Effect of ethanol distillery effluent on the water quality of the receiving waters of Lake Malawi during the rainy season

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A senior project report submitted to the department of Aquaculture and Fisheries, Bunda Collage of Agriculture

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BUNDA COLLEGE OF AGRICULTURE

14 FEBRUARY 2000

APROVAL

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DEDICATION

Dedicated to my parents, (Mr. G.M Msomphora and Mrs M.W Msomphora).

AGKNOWLEDGEMENTS

I owe my thanks to the following, Dr. Harvey Bootsma. Dr. Hiroki Eda, Dr. Stephen A Mc Cord, Mr. Nhamo Ndebele, Mr. Yewo Nyirenda, Mr. Bernard Kamanga, Mr. Karid Chirwa, Mr. Jeremiah Kang'ombe and Miss Susan Kondwani Nyirenda for their support and guidance in producing this senior project report. I am especially grateful to Miss Susan Kondwani Nyirenda for the assistance rendered in data collection and Dr. Harvey Bootsma for his much needed help in the analysis of the data. I am indebted to Dr. Stephen A Mc Cord, Mr. Bernard Kamanga and Mr. Nhamo Ndebele for leading through the script and making necessary comments. Special thanks are also given to the management of Ethanol Company especially to the Chief Executive Mr. Chanje, the General Manager Mr Luwimbi and the Processing Manager Miss Susan Kondwani Nyirenda for allowing me to conduct my research analysis on their premises.

Finally, this would not be enough without mentioning my mother Mrs. Margaret Winnie Msomphora, who providing emotional support and kept me smiling throughout.

ABSTRACT

A study was carried out in Dwangwa area of Nkhotakota district in Malawi to determine the effect of ethanol distillery effluent from the Ethanol Company on the water quality of the receiving waters of Lake Malawi. Water samples were collected from six sites located along Dwangwa River, in the effluent ponds and in the lake at week intervals for 8 weeks. The samples were analysed for BOD, COD, DO, pH, alkalinity, acidity, turbidity, ammonia, nitrate, phosphorous, potassium, calcium and chlorophyll. Concentration levels of pollutants, BOD, COD, DO and alkalinity generally decreased from the source downstream to the lake with a few exceptions. This was attributed to the dilution factor and evaporation of some components. Concentration levels in the receiving waters were found to be within the tolerable limits except for ammonia. On average the levels of DO, BOD, pH, Chlorophyll, Nitrate, Phosphorous and Ammonia were 6.24 ppm, 30.54 mg/l, 7.48, 5.05 ppm, 0.29 ppm, 0.22 ppm and 2.1 ppm respectively. The levels detected for ammonia were generally ranging between the suggested toxic concentration of 0.6 and 2 mg/l, for most of the species in water (Smith and Piper, 1975). However, concentration of pollutants in the effluent was found to be higher than the acceptable limits. It was therefore concluded that the ethanol effluent from the factory was potentially hazardous to the aquatic life in the receiving waters.

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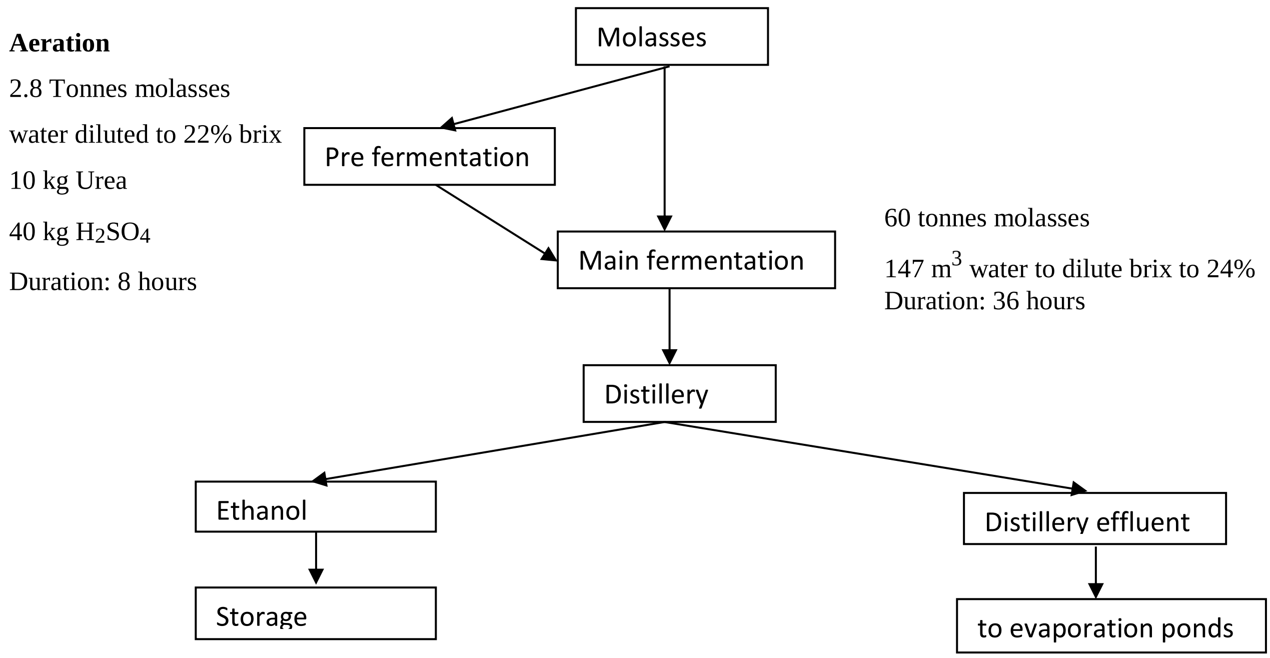
1.0. INTRODUCTION.

Aquatic life, including fish and the fishing industry, depends on good water quality. Water quality means the nature of water and its contents. Good water quality is that water with contents that are acceptable and causes no harm to aquatic life and human life. Conversely, bad quality water is harmful to life. For example, some of the world's major industrial areas are very contaminated by chemicals or effluents, such that there is potential hazard to human health, genetic structure and reproduction of living organisms including fish (Keating, 1994).

