



Analysis and Development of Models for Liquid Effluent from Textile Industry

O. D. ADENIYI

Department of Chemical Engineering, Federal University of Technology, Minna, Nigeria

lekanadeniyi2002@yahoo.co.uk

Abstract

The technology of transforming cotton and synthetic fibres into fabrics and dyed fabrics generates various kinds of effluent. The influence of effluents on water reserve depends on the physico-chemical properties of the present organic and inorganic impurities. This paper proposed some mathematical models for the prediction of certain concentrations of the effluents discharged from the textile industries. The parameters modelled for include the pH, alkalinity level, iron ions, chromium ions, manganese ions, total dissolved solid, chloride ions, copper ions and zinc ions. Results of the modelled equations compares favourably with the experimental values with the highest percentage deviation of 1.52% and the lowest of 0.16%. The models could serve as a tool of control and monitoring of environmental pollution.

Keywords

Pollution, modeling, textile, effluent, pH

Introduction

The textile industry processes natural fibres together with synthetic fibres produced by chemical industries from raw materials such as cotton, flax, silk, polyvinyl chloride, which are spanned into yarns and weaved into fabrics. Most fabric are soiled, wrinkled and dull looking

when they come out from the loom or other manufacturing machine making them to require certain finishing treatment before being labeled and sold. There are different finishing processes including the general finishing of pretreatment and coloration. Pretreatment processes include cleaning, singeing, scouring, bleaching, shrinkage resistance, shearing, stentering, calendaring, and adding substances to increase weight, softness, or stiffness (Fig. 1.). Other finishing processes that changes appearance or texture are mercerizing and desizing, which involve treating with resins (Annon., 1983; Lyle, 1982; Geigy, 1981; Annon., 1980).

The technology of transforming cotton and synthetic fibres into fabrics and dyed fabrics generates various kinds of waste, such as shaft and seed waste (while spinning), organic and chemical materials (while dyeing), minerals, and fibrous materials in the process of finishing. These kinds of wastes are sources of environmental pollution. A satisfactory and economically viable solution is important in the control of pollution emanating from high pH, high amounts of suspended and dissolved solids, and various ions discharged into the water body. This paper is aimed at developing a method of predicting the effect of various constituents present in a textile effluent, by generating an empirical model that could be used to simulate the textile effluent characteristic. This work is limited to the experimental results obtained from the composite samples collected from wastewater treatment holding tank and the point of discharge, and covers a period of six months.

Processing of Cotton

The three basic steps in cotton processing are spinning, weaving, and finishing. Cotton spinning and weaving are dry process while the finishing process are mostly wet involving dyeing and printing. Due to the natural and synthetic nature of textile fibrous materials, several methods of finishing operations are available for different materials. Examples are the cotton finishing processing and the wool processing, others are cotton and synthetic women fabric finishing, cotton and synthetic knit fabric finishing, cotton and synthetic raw stock and yarn dyeing, wool and animal hair scouring, dyeing and printing of carpets and synthetic fibres (Eckenfelder, 1989; Kemmer, 1988; Lorch, 1981). The fabrics received from the weaving section are normally harsh in handing and usually contained impurities either added

to facilitate the earlier process of manufacture or impurities, which were natural to the fibre due to growth reason. Therefore, the task of the dyeing section of the mill is to subject the fabric into the following processes: singeing, desizing, scouring, bleaching, mercerizing and drying (Fig. 1.)[Annon., 1983].

