MODELING OF WASTE STABILIZATION PONDS:

CASE STUDY OF HURUMA, ELDORET, WESTERN KENYA.

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF PHILOSOPHY IN ENVIRONMENTAL STUDIES, (ENVIRONMENTAL HEALTH DIVISION).

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NOVEMBER, 1999.

ABSTRACT

Eldoret, arguably the fastest growing town in Kenya, is situated on the Uasin-Gishu plateau in the Rift Valley region of Kenya. The establishment of the town dates back to 1908, after which it was elevated to a township in 1912, to finally become a Municipal board in 1927. In the last three decades, great emphasis has been put on the industrial development with the result that today the town has registered sixteen major industries, thus becoming the 5^{th} largest town in Kenya. These developments have resulted in high population growth which has gone from 24,900 inhabitants in 1969 to more than 211,355 today, and is expected to reach 407,783 by the year 2010. Unfortunately, the growth of Eldoret town has not kept pace with the increasing demand for additional water supply and sewerage facilities to service the ever-increasing industries and human settlement. Due to the rapid growth of population, the capacity of water works has had to be increased to meet the rising water demand from 5,000 m^3 in 1969 to a projected volume of 92,021 m^3 per day by the year 2010. Similarly, Eldoret town planners have had to deal with an overloaded and inadequate wastewater collection, treatment and disposal system that includes a set of trickling filters and waste stabilisation ponds (WSP)

A research project spanning over a period of seven months was therefore carried out on Eldoret Municipal Council (E.M.C.) wastewater. The objectives were to determine the sewage parameters which were then used in the establishment of a mathematical model describing the micro-organism growth, oxygen balance, nutrient and organic matter removal, thereby evaluating the performance of the sewage treatment facility. The results of the analysis of Eldoret wastewater characteristics indicate that the effluent BOD_5 (103.5 ± 65.4 mg/L), COD (504.3 ± 234.2 mg/L), TS (321.0 ± 170.8 mg/L) and TVS (268.2 ± 108.0 mg/L) are exceptionally high well beyond the standards provided under the Kenya Local Authority's Act. The Eldoret WSP originally designed for a maximum flow of 4800 m^3/day and a BOD load of 2650 kg/d and effluent BOD_5 of 8-20 mg/L, today runs at about 164% of its original design flow, which explains why Eldoret raw sewage sometimes had to be released directly into the river Sosiani without receiving adequate treatment. While additional WSP space may help the town relieve its outdated and overloaded wastewater treatment system, there is also the need to provide the operators of the system with a tool that will assist in monitoring the performance of the Huruma WSP.

A bench-scale reactor was set up to determine the kinetic coefficients needed in the formulation of the mathematical model. The experimental studies were conducted in a reactor tank of 80 litres capacity and hydraulic retention time ranging between 22 and 38 days. The kinetic coefficients: Y (maximum growth yield coefficient), k (maximum rate of substrate utilization), Kd (microbial decay coefficient), Ks (half substrate saturation constant), μ_m (maximum specific growth rate) were determined as 0.113 mg/mg, 1.35 d^{-1}, 3.34×10^{-4} d^{-1}, 1053 mg/L, and 0.152 d^{-1} respectively. These coefficients were subsequently used to generate a mathematical model for predicting the quality of the effluent and for monitoring the performance of the Huruma WSP. Using the Runge-Kutta method and a Fortran 90 computer package, five 1^{st} order

differential equations were solved simultaneously.

In order to validate the model, computed (predicted) and measured effluent pollution parameters using regression analysis tests at 95% confidence level. The validation of the model was carried out on the observed and predicted effluent chemical oxygen demand (COD), volatile suspended solids (VSS), total nitrogen (N_2), total phosphorus (P), and oxygen concentrations with correlation coefficients (R) values of 0.9934, 0.9302, 0.9083, 0.7112 and 0.7002 respectively. The R values obtained imply that the model generated could be used to predict the quality of the effluent thereby becoming a useful tool for monitoring the performance of Huruma WSP. When in full use, the model should make the work at the E.M.C. wastewater treatment plant much easier and less cumbersome since the operators will not have to cover the 4 km distance up to the discharge point for effluent collection necessary for daily report. It was suggested that further research that focuses on algae growth, inorganic carbon, ammonia, detritus, benthic growth and alkalinity be carried out and included in this model in order to make it more comprehensive and improve on its accuracy.

A correlation between COD and BOD_5 of the influent and effluent was also established. This relationship will provide E.M.C. with a useful tool for predicting the wastewater BOD_5 both at the discharge and intake points. It was determined that the relationship between COD and BOD_5 could be described by a polynomial or by a linear function. Polynomial functions of the form: $BOD_5 = 6.706 \times 10^2 - 9.498 \times 10^{-2} \times COD + 4.754 \times 10^{-5} \times COD^2$ and $BOD_5 = 5.229 \times 10^2 - 1.73 \times COD + 1.696 \times 10^{-3} \times COD^2$ were found to be more accurate with a correlation factors of R= 0.7999 and R= 0.9945 respectively. The Council will be able to keep track of the wastewater quality generated and discharged into public by domestic and industrial sources, and provide immediate remedies for process control.