Int. J. Environ. Res. Public Health **2006**, *3(2)*, 209-216

International Journal of
Environmental Research and Public Health
ISSN 1661-7827
www.ijerph.org

Effect of Low Quality Effluent from Wastewater Stabilization Ponds to Receiving Bodies, Case of Kilombero Sugar Ponds and Ruaha River, Tanzania

Magayane Machibya[1*] and Fredrick Mwanuzi[2]

[1]Water Resources & GIS Specialist, ITECO Consult (T) Limited, Dar Es Salaam, Tanzania.
[2] Water Resources Engineering, University of Dar Es Salaam, Tanzania.
*Correspondence to Dr. Magayane Machibya, Email: machibya_m@yahoo.com/magayane.machibya@itecoconsult.com

Received: 21 December 2005 / Accepted: 31 May 2006 / Published: 30 June 2006

Abstract: A study was conducted in a sewage system at Kilombero Sugar Company to review its design, configuration, effectiveness and the quality of influent and effluent discharged into the Ruaha river (receiving body). The concern was that, the water in the river, after effluent has joined the river, is used as drinking water by villages located downstream of the river. Strategic sampling at the inlet of the oxidation pond, at the outlet and in the river before and after the effluent has joined the receiving body (river) was undertaken. Samples from each of these locations were taken three times, in the morning, noon and evening. The sample were then analysed in the laboratory using standard methods of water quality analysis. The results showed that the configuration and or the layout of the oxidation ponds (treatment plant) were not in accordance with the acceptable standards. Thus, the BOD_5 of the effluent discharged into the receiving body (Ruaha River) was in the order of 41 mg/l and therefore not meeting several standards as set out both by Tanzanian and international water authorities. The Tanzanian water authorities, for example, requires that the BOD_5 of the effluent discharged into receiving bodies be not more that 30 mg/l while the World Health Organization (WHO) requires that the effluent quality ranges between 10 – 30 mg/l. The paper concludes that proper design of treatment plants (oxidation ponds) is of outmost importance especially for factories, industries, camps etc located in rural developing countries where drinking water from receiving bodies like rivers and lakes is consumed without thorough treatment. The paper further pinpoint that both owners of treatment plants and water authorities should establish monitoring/management plan such that treatment plants (oxidation ponds) could be reviewed regarding the change on quantity of influent caused by population increase.

Keywords: Effluent standard, oxidation ponds, receiving bodies, wastewater.

Introduction

Sewage can be defined as discharges from domestic and sanitary appliances or simply a complex mixture of materials from varied sources. This complex mixture contains both soluble and insoluble materials [1]. It is under these reasons that sewage from homestead has to be managed before is flushed away into receiving bodies like rivers, lakes and oceans as harmless stuff. Since the mixture is complex, it is usually treated by a mixture of settlement and biological processes. Settlement process permits materials which are suspended in a sewage to settle to the bottom of a container and therefore to be removed from the bulk of the liquid. The longer the materials are retained in the container, the greater the amount of suspended solids that will be able to settle out. Thus short retention times will only remove the largest particles, while long retention times provide greater solids removal. Biological processes convert materials in the sewage into biological cell materials which can usually be easily settled out from a solution by a settlement process.

Both settlement and biological process can only be achieved with a right design of treatment plants (wastewater stabilization ponds). However, the effectiveness of stabilization ponds will mainly depend among others the configuration and size of the ponds with respect to the sewage discharges [2]. The effectiveness referred here is the ability to treat the influent to a standard (allowable) effluent to be discharged into receiving bodies.

Based on this understanding of sewage systems and their complexity in management and design, the

Kilombero Sugar Company recently launched a study to review their sewage system in terms of design, configuration, effectiveness and the quality of influent and effluent discharged into the Ruaha River (receiving body). The concern was that the population at the company is increasing and the water in the river, after effluent from oxidation pond has joined the river, is used as raw drinking water by villages located further downstream.

Methods and Materials

Review of Existing Pond Layout

Generally there exist two types of waste stabilization pond systems. The Facultative – Maturation System (FM system) and the Anaerobic-Facultative – Maturation System (AFM-System). In the absence of the grit chambers and screen, the most layout of the conventional Waste Stabilization Pond (WSP) is given in Figure 1 [2]. Given the waste water discharge, the two systems require different area and configuration for proper functioning.