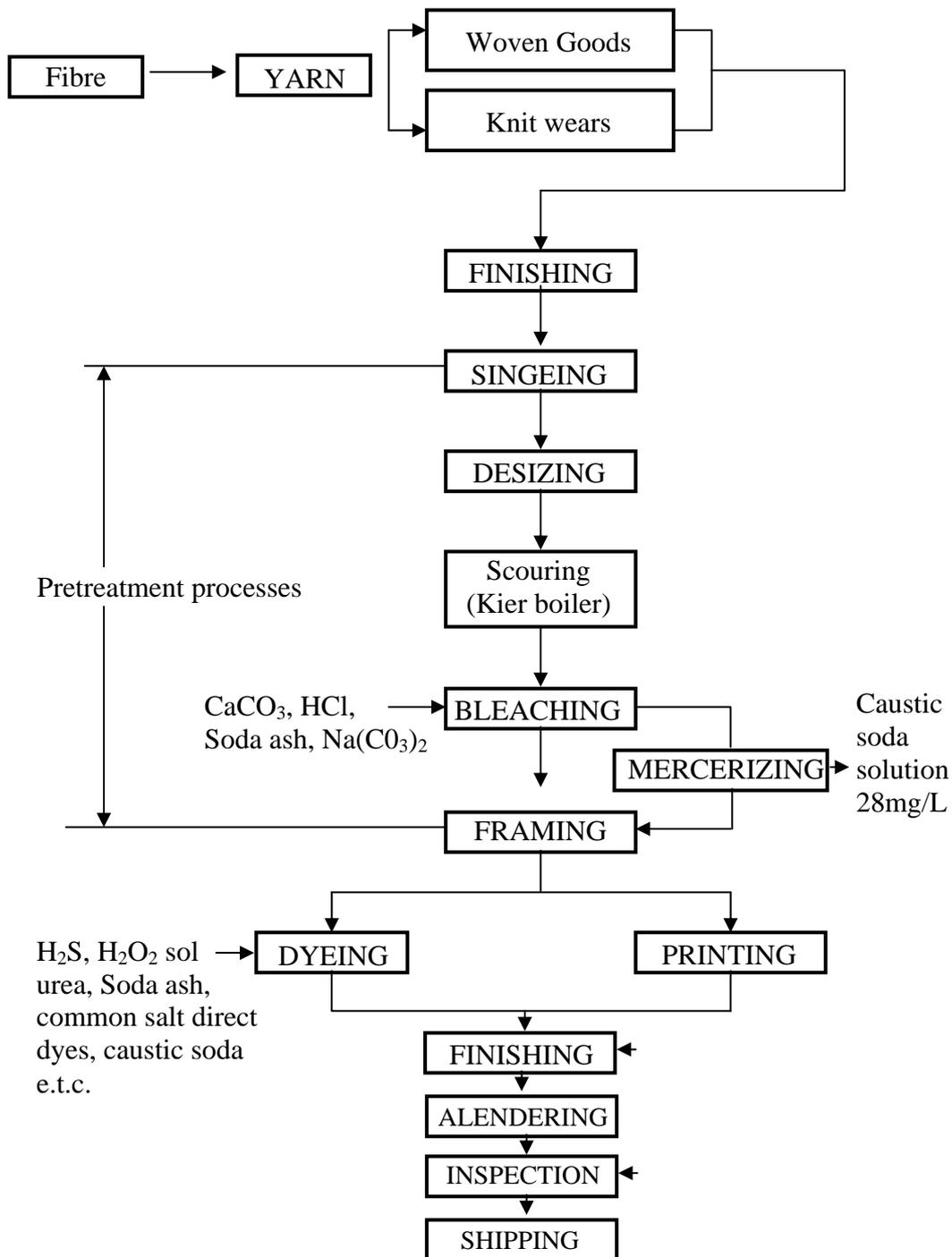


Figure 1. Schematic representation of cotton processing in textile industries

Modeling of textile effluent

The pH of a solution is a reflection of the resultant effects of the concentrations of the variables present. The pH was modeled using regression tool for statistical analysis. The method of the least square was employed to fit a relationship for the model. Now let:

$$\text{pH} = f(\text{COD}, \text{TSS}, \text{Alk}, \text{Fe}, \text{Cr}, \text{Mn}, \text{TDS}, \text{Cl}, \text{Cu}, \text{Zn}) \quad (1)$$

where COD is the chemical oxygen demand, TSS is the total suspended solid, Alk is the alkalinity, Fe is the iron ions, Cr is the chromium ions, Mn is the manganese ions, TDS is the total dissolved solid, Cl is the chloride ions, Cu is the copper ions, and Zn is the zinc ions.

The effects of each concentration on pH were established by determining the relationship between each variables and pH through the plotting of curves. The COD and TSS established a first degree relationship with pH and was expressed in the form $y = a + b \cdot x$ to give (Stroud, 1995a,b; Himmelblau, 1989; Carnahan et-al, 1969):

$$\text{pH}_1 = a_1 + b_1 \cdot (\text{COD}) \quad (2)$$

$$\text{pH}_2 = a_2 + b_2 \cdot (\text{TSS}) \quad (3)$$

The Alk, Fe, Cr and Mn established an exponential relationship with pH and were expressed in the form $y = a \cdot e^{b \cdot x}$ which could be linearize by multiplying both sides by natural logarithm (ln), so that:

$$\ln y = \ln a + b \cdot x \quad (4)$$

$$\text{pH}_3 = a_3 \cdot \exp \{b_3 \cdot (\text{Alk})\} \quad (5)$$

$$\text{pH}_4 = a_4 \cdot \exp \{b_4 \cdot (\text{Fe})\} \quad (6)$$

$$\text{pH}_5 = a_5 \cdot \exp \{b_5 \cdot (\text{Cr})\} \quad (7)$$

$$\text{pH}_6 = a_6 \cdot \exp \{b_6 \cdot (\text{Mn})\} \quad (8)$$

TDS, Cl, Cu and Zn established a logarithmic (log) relationship or a curve of the form $y = a \cdot x^b$ and could be linearize by taking the log of both side as:

$$\log y = \log a + b \cdot \log(x) \quad (9)$$

$$\text{pH}_7 = a_7 \cdot (\text{TDS})^{b_7} \quad (10)$$

$$\text{pH}_8 = a_8 \cdot (\text{Cl})^{b_8} \quad (11)$$

$$\text{pH}_9 = a_9 \cdot (\text{Cu})^{b_9} \quad (12)$$

$$\text{pH}_{10} = a_{10} \cdot (\text{Zn})^{b_{10}} \quad (13)$$

The combination of the Equations 1- 12 gives the general equation:

$$\ln \text{pH} = \ln k + a_1(\text{Alk}) + a_2(\text{Fe}) + a_3(\text{Cr}) + a_4(\text{Mn}) + a_5 \log_{10}(\text{TDS}) + a_6 \log(\text{Cl}) + a_7 \log(\text{Cu}) + a_8 \log(\text{Zn}) \quad (14)$$

In order to convert the $\log(x)$ values to $\ln(x)$ values, the $\log(x)$ functions values were divided by 0.4343. Now, let $\ln k = a_0$ so that Equation (13) becomes:

$$\ln \text{pH} = a_0 + a_1(\text{Alk}) + a_2(\text{Fe}) + a_3(\text{Cr}) + a_4(\text{Mn}) + a_5 \log_{10}(\text{TDS}) + a_6 \log(\text{Cl}) + a_7 \log(\text{Cu}) + a_8 \log(\text{Zn}) \quad (15)$$

Using the method of least squares are determined the coefficients (constants) (Himmeblau 1987; Carnahan *et al* 1969). $\ln \text{pH}$ is the dependent variable in the equation, $a_0, a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8$ are the coefficients (constants) which needs to be determined, and (Alk), (Fe), (Cr), (Mn), $\log(\text{TDS})$, $\log(\text{Cl})$, $\log(\text{Cu})$, $\log(\text{Zn})$ are the independent variables for the desired pH (Perry and Green, 1997; Stroud, 1995a,b; Luyben, 1995; Imre, 1984; Himmelblau, 1989; Carnahan *et al*, 1969).

Let E represent the square of the error between the observed pH_0 in $\log_e \text{pH}$ and it predicted value (pH_p) in natural logarithm, using the experimentally obtained data, which could be linearized by multiplying both sides of equation by natural logarithm (\ln) or logarithm. Since there is a relationship between logarithm and natural logarithm as given in Equation (15) and (16):

$$\log_e N = \log_{10} N / \log_{10} e = \log_{10} N / 0.4343 \quad (16)$$

$$\log_{10} N = \log_e N \cdot \log_{10} e = \log_e N \cdot 0.4343 \quad (17)$$

Thus applying to equation (15) we have:

$$\ln \text{pH} = \ln k + a_1 \cdot (\text{Alk}) + a_2 \cdot (\text{Fe}) + a_3 \cdot (\text{Cr}) + a_4 \cdot (\text{Mn}) + \{a_5 \log(\text{TDS}) + a_6 \log(\text{Cl}) + a_7 \log(\text{Cu}) + a_8 \log(\text{Zn})\} \cdot \{1/0.4343\} \quad (18)$$

$$E = \ln \text{pH}_0^2 - \ln \text{pH}_p^2 \quad (19)$$

where pH_0 is the observed pH and pH_p is the predicted pH value.