In general, most of the effluents in the world are discharged in the rivers and streams or reservoirs. These effluents find their way into the water bodies, through either seepage or surface runoff, streams and rivers. In most cases, the effluents that are discharged are toxic, such that they pose a great threat to aquatic biodiversity and their environment (Keating, 1994).

Although ethanol has a variety of uses, which can benefit the country's economy, the disposal of ethanol effluent has become a major concern in the modem world where environmental protection is of prime importance.

Ethanol effluent is an industrial waste produced during the production of ethanol at Ethanol Company in Dwangwa since 1980. The main aim of this company is to process the sugar mill effluent, primarily molasses, to avoid pollution (Ethanol: Malawi's Versatile Fuel, 1987). Ethanol is produced from fermented molasses as indicated in Fig.1.



Note: Brix means the percentage by mass of dissolved solids in a sample solution

Fig. l. Ethanol Production Sequence at the Dwangwa Ethanol Plant.

Ethanol is used for fuel blending for motor vehicles in the ratio 1:4 by volume. It is an excellent fuel for spark ignition engines and is a variable octane booster. Ethanol is also used for pharmaceuticals, potables, and as industrial solvents (paints).

Ethanol effluent, like most effluents, is highly acidic. The ethanol effluent has been observed to have pH of around 4. Acids can have an impact on aquatic life by changing the pH of the stream into which they are discharged, without being directly lethal to aquatic life such as fish or just bring about changes in their conditions of existence and rate of growth, which is not completely understood. Acids can be directly lethal and they may be harmful because they have anions of high toxicity such as Cl^-, NO_2^-, SO_3^{2-} (Jones, 1964). Lowering the concentration of dissolved oxygen (DO) and formation of sludge deposits are the most common environmental disturbances which may damage aquatic biota (Ramalho, 1977), for example ethanol effluent at Dwangwa (in the ethanol effluent ponds) has 0.15 DO with very high sludge deposits. It has been observed that ethanol effluent has caused the concentration levels of some organic and inorganic compounds to be toxic to aquatic life in same points of its receiving waters from the source downstream into the Lake. Hence, ethanol effluent can disrupt the ecosystem resulting into environmental degradation if not checked properly. About 70 per cent of marine pollution comes from sources on land (Ibid, 1997).

In Malawi, an ethanol distillery company operating at Dwangwa has its effluent being spilled into the river. It has been reported that water quality at this point has been affected as indicated by changes in fish colour, body size and test (fishermen, pers.com).

1.1. Justification

The problem of water quality where ethanol effluents are present is worrisome. Means to reduce this problem are not well known. No such research in Malawi has ever been conducted and the few found publications or books on pollution provide little or no information on contents and effects of effluents on the biodiversity of water bodies. At this time, it is important to quantify factors affecting water quality. The levels quantifying these factors will give directions as to whether the ethanol effluents at Dwangwa are beyond or within the acceptable levels to aquatic and human life. It is against this background that this study was conducted.

1.1.1. Main objective.

To determine the effects of ethanol distillery effluent on the water quality of the receiving waters of Lake Malawi.

1.1.2. Specific objective.

To identify and measure the determinants of water quality at different distances from the ethanol effluent ponds.

1.1.3. Postulated hypothesis.

There are no significant differences in water quality due to ethanol effluent at different distances from the effluent ponds.

2.0. LITERATURE REVIEW.

Degradation of the aquatic environment results from a wide range of contaminants. The contaminants that pose the greatest threat to the marine environment are sewage, chemicals, sediments, litter and plastics, metals, radioactive wastes and oil. Some of these materials are toxic, slow to break down in the environment and accumulate in living creatures (Keating, 1994).

When effluents containing organic matter are discharged into rivers, much of the materials they carry in suspension and solution are broken down by the microorganisms present in water, through a process, which requires using oxygen, resulting in the fall of oxygen concentration (Jones, 1964). This depletion of DO leads to undesirable disturbances of the environment and biota. The minimum DO necessary to maintain fish health is 5 ppm (Ibid, 1964).

The two measures that can be used to measure the quantity of oxygen used by the microbes during the decomposition of organic matter are biological oxygen demand (BOD) and chemical oxygen demand (COD) (Tchobanoglous and Schroeder, 1985). Both BOD and COD take place in aquatic environment, but the principal reactions in natural waters are biochemical (Ibid, 1985). BOD is a measure of the quantity of oxygen required or oxidation of biodegradable organic matter present in the water sample by aerobic biochemical action (the decline DO during decomposition is what is called BOD); thus, BOD is a valuable parameter in evaluating the polytonal strength of waste. COD is a measure of the total amount of oxygen required to completely oxidise all of the organic matter in a sample to carbon dioxide and water (Ramalho, 1977). In terms of oxygen demand, the most important type of biochemical reaction involves the oxidation of organic material as shown below (Tchobanoglous and Schroeder, 1985):

$$\text{Organic material} + O_2 + \text{nutrients} \xrightarrow{\text{microorganisms}} CO_2 + H_2O + \text{new cells} + \text{nutrients} + \text{energy}$$

In the case of pollution resulting from the presence of inorganic compounds, the main concern is their possible toxic effect, rather than oxygen depletion. There are however cases in which inorganic compounds exert an oxygen demand, so contributing to oxygen depletion, for example nitrification and oxidation of sulphites and nitrite to sulphate and nitrate, respectively (Ramalho, 1977). These chemical reactions are shown below:

(i) Nitrification

1. Ammonium ion is oxidised to nitrite in the presence of *Nitrosomonas* microorganisms.

$$2NH_4^+ + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2NO_2^- + 2H_2O + 4H^+$$

2. Nitrite are then oxidised to nitrate in presence of *Nitrobacter* microorganisms.

$$2NO_2^- + O_2 \xrightarrow{\text{Nitrobacters}} 2SO_4^{-2}$$

(ii) Oxidation

1. Sulfite are oxidized to Sulphates

$$2SO_3^{-2} + O_2 \longrightarrow 2SO_4^{-2}$$

(Ibid, 1985).