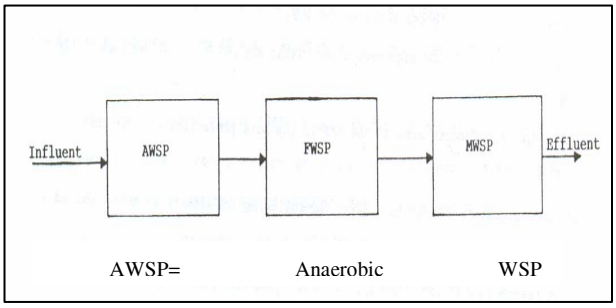

Figure 1: Conventional layout of waste stabilization ponds

The sewerage of the Kilombero Sugar Company (K2 side) consists of a network which gravitate to the pumping station thereafter gravitate to the wastewater stabilization ponds (treatment plant) [2]. The plant consists of a very basic, single series of ponds, one large pond connected to a much smaller pond. Earlier studies by different consultants have referred the first pond as Anaerobic pond and the second one as facultative pond. However, according to the layout and depth requirements the first pond can be regarded as facultative pond and the smaller one to be maturation pond thus a need for the anaerobic pond.

Review of Waste Water Discharges

For the design and operation of all treatment plants, an accurate knowledge of the sewage flow and sewage characteristics is essential. The daily volume of sewage per capita can vary from less than 50 l for a relatively primitive camping site to more than 300 l for an affluent high amenity residential area [1, 5].

In order to accurately determine the flow of a particular sewage system, the best method is to measure the flow over a representative time. If this procedure cannot be followed, some less rigorous method has to be adopted [1, 2]. Comparison with a similar site is advantageous, modifying the data in the light of particular circumstances. Often designs are based almost entirely upon educated estimates of flows. Even for cases when estimates are used, it is important to critically assess these design parameters.

During this study, Sewage flow was estimated using two methods. The first method was through use of population data and consideration of peak period and then the average flows were estimated. The second method of estimation made use of electronic flow measuring equipment called *Ultrasonic metre*. The equipment is capable of measuring both pressurized and non pressurized sewage flows in different piped materials.

Review of Waste Water Quality

The strength of sewage in an area drained by a sewerage system which permits the inclusion of surface water can be low, with a BOD5 of less than 100 mg/I, while the wastes from chemical closets can have a BOD5 in excess of 1,000 mg/I.

It therefore follows that before a waste water stabilization system is design, the influent and effluent standards need to be fixed to a certain level. In reviewing the Kilombero system it was necessary to investigate the level of quality of both influent and effluent. In addition, the quality of receiving body (the Ruaha river) before and after effluent has joined the river was investigated.

Data Collection and Results

Pond Layout and Size

The existing layout and configuration of the Kilombero wastewater stabilization pond probably does not belong into any of the two types of system mentioned above (FMS and AFMS) [2, 3]. The pond has only two chambers, one large (65 x 161 m) and another small (65 x 25 m). The existing pond calculates an area of 1.2ha. Figure 2 shows the layout of the existing pond.