$$E = \ln \text{pH}_0^2 - \{a_0 + a_1(\text{Alk}) + a_2(\text{Fe}) + a_3(\text{Cr}) + a_4(\text{Mn}) + a_5 \log(\text{TDS}) + a_6 \log(\text{Cl}) + a_7 \log(\text{Cu}) + a_8 \log(\text{Zn})\}^2 \quad (20)$$

For n experimental values of $\ln \text{pH}_0$ and $\ln \text{pH}_p$:

$$nE = \sum \{ \ln \text{pH}_{0,i} - a_{0,i} - a_1(\text{Alk})_i - a_2(\text{Fe})_i - a_3(\text{Cr})_i - a_4(\text{Mn})_i - a_5 \log(\text{TDS})_i - a_6 \log(\text{Cl})_i - a_7 \log(\text{Cu})_i - a_8 \log(\text{Zn})_i \}^2 \quad (21)$$

To minimize nE with respect to the coefficients $a_0, a_1, a_2, a_3, a_4, a_5, a_6, a_7$ and a_8 using the first partial derivatives of nE with respect to these constant and equating them to zero we obtain the necessary condition for a minimum:

$$\delta nE/\delta a_0 = -2\sum 1 \{ \text{LnpH}_{0,i} - a_{0,i} - a_1(\text{Alk})_i - a_2(\text{Fe})_i - a_3(\text{Cr})_i - a_4(\text{Mn})_i - a_5\log(\text{TDS})_i - a_6\log(\text{Cl})_i - a_7\log(\text{Cu})_i - a_8\log(\text{Zn})_i \} = 0 \quad (22)$$

$$\delta nE/\delta a_1 = -2\sum(\text{Alk}) \{ \text{LnpH}_{0,i} - a_{0,i} - a_1(\text{Alk})_i - a_2(\text{Fe})_i - a_3(\text{Cr})_i - a_4(\text{Mn})_i - a_5\log(\text{TDS})_i - a_6\log(\text{Cl})_i - a_7\log(\text{Cu})_i - a_8\log(\text{Zn})_i \} = 0 \quad (23)$$

$$\delta nE/\delta a_2 = -2\sum(\text{Fe}) \{ \text{LnpH}_{0,i} - a_{0,i} - a_1(\text{Alk})_i - a_2(\text{Fe})_i - a_3(\text{Cr})_i - a_4(\text{Mn})_i - a_5\log(\text{TDS})_i - a_6\log(\text{Cl})_i - a_7\log(\text{Cu})_i - a_8\log(\text{Zn})_i \} = 0 \quad (24)$$

$$\delta nE/\delta a_3 = -2\sum(\text{Cr}) \{ \text{LnpH}_{0,i} - a_{0,i} - a_1(\text{Alk})_i - a_2(\text{Fe})_i - a_3(\text{Cr})_i - a_4(\text{Mn})_i - a_5\log(\text{TDS})_i - a_6\log(\text{Cl})_i - a_7\log(\text{Cu})_i - a_8\log(\text{Zn})_i \} = 0 \quad (25)$$

$$\delta nE/\delta a_4 = -2\sum(\text{Mn}) \{ \text{LnpH}_{0,i} - a_{0,i} - a_1(\text{Alk})_i - a_2(\text{Fe})_i - a_3(\text{Cr})_i - a_4(\text{Mn})_i - a_5\log(\text{TDS})_i - a_6\log(\text{Cl})_i - a_7\log(\text{Cu})_i - a_8\log(\text{Zn})_i \} = 0 \quad (26)$$

$$\delta nE/\delta a_5 = -2\sum\log(\text{TDS}) \{ \text{LnpH}_{0,i} - a_{0,i} - a_1(\text{Alk})_i - a_2(\text{Fe})_i - a_3(\text{Cr})_i - a_4(\text{Mn})_i - a_5\log(\text{TDS})_i - a_6\log(\text{Cl})_i - a_7\log(\text{Cu})_i - a_8\log(\text{Zn})_i \} = 0 \quad (27)$$

$$\delta nE/\delta a_6 = -2\sum\log(\text{Cl}) \{ \text{LnpH}_{0,i} - a_{0,i} - a_1(\text{Alk})_i - a_2(\text{Fe})_i - a_3(\text{Cr})_i - a_4(\text{Mn})_i - a_5\log(\text{TDS})_i - a_6\log(\text{Cl})_i - a_7\log(\text{Cu})_i - a_8\log(\text{Zn})_i \} = 0 \quad (28)$$

$$\delta nE/\delta a_7 = -2\sum\log(\text{Cu}) \{ \text{LnpH}_{0,i} - a_{0,i} - a_1(\text{Alk})_i - a_2(\text{Fe})_i - a_3(\text{Cr})_i - a_4(\text{Mn})_i - a_5\log(\text{TDS})_i - a_6\log(\text{Cl})_i - a_7\log(\text{Cu})_i - a_8\log(\text{Zn})_i \} = 0 \quad (29)$$

$$\delta nE/\delta a_8 = -2\sum\log(\text{Zn}) \{ \text{LnpH}_{0,i} - a_{0,i} - a_1(\text{Alk})_i - a_2(\text{Fe})_i - a_3(\text{Cr})_i - a_4(\text{Mn})_i - a_5\log(\text{TDS})_i - a_6\log(\text{Cl})_i - a_7\log(\text{Cu})_i - a_8\log(\text{Zn})_i \} = 0 \quad (30)$$

Re-arranging these sets of linear equations where \sum is the sum from $i = 1$ to n , and $n = 6$ gives:

$$\sum \text{LnpH}_{0,i} = a_0\sum 1 + a_1\sum(\text{Alk}) + a_2\sum(\text{Fe}) + a_3\sum(\text{Cr}) + a_4\sum(\text{Mn}) + a_5\sum\log(\text{TDS}) + a_6\sum\log(\text{Cl}) + a_7\sum\log(\text{Cu}) + a_8\sum\log(\text{Zn}) \quad (31)$$

$$\sum \text{LnpH}_{0,i}(\text{Alk}) = a_0\sum(\text{Alk}) + a_1\sum(\text{Alk})^2 + a_2\sum(\text{Alk})(\text{Fe}) + a_3\sum(\text{Alk})(\text{Cr}) + a_4\sum(\text{Alk})(\text{Mn}) + a_5\sum(\text{Alk})\log(\text{TDS}) + a_6\sum(\text{Alk})\log(\text{Cl}) + a_7\sum(\text{Alk})\log(\text{Cu}) + a_8\sum(\text{Alk})\log(\text{Zn}) \quad (32)$$