In the treatment of industrial effluent, pH is often the single most important parameter that needs to be adjusted prior to discharge. Ethanol effluent has a pH of 4.5 to 5 (S.K. Nyirenda, pers.com, 1998) which obviously means it contains a strong acid. Therefore, ethanol effluent is undesirable for most of aquatic life like fish growth. According to Maree and Tonder (1996), water pH below 5.5 can be toxic to both plants and fish. Ninety per cent of water including the waters assessed in this study has a pH value in the range of 6.7 to 8.2, which is good for fish growth as reported by Piper et al. (1982). It was reported that fish should not be subjected to pH outside the rage of 6.5 to 9; otherwise, they would not survive (Piper et al., 1982). Many species can live in acid waters, but it appears that under these conditions the fish may grow more slowly, and fail to attain the same size as other individuals of the same species living in alkaline streams (Jones, 1964). Water with a pH lower than 4.5 contains a strong acid (Boyd, 1984) which is undesirable for most of aquatic life like fish growth. However, pH above 10 is also undesirable. Thus, alkalinity and acidity also affect water quality (Ibid, 1964).

Fish can sense small differences in free carbon dioxide (CO_2) concentration and apparently attempt to avoid areas with high CO_2 levels (Hoglund, 1961). Nevertheless, 10 mg/l or more of CO_2 may be tolerated provided DO concentrations are high. Most species survive in water containing up to 60 mg/l of free CO_2 (Hart, 1944; Haskel and Davies, 1958). Water supporting good fish populations normally contain less than 5 mg/l of free CO_2 (Ellis, 1937). Since high concentration of carbon dioxide interfere with respiration (Basu, 1959), the minimum concentration of DO, which fish may tolerate increases with increasing carbon dioxide levels. Carbon dioxide can also affect the water quality since when it reacts with H_2O, an acid product is produced, hence pH decreased but not less than pH 4.5 and appreciable carbon dioxide does not occur in water with pH above 8.34 (Boyd, 1984). Thus, CO_2 can create unfavorable conditions for fish growth at times.

Un-ionised ammonia (NH3) is toxic to fish, but the ammonium ion (NH4+) is not toxic (Downing and Merkens, 1955). The European Inland Fisheries Advisory Commission (1973) stated that toxic concentrations of ammonia for short-terrn exposure are between 0.6 and 2 mg/litre of NH3 for most species. Un-ionised ammonia is more toxic when DO concentration is low (Merkens and Downing, 1957). However, the effect is probably nullified in fish ponds since *C02* concentration are usually high when DO levels are low. Lloyd and Herbert (1960) showed that the toxicity of NH3 decreases with increasing CO_2 concentrations. A number of workers demonstrated that sublethal concentrations of NH3 cause pathological changes in fish organs and tissues (Smith and Piper, 1975).

Nitrogen and phosphorous in effluents cause problems in same receiving waters. High concentration of these elements in water creates conditions especially favourable for growing green plants. If the water is quiescent (as for a lake), eutrophication may result into natural lake ageing (Ramalho, 1977). Enrichment and sedimentation are the principle contributors to the ageing of the lake (Append. l) (Ibid, 1977).

High levels of phosphorous can cause problems related to cyanobacteria blooms when nitrogen is limited. Under these conditions, cyanobacteria often cann ot support the normal phytoplankton grazers in a water body or pond, and sometimes actually release toxins or decompose, causing a sudden depletions of the DO (Landau, 1992).

Nitrites are very toxic to fish. Available information on safety limits of nitrites (NO_2) is very limited although studies indicate that nitrite may be a significant factor in channel catfish production ponds (Boyd, 1984). During the fall of 1978, a number of fish kills were reported in Mississippi and Alabama (USA) in which fish mortality could not be attributed to low dissolved oxygen, parasites, diseases, or other common causes. All dead or dying fish had "chocolate" coloured blood, which indicated that hemoglobin had been converted to methaemoglobin. Nitrite poisoning results in methemoglobin formation, so nitrite toxicity was suspected as the cause of the fish kills (Ibid, 1984). The suggested maximum nitrite concentration levels for prolonged exposure in hard fresh water is 0.1 mg/L Nitrate (NO^-_3) levels suggested are below 100mg/l

Un-ionised hydrogen sulphide (H_2S) is extremely toxic to fish at concentration that may occur in natural waters as well as in aquaculture farms (Boyd, 1984). It has been demonstrated that concentration of H_2S could result in poor growth of channel catfish (Ibid, 1984). Bioassays of several species of fish suggest that any detectable concentration of H_2S should be considered detrimental to fish production (Ibid, 1984). Even sulphates can be toxic to fish if it is above the allowable maximum limit.

Turbidity is a1so an important water quality parameter, which has to be controlled since high turbidity of water caused by suspended solids, can affect productivity and fish life (Boyd, 1984). It restricts light penetration and limits photosynthesis. A1so, sedimentation of soil particles can destroy benthic communities and smother fish eggs (Ibid, 1984). In certain cases, oxygen deficiency has also been reported as a result of sudden increase in turbidity. The suspended solids may clog digestive organs of planktonic organisms. The gills of fish may be injured by turbid water. Although the effect will depend on the species and the nature of the suspended matter, pronounced effects are seen when the water contains about 4 per cent total solids by volume (Pillay, 1995).

The minimum water quality condition for alkalinity, necessary to maintain fish health should be at least 20ppm (as $CaCO_3$) (Pillay, 1995). The concentration of calcium plus magnesium expressed as equivalent $CaCO_3$ are traditionally taken as a measure of total hardness (Ibid, 1995). Other divalent metals ions also contribute to hardness, but their concentration are usually insignificant in natural waters (Ibid, 1995).