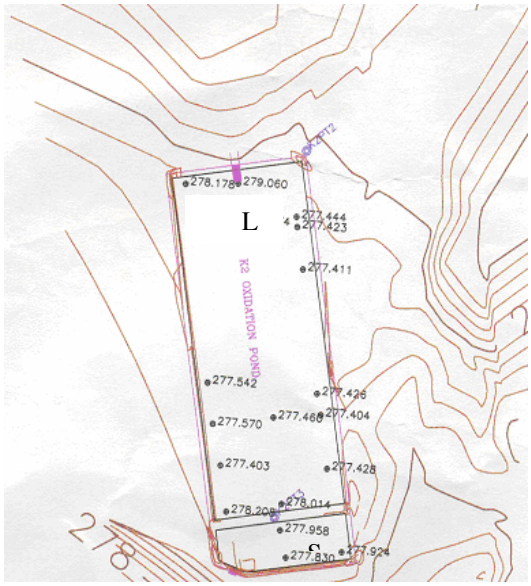

Figure 2: Existing layout of the K2 pond

Discharge Data

Three types of data were collected in order to be able to review the sewage system of the Kilombero sugar company (K2 side). The first key data collected was the waste water discharge from the whole system. The two approaches which were used included the use of the social and quantitative approach where by a population and an estimated waste water discharge of 80 litres per day per capita were used to calculate the discharge. The second approach where special equipment called *Ultrasonic meter* was used to estimate the flows in the main pipe. The results from the two methods did not differ significantly as P = 0.61 which is greater than 0.05 in the ANOVA analysis Table 1 (a & b).

Table 1(a): Estimated waste discharges to waste stabilization ponds

Reading	*Population approach estimation (m^3/day)*	*Ultrasonic meter readings (m^3/day)*
1st	600.56	600.00
2nd	600.56	604.18
3rd	600.56	591.20
Average	*600.56*	*598.46*

Table 1(b): ANOVA Analysis on difference of data from the two approaches

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Methods	6.62	1.00	6.62	0.30	0.61	7.71
Within Methods	87.80	4.00	21.95			
Total	*94.41*	*5.00*				

When the results from the two approaches were compared, the result from the social method showed higher daily discharges (600.56m^3/day) compared to the ultrasonic meter results which showed 598.46m^3/day. As it is usual with all designs, the higher parameter was considered during the design stage.

Water Quality Data

Water samples were taken at the inlet and outlet of the water stabilization ponds in a repetitive ways three times a day (morning, afternoon and evening). In addition water samples were taken from the receiving body (Ruaha River) before and after the effluent joined the river. The sampling locations were as illustrated by Figure 3.

The collected samples were then analyzed in the laboratory using standard procedures [6] as illustrated in Table 2. The results from the analysis in the laboratory, for each of the sample, are presented in Tables 3 and 4.

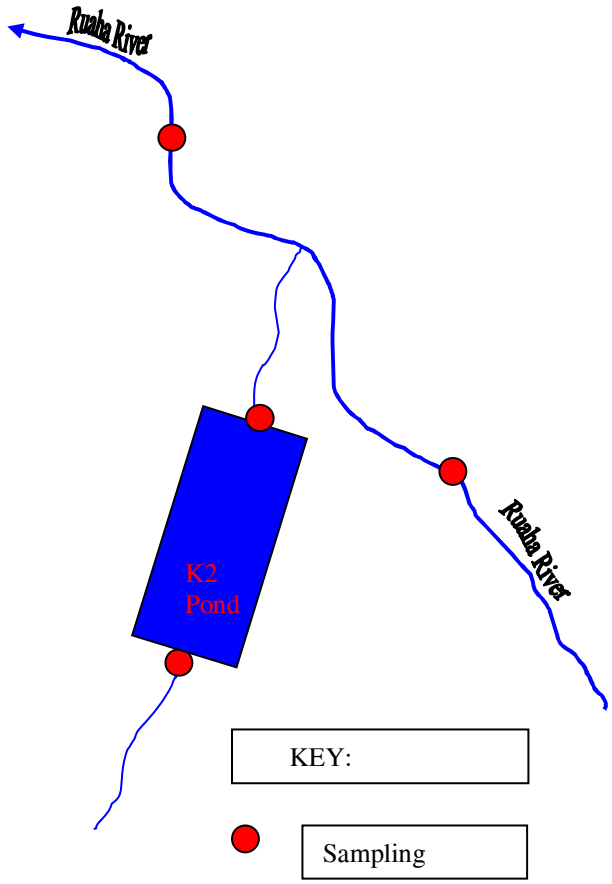

Figure 3: Schematic layout showing sampling locations

Table 2: Analysed parameters and method of analysis used

Parameter	*Method of Analysis*
pH	Inolab WTW
Total dissolved solids	Slow drying followed by weighing using analytical balance.
Color	APHA plantinum – Cobalt Standard method
Turbidity	Hanna Instrument HI 93703 microprocessor
Ortho phosphate	Ascorbic method using Spectronic 20 genesys spectrophotometer.
Nitrate	Devarder's Method
Sulphate	Spectronic 20 genesys spectrophotometer.
Escherchia coli	Membrane filtration method
Total suspended solids	Filtration followed by oven drying at 105°C
Residual Chlorine	N,N – diethylparaphenylenediamine (DPD) method
Dissolved Oxygen	WTW Multiline F/set P4 universal meter
BOD_5	Oxi top set up.
Chemical Oxygen Demand (COD)	Dr Lange ampoules measured by LASA 100 photometer