$$\sum \text{LnpH}_{0,i}(\text{Fe}) = a_0\sum(\text{Fe}) + a_1\sum(\text{Alk})(\text{Fe}) + a_2\sum(\text{Fe})^2 + a_3\sum(\text{Cr})(\text{Fe}) + a_4\sum(\text{Mn})(\text{Fe}) + a_5\sum(\text{Fe})\log(\text{TDS}) + a_6\sum\log(\text{Cl})(\text{Fe}) + a_7\sum\log(\text{Cu})(\text{Fe}) + a_8\sum\log(\text{Zn})(\text{Fe}) \quad (33)$$

$$\sum \text{LnpH}_{0,i}(\text{Cr}) = a_0\sum(\text{Cr}) + a_1\sum(\text{Alk})(\text{Cr}) + a_2\sum(\text{Fe})(\text{Cr}) + a_3\sum(\text{Cr})^2 + a_4\sum(\text{Mn})(\text{Cr}) + a_5\sum\log(\text{TDS})(\text{Cr}) + a_6\sum\log(\text{Cl})(\text{Cr}) + a_7\sum\log(\text{Cu})(\text{Cr}) + a_8\sum\log(\text{Zn})(\text{Cr}) \quad (34)$$

$$\begin{aligned} \sum LnpH_{0,i}(Mn) = & a_0 \sum(Mn) + a_1 \sum(Alk)(Mn) + a_2 \sum(Fe)(Mn) + \\ & a_3 \sum(Cr)(Mn) + a_4 \sum(Mn)^2 + a_5 \sum \log(TDS)(Mn) + \\ & a_6 \sum \log(Cl)(Mn) + a_7 \sum \log(Cu)(Mn) + a_8 \sum \log(Zn)(Mn) \end{aligned} \quad (35)$$

$$\begin{aligned} \sum LnpH_{0,i}(TDS) = & a_0 \sum \log(TDS) + a_1 \sum(Alk) \log(TDS) + a_2 \sum(Fe) \log(TDS) + \\ & a_3 \sum(Cr) \log(TDS) + a_4 \sum(Mn) \log(TDS) + a_5 \sum \log(TDS)^2 + \\ & a_6 \sum \log(TDS)(Cl) + a_7 \sum \log(TDS)(Cu) + a_8 \sum \log(TDS)(Zn) \end{aligned} \quad (36)$$

$$\begin{aligned} \sum LnpH_{0,i} \log(Cl) = & a_0 \sum \log(Cl) + a_1 \sum(Alk) \log(Cl) + a_2 \sum(Fe) \log(Cl) + \\ & a_3 \sum(Cr) \log(Cl) + a_4 \sum(Mn) \log(Cl) + a_5 \sum \log(TDS)(Cl) + \\ & a_6 \sum \log(Cl)^2 + a_7 \sum \log(Cu)(Cl) + a_8 \sum \log(Zn)(Cl) \end{aligned} \quad (37)$$

$$\begin{aligned} \sum LnpH_{0,i} \log(Cu) = & a_0 \sum \log(Cu) + a_1 \sum(Alk) \log(Cu) + a_2 \sum(Fe) \log(Cu) + \\ & a_3 \sum(Cr) \log(Cu) + a_4 \sum(Mn) \log(Cu) + a_5 \sum \log(TDS)(Cl) + \\ & a_6 \sum \log(Cl)(Cu) + a_7 \sum \log(Cu)^2 + a_8 \sum \log(Zn)(Cu) \end{aligned} \quad (38)$$

$$\begin{aligned} \sum LnpH_{0,i} \log(Zn) = & a_0 \sum \log(Zn) + a_1 \sum(Alk) \log(Zn) + a_2 \sum(Fe) \log(Zn) + \\ & a_3 \sum(Cr) \log(Zn) + a_4 \sum(Mn) \log(Zn) + a_5 \sum \log(TDS)(Zn) + \\ & a_6 \sum \log(Cl)(Zn) + a_7 \sum \log(Cu)(Zn) + a_8 \sum \log(Zn)^2 \end{aligned} \quad (39)$$

Equations 30 to 39 form a 9×9 symmetric matrix. Using a combination of computer software and Gauss Jordan Elimination method the results of the summation and the constants were obtained (Stroud, 1995a,b; Himmelblau, 1989; Carnahan et-al, 1969):

$\sum(Alk)$	= 3407	$\sum(Fe)$	= 6.92
$\sum(Alk)^2$	= 1937055	$\sum(Fe)^2$	= 7.99
$\sum(Alk) \cdot (Fe)$	= 3935.91	$\sum(Fe) \cdot (Cr)$	= 0.77498
$\sum(Alk) \cdot (Cr)$	= 381.26	$\sum(Fe) \cdot (Mn)$	= 0.11935
$\sum(Alk) \cdot (Mn)$	= 58.767	$\sum(Fe) \cdot \log(TDS)$	= 48.2996
$\sum(Alk) \cdot \log(TDS)$	= 23738.92	$\sum(Fe) \cdot \log(Cl)$	= 29.66436
$\sum(Alk) \cdot \log(Cl)$	= 14604.29	$\sum(Fe) \cdot \log(Cu)$	= -6.13587
$\sum(Alk) \cdot \log(Cu)$	= -3021.95	$\sum(Fe) \cdot \log(Zn)$	= -8.28623
$\sum(Alk) \cdot \log(Zn)$	= -4081.03	$\sum \log(TDS)$	= 41.8162
$\sum(Cr)$	= 0.67	$\sum \log(TDS)^2$	= 126.9664
$\sum(Cr)^2$	= 0.075118	$\sum \log(TDS) \cdot \log(Cl)$	= 77.93796
$\sum(Cr) \cdot (Mn)$	= 0.011572	$\sum \log(TDS) \cdot \log(Cu)$	= -16.1441