In developing countries, less than ten per cent of the urban wastes are treated, and only a small proportion of that treatment meets acceptable standards (Keating, 1994). By the end of the century, over 2 billion people will lack basic sanitation, and about half the urban population in developing countries will not have adequate waste disposal (Ibid, 1994). This will adversely affect the aquatic life as well unless national environmental protection plans, include targets for hazardous waste reduction.

3.0. MATERIALS AND METHODS.

Site.

The study was carried out at Ethanol Company premises at Dwangwa in Nkhotakota District, Central Region, within latitudes 13°30' S and longitudes 34° 5' E. The study was conducted during the rainy season because it is the time when there is a lot of water movements and the effluent pond usually breaks or floods, with ethanol effluent carried into the lake. The research was conducted before flooding because the rains did not come in time as expected.

This particular site was chosen because the Ethanol plant is near Lake Malawi and there is Dwangwa River passing, just close to the ethanol effluent ponds, to the lake. Therefore, there is a possibility of effluent polluting Lake Malawi through seepage and streams or rivers. See Append. 2.

3.2. Design and layout of experiment.

Six treatments (sampling points) were strategically chosen. The first point was up stream in Dwangwa River as a starting point. The second point was downstream 2 km from the first point in Dwangwa River. Then along the coast in Lake Malawi, there were 3 points equidistant from each other and these were points 3, 4 and 5. Point 3 and 4 were 4 km each from the first point and point 5 was 3 km from the fist point. Sampling point 6 was the last point in the effluent ponds themselves. See Fig. 2 below.

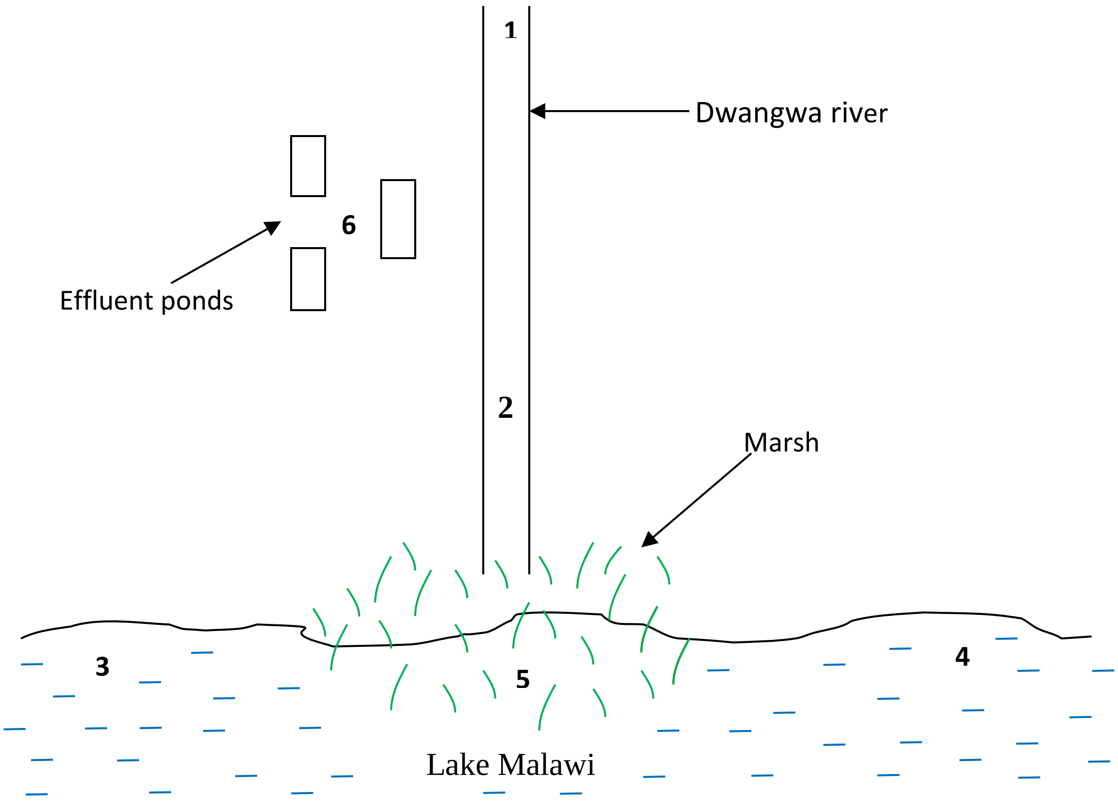


Fig. 2. Lay out of the sampling points in the study area of the Dwangwa Estate.

3.2.1. Data collection

Water samples were collected in sampling bottles from the water profile once a week, for 8 weeks. The samples were analysed for the water quality parameters, within the same week. The water parameters to be measured were, Dissolved Oxygen (DO) Titration method, Biological Oxygen Demand (BOD) using BOD incubator, Chemical Oxygen Demand (COD) using Titration method and fluxing, pH using pH meter (titration), Alkalinity, Acidity using EDTA Titration method. Total solids using Gravimetric method, Turbidity using Secchi disk, Ammonia, Nitrate, Phosphorous using Colorimetric method, Potassium, Calcium using Flame photometer, and Chlorophyll using Fluorometric method.

3.2.2 Data analysis.

The data was then subjected to MSTAT package for analysis. Where significant, means were separated using Duncan's Multiple Range Test. The model used in the analysis is given below:

$$Yij = \mu + \chi i + eij$$

Where: Yij = j^{th} observation at the i^{th} distance.

μ = overall mean of observation.

χi = effect due to distance (i = l, 2, 3, 4, 5, 6)

eij = residual error

4.0. RESULTS AND DISCUSSIONS.

The observations of most selected pollutants for determining pollution on the receiving waters of Lake Malawi, indicates that their levels of concentration are within the tolerable limits except for ammonia. But, the same pollutants analysed from the effluent source (in the ponds where ethanol effluent is damped) show to be toxic enough to aquatic life. However, it was designed that there will be no release of these effluents to water bodies but from the look of things, this does not hold at all. The variation in concentration levels of most pollutants from the entry point downstream towards the lake confirms that the toxic effluent finds its way into the water bodies (Fig. 3).