Table 3: Water quality from oxidation ponds

Parameters analysed	*K2 - Influent*				*K2 - Effluent*			
	Mor.	*Noon*	*Even.*	*Aver.*	*Mor.*	*Noon*	*Even.*	*Aver.*
pH	7.58	7.25	7.04	7.29	7.04	6.95	7.03	7.01
Turbidity (F.T.U)	40	71	64	58	12	11	12	12
Total Dissolved Solds (mg/l)	205	365	360	310	195	150	150	165
Conductivity[µS/cm]	481	605	412	499	378	382	384	381
Color (mg Pt.Co/l)	91	91	195	126	51	91	59	67
Total Suspended Solids (mg/l)	65	75	725	288	265	80	175	173
Nitrates (mg/l)	1.25	0.71	0.52	0.83	0.85	1.17	0.27	0.76
Sulphate (mg/l)	17.24	21.61	22.29	20.38	16.09	16.78	16.09	16.32
Ortho Phosphate (mg/l)	7.10	11.30	3.85	7.42	5.60	5.10	5.15	5.28
Residue Chlorine (mg/l)	0.35	0.04	0.09	0.16	0.03	0.04	0.06	0.04
Dissolved Oxygen (mg/l)	1.70	1.08	1.47	1.41	3.39	3.33	3.50	3.40
BOD5 (mg/l)	65.0	79.7	82.0	75.6	27.7	33.2	63.1	41.3
COD (mg/l)	209	307	388	301	91	97	148	112
Escherichia coli (No./100 ml)	2.3E+05	1.6E+05	2.1E+05	2.0E+05	7.0E+04	4.0E+04	1.1E+05	7.3E+04

NOTE: Mor = Morning; Even = Evening;
Aver = Average.

Table 4: Water quality from Ruaha river

Parameters analysed	*Ruaha river*				*River-k2 mix*			
	Mor.	*Noon*	*Even.*	*Aver.*	*Mor.*	*Noon*	*Even.*	*Aver.*
pH	7.66	7.95	7.72	7.78	7.63	7.75	7.8	7.73
Turbidity (F.T.U)	5	5	5	5	5	6	5	5
Total Dissolved Solds (mg/l)	175	225	205	202	170	170	155	165
Conductivity[µS/cm]	231	233	231	232	235	228	229	231
Color (mg Pt.Co/l)	22	22	29	24	22	22	22	22
Total Suspended Solids (mg/l)	20	40	38	33	36	30	35	34
Nitrates (mg/l)	1.25	0.64	0.46	0.78	1.00	0.81	0.41	0.74
Sulphate (mg/l)	18.62	19.31	16.09	18.01	20.46	15.63	19.31	18.47
Ortho Phosphate (mg/l)	0.19	0.16	0.13	0.16	0.13	0.34	0.16	0.21
Residue Chlorine (mg/l)	0.17	0.09	0.03	0.09	0.03	0.11	0.21	0.12
Dissolved Oxygen (mg/l)	6.99	7.16	7.01	7.05	7.40	7.54	7.10	7.35
BOD5 (mg/l)	7	6	5	6	6	4	4	5
COD (mg/l)	37	21	15	24	10	12	15	13
Escherichia coli (No./100 ml)	72	97	110	93	285	366	714	455

NOTE: Mor = Morning; Even = Evening;
Aver = Average.