$\Sigma(\text{Cr}) \cdot \log(\text{TDS})$	= 4.67592	$\Sigma \log(\text{TDS}) \cdot \log(\text{Zn})$	= -21.8022
$\Sigma(\text{Cr}) \cdot \log(\text{Cl})$	= 2.872287	$\Sigma \log(\text{Cl})$	= 25.71485
$\Sigma(\text{Cr}) \cdot \log(\text{Cu})$	= -0.59387	$\Sigma \log(\text{Cl})^2$	= 47.86497
$\Sigma(\text{Cr}) \cdot \log(\text{Zn})$	= -0.80199	$\Sigma \log(\text{Cl}) \cdot \log(\text{Cu})$	= -9.91417
$\Sigma(\text{Mn})$	= 0.103000	$\Sigma \log(\text{Cl}) \cdot \log(\text{Zn})$	= -13.3888
$\Sigma(\text{Mn})^2$	= 0.001791	$\Sigma \log(\text{Cu})$	= -5.32718
$\Sigma(\text{Mn}) \cdot \log(\text{TDS})$	= 0.719059	$\Sigma \log(\text{Cu})^2$	= 2.055887
$\Sigma(\text{Mn}) \cdot \log(\text{Cl})$	= 0.441667	$\Sigma \log(\text{Cu}) \cdot \log(\text{Zn})$	= 2.776442
$\Sigma(\text{Mn}) \cdot \log(\text{Cu})$	= -0.09119	$\Sigma \log(\text{Zn})$	= -7.19422
$\Sigma(\text{Mn}) \cdot \log(\text{Zn})$	= -0.12314	$\Sigma \log(\text{Zn})^2$	= 3.749541

The derived model equations are represented as:

$$-\ln(\text{pH}) = 0.002 + 0.00884(\text{Alk}) - 2.51121(\text{Fe}) + 3.172977(\text{Cr}) - 18.6272(\text{Mn}) + 2.553002\log(\text{TDS}) - 4.00885\log(\text{Cl}) + 28.78356\log(\text{Cu}) - 20.7841\log(\text{Zn}) \quad (40)$$

$$(\text{Alk}) = -0.022624434 + 284.0735294(\text{Fe}) - 358.934(\text{Cr}) + 2107.142(\text{Mn}) - 288.801\log(\text{TDS}) + 453.489\log(\text{Cl}) - 3256.052\log(\text{Cu}) + 2351.142\log(\text{Zn}) + 113.1221719\text{LnpH} \quad (41)$$

$$(\text{Fe}) = 0.000079642 + 0.003520215(\text{Alk}) + 1.263525153(\text{Cr}) + 7.417619395(\text{Mn}) + 1.016642176\log(\text{TDS}) - 1.596381824\log(\text{Cl}) + 11.46202827\log(\text{Cu}) - 8.276528048\log(\text{Zn}) - 0.398214406\text{LnpH} \quad (42)$$

$$(\text{Cr}) = -0.000063032 + 0.791436559(\text{Fe}) - 0.002786027(\text{Alk}) + 5.870575173(\text{Mn}) - 0.804607786\log(\text{TDS}) + 1.263434938\log(\text{Cl}) - 9.071468214\log(\text{Cu}) + 6.550346882\log(\text{Zn}) + 0.31516143\text{LnpH} \quad (43)$$

$$(\text{Mn}) = 0.00001073 + 0.000474574(\text{Alk}) - 0.1348814142(\text{Fe}) + 0.17034106(\text{Cr}) + 0.137057743\log(\text{TDS}) - 0.215214847\log(\text{Cl}) + 1.545243515\log(\text{Cu}) - 1.115793034\log(\text{Zn}) - 0.053684933\text{LnpH} \quad (44)$$

$$\log(\text{TDS}) = -0.00078339 + 0.983630251(\text{Fe}) - 0.00346259(\text{Alk}) - 1.242841565(\text{Cr}) + 7.296194833(\text{Mn}) + 1.570249455\log(\text{Cl}) - 11.27439775\log(\text{Cu}) + 8.141043368\log(\text{Zn}) + 0.391695737\text{LnpH} \quad (45)$$

$$\log(\text{Cl}) = 0.000049889 + 0.002205121(\text{Alk}) - 0.626416555(\text{Fe}) + 0.791493071(\text{Cr}) - 4.646519575(\text{Mn}) + 0.636841488\log(\text{TDS}) + 7.180004241\log(\text{Cu}) - 5.184554174\log(\text{Zn}) - 0.249448196\text{LnpH} \quad (46)$$

$$\begin{aligned} \log(\text{Cu}) = & -0.00006948 + 0.087244593(\text{Fe}) - 0.000307119(\text{Alk}) - \\ & 0.110235738(\text{Cr}) + 0.647147191(\text{Mn}) - 0.088696533\log(\text{TDS}) + \\ & 0.139275683\log(\text{Cl}) + 0.722082327\log(\text{Zn}) + 0.034742054\text{Ln pH} \quad (47) \end{aligned}$$

$$\begin{aligned} \log(\text{Zn}) = & 0.000009622 + 0.000042532(\text{Alk}) - 0.12082361(\text{Fe}) + \\ & 0.15266367(\text{Cr}) - 0.896223555(\text{Mn}) + 0.122834378\log(\text{TDS}) - \\ & 0.192880615\log(\text{Cl}) + 1.384883637\log(\text{Cu}) - 0.048113702\text{Ln pH} \quad (48) \end{aligned}$$

Results and Discussion

The experimental values for a period of six months are presented in Table 1. The comparative values of the experimental and the model pH values are presented in Table 2. The modelled values for the other parameters derived are presented in Table 3.

Table 1. Experimental results (mg/l) for six months

Period	pH	COD	TSS	Alk	Fe	Cr	Mn	Cl	TDS	Cu	Zn
Jan	8.98	2050	40.0	600	1.23	0.120	0.020	76.0	1110	0.43	0.32
Feb	8.40	1975	35.0	538	1.07	0.100	0.015	71.0	1045	0.40	0.29
Mar	8.65	2008	37.0	569	1.15	0.115	0.018	72.5	1069	0.41	0.30
Apr	8.83	2035	38.9	585	1.21	0.118	0.019	73.5	1109	0.42	0.31
May	8.50	1990	35.2	555	1.11	0.105	0.016	71.4	1050	0.40	0.29
Jun	8.60	2000	36.5	560	1.15	0.112	0.015	72.0	1060	0.41	0.30
AVE	8.66	2010	37.0	568	1.15	0.112	0.017	73.0	1074	0.41	0.30
FEPA Limit	6-9	80	30.0	600	<0.1	<0.1	<0.1	600	200	<0.1	<0.1

FEPA-Federal Environmental Protection Agency (FEPA, 1991)

Table 2. Comparative values for experimental and model pH

Period	Experimental Value	ln pH	Model pH	Percentage Error
Jan	8.98	2.1933	8.965	0.16
Feb	8.40	2.1129	8.272	1.52
Mar	8.65	2.1692	8.751	1.16
Apr	8.83	2.1729	8.784	0.52
May	8.50	2.1461	8.551	0.60
Jun	8.60	2.1384	8.490	1.28