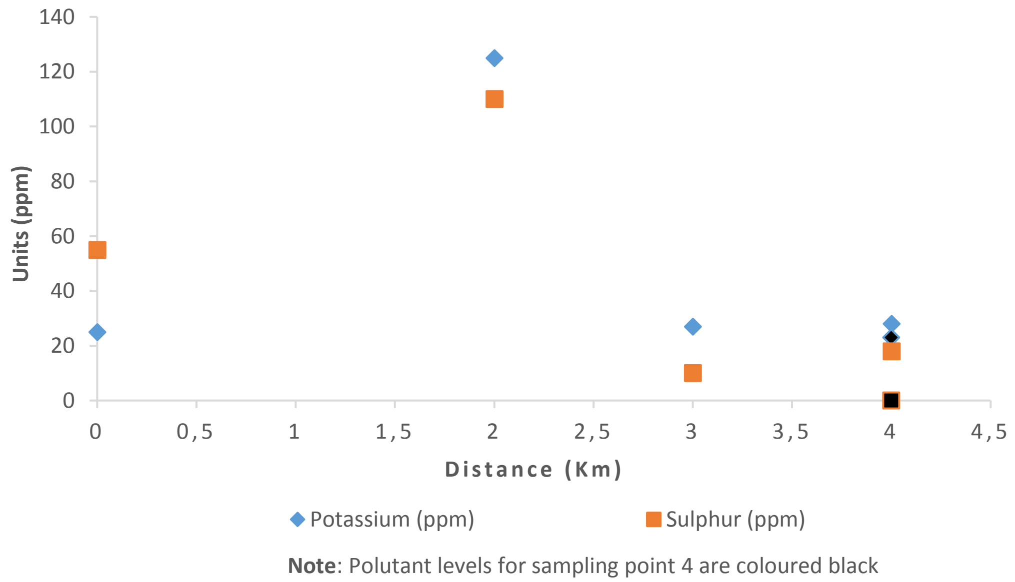


Fig. 3. Levels of Sulphur and Potassium across the sampling points, excluding sampling point 6.

Therefore, there is a danger of polluting the receiving waters of Lake Malawi in the near future, should the way of depositing this effluent not improve.

The average concentration of selected constituents in the effluent from the ethanol plant in Dwangwa, are listed in Table l below. Comparing these results with the standards, the values are considerably higher than the mean value recommended in Malawi, Republic of South Africa (RSA) and Zimbabwe, for industrial wastewater to be discharged or permitted to flow into any water, including private water, whether direct or through seepage or drainage. This is high enough to cause pollution problems. The BODs for example is over 60 times the typical BODs concentration in recommended standards by the WHO and MBS guidelines, 1989. The rest pollutants in this effluent disposed are still well above values considered safe for water contact. As a result the government should really look into it since such discharges of any effluent into the water as they will or are likely to create a nuisance or to render such water harmful, detrimental or injurious to health, safety or welfare of the public or any section of the public or to any user of the water or to any livestock, wild animals, birds, fish or other aquatic life.

TABLE l. Comparison table for values considered safe for wastewater:

CONSTITUENT	EFFLUENT	STANDARD			
		MALAWI	RSA	ZIMBABWE	FOR FISHERIES WATER
Phosphorous (ppm)	18.972	15	-	-	-
Nitrate (ppm)	140.00	50	-	-	<100
Ammonia (ppm)	134.750	-	-	0.5	<.6
Sulphate (ppm)	2500.184	800	-	100	<250
Calcium (ppm)	32.276	-	-	-	-
Potassium {ppm)	73335.061	-	-	-	-
Acidity (ppm)	8341.668	-	-	-	-
Alkalinity (ppm)	4687.501	-	-	-	>20
Temperature ^{O}C	27.402	40	35	25	No big change in temperature
Chlorophyll a (ppm)	0	-	-	-	-
pH	4.912	6.5 - 9	5.5-9.5	6-7.5	6.7 ≤pH≤ 7.5
Turbidity (cm)	0.509	5(NTU)	-	5	-
TSS (ppm)	33527.489	30	25	10	River ≤ 25 and Lake< 3.0
DO (ppm)	0.147	-	75% saturation	75% saturation	≥6
COD (ppm)	255271.043	50	75	30	≤5
BOD mg/l	1550.00	20	-	-	≤5

* A dash (-) indicates that the standard is not yet found.

Source: WHO and MBS guidelines, 1989 and Water Quality Management Course-notes prepared by Dr. Hiroki Eda, 1997, Bunda College.

According to the results shown in Tables 2 and or 3 below, the concentration levels of pollutants were generally decreasing from the source downstream to the lake, with a few exceptions. The concentration levels of pollutants keep decreasing from the entry point downstream in the receiving waters because of dilution, evaporation of same compounds like Sulphur and NH^{4}+ and plant uptake of same substances like phosphorous and nitrates.

TABLE 2. Concentration levels of different water quality parameters between the source and the sampling points.

