1,174,160	1,173,518
62	1,132,921	1,132,921	1,132,921	1,132,921	1,132,921	1,132,921	1,132,921	1,132,921	1,132,921	1,132,278
63	1,053,677	1,053,677	1,053,677	1,053,677	1,053,677	1,053,677	1,053,677	1,053,677	1,053,677	1,053,034
64	1,005,583	1,005,583	1,005,583	1,005,583	1,005,583	1,005,583	1,005,583	1,005,583	1,005,583	1,004,940
65	994,758	994,758	994,758	994,758	994,758	994,758	994,758	994,758	994,758	994,116
66	1,022,312	1,022,312	1,022,312	1,022,312	1,022,312	1,022,312	1,022,312	1,022,312	1,022,312	1,021,669
67	1,052,829	1,052,829	1,052,829	1,052,829	1,052,829	1,052,829	1,052,829	1,052,829	1,052,829	1,052,187
68	1,050,751	1,050,751	1,050,751	1,050,751	1,050,751	1,050,751	1,050,751	1,050,751	1,050,751	1,050,109
69	1,016,969	1,016,969	1,016,969	1,016,969	1,016,969	1,016,969	1,016,969	1,016,969	1,016,969	1,016,327
70	953,378	953,378	953,378	953,378	953,378	953,378	953,378	953,378	953,378	952,735
71	873,830	873,830	873,830	873,830	873,830	873,830	873,830	873,830	873,830	873,187
72	783,043	783,043	783,043	783,043	783,043	783,043	783,043	783,043	783,043	782,400
73	681,718	681,718	681,718	681,718	681,718	681,718	681,718	681,718	681,718	681,076
74	579,335	579,335	579,335	579,335	579,335	579,335	579,335	579,335	579,335	578,692
75	505,789	505,789	505,789	505,789	505,789	505,789	505,789	505,789	505,789	505,146
76	465,343	465,343	465,343	465,343	465,343	465,343	465,343	465,343	465,343	464,701
77	460,100	460,100	460,100	460,100	460,100	460,100	460,100	460,100	460,100	459,458
Final	473,347	473,347	473,347	473,347	473,347	473,347	473,347	473,347	473,347	472,704
AVG	459,038	459,038	459,038	459,038	459,038	459,038	459,038	459,038	458,076	458,065
S.D	403,928	403,928	403,928	403,928	403,928	403,928	403,928	403,928	404,991	404,540

Appendix B
Table B-6 continued.

Days	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
0	########	########	########	########	########	########	########	########	########	########	########
1	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000
2	107,507	107,507	107,507	107,507	107,507	107,507	107,507	107,507	107,507	107,507	107,507
3	296,833	296,833	296,833	296,833	296,833	296,833	296,833	296,833	296,833	296,833	296,833
4	678,783	678,783	678,783	678,783	678,783	678,783	678,783	678,783	678,783	678,783	678,783
5	887,857	887,857	887,857	887,857	887,857	887,857	887,857	887,857	887,857	887,857	887,857
6	906,775	906,775	906,775	906,775	906,775	906,775	906,775	906,775	906,775	906,775	906,775
7	866,475	866,475	866,475	866,475	866,475	866,475	866,475	866,475	866,475	866,475	866,475
8	879,834	879,834	879,834	879,834	879,834	879,834	879,834	879,834	879,834	879,834	879,834
9	897,492	897,492	897,492	897,492	897,492	897,492	897,492	897,492	897,492	897,492	897,492
10	912,292	912,292	912,292	912,292	912,292	912,292	912,292	912,292	912,292	912,292	912,292
11	923,994	923,994	923,994	923,994	923,994	923,994	923,994	923,994	923,994	923,994	923,994
12	894,797	894,797	894,797	894,797	894,797	894,797	894,797	894,797	894,797	894,797	894,797
13	798,876	798,876	798,876	798,876	798,876	798,876	798,876	798,876	798,876	798,876	798,876
14	654,052	654,052	654,052	654,052	654,052	654,052	654,052	654,052	654,052	654,052	654,052
15	478,947	478,947	478,947	478,947	478,947	478,947	478,947	478,947	478,947	478,947	478,947
16	297,105	297,105	297,105	297,105	297,105	297,105	297,105	297,105	297,105	297,105	297,105
17	125,008	125,008	125,008	125,008	125,008	125,008	125,008	125,008	125,008	125,008	125,008
18	46,878	46,878	46,878	46,878	46,878	46,878	46,878	46,878	46,878	46,878	46,878
19	17,579	17,579	17,579	17,579	17,579	17,579	17,579	17,579	17,579	17,579	17,579
20	6,592	6,592	6,592	6,592	6,592	6,592	6,592	6,592	6,592	6,592	6,592
21	2,472	2,472	2,472	2,472	2,472	2,472	2,472	2,472	2,472	2,472	2,472
22	927	927	927	927	927	927	927	927	927	927	927
23	348	348	348	348	348	348	348	348	348	348	348
24	130	130	130	130	130	130	130	130	130	130	130
25	49	49	49	49	49	49	49	49	49	49	49
26	18	18	18	18	18	18	18	18	18	18	18
27	7	7	7	7	7	7	7	7	7	7	7
28	3	3	3	3	3	3	3	3	3	3	3
29	1	1	1	1	1	1	1	1	1	1	1
30	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0
33	19,543	19,543	19,543	19,543	19,543	19,543	19,543	19,543	19,543	19,543	19,543
34	87,717	87,717	87,717	87,717	87,717	87,717	87,717	87,717	87,717	87,717	87,717
35	192,569	192,569	192,569	192,569	192,569	192,569	192,569	192,569	192,569	192,569	192,569
36	340,054	340,054	340,054	340,054	340,054	340,054	340,054	340,054	340,054	340,054	340,054
37	524,856	524,856	524,856	524,856	524,856	524,856	524,856	524,856	524,856	524,856	524,856
38	612,450	612,450	612,450	612,450	612,450	612,450	612,450	612,450	612,450	612,450	612,450
39	584,052	584,052	584,052	584,052	584,052	584,052	584,052	584,052	584,052	584,052	584,052
40	467,798	467,798	467,798	467,798	467,798	467,798	467,798	467,798	467,798	467,798	467,798
41	311,473	311,473	311,473	311,473	311,473	311,473	311,473	311,473	311,473	311,473	311,473
42	195,605	195,605	195,605	195,605	195,605	195,605	195,605	195,605	195,605	195,605	195,605
43	130,630	130,630	130,630	130,630	130,630	130,630	130,630	130,630	130,630	130,630	130,630
44	121,637	121,637	121,637	121,637	121,637	121,637	121,637	121,637	121,637	121,637	121,637
45	122,936	122,936	122,936	122,936	122,936	122,936	122,936	122,936	122,936	122,936	122,936
46	86,086	86,086	86,086	86,086	50,476	86,086	86,086	86,086	86,086	86,086	86,086
47	33,552	33,552	33,552	33,552	18,929	33,552	33,552	33,552	33,552	33,552	33,552
48	12,582	12,582	12,582	12,582	7,098	12,582	12,582	12,582	12,582	12,582	12,582
49	4,718	4,718	4,718	4,718	2,662	4,718	4,718	4,718	4,718	4,718	4,718
50	1,769	1,769	1,769	1,769	998	1,769	1,769	1,769	1,769	1,769	1,769

Appendix B

Table B-6 continued.

Days	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
51	22,807	22,807	22,807	22,807	22,164	22,807	22,807	22,807	22,807	22,807	22,807
52	87,495	87,495	87,495	87,495	86,852	87,495	87,495	87,495	87,495	87,495	87,495
53	172,356	172,356	172,356	172,356	171,713	172,356	172,356	172,356	172,356	172,356	172,356
54	275,732	275,732	275,732	275,732	275,089	275,732	275,732	275,732	275,732	275,732	275,732
55	397,859	397,859	397,859	397,859	397,217	397,859	397,859	397,859	397,859	397,859	397,859
56	535,910	535,910	535,910	535,910	535,268	535,910	535,910	535,910	535,910	535,910	535,910
57	688,040	688,040	688,040	688,040	687,397	688,040	688,040	688,040	688,040	688,040	688,040
58	855,961	855,961	855,961	855,961	855,318	855,961	855,961	855,961	855,961	855,961	855,961
59	########	########	########	########	########	########	########	########	########	########	1,034,944
60	########	########	########	########	########	########	########	########	########	########	1,145,701
61	########	########	########	########	########	########	########	########	########	########	1,174,160
62	########	########	########	########	########	########	########	########	########	########	1,132,921
63	########	########	########	########	########	########	########	########	########	########	1,053,677
64	########	########	########	########	########	########	########	########	########	########	1,005,583
65	994,758	994,758	994,758	994,758	994,116	994,758	994,758	994,758	994,758	994,758	994,758
66	########	########	########	########	########	########	########	########	########	########	1,022,312
67	########	########	########	########	########	########	########	########	########	########	1,052,829
68	########	########	########	########	########	########	########	########	########	########	1,050,751
69	########	########	########	########	########	########	########	########	########	########	1,016,969
70	953,378	953,378	953,378	953,378	952,735	953,378	953,378	953,378	953,378	953,378	953,378
71	873,830	873,830	873,830	873,830	873,187	873,830	873,830	873,830	873,830	873,830	873,830
72	783,043	783,043	783,043	783,043	782,400	783,043	783,043	783,043	783,043	783,043	783,043
73	681,718	681,718	681,718	681,718	681,076	681,718	681,718	681,718	681,718	681,718	681,718
74	579,335	579,335	579,335	579,335	578,692	579,335	579,335	579,335	579,335	579,335	579,335
75	505,789	505,789	505,789	505,789	505,146	505,789	505,789	505,789	505,789	505,789	505,789
76	465,343	465,343	465,343	465,343	464,701	465,343	465,343	465,343	465,343	465,343	465,343
77	460,100	460,100	460,100	460,100	459,458	460,100	460,100	460,100	460,100	460,100	460,100
Final	473,347	473,347	473,347	473,347	472,704	473,347	473,347	473,347	473,347	473,347	473,347
Average	459,038	459,038	459,038	459,038	458,065	459,038	459,038	459,038	459,038	459,038	459,038
S.D	403,928	403,928	403,928	403,928	404,540	403,928	403,928	403,928	403,928	403,928	403,928