Table 3: Modelled values for other parameters (mg/l)

Period	Model values for other parameters							
	Alk	Fe	Cr	Mn	TDS	Cl	Cu	Zn
Jan	600.18	1.2294	0.121	0.0199	1109.8	75.93	0.430	0.3199
Feb	539.74	1.065	0.105	0.0142	1057.9	70.38	0.400	0.2895
Mar	569.69	1.155	0.112	0.0186	1056.2	72.98	0.4096	0.3000
Apr	585.58	1.208	0.119	0.0187	1112.4	73.28	0.4200	0.3098
May	554.32	1.113	0.103	0.0168	1042.6	71.65	0.399	0.2902
Jun	561.48	1.145	0.116	0.0143	1070.9	71.46	0.410	0.2996

The characterization of the textile effluent being outlined in Table 1 was brought about by the nature of the textile raw materials used in the industry, the production processes in the dyeing and printing of textiles, and the technological conditions. The major problems associated with the industry is in terms of large volumes of weak solution coloured liquid generated after a prolonged absorption of dye by the fabrics. This culminated into the needs for the analysis of the constituents that exhibits the characteristic with their respective effects and load on the effluent. The experimental result shows that the discharged effluent would affect the natural quality of water and the environment considerably.

The levels in the COD, TDS were greater than the permissive level given by the Federal Environmental Protection Agency (FEPA), a monthly average of 2010 mg/l and 1074 mg/l respectively were noticed against the FEPA limits of 80 mg/l and 200 mg/l respectively. The other parameters varied slightly from the stipulated limits (FEPA, 1991; Solomon, 1989). Cluster bar charts of the comparison of the simulated and experimental readings for the other eight parameters modelled for are presented in Fig. 2 to 9. Fig. 2 shows a little variation between the simulated and experimental concentration. Fig. 3, 8 and 9 shows very close readings between the simulated and experimental values. On the other hand, Fig. 4, 5 and 6 shows various degrees of variations.

Colour is a threat to water quality because it deteriorates the aesthetic value and purity of water due to the presence of organic matter like dyes (sulphur, reactive, azoic, and direct dyes) and pigments that were used on the cotton. Most fabrics are hydrocarbon derivatives having keto or carbonyl groups and are insoluble in water. Others contains amino and nitro groups (sulphur), sodium sulphonate groups (reactive dyes) which are also insoluble but could be made soluble by treating with alkali. In some cases colour were due to the presence of phenols and some inorganic matters like suspended solids or precipitated metallic compounds, which enhance the colour changes. (Nikoladze *et-al*, 1989; Lyle, 1982; Suess, 1982; Welson and Wenetow, 1982).