Configuration Analysis of the Ponds

The analysis of pond configuration is an attempt to re-design the current wastewater stabilization pond in Kilombero Sugar Company so as the discharged effluent into receiving water bodies is of acceptable standard. In this study, two systems were considered. The FM and AFM systems as discussed in detail below

Facultative Pond Plus Maturation Pond System

(a) Facultative Pond

The main purpose of facultative pond is the BOD reduction. It is assumed that the pond is a completely mixed reactor in which BOD_5 removal follows the first order kinetics [1].

$$\frac{Le}{Li} = \frac{1}{1 + k_1 t}$$

Where Li = BOD_5 in the influent in mg/l
Le = BOD_5 in the effluent in mg/l
t = retention time in days
K_1 = first order rate constant for BOD removal in d^{-1}

Retention time (t)

$$t = \frac{AxH}{Q}$$

Where A = Pond surface area at the middle
H is the depth
Q = waste water flow in m^3/day

The area (A) is given by

$$A = \frac{Q}{Hxk_1}\left(\frac{Li}{Le} - 1\right)$$

Values of $K_1 = 0.3x1.05)^{(T-20)}$
Depths of 1.0 to 1.5 m are generally used.
H = 1.2m
Li = 200mg/l
Le = 30mg/l
Q = 600.56m^3/d
A=600.56x{(200/30)-1}/(1.2x0.3) = 9453.3 m2 = 0.95ha
D = Retention time t=9453.3x1.2/600.56 = 18.9 days.

It is recommended that a minimum retention time of 7days should be used for individual ponds because of short circuiting in ponds with shorter retention time [1, 5]. Sufficiently long retention time of about 5-10 days should be allowed.

(b) Maturation pond

Maturation ponds are designed to achieve bacterial removal as a final step after BOD_5 has been reduced in the anaerobic and facultative ponds. Facultative can also remove the bacteria.

$$Ne = \frac{Ni}{[1 + K_b t_f][1 + K_b(T)t_m]^n}$$

Where, Ne and Ni are number of E-coli per 100ml in the influent and effluents respectively.
$K_b(T) = 2.6x(1.19)^{T-20}$ in all ponds

For the design purposes a value of 200mg/l BOD5 (average strength) inlet is assumed and an outlet to be fixed at 30mg/l. E-coli was established to be $2.0x10^6$ per 100ml in the influent (normally influent can contain up to 10^9 E-coli per 100ml. For receiving stream it is required that the E-coli should be less than 1,000 per 100ml. K_b is E-coli removal rate constant; t_f is the retention time in the facultative pond; t_m retention time in one maturation pond usually 5-7 days.

$$1000 = \frac{2.0x10^6}{[1 + 2.6x18.9][1 + 2.6x7]^n}$$

From above equation n = 1.2, minimum n should be equal to 2;
Thus the required number of maturation ponds for K2 facility is n = 2;
Maturation pond volume = 7 days x 600.56m3/day = 4203.9 m^3
For a depth of 1.2 m the mid pond area is 4203.9/1.2 = 3503.3 m^2 = 0.35ha.
Total area coverage for three (3) ponds is 0.95ha + 0.35ha + 0.35ha = 1.65ha.

Anaerobic, Facultative and Maturation system

(a) Anaerobic pond

Anaerobic ponds should be designed mainly on the basis of volumetric organic loading (g.BOD_5/m^3/d) but detention time should also be taken into account. Anaerobic ponds are designed to receive BOD loadings between 100 - 400g.BOD_5/m^3/d. The actual loading will depend on climate, with higher loadings possibility at higher temperatures. The hydraulic detention time is usually between 2.5-5 days and the rate of BOD removal is between 50-80% [1, 2, 5]. Normally 60% volumetric loading is given by:

$$v = \frac{L_i Q}{V}$$

Where v = Volumetric loading g.BOD_5/m^3/day
Li = Inflow BOD5 concentration in mg/l
Q = Influent flow rate in m^3/d;
V = Volume of the pond in m^3;
Depth of the pond is usually between 2.5 and 5.0m;
The BOD load = 200mg/l x 600.56 m^3x 1000l/m^3/day = 120.1 Kg/day;
Assuming a volumetric loading of 200g.BOD_5/m^3/day;
Then the required volume = (120.1/200) x 1000 = 600.5 m^3; Thus retention time = 600.5/600.56 = 1.0 days.
Taking the depth to be 4.0m then the area at the mid-pond depth is 600.56/4=150.1m^2 (0.015ha).