Appendix B

Table B-7: The sensitivity analysis for BOD_5 (FC counts per 100ml)

Days	-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%
0	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
1	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000
2	93,750	93,750	94,203	95,679	97,657	99,275	101,181	102,555	104,398
3	195,457	203,503	214,470	223,702	235,817	246,168	257,831	266,407	277,668
4	510,061	524,458	543,292	558,637	578,329	595,951	614,887	629,117	647,394
5	675,359	693,971	717,803	737,203	761,705	784,336	807,881	825,856	848,574
6	669,014	690,094	716,770	738,544	765,781	791,381	817,546	837,708	862,951
7	616,571	638,849	666,882	689,807	718,350	745,386	772,800	794,023	820,469
8	625,799	648,488	676,981	700,301	729,285	756,808	784,645	806,231	833,084
9	640,093	663,119	691,986	715,630	744,974	772,889	801,066	822,951	850,136
10	651,760	675,103	704,319	728,267	757,946	786,224	814,710	836,875	864,369
11	660,531	684,174	713,716	737,952	767,944	796,561	825,324	847,754	875,537
12	626,940	651,035	681,069	705,740	736,204	765,327	794,487	817,317	845,535
13	523,688	548,540	579,390	604,801	636,050	666,010	695,820	719,320	748,262
14	368,871	394,752	426,708	453,152	485,460	516,550	547,249	571,660	601,581
15	183,768	208,709	241,996	269,735	303,321	335,766	367,580	393,092	424,193
16	68,913	78,968	92,894	104,508	127,143	155,051	182,310	207,904	240,131
17	25,842	29,613	34,835	39,190	47,679	58,144	68,366	78,870	92,342
18	9,691	11,105	13,063	14,696	17,879	21,804	25,637	29,576	34,628
19	3,634	4,164	4,899	5,511	6,705	8,177	9,614	11,091	12,986
20	1,363	1,562	1,837	2,067	2,514	3,066	3,605	4,159	4,870
21	511	586	689	775	943	1,150	1,352	1,560	1,826
22	192	220	258	291	354	431	507	585	685
23	72	82	97	109	133	162	190	219	257
24	27	31	36	41	50	61	71	82	96
25	10	12	14	15	19	23	27	31	36
26	4	4	5	6	7	9	10	12	14
27	1	2	2	2	3	3	4	4	5
28	1	1	1	1	1	1	1	2	2
29	0	0	0	0	0	0	1	1	1
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
33	12,658	13,363	14,061	14,801	15,532	16,241	16,884	17,623	18,296
34	72,199	73,798	75,364	77,040	78,677	80,285	81,726	83,398	84,906
35	167,936	170,485	172,964	175,630	178,220	180,784	183,060	185,722	188,107
36	305,853	309,399	312,839	316,541	320,130	323,705	326,848	330,555	333,859
37	480,775	485,345	489,783	494,547	499,172	503,799	507,828	512,617	516,876
38	559,591	565,060	570,395	576,093	581,643	587,209	592,018	597,772	602,885
39	523,818	530,038	536,129	542,610	548,941	555,297	560,758	567,322	573,159
40	401,457	408,295	415,013	422,146	429,123	436,133	442,130	449,364	455,807
41	239,882	247,250	254,508	262,207	269,737	277,307	283,765	291,572	298,543
42	118,612	126,524	134,336	142,625	150,723	158,866	165,797	174,191	181,709
43	48,214	56,492	64,884	73,787	82,479	91,214	98,636	107,641	115,731
44	33,386	42,247	51,245	60,786	70,097	79,443	87,372	97,013	105,694
45	28,882	38,320	47,927	58,097	68,029	77,978	86,411	96,688	105,954
46	11,050	15,006	19,034	24,918	33,101	41,776	49,126	58,287	68,107
47	4,144	5,627	7,138	9,344	12,413	15,666	18,422	21,906	26,020

Appendix B

Table B-7 Continued.

Days	-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%
48	1,554	2,110	2,677	3,504	4,655	5,875	6,908	8,215	9,758
49	583	791	1,004	1,314	1,746	2,203	2,591	3,081	3,659
50	219	297	376	493	655	826	971	1,155	1,372
51	17,185	17,672	18,189	18,772	19,363	19,949	20,461	21,085	21,686
52	76,652	77,645	78,704	79,877	81,015	82,138	83,121	84,315	85,420
53	156,330	157,825	159,419	161,181	162,860	164,520	165,967	167,730	169,332
54	254,566	256,560	258,681	261,031	263,242	265,439	267,345	269,675	271,767
55	371,593	374,086	376,727	379,664	382,399	385,132	387,491	390,385	392,960
56	504,465	507,469	510,635	514,169	517,434	520,714	523,530	526,999	530,061
57	651,226	654,762	658,471	662,626	666,438	670,286	673,576	677,641	681,207
58	813,595	817,682	821,955	826,749	831,127	835,562	839,344	844,023	848,110
59	986,893	991,544	996,396	1,001,842	1,006,802	1,011,835	1,016,124	1,021,428	1,026,052
60	1,092,379	1,097,550	1,102,942	1,108,989	1,114,492	1,120,076	1,124,839	1,130,719	1,135,842
61	1,116,118	1,121,753	1,127,632	1,134,216	1,140,206	1,146,280	1,151,471	1,157,863	1,163,435
62	1,070,676	1,076,722	1,083,034	1,090,097	1,096,521	1,103,029	1,108,606	1,115,452	1,121,423
63	987,601	994,022	1,000,728	1,008,230	1,015,048	1,021,951	1,027,883	1,035,139	1,041,473
64	935,673	942,467	949,566	957,510	964,721	972,018	978,308	985,974	992,671
65	920,983	928,153	935,647	944,038	951,645	959,340	965,991	974,071	981,131
66	944,640	952,189	960,079	968,924	976,927	985,025	992,040	1,000,538	1,007,963
67	971,320	979,239	987,519	996,813	1,005,205	1,013,702	1,021,075	1,029,986	1,037,769
68	965,546	973,822	982,475	992,204	1,000,968	1,009,850	1,017,568	1,026,878	1,035,005
69	928,203	936,822	945,834	955,983	965,106	974,359	982,411	992,104	1,000,560
70	861,183	870,131	879,488	890,044	899,511	909,121	917,495	927,557	936,330
71	778,358	787,621	797,306	808,254	818,048	827,998	836,683	847,096	856,170
72	684,450	694,012	704,009	715,331	725,436	735,709	744,693	755,438	764,800
73	580,155	590,000	600,294	611,974	622,375	632,954	642,224	653,285	662,918
74	474,895	485,015	495,596	507,623	518,309	529,184	538,734	550,099	559,995
75	398,399	408,801	419,675	432,060	443,038	454,215	464,054	475,729	485,894
76	354,919	365,611	376,786	389,540	400,819	412,303	422,443	434,437	444,878
77	346,554	357,548	369,031	382,162	393,753	405,550	416,004	428,323	439,046
Final	356,655	367,954	379,748	393,258	405,163	417,272	428,046	440,693	451,700
Average	380,222	387,206	395,317	402,984	411,540	419,994	428,018	435,680	443,928
S.D	365,920	369,086	372,871	376,620	380,572	384,508	388,465	392,179	396,263

Appendix B

Table B-7 continued.