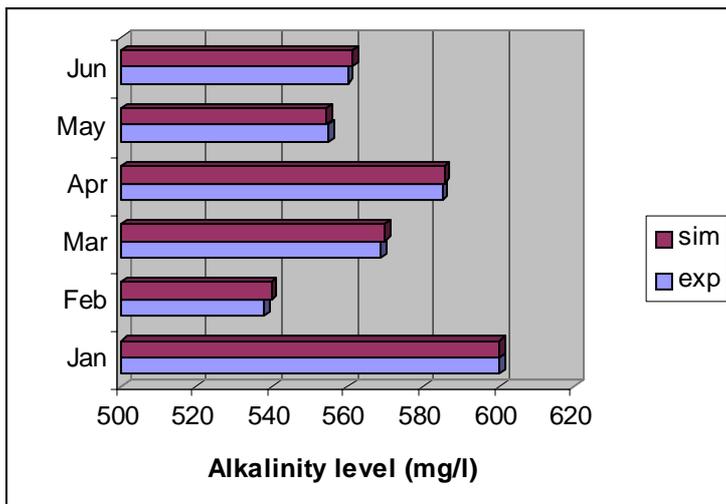


Figure 2. Cluster chart of simulated and experimental level of alkalinity

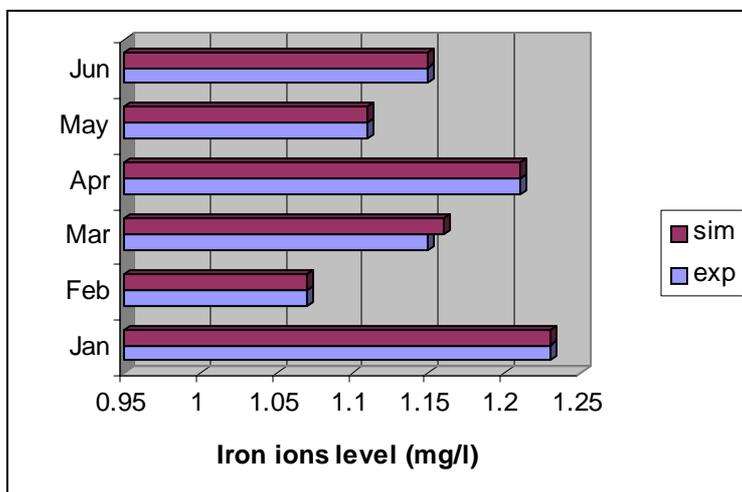


Figure 3. Cluster chart of simulated and experimental level of iron ions

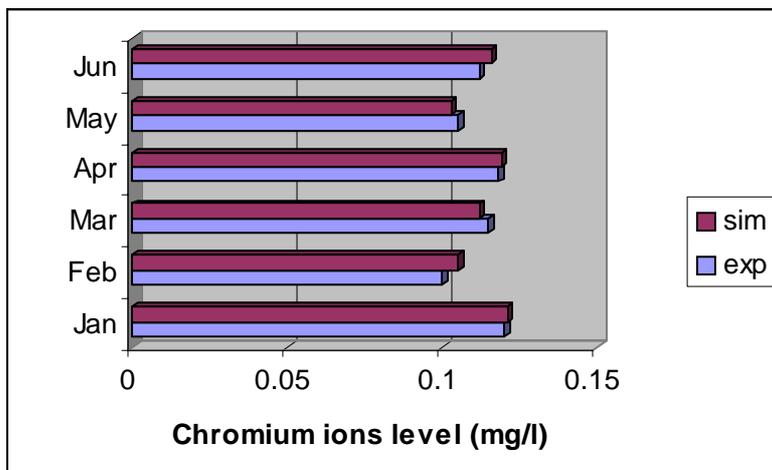


Figure 4. Cluster chart of simulated and experimental level of chromium ions

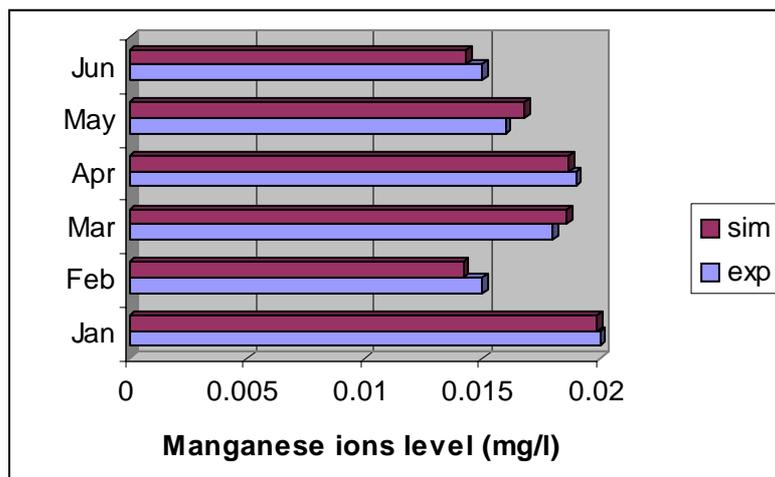


Figure 5. Cluster chart of simulated and experimental level of manganese ions

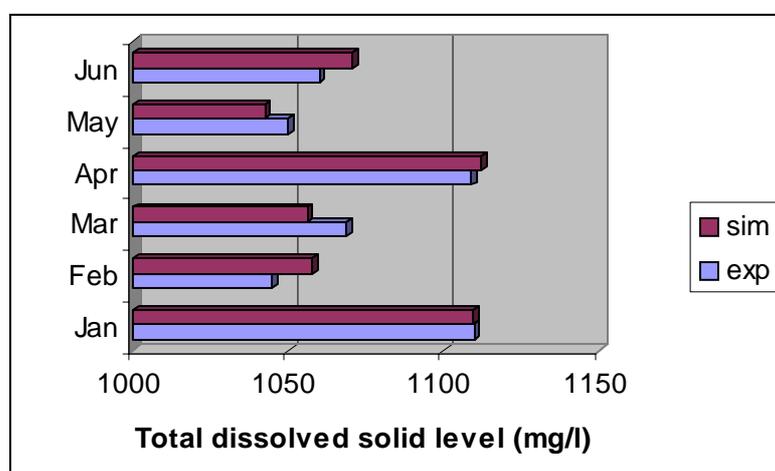


Figure 6. Cluster chart of simulated and experimental level of total dissolved solid

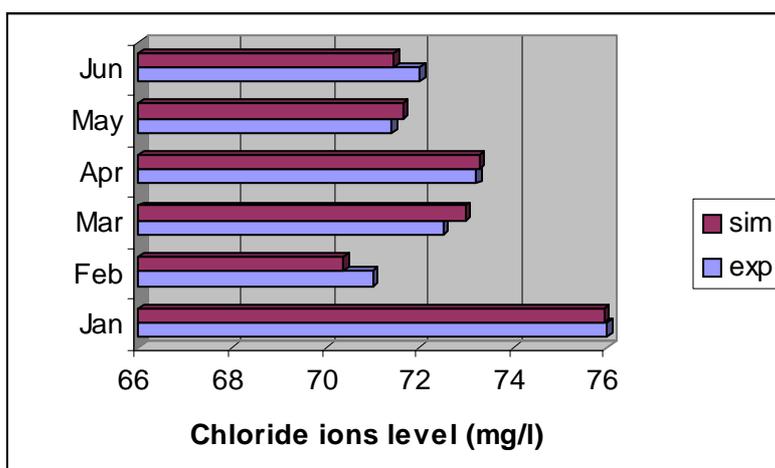


Figure 7. Cluster chart of simulated and experimental level of chloride ions

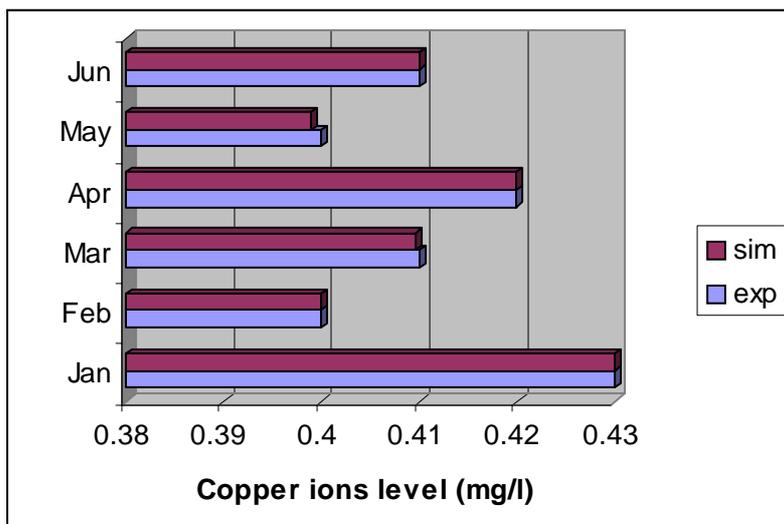


Figure 8. Cluster chart of simulated and experimental level of copper ions

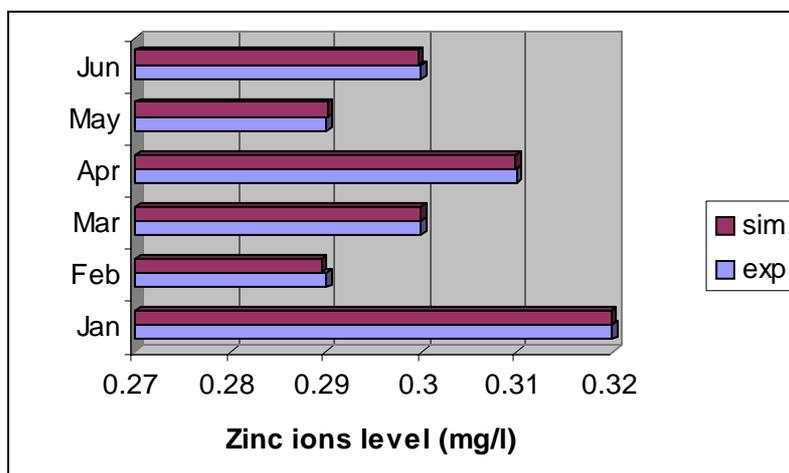


Figure 9. Cluster chart of simulated and experimental level of zinc ions

The pollutant association was determined through the empirical analytical statements that prove the relationship of the chosen pH (dependent variable) and the independent variables, by the correctness of the modelled equation through the percentage error that was calculated for each month and compared with the experimental values. The percentage deviation ranges from 0.16 to 1.52%. From the model equation, it was observed that pH was mostly affected by the concentration of copper ions (Cu) and least affected by the concentration of alkalinity content of the effluent. The presence of the high concentration of Cu could be attributed to the waste generated in the electroplating of copper at the engraving section of the textile wax-printing department of the mill. The chromium exhibiting the next

high effect could also be traced to the chromium present in metallized dyes containing metallic salt (Karapetyant and Drakin, 1981; Kriton, 1980; Jenkin, 1978).