(b) Facultative pond

60% of BOD is removed in the anaerobic pond the remaining BOD is 200 (1-0.60) = 80mg/l as Li and Le = 30mg/l. Thus the area of the facultative pond becomes:

$$A = \frac{Q}{Hxk_1}\left(\frac{Li}{Le} - 1\right)$$

A = 600.56 x (80/30-1)/(1.2x0.3) = 2780.4 m^2 = 0.28ha
Detention time t=2780.4x1.2/600.56 = 5.6 days

(c) Maturation pond

Bacteria will be removed in all of the ponds. Anaerobic and facultative can also remove the bacteria though in the anaerobic pond the removal is about half way:

$$Ne = \frac{Ni}{[1+(\frac{K_b}{2}t_a)][1+K_b t_f][1+K_b(T)t_m]^n}$$

$K_b(T) = 2.6x(1.19)^{T-20}$ in all ponds;

Where Ne and Ni are number of E-coli per 100ml in the influent and effluents respectively;
K_b is E-coli removal rate constant
t_a is the retention time in anaerobic pond
t_f is the retention time in the facultative pond
t_m retention time in one maturation pond usually 5-7 days.

Thus taking n = 1:

$$Ne = \frac{2x10^6}{[1+(\frac{2.6}{2}x2)][1+2.6x5.6][1+2.6x7]} = 1{,}891$$

The value obtained is above 1,000 thus providing TWO maturation ponds as above each with mid-pond area of 0.35ha.

Total area coverage for four (4) ponds is (0.015 + 0.28 + 0.35 + 0.35) = 0.995ha.

Configuration and Sizes Required for Proper Function of the Pond

The result of the calculations in revealing the existing configuration, layout and design of the oxidation ponds in K2 shows that the ponds are neither Facultative Maturation system (FMS) nor Anaerobic Facultative Maturation system (AFMS). This has been illustrated by a review design calculation above. The review design calculation shows configuration indicated in Table 5 for the proper functioning of the ponds. The layout would be as shown in Figures 4 and 5.

Table 5: Supposed sizes of oxidation pond

Facultative - Maturation			Anaerobic – Facultative - Maturation		
Chamber	*Area (ha)*	*Depth (m)*	*Chamber*	*Area (ha)*	*Depth (m)*
Facultative (WSP)	0.95	1.2	Anaerobic (WSP)	0.15	3.0
Maturation (WSP)	0.35	1.2	Facultative (WSP)	0.28	1.2
Maturation (WSP)	0.35	1.2	Maturation (WSP)	0.35	1.2
			Maturation (WSP)	0.35	1.2
Total area (ha)	1.65			0.995	