-1%	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000
105,726	107,507	109,255	110,515	112,207	113,427	115,227	116,406	117,990	121,267	126,553	130,327
285,952	296,833	307,506	315,359	325,681	333,278	344,476	351,813	361,460	370,700	383,795	393,345
661,132	678,783	696,093	709,111	725,844	738,431	756,976	769,120	784,739	798,629	817,503	831,554
865,922	887,857	909,369	925,802	946,591	962,477	985,857	1,001,174	1,020,563	1,037,522	1,060,043	1,077,062
882,407	906,775	930,673	949,101	972,193	990,004	1,016,175	1,033,343	1,054,871	1,073,618	1,098,207	1,116,956
840,947	866,475	891,511	910,905	935,094	953,838	981,339	999,404	1,021,950	1,041,563	1,067,137	1,086,724
853,913	879,834	905,254	924,979	949,540	968,603	996,551	1,014,922	1,037,813	1,057,723	1,083,629	1,103,503
871,252	897,492	923,225	943,222	968,084	987,410	1,015,716	1,034,335	1,057,507	1,077,660	1,103,837	1,123,945
885,755	912,292	938,317	958,570	983,713	1,003,284	1,031,920	1,050,766	1,074,198	1,094,580	1,121,008	1,141,338
897,178	923,994	950,292	970,785	996,192	1,015,995	1,044,936	1,063,986	1,087,662	1,108,260	1,134,924	1,155,462
867,563	894,797	921,505	942,363	968,165	988,319	1,017,715	1,037,056	1,061,100	1,082,024	1,109,043	1,129,895
770,945	798,876	826,267	847,744	874,204	894,943	925,100	944,909	969,564	991,043	1,018,652	1,040,030
625,180	654,052	682,367	704,708	732,056	753,592	784,790	805,225	830,706	852,959	881,365	903,458
448,941	478,947	508,374	531,798	560,217	582,716	615,197	636,389	662,865	686,089	715,454	738,411
266,017	297,105	327,593	352,092	381,532	404,957	438,689	460,614	488,039	512,224	542,505	566,294
103,173	125,008	151,061	172,145	200,228	224,507	259,380	281,975	310,257	335,331	366,438	390,992
38,690	46,878	56,648	64,554	75,819	85,969	100,545	114,224	138,317	159,762	187,302	212,571
14,509	17,579	21,243	24,208	28,432	32,238	37,704	42,834	51,869	59,911	70,517	81,075
5,441	6,592	7,966	9,078	10,662	12,089	14,139	16,063	19,451	22,467	26,444	30,403
2,040	2,472	2,987	3,404	3,998	4,534	5,302	6,024	7,294	8,425	9,917	11,401
765	927	1,120	1,277	1,499	1,700	1,988	2,259	2,735	3,159	0	4,275
287	348	420	479	562	638	746	847	1,026	1,185	0	1,603
108	130	158	180	211	239	280	318	385	444	0	601
40	49	59	67	79	90	105	119	144	167	0	225
15	18	22	25	30	34	39	45	54	62	0	85
6	7	8	9	11	13	15	17	20	23	0	32
2	3	3	4	4	5	6	6	8	9	0	12
1	1	1	1	2	2	2	2	3	3	0	4
0	0	0	1	1	1	1	1	1	1	0	2
0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0
18,950	19,543	20,147	20,796	21,376	22,001	22,658	23,162	23,700	24,234	23,729	25,403
86,387	87,717	89,085	90,539	91,855	93,255	94,738	95,869	97,089	98,285	96,814	100,916
190,463	192,569	194,753	197,045	199,146	201,359	203,713	205,505	207,453	209,341	206,517	213,513
337,132	340,054	343,102	346,263	349,195	352,259	355,522	358,010	360,729	363,334	358,818	369,125
521,086	524,856	528,804	532,851	536,649	540,593	544,784	547,998	551,520	554,857	548,385	562,325
607,918	612,450	617,202	622,026	626,600	631,330	636,335	640,200	644,439	648,421	640,160	657,382
578,878	584,052	589,482	594,954	600,185	605,577	611,257	615,673	620,516	625,041	615,424	635,257
462,091	467,798	473,788	479,793	485,574	491,513	497,749	502,622	507,965	512,942	502,479	524,195
305,309	311,473	317,945	324,405	330,666	337,073	343,783	349,049	354,821	360,192	349,349	372,332
188,972	195,605	202,568	209,498	216,255	223,144	230,338	236,007	242,220	248,001	237,065	261,049
123,511	130,630	138,103	145,522	152,798	160,188	167,883	173,970	180,642	186,853	175,962	200,842
114,016	121,637	129,635	137,564	145,378	153,290	161,502	168,020	175,172	181,828	170,976	196,793
114,820	122,936	131,454	139,897	148,241	156,677	165,398	172,344	179,977	187,074	176,141	203,009
77,497	86,086	95,096	104,036	112,883	121,821	131,028	138,381	146,475	153,993	142,895	170,855
29,955	33,552	37,327	41,969	48,720	56,490	64,475	70,862	77,903	84,439	75,062	101,310

Appendix B

Table B-7 Continued.

-1%	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
11,233	12,582	13,998	15,739	18,270	21,184	0	26,573	29,214	31,665	28,148	38,549
4,212	4,718	5,249	5,902	6,851	7,944	0	9,965	10,955	11,874	10,556	14,456
1,580	1,769	1,968	2,213	2,569	2,979	0	3,806	4,289	4,740	4,169	5,960
22,288	22,807	23,348	23,957	24,635	25,378	23,270	27,048	27,955	28,817	28,097	30,905
86,543	87,495	88,487	89,588	90,723	91,938	90,293	94,458	95,789	97,068	96,155	100,030
170,975	172,356	173,794	175,385	176,972	178,659	177,470	182,023	183,773	185,468	184,314	189,296
273,929	275,732	277,613	279,690	281,725	283,879	283,144	288,082	290,248	292,356	290,927	297,042
395,639	397,859	400,182	402,739	405,221	407,836	407,551	412,871	415,451	417,967	416,241	423,504
533,268	535,910	538,684	541,725	544,663	547,744	547,917	553,623	556,625	559,554	557,508	565,952
684,961	688,040	691,284	694,824	698,237	701,797	702,448	708,552	711,995	715,348	712,956	722,639
852,429	855,961	859,696	863,747	867,654	871,705	872,854	879,367	883,268	887,056	884,295	895,273
1,030,946	1,034,944	1,039,185	1,043,756	1,048,172	1,052,723	1,054,382	1,061,312	1,065,685	1,069,917	1,066,766	1,079,084
1,141,266	1,145,701	1,150,412	1,155,463	1,160,353	1,165,364	1,167,500	1,174,814	1,179,626	1,184,267	1,180,761	1,194,318
1,169,333	1,174,160	1,179,295	1,184,775	1,190,089	1,195,511	1,198,074	1,205,732	1,210,937	1,215,944	1,212,154	1,226,790
1,127,744	1,132,921	1,138,432	1,144,295	1,149,987	1,155,772	1,158,719	1,166,681	1,172,238	1,177,572	1,173,587	1,189,125
1,048,181	1,053,677	1,059,531	1,065,744	1,071,780	1,077,895	1,081,193	1,089,432	1,095,307	1,100,942	1,096,851	1,113,141
999,769	1,005,583	1,011,778	1,018,345	1,024,723	1,031,168	1,034,819	1,043,335	1,049,528	1,055,465	1,051,331	1,068,311
988,625	994,758	1,001,297	1,008,223	1,014,945	1,021,722	1,025,729	1,034,526	1,041,037	1,047,282	1,043,131	1,060,780
1,015,857	1,022,312	1,029,194	1,036,484	1,043,551	1,050,664	1,055,030	1,064,111	1,070,942	1,077,499	1,073,329	1,091,654
1,046,059	1,052,829	1,060,049	1,067,700	1,075,104	1,082,551	1,087,267	1,096,631	1,103,775	1,110,642	1,106,429	1,125,444
1,043,678	1,050,751	1,058,295	1,066,295	1,074,023	1,081,792	1,086,846	1,096,483	1,103,928	1,111,094	1,106,827	1,126,519
1,009,605	1,016,969	1,024,824	1,033,162	1,041,201	1,049,280	1,054,659	1,064,561	1,072,294	1,079,751	1,075,438	1,095,776
945,734	953,378	961,531	970,196	978,534	986,911	992,604	1,002,761	1,010,770	1,018,509	1,014,176	1,035,112
865,919	873,830	882,268	891,247	899,869	908,531	914,525	924,925	933,198	941,207	936,883	958,362
774,879	783,043	791,751	801,032	809,924	818,855	825,139	835,769	844,292	852,561	848,266	870,241
673,314	681,718	690,683	700,252	709,401	718,588	725,148	735,997	744,758	753,275	749,021	771,455
570,697	579,335	588,548	598,397	607,793	617,227	624,056	635,116	644,107	652,866	648,658	671,527
496,913	505,789	515,255	525,393	535,041	544,728	551,834	563,111	572,336	581,344	577,187	600,498
456,223	465,343	475,069	485,507	495,414	505,359	512,751	524,251	533,718	542,982	538,881	562,641
450,729	460,100	470,093	480,838	491,011	501,222	508,909	520,636	530,353	539,881	535,838	560,058
463,723	473,347	483,607	494,664	505,103	515,580	523,566	535,523	545,492	555,284	551,302	575,984
451,198	459,038	467,046	474,132	482,139	489,190	496,618	504,595	512,456	519,623	522,345	535,902

Appendix B

Table B-8: The sensitivity analysis of DO (FC Counts per 100ml)