PARAMETER	SAMPLING POINTS								
	1	2	3	4	5	6	LSD	CV (%)	MEAN
Phosphorous(ppm)	0.34^{b}	0.28^{b}	0.17^{b}	0.18^{b}	0.15^{b}	18.98^{a}	*6.55*	152.28	3.35
Nitrate (ppm)	0.49^{b}	0.66^{b}	0.16^{b}	0.07^{b}	0.09^{b}	140.00^{a}	6.43	21.22	23.574
Ammonia (ppm)	4.04^{b}	2.85^{b}	1.99^{b}	0.09^{b}	1.46^{b}	134.80^{a}	18.58	59.76	24.19
Sulphur (ppm)	52.98^{b}	111.00^{b}	20.89^{b}	0.28^{b}	9.38^{b}	2500.00^{a}	493.70	85.53	449.11
Calcium (ppm)	3.51^{b}	7.79^{b}	7.43^{b}	0.59^{b}	0.60^{b}	32.28^{a}	14.56	130.24	8.70
Potassium (ppm)	26.30^{b}	122.40^{b}	31.47^{b}	25.72^{b}	30.81^{b}	7335.00^{a}	958.60	59.10	1261.96
Acidity (ppm)	33.34^{b}	38.19^{b}	33.34^{b}	37.50^{b}	50.00^{b}	8342.00^{a}	2156.00	117.92	1422.34
Alka1inity (ppm)	188.80^{b}	235.6^{b}	238.50^{b}	179.20^{b}	243.70^{b}	4688.00^{a}	1047.00	84.65	962.20
Temperature (^{O}C)	24.28^{b}	24.27^{b}	27.44^{a}	27.52^{a}	27.20^{a}	27.41^{a}	1.85	5.45	26.35
Ch1orophyll (ppm)	3.28^{b}	5.30^{b}	2.98^{b}	3.72^{b}	9.97^{b}	95.31^{a}	31.68	122.72	20.09
pH	7.09^{b}	7.02^{b}	7.59^{ab}	8.11^{a}	7.59^{ab}	4.92^{c}	0.58	6.38	7.05
*Turbidity (cm)	4.74^{b}	11.01^{b}	55.26^{a}	76.19^{a}	51.82^{a}	0.51^{b}	36.20	84.48	33.35
TSS (ppm)	2320.00^{b}	3368.00^{b}	535.60^{b}	114.10^{b}	127.50^{b}	33530.00^{a}	11000.00	128.37	6665.44
DO (ppm)	7.06^{b}	6.23^{ab}	5.51^{b}	6.72^{ab}	5.73^{ab}	0.15^{c}	1.31	19.56	5.23
COD(ppm)	392.50^{b}	438.90^{b}	308.10^{b}	354.60^{b}	305.00^{b}	255271.04^{a}	5297.00	96.18	42845.04
BOD (mg/l)	27.43^{b}	39.29^{b}	28.58^{b}	20.72^{b}	36.72^{b}	1550.00^{a}	92.17	76.12	94.21

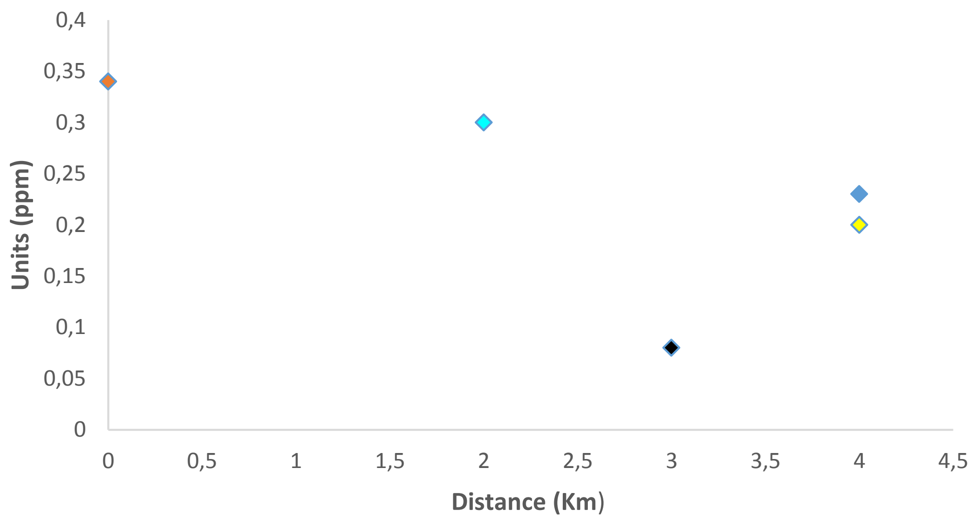
Means followed by different letters abc on each point in a row are significantly different at $P< 0.05$.
*The values do not really indicate the turbidity of water because the water was too muddy since it was raining

TABLE 3. Concentration levels of water quality parameters at different sampling points

PARAMETER	SAMPLING POINT							
	1	2	3	4	5	LSD	CV (%)	MEAN
Phosphorous (ppm)	0.34^{a}	0.28^{a}	0.17^{b}	0.18^{b}	0.14^{b}	0.09	28.30	.22
Nitrate (ppm)	0.48^{ab}	0.65^{a}	0.16^{ab}	0.07^{b}	0.09^{ab}	0.56	139.96	.29
Temperature (^{O}C)	24.27^{b}	24.27^{b}	27.43^{a}	27.51^{a}	27.20^{a}	1.06	2.93	26.14
Chlorophyll (ppm)	3.27^{b}	5.30^{ab}	2.98^{b}	3.71^{b}	9.97^{a}	4.71	40.59	5.05
pH	7.09^{ab}	7.01^{b}	7.59^{ab}	8.10^{a}	7.59^{ab}	1.04	6.01	7.48
*Turbidity (cm)	4.74^{b}	11.01^{ab}	55.25^{ab}	76.19^{a}	51.81^{ab}	67.71	73.90	39.80
TSS (ppm)	2320.00^{ab}	3368.00^{a}	535.60^{b}	114.10^{b}	127.50^{b}	2193.0	122.16	1292.99
DO (ppm)	7.05^{a}	6.23^{ab}	5.50^{b}	6.72^{ab}	5.72^{ab}	1.45	16.71	6.24
COD (ppm)	392.50^{ab}	438.90^{a}	308.10^{b}	354.60^{ab}	305.00^{b}	118.20	23.66	359.83
BOD (mg/1)	27.43^{ab}	39.29^{a}	28.57^{ab}	20.71^{b}	36.71^{ab}	4.04	37.40	30.54

Means followed by different letters ab on each point in a row are significantly different at $P< 0.05$.
*The values do not really indicate the turbidity of water because the water was too muddy since it was raining.