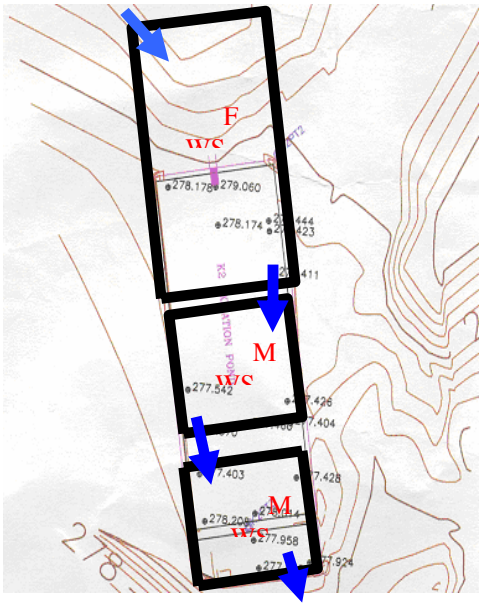

Figure 4: Layout of the K2 pond with FM system

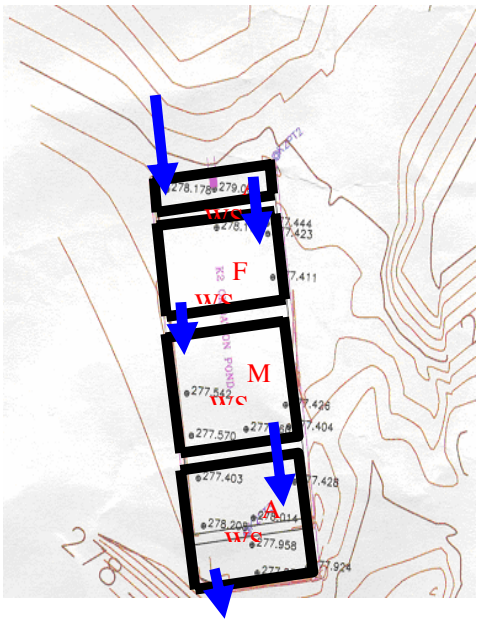

Figure 5: Layout of the K2 pond with AFM system

Discussion of the Results

Before the design options was made for the waste water treatment, the water quality samples were analyzed first. The main parameters looked at were the bacterial quality, BOD loads and residual chlorine status. These could give pollution levels in the environment [7-9]. The Ruaha river was found to be polluted even before the ponds effluents thus there are more polluters upstream. The existing pond system was not functioning properly as the effluents were of poor quality when compared with the standards [10-12, 14], requiring the need for new system design. The BOD load variation was quite remarkable for morning hours and evening hours. During the evening most of the workers are at home and thus produce more pollution during this time of the day. This paper provides five points which are supposed to discuss the results as fully as possible. These are given below:

1 The Ruaha River is not safe bacteriologically even before the influence of the effluent from the Sugar Company as some levels of bacteria are observed. For drinking water without disinfection or boiling, the recommended standard is ZERO/100ml.

2 Though there is a reduction in the number of E.Coli between influent and effluent still the levels at the ponds outlets are quite high indicating that the ponds are not adequately removing the bacteria. For immediate raw re-use by the villagers located just downstream, after the effluent has joined the river, the number should not exceed 200/100ml.

3 BOD5 from K2 effluents which has a maximum of 63.1mg/l experienced in the evenings might be the results of the attendants who was harvesting water hyacinths in the evening and this might have affected the results) but generally effluents from the K2 ponds are of the order 27.7 and 33.2 mg/l which is a bit high to be discharged into the receiving water body (Tables 3 & 6).

4 The general trend has shown that there are more BODs during the evenings compared to the rest of time. This is an indication that the peak hour is in the evening.

5 Highest recorded residual chlorine is 0.47 mg/l in the evening but in other cases the residual chloride is quite low indicating a proper disinfectants management (Table 7).

Table 6: Key Water Quality Parameters Levels

Parameter	*Acceptable/permissible*		*Allowable/excessive*	
	Tanzania m/l	*WHO mg/l*	*Tanzania mg/l*	*WHO mg/l*
Total Solids	N.M.	500	N.M.	1500
Iron (Fe)	0.3	0.3	N.M.	1.5
Manganese (Mn)	0.5	0.1	1.5	0.5
Calcium (Ca)	N.M.	75	N.M.	200
Sulphate (SO_4)	N.M	200	600	400
Chloride (C10	N.M.	200	800	600
Fluoride (F)	2.0	1.5	8.0	2.0
Nitrate (NO_3)	100	30	N.M.	N.M.
BOD5 *	30	6	60	10
Coliform bacteria per 100 ml	N.M.	N.M.	600	N.M.

*Effluents to be discharged directly into receiving water body

Table 7: Determinants with aesthetic/physical implications

Determinants	*Units*	*Limits For Groups*			
		A	*B*	*C*	*D**
Colour		30	-	-	-
Conductivity	µS /cm	1500	3000	4000	4000
Total hardness	mg/l $CaCO_3$	300	650	1 300	1 300
Turbidity	F.T.U	1	5	10	10
Chloride	mg/l Cl	250	600	1 200	1 200
Chlorine (free)	mg/l Cl	0,1-5,0	0,1-5,0	0,1-5,0	5,0
Fluoride	mg/l F	1,5	3,0	3,0	3,0
Sulphate	mg/l SO_4	200	1 200	1 200	1 200
Copper	µg/l Cu	500	2 000	2 000	2 000
Nitrate	mg/l N	10	40	40	40
Hydrogen Sulphide	µg/l H_2S	100	600	600	600
Iron	µg/l Fe	100	2 000	2 000	2 000
Manganese	µg/l Mn	50	2 000	2 000	2 000
Zinc	mg/l Zn	1	10	10	10
pH	pH-unit	6,0-9,0	4,0-11,0	4,0-11,0	4,0-11,0