Days	-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%	-1%
0	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
1	375,000	375,000	375,000	250,000	375,000	375,000	375,000	250,000	375,000	250,000
2	140,625	142,278	144,305	94,541	148,576	150,494	152,380	102,151	156,360	106,065
3	211,776	226,060	240,497	204,941	270,928	284,596	298,033	259,163	326,386	287,049
4	477,188	504,192	531,157	509,881	587,906	613,407	638,479	611,050	691,380	663,079
5	612,385	649,474	686,706	676,414	763,981	798,862	833,156	814,794	905,515	885,961
6	598,567	642,405	686,803	683,568	777,521	818,679	859,145	846,852	944,526	930,826
7	549,935	597,389	645,782	646,171	743,546	788,068	831,840	822,799	924,197	913,633
8	562,572	611,362	661,282	662,963	761,614	807,379	852,385	844,545	947,322	937,917
9	577,155	627,108	678,370	681,172	780,986	827,833	873,963	867,169	971,156	962,761
10	586,005	637,103	689,696	693,602	794,619	842,533	889,826	884,063	989,250	981,851
11	588,814	641,036	694,950	699,941	802,204	851,166	899,662	894,913	1,001,290	994,871
12	541,335	595,939	651,892	658,650	762,883	813,552	863,953	860,853	969,070	964,247
13	408,021	468,675	528,056	538,085	645,628	699,457	753,056	753,010	864,320	862,450
14	207,874	273,753	337,847	352,836	464,931	523,551	581,547	586,131	701,692	704,300
15	77,953	104,734	131,661	140,753	237,783	302,881	366,298	377,143	497,960	506,606
16	29,232	39,275	49,373	52,782	89,320	116,727	159,295	172,629	291,814	306,416
17	10,962	14,728	18,515	19,793	33,495	43,773	59,735	64,736	113,142	125,408
18	4,111	5,523	6,943	7,423	12,561	16,415	22,401	24,276	42,428	47,028
19	1,542	2,071	2,604	2,783	4,710	6,156	8,400	9,103	15,911	17,636
20	578	777	976	1,044	1,766	2,308	3,150	3,414	5,966	6,613
21	217	291	366	391	662	866	1,181	1,280	2,237	2,480
22	81	109	137	147	248	325	443	480	839	930
23	30	41	51	55	93	122	166	180	315	349
24	11	15	19	21	35	46	62	68	118	131
25	4	6	7	8	13	17	23	25	44	49
26	2	2	3	3	5	6	9	9	17	18
27	1	1	1	1	2	2	3	4	6	7
28	0	0	0	0	1	1	1	1	2	3
29	0	0	0	0	0	0	0	1	1	1
30	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	401	1,799	3,172	4,298
34	0	0	0	0	1,279	6,531	13,743	23,862	33,605	41,949
35	0	711	3,690	10,724	21,581	36,544	52,362	71,863	90,197	106,723
36	8,353	19,132	33,059	49,063	70,504	95,860	121,352	150,888	177,967	203,692
37	39,543	62,060	87,509	112,981	145,563	181,859	217,989	258,110	293,975	329,818
38	21,392	46,742	80,481	114,820	157,416	203,548	249,342	299,307	343,300	388,328
39	8,022	17,528	31,586	52,759	94,027	148,076	202,049	260,712	311,937	364,734
40	3,008	6,573	11,845	19,785	35,260	58,047	101,371	161,791	219,328	278,582
41	1,128	2,465	4,442	7,419	13,223	0	38,014	62,310	100,909	162,952
42	423	924	1,666	2,782	4,958	0	14,255	23,366	37,841	72,634
43	159	347	625	1,043	1,859	0	5,346	8,762	14,190	27,238
44	59	130	234	391	697	0	2,005	3,286	5,321	10,214
45	22	49	88	147	261	0	752	1,232	1,996	3,830
46	8	18	33	55	98	0	282	462	748	1,436
47	3	7	12	21	37	0	106	173	281	539

Appendix B

Table B-8 Continued.

Days	-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%	-1%
48	1	3	5	8	14	0	40	65	105	202
49	0	1	2	3	5	0	15	24	39	76
50	0	0	1	1	2	0	6	9	15	28
51	0	0	0	0	1	0	976	2359	3619	8895
52	0	0	74	1490	8403	15432	23226	32789	41904	53836
53	398	3306	10085	19813	35347	50841	66012	83757	100487	119433
54	12241	24271	39397	57065	81254	105247	128200	154154	178161	204507
55	43166	64350	88259	113492	146369	178893	210038	244227	275169	309306
56	88488	119085	152234	185863	227052	268347	308107	350568	388642	430975
57	144611	185104	227967	272142	320776	371287	420099	470849	516819	567765
58	213415	264284	317336	374366	429456	489624	547923	606942	661608	721582
59	291453	353102	416735	488795	549349	619542	687665	754881	818988	888335
60	313678	385495	459110	544722	611154	690803	767870	843050	916153	994342
61	269053	350137	432852	529617	602606	690875	775714	858534	939838	1026087
62	168629	258107	349064	454841	534858	630934	722466	812554	901285	994836
63	65069	134981	234892	346868	433914	537540	635036	732126	827758	928022
64	24401	51486	148660	260969	354017	466722	570345	674669	777409	884289
65	9150	0	95556	201728	299579	423148	533133	644968	755087	868509
66	3431	0	76554	169719	271066	407409	524001	643634	761414	881286
67	1287	0	59019	137243	243801	392974	516380	643843	769141	895491
68	483	0	23204	76733	193143	353324	483700	618765	751026	884004
69	181	0	8701	28877	119604	289069	426554	568997	707691	847430
70	68	0	3263	10829	46302	201404	346087	495693	640348	786934
71	25	0	1224	4061	17363	100295	250049	406630	557262	710343
72	10	0	459	1523	6511	37610	141414	304789	461542	620649
73	4	0	172	571	2442	14104	54145	190978	353981	518657
74	1	0	65	214	916	5289	20304	79975	244031	414037
75	1	0	24	80	343	1983	7614	29991	161213	336984
76	0	0	9	30	129	744	2855	11247	109668	291712
77	0	0	3	11	48	279	1071	4217	91398	280243
Final	0	0	1	4	18	105	402	1582	90622	286539
Average	119145	134740	155938	169636	206969	240492	275821	303129	360062	396467
S.D	215578	230781	245768	250201	280818	300482	321049	332968	367440	384507

Appendix B

Table B-8 Continued.

Days	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
0	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
1	250,000	250,000	250,000	250,000	250,000	250,000	375,000	250,000	250,000	250,000	250,000
2	107,507	109,557	111,261	113,214	114,860	116,481	195,682	119,647	122,212	126,655	131,032
3	296,833	311,925	324,065	337,984	349,712	361,257	450,229	383,814	397,418	411,168	424,713
4	678,783	709,493	732,142	758,113	779,995	801,535	900,347	843,622	868,322	891,468	914,245
5	887,857	949,446	980,426	1,015,949	1,045,879	1,075,341	1,181,953	1,132,908	1,166,145	1,196,994	1,227,088
6	906,775	1,005,734	1,042,289	1,084,204	1,119,519	1,154,283	1,266,114	1,222,207	1,260,932	1,297,161	1,332,152
7	866,475	994,662	1,034,204	1,079,543	1,117,743	1,155,346	1,269,973	1,228,819	1,270,365	1,309,594	1,347,208
8	879,834	1,021,229	1,061,874	1,108,481	1,147,747	1,186,410	1,302,070	1,261,943	1,304,495	1,344,871	1,383,463
9	897,492	1,048,154	1,089,761	1,137,479	1,177,675	1,217,304	1,333,865	1,294,674	1,338,100	1,379,486	1,418,971
10	912,292	1,069,399	1,111,953	1,160,775	1,201,887	1,242,517	1,359,966	1,321,746	1,366,032	1,408,423	1,448,832
11	923,994	1,084,650	1,128,136	1,178,053	1,220,068	1,261,735	1,380,057	1,342,842	1,387,976	1,431,363	1,472,731
12	894,797	1,057,603	1,102,561	1,154,216	1,197,656	1,241,007	1,360,711	1,325,128	1,371,601	1,416,571	1,459,456
13	798,876	961,958	1,009,508	1,064,224	1,110,174	1,156,489	1,278,625	1,245,915	1,294,745	1,342,500	1,387,935
14	654,052	812,487	863,781	922,919	972,494	1,023,092	1,148,741	1,120,181	1,172,416	1,224,195	1,273,135
15	478,947	625,791	681,933	746,796	801,080	857,223	987,419	964,231	1,020,888	1,077,862	1,131,140
16	297,105	436,892	497,944	568,604	627,857	689,612	824,413	806,664	867,985	930,033	987,834
17	125,008	253,627	319,331	395,483	459,688	526,757	665,919	653,323	719,291	785,918	848,227
18	46,878	98,149	149,794	226,750	295,870	367,965	511,251	503,529	574,108	644,851	711,636
19	17,579	36,806	56,173	87,533	140,970	216,328	363,544	360,367	435,450	509,912	581,068
20	6,592	13,802	21,065	32,825	52,864	89,794	234,023	234,890	314,175	392,085	467,318
21	2,472	5,176	7,899	12,309	19,824	33,673	123,082	127,502	210,663	291,756	370,751
22	927	1,941	2,962	4,616	7,434	12,627	47,043	49,022	124,537	208,541	290,977
23	348	728	1,111	1,731	2,788	4,735	17,641	18,383	48,785	126,215	212,113
24	130	273	417	649	1,045	1,776	6,615	6,894	18,295	48,846	118,628
25	49	102	156	243	392	666	2,481	2,585	6,860	18,317	45,231
26	18	38	59	91	147	250	930	969	2,573	6,869	16,962
27	7	14	22	34	55	94	349	364	965	2,576	6,361
28	3	5	8	13	21	35	131	136	362	966	2,385
29	1	2	3	5	8	13	49	51	136	362	894
30	0	1	1	2	3	5	18	19	51	136	335
31	0	0	0	1	1	2	7	7	19	51	126
32	0	0	0	0	0	258	1,391	2,454	3,422	4,466	6,006
33	19,543	12,116	17,339	23,508	29,464	35,062	43,206	51,008	57,789	65,371	73,494
34	87,717	66,207	78,296	92,176	105,893	118,033	133,698	148,898	161,749	176,509	191,693
35	192,569	148,674	168,542	190,334	212,404	231,959	255,716	278,875	298,260	320,743	343,526
36	340,054	264,575	293,185	323,027	354,040	381,927	414,341	446,015	472,390	503,138	534,053
37	524,856	410,624	448,845	486,773	527,222	564,274	605,795	646,427	680,179	719,624	759,098
38	612,450	487,039	533,988	579,397	628,618	673,988	723,690	772,373	813,030	860,287	907,451
39	584,052	478,592	532,927	584,996	641,960	694,361	750,983	806,476	853,276	907,140	960,808
40	467,798	405,037	465,516	523,398	587,069	645,315	707,689	768,844	821,004	880,360	939,435
41	311,473	300,398	366,185	429,329	498,931	562,275	629,667	695,712	752,724	816,820	880,613
42	195,605	221,310	292,624	361,512	437,101	505,999	578,858	649,996	712,307	781,343	850,276
43	130,630	173,798	250,930	326,172	407,817	482,864	561,770	638,276	706,451	780,691	855,312
44	121,637	159,852	243,086	325,346	413,054	494,898	580,488	662,625	737,280	816,982	897,889
45	122,936	149,083	238,603	327,930	421,729	510,578	603,055	690,994	772,177	857,508	944,893
46	86,086	110,166	206,056	301,866	401,838	497,426	596,529	690,349	777,519	868,554	962,171
47	33,552	49,681	145,879	247,621	353,832	455,902	561,382	661,141	753,790	850,590	950,201

Appendix B

Table B-8 Continued.