However, some pollutants are not following this trend because of some experimental errors. Besides, there are sugar and tobacco plantations up stream, some of the fertilisers and other chemicals applied could be flowing into the rivers through seepage or runoff, causing high concentrations of same pollutants up steam, before the effluent entry source. For example phosphorous (Fig. 4).



Note: Phosphorous level for sampling point 4 is coloured yellow

Fig. 4. Levels of Phosphorous across the sampling points, excluding sampling point 6.

The pollutant concentration levels are also affected by siltation of upstream erosion since Dwangwa is at a delta. Nevertheless, this study shows that ethanol effluent has the potential to pollute water, since the results obtained show that it has more impact on the concentration levels of pollutants including BOD, COD and DO in the water. Therefore the water quality of the receiving waters can be affected, rendering poor fish growth and even fish kills, with time. Deposition of ethanol effluents should be targeting for the hazardous waste reduction. Otherwise, in the near future ethanol effluents in addition to other deposits from up streams can significantly pollute the aquatic environment in the receiving waters of Lake Malawi.

Effluent from ethanol distilleries is a potential hazardous pollutant if left to enter large bodies of water, mostly because it contains a lot of TSS of 33527.489 ppm which renders the effluent a high BOD of 1550 ppm and high COD of 255271.043 ppm (Tables 2 and or 3). This may cause oxygen depletion for normal aquatic biota. It is also very important to note that it does not carry any toxic chemical (heavy metals) although it originates from a sugar refinery as molasses. To the dilution molasses is added urea and diammonium phosphate (DAP) which themselves are nutrients to the soil. See figure 1. However, ethanol effluent becomes toxic to aquatic life, depending on their concentration levels in the water.

The Sulphuric acid also added in the fermentation is converted to various Sulphates in the process and may also pollute the water if effluent is not taken care of during deposition resulting in poor growth of fish like channel eat fish (Boyd 1984). Bioassays of several species of fish suggest that any detectable concentration of H_2S should be considered detrimental to fish production (Ibid, 1995), but for Sulphates the toxicity may result above 250 mg/l (HACH Company, 1987). The Sulphate data obtained in this study appear lower than the recommended maximum limit of 250 mg/l. On average, the receiving waters contain 38.99 ppm, which is still within the allowable maximum limit of 250 ppm. According to HACH Company (1987), the water quality around this area is still unpolluted with sulphates.

The levels of Calcium are detected to be below the recommended maximum limit of 200 mg/l by WHO (1989). This is good for human beings and also for fish. According to literature, fish requires high levels of calcium for bone formation, good growth and good survival, Calcium also reduces the toxicity of hydrogen ion, ammonia and metal ions. Point 2, just after the disposing point, has the highest levels of Calcium and decreases as you go further away from the source, downstream.

The DO concentration varied with distance in a river downs tream from the industry discharging wastewater with high BOD of 1550 ppm. This scenario is not new and has been reported by Laws (1993) in Hawaii. The DO concentration increases downs tream because the oxidation of the organic substances in the wastewater by microbes initially consumes O_2 faster than the exchange of O_2 between the stream and the atmosphere can resupply O_2. Therefore, the O_2 concentration in the water drops rapidly downstream from the wastewater outfall. Due to metabolic activity of the microbes, the concentration of oxidizable organic wastes steadily decreases with increasing distance from the outfall. Since the respiration ratio rate of the microbes is correlated positively with the concentration of their food supply, the rate of microbial O_2 consumption also steadily decreases with distance from the outfall. The next influx of 02 from the atmosphere to the stream is proportional to the difference between the O_2 concentration at 100% saturation (Landau, 1992). However the results in this study indicates lower oxygen concentration being experienced at sampling point 3 and 5 downstream than upstream near the discharging point (Figure 7). This may be because point 3 is near the damping area for effluents from Dwangwa Sugar Co-operation within the lake, and on point 5, the water is quite or nearly stagnant as a result water contaminants accumulate around the area. This result into high metabolic activity of microbes hence BOD increases, resulting into low oxygen concentration of 5.5 ppm and 5.72 ppm respectively (Fig. 5). However, the oxygen concentration on these two points (3 and 5) did not go below the allowable minimum limit of 5 ppm (Ibid, 1992). Although at the same time this allowable minimum limit is not true for some fish species, for example salmons are very sensitive to drop in DO as compared to others like gouramis or catfish. Therefore, it may be concluded that the actual level of oxygen needed by particular species tends to vary greatly with the species and size of the animal, temperature, and stress.