Group A: Water with an excellent quality; **Group B**: Water with good quality; **Group C**: Water with low health risk; **Group D**: Water with a higher health risk or water unsuitable for human consumption

Conclusion

The design of the waste water stabilization pond in K2 is not in accordance with specification standards defined in different design books and manuals and that is why it does not produce effluent of acceptable standards in receiving bodies. A review and its proposed re-design for proper functioning of the existing stabilization ponds have been conducted and design options suggested in this paper.

In most developing countries like Tanzania, the low effluent which is discharged into receiving bodies and their effect to the downstream communities will need more investigation particularly on ways in which the effect can be minimized. There exists a number of water quality models that can trace the fate and transport of pollutants once discharged into the receiving water bodies. The impact of pollution can then be established to know the distance down stream to which pollution is still experienced. Application of models such as these will allow the governing authorities to advise the communities of where they should collect water. Also this can even optimize the pond design in terms of size, which can save cost.

In addition, studies of relation between water levels in receiving bodies and their relative level of pollutant can help in decision making by governing authorities to advise the communities living in the downstream to treat the water before using them at critical levels of pollution. Alternatively, the water collection point can be defined according to the seasonal calendar and or flow levels in receiving bodies.

References

1. ITECO: Final Report on design of the configuration of K2 oxidation pond, sewage network in block "A" hauses, Kantui school and the Mkamba cane cutter camp, *Main report*, **2004,** *19* pp.
2. ITECO: Phase I technical report on the studies to improve the drainage and sewage system of the Kilombero Sugar Company, *K1 and K2 sides*, **2004,** 24pp.
3. COWI: Study of waste water systems at Kilombero Sugar Company *Limited – K1 and K2 factories – Kidatu, Tanzania*, **2003,** *61pp*.
4. ITECO: Phase I technical report on the studies to improve the drainage and sewage system of the Kilombero Sugar Company, *K1 and K2 sides, ANNEX 9*, **2004,** *7pp*.
5. Mara Duncan: Design Manual for WASTE STABILIZATION PONDS in India, Lagoon Technology International Limited, University of Leads, England, **1997**, *125pp*.
6. American Public Health Association. Standard methods for the analysis of water and wastewater, 19th edition. American Public Health Association, Washington DC. *APHA*, **1995**.
6 Bartram, J.; Balance editors. Water quality monitoring – A practical guide to the design and implementation of freshwater quality studies and monitoring programes. 1st edition. *London: Chapman and Hall,* **1996**.
7. Chapman & Hall: Water Quality assessments – A guide to the use of biota, sediments and water in environmental monitoring. 2nd Edition. London: Chapman and Hall. *London,* **1996**.
8. Sundbland, K., Tonderski, A., Rulewski, J.: Nitrogen and Phosphorus in the Vistula River, Poland – Changes from sources to mouth. *Journal of Water Science and Technology*. **1994,** *30:* 177-186.
9. World Health Organization (WHO). Guidelines for drinking-water quality, 2nd ed. Vol. 2. Health criteria and other supporting information. *Geneva*, **1996**. pp. 370-373.
10. World Health Organization (WHO): Water Quality: Guidelines, Standards and Health. **2001**.
11. WRC. Water Research Commission No. TT101. Quality of domestic water supply. Volume1: Assessment Guide, **1998**.
12. Wu, C.; Maurer, C.; Wang, Y.; Xue, S.; Davis, D. L.: Water Pollution and Human Health in China. In: The Journal of the National Institute of Environmental Health Sciences. *Environmental Health Perspectives,* **1999**, *107 (4)*: 251-256.
13. Hammer, M. J.: Water and Wastewater Technology. SI Version. *John Wiley & Sons, INC, New York.* **1975**.