Days	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
48	12,582	18,630	65,573	169,464	281,817	390,309	501,931	607,689	705,388	807,996	913,395
49	4,718	6,986	24,590	117,288	233,686	351,041	468,722	580,675	683,692	792,084	903,403
50	1,769	2,773	11,980	107,642	225,165	354,815	478,497	596,896	705,730	819,852	937,326
51	22,807	23,960	39,492	142,033	257,499	403,149	532,760	657,861	773,040	892,821	1,016,693
52	87,495	84,249	106,115	215,933	327,430	491,422	626,968	758,978	880,870	1,006,315	1,136,785
53	172,356	165,278	193,814	310,649	421,143	600,591	742,390	881,346	1,009,710	1,141,125	1,278,227
54	275,732	265,838	301,410	424,945	537,780	729,396	877,791	1,023,714	1,158,263	1,295,975	1,439,732
55	397,859	386,176	429,150	559,069	677,587	878,081	1,033,418	1,186,330	1,326,771	1,471,112	1,621,545
56	535,910	523,819	574,577	711,058	836,949	1,044,867	1,207,506	1,367,602	1,514,103	1,665,416	1,822,709
57	688,040	677,396	736,335	880,076	1,013,355	1,229,076	1,399,392	1,567,040	1,720,246	1,878,882	2,043,385
58	855,961	848,810	916,326	1,068,059	1,208,702	1,432,605	1,610,968	1,786,535	1,947,124	2,113,435	2,285,491
59	1,034,944	1,033,834	1,110,257	1,270,661	1,418,601	1,650,979	1,837,701	2,021,492	2,190,093	2,364,371	2,544,267
60	1,145,701	1,157,077	1,241,902	1,410,569	1,565,594	1,805,684	2,000,293	2,191,843	2,368,080	2,549,872	2,737,165
61	1,174,160	1,204,535	1,297,019	1,473,219	1,635,037	1,881,824	2,083,623	2,282,247	2,465,445	2,654,088	2,848,125
62	1,132,921	1,187,517	1,286,939	1,469,962	1,638,237	1,890,788	2,099,099	2,304,131	2,493,636	2,688,486	2,888,632
63	1,053,677	1,133,926	1,240,375	1,429,091	1,603,586	1,861,333	2,075,634	2,286,619	2,481,983	2,682,541	2,888,364
64	1,005,583	1,103,820	1,220,048	1,411,812	1,592,735	1,856,092	2,076,295	2,293,416	2,494,816	2,701,002	2,912,677
65	994,758	1,102,195	1,231,345	1,423,203	1,610,805	1,880,288	2,106,325	2,329,820	2,537,491	2,749,242	2,966,998
66	1,022,312	1,129,673	1,275,092	1,463,877	1,658,418	1,934,572	2,166,363	2,396,477	2,610,659	2,827,900	3,051,974
67	1,052,829	1,158,643	1,320,397	1,505,940	1,707,453	1,990,462	2,228,030	2,464,790	2,685,363	2,908,118	3,138,538
68	1,050,751	1,161,493	1,336,333	1,521,507	1,729,792	2,019,460	2,262,936	2,506,148	2,732,640	2,961,035	3,197,617
69	1,016,969	1,138,840	1,323,665	1,511,202	1,726,063	2,022,198	2,271,699	2,521,174	2,753,132	2,987,280	3,229,843
70	953,378	1,091,860	1,283,852	1,476,213	1,697,459	1,999,874	2,255,475	2,511,028	2,748,052	2,988,025	3,236,395
71	873,830	1,028,429	1,226,594	1,424,456	1,651,919	1,960,448	2,221,837	2,483,310	2,725,412	2,970,912	3,224,936
72	783,043	951,550	1,155,443	1,358,943	1,592,459	1,906,941	2,173,701	2,440,939	2,688,245	2,938,872	3,198,403
73	681,718	862,024	1,071,215	1,280,474	1,519,877	1,840,147	2,111,873	2,384,723	2,637,340	2,892,707	3,157,596
74	579,335	769,572	983,171	1,199,044	1,444,250	1,770,226	2,046,705	2,325,032	2,583,080	2,842,983	3,113,155
75	505,789	704,540	920,017	1,145,924	1,397,120	1,728,986	2,010,604	2,294,339	2,558,006	2,822,816	3,098,438
76	465,343	671,116	885,601	1,125,413	1,382,806	1,720,767	2,007,975	2,297,034	2,566,518	2,836,663	3,117,923
77	460,100	671,283	881,679	1,139,535	1,403,335	1,747,595	2,040,861	2,335,146	2,610,643	2,886,572	3,173,656
Final	473,347	689,097	893,775	1,171,839	1,442,150	1,792,814	2,092,377	2,391,832	2,673,441	2,955,384	3,248,387
AVG	459,038	507,213	571,194	657,865	746,578	862,481	985,819	1,065,605	1,162,113	1,261,851	1,364,657
S.D	403,928	445,922	486,410	538,465	596,502	688,298	762,500	847,603	922,701	998,645	1,077,995

Appendix B

Table B-9: The sensitivity of pH (FC Counts per 100ml)

Days	-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%	-1%	0%
0	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
1	375,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000
2	140,625	93,750	93,750	93,750	93,750	93,750	93,750	93,750	93,750	95,758	107,507
3	52,734	35,156	35,156	35,156	35,156	35,156	45,306	90,864	151,123	213,075	296,833
4	19,775	13,184	13,184	13,184	15,567	72,258	146,075	264,137	396,901	522,520	678,783
5	7,416	4,944	4,944	4,944	5,838	34,689	134,425	308,708	497,692	675,374	887,857
6	2,781	1,854	1,854	1,854	2,189	13,008	52,378	218,403	443,829	657,850	906,775
7	1,043	695	695	695	821	4,878	19,642	120,063	364,343	598,697	866,475
8	391	261	261	261	308	1,829	12,442	112,115	363,143	605,307	879,834
9	147	98	98	98	115	686	6,046	111,189	368,085	617,097	897,492
10	55	37	37	37	43	257	2,267	107,617	370,315	626,095	912,292
11	21	14	14	14	16	96	850	101,164	369,595	632,064	923,994
12	8	5	5	5	6	36	319	53,710	320,833	593,837	894,797
13	3	2	2	2	2	14	120	20,141	190,828	482,185	798,876
14	1	1	1	1	1	5	45	7,553	72,648	314,876	654,052
15	0	0	0	0	0	2	17	2,832	27,243	127,880	478,947
16	0	0	0	0	0	1	6	1,062	10,216	47,955	297,105
17	0	0	0	0	0	0	2	398	3,831	17,983	125,008
18	0	0	0	0	0	0	1	149	1,437	6,744	46,878
19	0	0	0	0	0	0	0	56	539	2,529	17,579
20	0	0	0	0	0	0	0	21	202	948	6,592
21	0	0	0	0	0	0	0	8	76	356	2,472
22	0	0	0	0	0	0	0	3	28	133	927
23	0	0	0	0	0	0	0	1	11	50	348
24	0	0	0	0	0	0	0	0	4	19	130
25	0	0	0	0	0	0	0	0	2	7	49
26	0	0	0	0	0	0	0	0	1	3	18
27	0	0	0	0	0	0	0	0	0	1	7
28	0	0	0	0	0	0	0	0	0	0	3
29	0	0	0	0	0	0	0	0	0	0	1
30	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	1,160	19,543
34	0	0	0	0	0	0	0	0	0	19,695	87,717
35	0	0	0	0	0	0	0	0	5,166	64,731	192,569
36	0	0	0	0	0	0	0	263	42,897	141,264	340,054
37	0	0	0	0	0	0	0	10,825	111,164	244,740	524,856
38	0	0	0	0	0	0	0	4,060	92,044	261,826	612,450
39	0	0	0	0	0	0	0	1,522	35,249	178,692	584,052
40	0	0	0	0	0	0	0	571	13,218	69,265	467,798
41	0	0	0	0	0	0	0	214	4,957	25,974	311,473
42	0	0	0	0	0	0	0	80	1,859	9,740	195,605
43	0	0	0	0	0	0	0	30	697	3,653	130,630
44	0	0	0	0	0	0	0	11	261	1,370	121,637
45	0	0	0	0	0	0	0	4	98	514	122,936
46	0	0	0	0	0	0	0	2	37	193	86,086
47	0	0	0	0	0	0	0	1	14	72	33,552

Appendix B

Table B-9 Continued.