TDS effect on pH was predominantly of organic origin on the solution. And could be associated with the hydrolysis of complex organic compound converted to less complex soluble ones by enzymatic hydrolysis. This could be traced to the enzymatic desizing of the fabrics. Thus, organic compounds such as cellulose on hydrolysis produce organic weak acids or weak base. The total alkalinity content, which, slightly affect the pH, was as a result of the capacity of some of the effluent's component to accept proton (the binding of an equivalent amount of strong acid). Such components are hydroxyl ions and anions of weak acids (hydroxyl from bleaching and scouring process) [Odigure and Adeniyi 2002; Karapetyant and Drakin, 1981].

Fe, Zn, and Mn possess negative signs, which could be attributed to the possibility of being precipitated from the solution, that is, in principle, they contribute little effect to the overall pH, because they are insoluble and cannot be hydrolyzed (Odigure and Adeniyi 2002; Odigure, 1998; Karapetyant and Drakin, 1981). Cl also possess negative ions which could also possibly be precipitated along side with the metals as a result of its deleterious effects on metallic pipes and other metallic compounds. From the model equation it could be concluded that the extent of these reactions and interactions depends on the prevailing relationship of the constituent and environmental conditions.

Conclusion

The influence of effluents on water reserve depends on the physico-chemical properties of the contained organic and inorganic impurities. From the developed model, the obtained coefficients for the various optimized variables show that the obtained values and signs to a great extent are a reflection of the chemical nature of the pollutant constituents. As the increase in the degree of alkalinity, which enhances the increasing order of acidification, was given by the values of the positive parametric coefficients, and also the order of influencing acidity, which enhances the increasing order of alkalization was prescribed by the value of the negative coefficients. Hence, the overall pH from the model equation is a



reflection of the influence of the prevailing parameters. Both the experimental and the model pH of the effluent were found to be within the permissible limit of the FEPA standard.

References

1. Suess M.J., Examination of water for pollution control, a Reference Handbook, Pergamon Press, England, Vol. 3, pp. 276-300, 1982.
2. Karapetyant M.X and Drakin C.I., General and Inorganic Chemistry, Ximiya, Moscow, pp. 230-286, 1981.
3. Kemmer F.N, The NALCO water handbook, 2-nd edition, McGraw Hill Inc., U.S.A., pp. 20.1- 40.1., 1988.
4. Odigure J.O, Safety, loss and pollution prevention in chemical process industries, Jodigs and Associates, Minna, Nigeria, pp. 89-115, 1998.
5. Lorch W., Handbook of water purification, Ellis Horwood Ltd, 2nd edition, pp.67-90, 1981.
6. Stroud K.A., Engineering Mathematics, 4th Edition, Macmillan Press Ltd., London, pp. 500-536, 1995a.
7. Geigy C., Pretreatment with alkali, Ciba Geigy Ltd, Edition 1981, Switzerland, 1981.
8. Anon., The dyeing primer, AATCC monograph, Modern textiles, pp. 410-415, 1980.
9. Lyle D.S., Modern textiles, 2nd edition, John Wiley and Sons Inc., U.S.A., pp. 80-415, 1982.
10. Carnahan B., Luther H.A. and Wilkes J.O. Applied numerical methods, John Wiley and Sons Inc., U.S.A, pp. 210-340, 1969.
11. FEPA, A guidelines and standard for environmental pollution control in Nigeria, Decree No. 58, 1991.
12. Eckenfelder W.W., Industrial water pollution control, McGraw Hill, Singapore, pp.1-28, 1989.
13. Imre H., Modelling in technology of waste water treatment, Pergamon Press, Hungary, pp. 176-177, 1984.
14. Himmelblau D.M., Basic principles and calculations in Chemical engineering, 3rd ed., Prentice Hill Inc., New Jersey, 1987.
15. Jenkins S.H., Water pollution control problems in developing countries, Proc. of the Int. Conf., Bangkok, Thailand, Vol 2, pp. 3-19, 1978.

16. Luyben W.W., Process modelling, simulation and control for chemical engineers, McGraw Hill, pp. 13-77, 1995.
17. Nikoladze G., Mints D. and Kastassky A., Water treatment for public and industrial supply, Mir publication, Moscow, pp. 9-40, 1989.
18. Kriton C., Treatment and disposal of liquid and solid industrial wastes, Pergamon Press, U.K., pp. 122-150, 1980.
19. Welson L. and Wenetow A.D., Industrial and hazardous waste treatment, Nannstrand Reinhold, New York, pp. 73, 125, 1982.
20. Odigure J.O. and Adeniyi O.D., Modeling of Brewery pH value, J. Ass. for the Adv. of Modelling & Sim. in Ent. (AMSE.), Lyon, France, Vol. 63. No. 3, pp. 55-64, 2002.
21. Solomon H.M., Laboratory manual of chemical methods of food and non-foods, FIIRO Analytical Services division, Oshodi, Lagos, pp. 12-20, 1989.
22. Perry R.H. and Green D.W., Chemical Engineer's Handbook, Int'l ed., McGraw Hill Book Company, 7th ed., pp. 25-58, 80, 1997.
23. Stroud, K. A.. Further Engineering Mathematics, Macmillan Press Ltd., London, 4th ed., 1995b.
24. Anon., Pretreatment of cotton fabrics, Hoechst, D-6230 Frankfurt Am Main 80, Germany, 1983.

Acknowledgment

The help rendered by Mr. A. T. Mukaila of the Department of Chemical Engineering, Federal University of Technology, Minna, Nigeria is highly appreciated.