Days	-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%	-1%	0%
48	0	0	0	0	0	0	0	0	5	27	12,582
49	0	0	0	0	0	0	0	0	2	10	4,718
50	0	0	0	0	0	0	0	0	1	4	1,769
51	0	0	0	0	0	0	0	0	0	463	22,807
52	0	0	0	0	0	0	0	0	0	20,946	87,495
53	0	0	0	0	0	0	0	0	1,283	61,069	172,356
54	0	0	0	0	0	0	0	0	17,003	119,299	275,732
55	0	0	0	0	0	0	0	140	48,907	195,871	397,859
56	0	0	0	0	0	0	0	2,934	92,925	286,906	535,910
57	0	0	0	0	0	0	0	10,645	145,993	389,505	688,040
58	0	0	0	0	0	0	0	24,784	209,821	505,379	855,961
59	0	0	0	0	0	0	0	41,832	280,497	630,267	1,034,944
60	0	0	0	0	0	0	0	17,279	289,316	690,889	1,145,701
61	0	0	0	0	0	0	0	6,480	225,201	674,770	1,174,160
62	0	0	0	0	0	0	0	2,430	108,950	594,202	1,132,921
63	0	0	0	0	0	0	0	911	40,856	479,030	1,053,677
64	0	0	0	0	0	0	0	342	15,321	393,199	1,005,583
65	0	0	0	0	0	0	0	128	5,745	342,385	994,758
66	0	0	0	0	0	0	0	48	2,155	327,643	1,022,312
67	0	0	0	0	0	0	0	18	808	315,022	1,052,829
68	0	0	0	0	0	0	0	7	303	270,456	1,050,751
69	0	0	0	0	0	0	0	3	114	194,839	1,016,969
70	0	0	0	0	0	0	0	1	43	94,319	953,378
71	0	0	0	0	0	0	0	0	16	35,370	873,830
72	0	0	0	0	0	0	0	0	6	13,264	783,043
73	0	0	0	0	0	0	0	0	2	4,974	681,718
74	0	0	0	0	0	0	0	0	1	1,865	579,335
75	0	0	0	0	0	0	0	0	0	699	505,789
76	0	0	0	0	0	0	0	0	0	262	465,343
77	0	0	0	0	0	0	0	0	0	98	460,100
Final	0	0	0	0	0	0	0	0	0	37	473,347
AVG	20,513	17,949	17,949	17,949	17,998	19,316	22,611	38,327	90,892	201,991	459,038
S.D	121,185	116,641	116,641	116,641	116,638	116,777	118,223	127,168	168,992	253,445	403,928

Appendix B

Table B-9 Continued.

Days	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
0	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
1	250,000	250,000	250,000	375,000	258,003	375,000	278,023	288,152	381,018	308,172
2	119,257	145,989	201,488	343,940	318,973	469,427	445,577	510,713	666,070	660,674
3	380,592	470,332	597,840	775,433	853,198	1,072,805	1,120,964	1,251,964	1,476,473	1,543,087
4	835,045	988,453	1,188,466	1,388,106	1,580,552	1,872,107	1,992,899	2,187,994	2,484,451	2,623,698
5	1,100,340	1,305,811	1,562,044	1,783,120	2,062,413	2,410,188	2,588,841	2,834,359	3,187,037	3,384,144
6	1,155,700	1,397,510	1,690,185	1,931,819	2,263,336	2,647,553	2,865,192	3,144,505	3,533,625	3,769,718
7	1,134,254	1,396,396	1,707,925	1,964,138	2,320,262	2,723,332	2,962,017	3,259,471	3,667,444	3,924,583
8	1,154,360	1,424,313	1,742,589	2,005,390	2,369,484	2,779,302	3,025,764	3,329,939	3,744,719	4,009,636
9	1,177,886	1,454,686	1,778,831	2,047,501	2,418,442	2,834,129	3,087,126	3,397,170	3,818,130	4,089,582
10	1,198,489	1,482,058	1,812,005	2,086,477	2,464,187	2,885,676	3,144,872	3,460,718	3,888,051	4,165,701
11	1,215,924	1,506,181	1,841,861	2,122,066	2,506,464	2,933,687	3,198,746	3,520,324	3,954,216	4,237,729
12	1,195,987	1,496,550	1,841,490	2,130,725	2,525,659	2,961,911	3,236,231	3,566,840	4,011,266	4,303,810
13	1,116,896	1,434,713	1,796,482	2,101,449	2,514,735	2,966,718	3,257,867	3,604,207	4,066,986	4,375,261
14	997,138	1,338,606	1,725,442	2,052,893	2,492,412	2,966,880	3,283,095	3,651,919	4,140,931	4,471,691
15	855,342	1,226,020	1,646,165	2,002,547	2,475,654	2,978,977	3,328,577	3,726,256	4,248,932	4,608,546
16	706,909	1,108,298	1,561,851	1,948,944	2,455,460	2,988,377	3,372,503	3,799,776	4,356,978	4,746,186
17	553,702	986,052	1,470,575	1,888,629	2,426,114	2,987,614	3,405,087	3,860,944	4,451,493	4,869,284
18	395,763	859,223	1,372,358	1,821,522	2,387,619	2,976,683	3,426,314	3,909,734	4,532,441	4,977,797
19	239,074	733,161	1,272,673	1,752,464	2,344,938	2,960,312	3,440,638	3,950,368	4,603,770	5,075,435
20	106,153	624,490	1,188,311	1,696,462	2,313,245	2,952,927	3,461,612	3,995,651	4,677,412	5,173,386
21	39,807	533,811	1,119,876	1,653,977	2,293,003	2,954,929	3,489,565	4,045,847	4,753,559	5,271,775
22	14,928	460,515	1,066,752	1,624,388	2,283,587	2,965,685	3,523,857	4,100,312	4,831,558	5,369,948
23	5,598	342,553	1,015,671	1,596,864	2,276,255	2,978,545	3,560,273	4,156,919	4,911,722	5,470,304
24	2,099	140,308	954,013	1,561,229	2,262,925	2,987,519	3,595,270	4,214,221	4,995,048	5,575,934
25	787	52,615	882,194	1,517,902	2,244,021	2,993,038	3,629,281	4,272,655	5,081,974	5,687,283
26	295	19,731	801,296	1,467,904	2,220,508	2,996,080	3,663,155	4,333,015	5,173,234	5,805,028
27	111	7,399	720,668	1,419,710	2,200,114	3,004,543	3,702,993	4,400,653	5,273,305	5,932,899
28	42	2,775	643,534	1,376,274	2,185,562	3,021,287	3,751,025	4,477,569	5,383,919	6,072,398
29	4,632	1,040	570,369	1,338,075	2,177,334	3,046,893	3,807,732	4,564,247	5,505,563	6,224,012
30	52,515	390	513,100	1,317,292	2,188,145	3,094,113	3,886,303	4,674,412	5,652,214	6,402,258
31	135,130	146	512,685	1,355,704	2,261,610	3,206,405	4,031,876	4,855,038	5,871,668	6,656,765
32	254,407	31,622	579,113	1,463,371	2,408,114	3,394,148	4,254,967	5,116,966	6,174,834	6,998,768
33	413,490	134,747	719,659	1,647,575	2,635,134	3,664,826	4,563,066	5,467,880	6,569,406	7,436,155
34	556,302	296,645	922,651	1,897,429	2,931,849	4,007,477	4,946,811	5,898,487	7,046,875	7,960,486
35	615,406	503,216	1,175,801	2,201,439	3,286,719	4,410,222	5,396,134	6,398,670	7,597,918	8,562,389
36	576,755	760,455	1,485,435	2,565,950	3,706,106	4,879,128	5,917,436	6,974,848	8,228,973	9,248,321
37	437,068	1,061,793	1,844,477	2,983,322	4,182,057	5,405,204	6,501,341	7,616,959	8,929,414	10,006,967
38	324,729	1,256,099	2,091,271	3,284,341	4,540,783	5,805,190	6,955,553	8,123,658	9,490,339	10,620,379
39	270,741	1,319,950	2,199,547	3,440,440	4,751,493	6,046,705	7,244,890	8,457,421	9,871,924	11,046,390
40	262,906	1,282,044	2,198,538	3,480,883	4,842,498	6,159,574	7,399,211	8,648,639	10,104,594	11,315,957
41	279,175	1,194,425	2,142,995	3,462,290	4,870,607	6,204,729	7,481,316	8,762,819	10,255,405	11,498,843
42	278,751	1,149,907	2,133,160	3,490,875	4,945,084	6,300,929	7,615,936	8,932,123	10,461,375	11,739,497
43	256,435	1,159,873	2,181,127	3,579,195	5,078,460	6,461,837	7,817,197	9,171,384	10,737,577	12,053,699
44	209,777	1,229,422	2,292,151	3,732,510	5,275,703	6,692,878	8,090,529	9,486,191	11,089,452	12,447,049
45	168,877	1,310,473	2,416,144	3,898,612	5,484,748	6,938,730	8,379,325	9,817,095	11,457,998	12,857,704
46	164,620	1,352,181	2,500,153	4,022,451	5,650,887	7,141,128	8,624,023	10,101,624	11,781,255	13,220,790

Appendix B

Table B-9 Continued.

Days	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
48	260,236	1,326,204	2,556,846	4,152,423	5,863,619	7,424,886	8,990,452	10,541,331	12,301,469	13,814,283
49	348,797	1,327,426	2,598,381	4,231,030	5,983,895	7,582,233	9,188,112	10,776,063	12,577,870	14,127,756
50	459,222	1,380,117	2,690,610	4,362,803	6,158,250	7,796,132	9,441,548	11,069,043	12,913,432	14,502,862
51	592,123	1,486,241	2,835,427	4,549,708	6,388,652	8,068,622	9,752,732	11,422,314	13,310,201	14,941,719
52	747,510	1,639,436	3,026,689	4,785,175	6,668,420	8,392,596	10,115,157	11,828,946	13,760,749	15,436,472
53	923,881	1,813,772	3,239,372	5,042,595	6,970,578	8,739,492	10,502,434	12,260,960	14,235,466	15,955,927
54	1,121,362	2,007,440	3,471,737	5,320,107	7,293,236	9,107,296	10,912,748	12,716,420	14,732,260	16,497,868
55	1,340,221	2,220,679	3,724,022	5,617,948	7,636,632	9,496,247	11,346,368	13,195,596	15,251,369	17,062,532
56	1,534,666	2,452,762	3,997,330	5,938,271	8,003,972	9,909,679	11,806,817	13,703,061	15,800,058	17,658,237
57	1,653,598	2,703,953	4,293,878	6,284,351	8,399,582	10,351,917	12,298,585	14,244,360	16,386,714	18,294,424
58	1,689,321	2,975,967	4,615,581	6,658,100	8,825,378	10,824,682	12,823,396	14,821,217	17,013,260	18,973,017
59	1,642,125	3,263,257	4,956,616	7,053,230	9,274,720	11,320,958	13,373,884	15,426,382	17,671,589	19,685,440
60	1,608,837	3,475,952	5,221,114	7,367,862	9,641,156	11,731,797	13,836,527	15,947,506	18,236,169	20,300,155
61	1,615,987	3,596,985	5,390,143	7,581,471	9,902,759	12,034,539	14,187,264	16,359,902	18,679,480	20,788,045
62	1,658,380	3,639,270	5,476,622	7,707,278	10,072,762	12,242,423	14,439,342	16,675,641	19,015,083	21,162,976
63	1,720,064	3,636,988	5,515,733	7,782,317	10,189,192	12,394,332	14,632,644	16,932,190	19,285,346	21,469,168
64	1,762,833	3,666,535	5,587,086	7,891,407	10,340,089	12,581,063	14,861,181	17,218,814	19,591,525	21,813,083
65	1,783,092	3,734,582	5,697,603	8,041,914	10,533,065	12,810,442	15,133,030	17,543,051	19,942,245	22,203,793
66	1,780,036	3,842,240	5,848,394	8,235,000	10,769,285	13,083,633	15,449,354	17,905,861	20,338,674	22,642,517
67	1,756,471	3,952,873	6,002,167	8,431,073	11,008,497	13,359,821	15,768,682	18,267,490	20,738,117	23,084,261
68	1,716,025	4,029,700	6,121,480	8,590,393	11,210,304	13,598,046	16,049,393	18,588,207	21,097,733	23,483,883
69	1,659,133	4,073,612	6,207,227	8,713,902	11,375,648	13,799,249	16,292,432	18,869,008	21,418,466	23,842,378
70	1,588,817	4,086,178	6,261,120	8,803,513	11,506,321	13,965,281	16,499,526	19,111,820	21,701,982	24,161,612
71	1,538,532	4,077,086	6,294,650	8,872,650	11,614,194	14,108,762	16,681,742	19,329,644	21,958,541	24,453,779
72	1,516,882	4,050,018	6,311,891	8,925,896	11,703,451	14,234,023	16,843,015	19,526,921	22,191,830	24,723,072
73	1,521,932	4,005,968	6,313,643	8,963,951	11,774,893	14,341,768	16,984,147	19,704,356	22,402,652	24,970,197
74	1,545,882	3,957,410	6,311,646	8,998,711	11,841,308	14,444,939	17,119,293	19,875,938	22,606,209	25,210,511
75	1,568,413	3,943,315	6,342,923	9,067,969	11,943,121	14,584,734	17,293,374	20,086,270	22,850,827	25,493,110
76	1,587,528	3,968,926	6,412,384	9,176,699	12,085,511	14,766,393	17,512,011	20,340,858	23,142,393	25,823,945
77	1,602,719	4,036,649	6,522,238	9,327,112	12,270,689	14,992,131	17,777,522	20,641,919	23,483,227	26,205,339
Final	1,615,965	4,126,422	6,653,219	9,499,300	12,478,196	15,240,845	18,067,443	20,967,160	23,849,675	26,612,993
Avera	823,776	1,717,436	2,786,162	4,066,391	5,443,061	6,755,058	8,006,274	9,289,648	10,702,791	11,924,613

Appendix B

Table B-10: The sensitivity of Ammoniacal-Nitrogen (FC Counts per 100ml)

Days	-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%	-1%
0	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
1	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000
2	107,289	107,297	107,317	107,342	107,368	107,392	107,416	107,439	107,462	107,485
3	295,368	295,434	295,567	295,732	295,910	296,069	296,227	296,382	296,534	296,685
4	676,225	676,362	676,593	676,878	677,187	677,463	677,735	678,003	678,267	678,527
5	884,543	884,740	885,038	885,406	885,803	886,159	886,509	886,854	887,193	887,528
6	903,018	903,253	903,592	904,007	904,456	904,858	905,253	905,643	906,026	906,403
7	862,508	862,762	863,120	863,559	864,031	864,454	864,871	865,282	865,685	866,083
8	875,797	876,058	876,423	876,869	877,348	877,779	878,203	878,621	879,031	879,435
9	893,401	893,668	894,038	894,489	894,975	895,411	895,841	896,263	896,678	897,088
10	908,154	908,426	908,800	909,256	909,747	910,188	910,623	911,050	911,470	911,884
11	919,812	920,088	920,467	920,928	921,423	921,869	922,308	922,740	923,163	923,582
12	890,552	890,834	891,219	891,687	892,189	892,642	893,087	893,525	893,954	894,379
13	794,528	794,821	795,216	795,696	796,208	796,671	797,127	797,575	798,014	798,448
14	649,566	649,873	650,282	650,776	651,303	651,780	652,250	652,712	653,164	653,612
15	474,291	474,616	475,043	475,555	476,099	476,594	477,081	477,559	478,027	478,491
16	292,286	292,628	293,071	293,601	294,162	294,674	295,177	295,672	296,155	296,634
17	120,892	121,187	121,567	122,019	122,497	122,934	123,363	123,785	124,197	124,606
18	45,335	45,445	0	45,757	45,937	46,100	46,261	46,419	46,574	46,727
19	17,000	17,042	0	17,159	17,226	17,288	17,348	17,407	17,465	17,523
20	6,375	6,391	0	6,435	6,460	6,483	6,505	6,528	6,549	6,571
21	2,391	2,397	0	2,413	2,422	2,431	2,440	2,448	2,456	2,464
22	897	899	0	905	908	912	915	918	921	924
23	336	337	0	339	341	342	343	344	345	347
24	126	126	0	127	128	128	129	129	130	130
25	47	47	0	48	48	48	48	48	49	49
26	18	18	0	18	18	18	18	18	18	18
27	7	7	0	7	7	7	7	7	7	7
28	2	3	0	3	3	3	3	3	3	3
29	1	1	0	1	1	1	1	1	1	1
30	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0
33	19,453	19,462	19,472	19,482	19,491	19,500	19,500	19,513	19,527	19,535
34	87,512	87,534	87,555	87,578	87,599	87,620	87,620	87,650	87,679	87,699
35	192,243	192,278	192,312	192,348	192,381	192,414	192,414	192,462	192,509	192,540
36	339,599	339,648	339,695	339,747	339,791	339,837	339,838	339,905	339,970	340,013
37	524,268	524,331	524,392	524,462	524,516	524,577	524,578	524,664	524,748	524,803
38	611,742	611,818	611,891	611,978	612,041	612,113	612,116	612,218	612,319	612,386
39	583,243	583,330	583,414	583,515	583,585	583,667	583,672	583,788	583,903	583,979
40	466,905	467,001	467,094	467,207	467,282	467,373	467,379	467,507	467,633	467,717
41	310,509	310,613	310,713	310,835	310,916	311,015	311,022	311,159	311,296	311,386
42	194,567	194,678	194,787	194,918	195,005	195,111	195,119	195,267	195,414	195,511
43	129,516	129,635	129,751	129,892	129,986	130,100	130,110	130,268	130,425	130,529
44	120,443	120,571	120,695	120,846	120,947	121,069	121,080	121,249	121,417	121,528
45	121,663	121,800	121,932	122,094	122,201	122,331	122,344	122,524	122,702	122,820
46	84,737	84,882	85,022	85,194	85,307	85,445	85,460	85,650	85,838	85,963
47	32,987	33,048	33,107	33,179	33,226	33,284	33,290	33,370	33,448	33,501

Appendix B

Table B-10 Continued.

Days	-10%	-9%	-8%	-7%	-6%	-5%	-4%	-3%	-2%	-1%
48	12370	12393	12415	12442	12460	12481	12484	12514	12543	12563
49	4639	4647	4656	4666	4672	4681	4681	4693	4704	4711
50	1740	1743	1746	1750	1752	1755	1756	1760	1764	1767
51	22723	22732	22740	22750	22758	22767	22769	22780	22791	22799
52	87339	87355	87372	87389	87405	87421	87425	87446	87466	87481
53	172128	172152	172176	172202	172224	172247	172254	172284	172314	172335
54	275432	275464	275496	275529	275559	275590	275599	275638	275677	275704
55	397489	397527	397568	397609	397646	397684	397696	397744	397792	397826
56	535468	535515	535562	535611	535655	535700	535715	535772	535829	535870
57	687523	687598	687632	687690	687741	687794	687812	687878	687945	687993
58	855366	855509	855492	855558	855617	855678	855699	855775	855852	855906
59	1034269	1034532	1034413	1034487	1034555	1034624	1034647	1034734	1034820	1034882
60	1144952	1145368	1145111	1145194	1145268	1145345	1145372	1145468	1145563	1145632
61	1173345	1173922	1173518	1173608	1173689	1173773	1173803	1173907	1174011	1174086
62	1132046	1132777	1132232	1132328	1132416	1132505	1132538	1132649	1132761	1132841
63	1052748	1053622	1052945	1053048	1053140	1053236	1053270	1053389	1053507	1053592
64	1004599	1005614	1004808	1004917	1005015	1005115	1005152	1005278	1005402	1005493
65	993720	994875	993941	994055	994159	994265	994305	994437	994568	994663
66	1021218	1022514	1021450	1021571	1021680	1021792	1021834	1021973	1022111	1022212
67	1051681	1053114	1051925	1052052	1052166	1052284	1052328	1052474	1052619	1052724
68	1049550	1051114	1049805	1049938	1050058	1050181	1050228	1050380	1050531	1050641
69	1015717	1017406	1015983	1016121	1016246	1016375	1016424	1016582	1016740	1016854
70	952077	953885	952353	952497	952627	952760	952812	952976	953139	953259
71	872482	874403	872769	872917	873052	873190	873244	873414	873583	873706
72	781651	783678	781947	782100	782239	782382	782438	782613	782788	782915
73	680284	682411	680589	680747	680890	681037	681095	681276	681456	681587
74	577860	580082	578173	578336	578483	578634	578695	578880	579065	579200
75	504271	506591	504594	504761	504912	505068	505131	505321	505511	505650
76	463782	466201	464114	464286	464442	464602	464667	464863	465057	465200
77	458495	461015	458836	459013	459173	459338	459405	459606	459806	459953
Final	471696	474317	472047	472229	472394	472563	472633	472839	473044	473195
Average	457784	458220	457071	458147	458284	458416	458512	458655	458796	458918
S.D	403297	403630	404439	403474	403546	403613	403668	403737	403805	403866

Appendix B

Table B-10 Continued.

Days	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
0	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
1	250000	250000	250000	250000	250000	250000	250000	250000	250000	250000	250000
2	107507	107529	107551	107573	107594	107615	107636	107658	107678	107698	107718
3	296833	296980	297124	297267	297407	297546	297682	297831	297964	298095	298224
4	678783	679035	679284	679529	679771	680010	680245	680500	680728	680953	681176
5	887857	888182	888502	888817	889127	889433	889735	890062	890355	890643	890928
6	906775	907142	907502	907858	908208	908553	908893	909261	909591	909916	910237
7	866475	866861	867241	867615	867984	868348	868706	869092	869440	869782	870120
8	879834	880226	880612	880992	881367	881737	882101	882493	882846	883195	883538
9	897492	897889	898280	898665	899044	899419	899787	900184	900542	900894	901242
10	912292	912694	913090	913478	913862	914241	914613	915014	915376	915732	916083
11	923994	924400	924799	925192	925579	925961	926338	926743	927108	927467	927822
12	894797	895208	895614	896011	896405	896792	897174	897584	897954	898319	898678
13	798876	799297	799712	800118	800520	800916	801307	801725	802104	802477	802844
14	654052	654486	654913	655331	655746	656154	656556	656985	657375	657759	658138
15	478947	479396	479839	480271	480700	481122	481538	481982	482385	482783	483175
16	297105	297569	298026	298473	298916	299352	299782	300238	300655	301065	301470
17	125008	125404	125794	126174	126552	126924	127291	127679	128035	128385	128729
18	46878	47027	47173	47315	47457	47597	47734	47880	0	48144	48273
19	17579	17635	17690	17743	17796	17849	17900	17955	0	18054	18103
20	6592	6613	6634	6654	6674	6693	6713	6733	0	6770	6788
21	2472	2480	2488	2495	2503	2510	2517	2525	0	2539	2546
22	927	930	933	936	938	941	944	947	0	952	955
23	348	349	350	351	352	353	354	355	0	357	358
24	130	131	131	132	132	132	133	133	0	134	134
25	49	49	49	49	49	50	50	50	0	50	50
26	18	18	18	19	19	19	19	19	0	19	19
27	7	7	7	7	7	7	7	7	0	7	7
28	3	3	3	3	3	3	3	3	0	3	3
29	1	1	1	1	1	1	1	1	0	1	1
30	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0
33	19543	19461	19559	19567	19575	19582	19590	19597	19605	19612	19618
34	87717	87535	87754	87771	87789	87806	87823	87839	87856	87871	87887
35	192569	192285	192627	192656	192684	192710	192737	192763	192790	192815	192840
36	340054	339664	340135	340174	340213	340250	340288	340323	340361	340396	340430
37	524856	524361	524961	525012	525062	525110	525159	525205	525253	525299	525343
38	612450	611863	612575	612637	612697	612755	612814	612869	612927	612982	613036
39	584052	583390	584196	584266	584335	584401	584468	584531	584598	584660	584721
40	467798	467076	467956	468033	468110	468183	468256	468326	468399	468468	468536
41	311473	310701	311644	311728	311810	311889	311969	312044	312123	312197	312271
42	195605	194783	195789	195879	195968	196053	196138	196220	196305	196384	196463
43	130630	129758	130828	130924	131020	131111	131203	131290	131381	131467	131551
44	121637	120713	121848	121952	122054	122151	122250	122344	122441	122533	122623
45	122936	121964	123162	123272	123381	123485	123591	123690	123794	123892	123989
46	86086	85067	86325	86442	86558	86668	86779	86885	86995	87099	87201

Appendix B

Table B-10 Continued

Days	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
48	12,563	12,582	12,422	12,620	12,638	12,656	12,674	12,691	0	12,725	12,741
49	4,711	4,718	4,658	4,732	4,739	4,746	4,753	4,759	0	4,772	4,778
50	1,767	1,769	1,747	1,775	1,777	1,780	1,782	1,785	0	1,789	1,792
51	22,799	22,807	22,757	22,822	22,829	22,836	22,843	22,850	21,368	22,864	22,870
52	87,481	87,495	87,407	87,522	87,536	87,550	87,562	87,575	86,098	87,600	87,612
53	172,335	172,356	172,232	172,396	172,416	172,436	172,454	172,473	171,001	172,509	172,527
54	275,704	275,732	275,572	275,785	275,811	275,836	275,861	275,885	274,419	275,933	275,956
55	397,826	397,859	397,665	397,925	397,957	397,989	398,019	398,049	396,589	398,108	398,137
56	535,870	535,910	535,682	535,988	536,027	536,065	536,101	536,137	534,682	536,208	536,242
57	687,993	688,040	687,777	688,131	688,176	688,221	688,263	688,305	686,856	688,388	688,428
58	855,906	855,961	855,662	856,066	856,118	856,169	856,217	856,266	854,823	856,361	856,407
59	1,034,882	1,034,944	1,034,610	1,035,063	1,035,122	1,035,180	1,035,235	1,035,290	1,033,854	1,035,398	1,035,450
60	1,145,632	1,145,701	1,145,334	1,145,833	1,145,899	1,145,963	1,146,023	1,146,085	1,144,654	1,146,205	1,146,262
61	1,174,086	1,174,160	1,173,765	1,174,304	1,174,376	1,174,446	1,174,511	1,174,579	1,173,153	1,174,709	1,174,772
62	1,132,841	1,132,921	1,132,501	1,133,075	1,133,152	1,133,227	1,133,298	1,133,370	1,131,949	1,133,510	1,133,577
63	1,053,592	1,053,677	1,053,235	1,053,841	1,053,923	1,054,002	1,054,077	1,054,154	1,052,737	1,054,302	1,054,374
64	1,005,493	1,005,583	1,005,119	1,005,756	1,005,842	1,005,927	1,006,006	1,006,087	1,004,674	1,006,244	1,006,320
65	994,663	994,758	994,273	994,941	995,033	995,122	995,206	995,291	993,883	995,457	995,537
66	1,022,212	1,022,312	1,021,805	1,022,505	1,022,601	1,022,695	1,022,783	1,022,873	1,021,469	1,023,047	1,023,132
67	1,052,724	1,052,829	1,052,302	1,053,032	1,053,133	1,053,231	1,053,324	1,053,419	1,052,018	1,053,602	1,053,690
68	1,050,641	1,050,751	1,050,204	1,050,963	1,051,069	1,051,171	1,051,268	1,051,368	1,049,971	1,051,559	1,051,652
69	1,016,854	1,016,969	1,016,403	1,017,190	1,017,300	1,017,407	1,017,508	1,017,611	1,016,219	1,017,811	1,017,908
70	953,259	953,378	952,794	953,607	953,721	953,833	953,938	954,045	952,657	954,252	954,353
71	873,706	873,830	873,230	874,067	874,186	874,301	874,410	874,521	873,136	874,736	874,840
72	782,915	783,043	782,428	783,288	783,411	783,530	783,642	783,757	782,376	783,979	784,086
73	681,587	681,718	681,089	681,971	682,097	682,220	682,336	682,454	681,076	682,683	682,794
74	579,200	579,335	578,692	579,595	579,725	579,851	579,970	580,092	578,717	580,327	580,441
75	505,650	505,789	505,132	506,056	506,190	506,320	506,442	506,567	505,196	506,809	506,926
76	465,200	465,343	464,673	465,618	465,756	465,890	466,015	466,144	464,776	466,393	466,513
77	459,953	460,100	459,415	460,383	460,524	460,662	460,791	460,924	459,559	461,179	461,304
Final	473,195	473,347	472,648	473,638	473,783	473,924	474,057	474,193	472,832	474,456	474,584
AVG	458,918	459,038	458,845	459,272	459,387	459,500	459,609	459,719	459,069	458,953	460,042
S.D	403,866	403,928	403,901	404,046	404,105	404,163	404,218	404,274	404,249	405,476	404,440