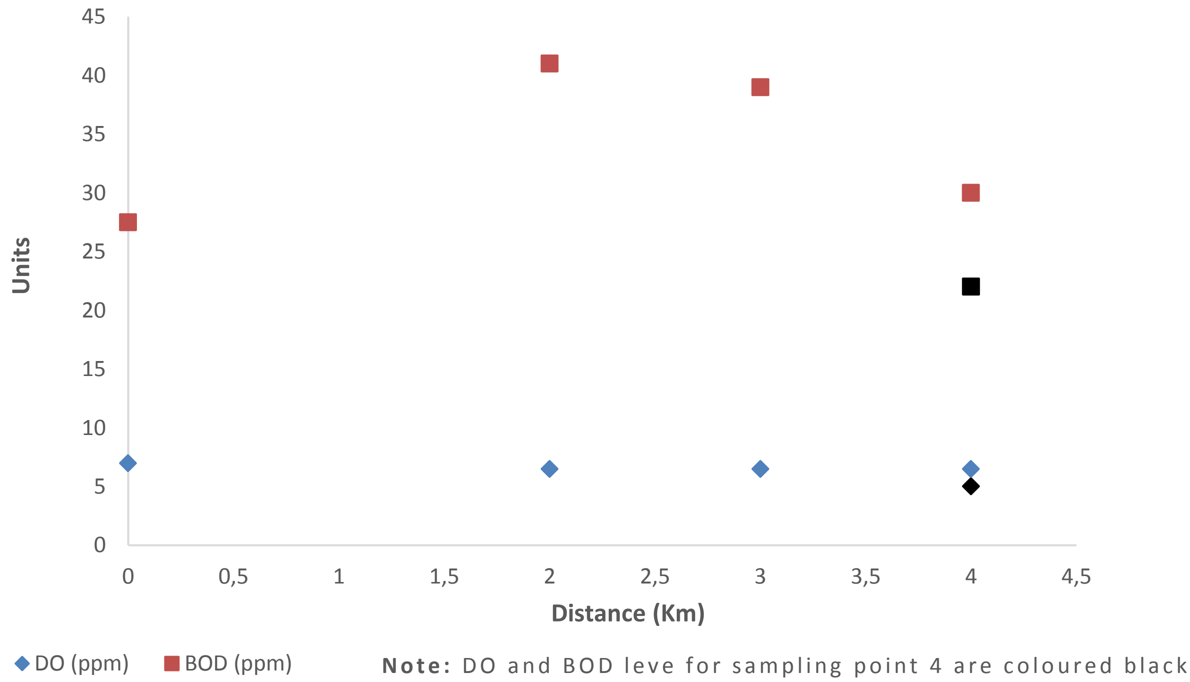
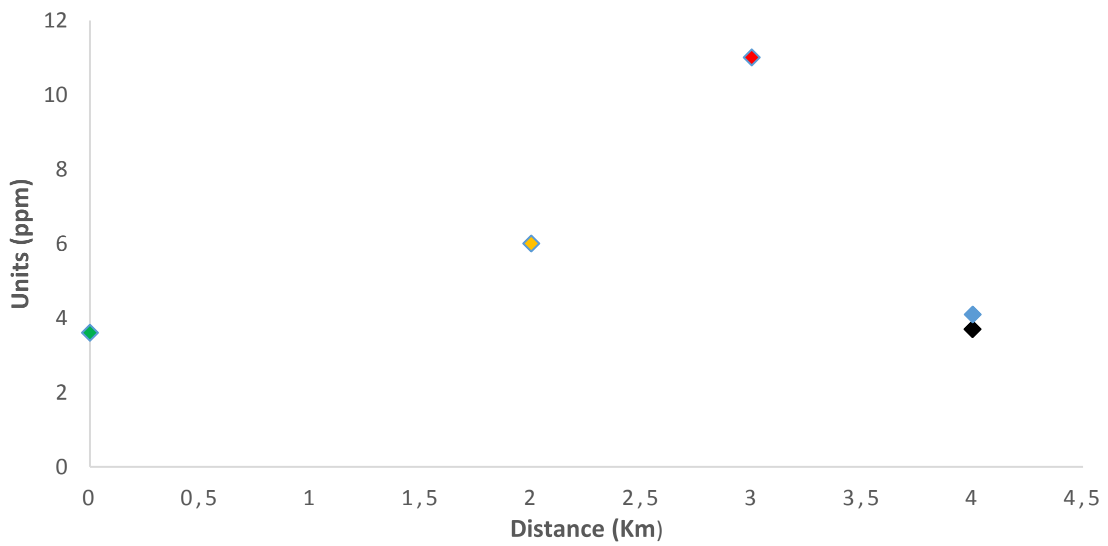


Fig. 5. Levels of DO and BOD across the sampling points, excluding sampling point 6

For purpose of biological treatment, desirable pH range is 6.5 to 8.0 (Mccubbin, 1983) and the pH values found in the receiving waters are within the range. Therefore, these results indicate the effectiveness of water mixing process in dispensing the effluents and in promoting oxygen exchange within the atmosphere because there would be a considerable potential for anoxia to develop if the receiving waters were not well mixed. It is likely that ethanol effluent discharged into a confined body of water would create serious oxygen depletion problems since its pH of 4.5 is below the desirable range.

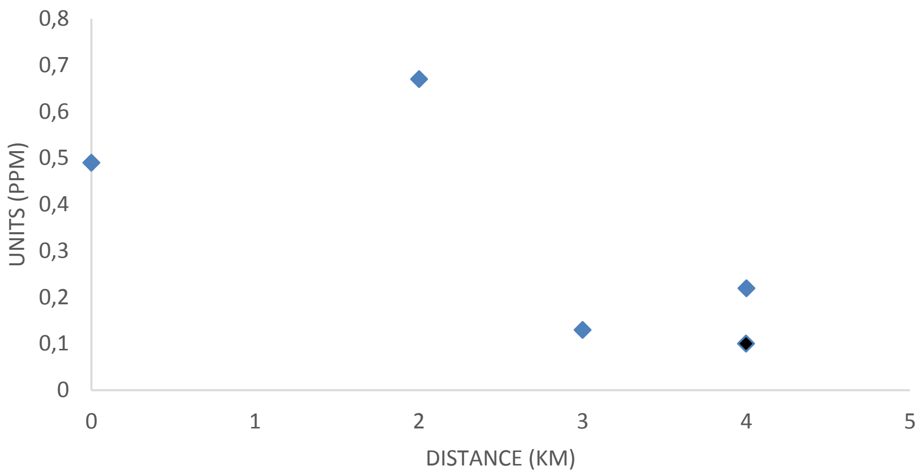
Chlorophyll a is highest at sampling point 5, 3 km from the starting point (Fig. 6). At this point, the water is nearly stagnant and water contaminants accumulate. Plant growth in such waters is encouraged hence more chlorophyll. That is why eutrophication is experienced or advancing around this area towards the lake. Hence, with time, if preventive measures are not considered, a secondary effect of eutrophication may result in a greater DO fluctuation that can kill respiring organisms. Besides ageing of the lake may also result especially around point 3 of sampling, where the Dwangwa River enters the lake (Append. 2)



Note: Chlorophyll leve for sampling point 4 is coloured black

Fig. 6. Levels of chlorophyll across the sampling points, excluding sampling point 6

The presence of nitrate and sulphate shows that there are some traces of nitrite and Sulphites, since nitrate and Sulphates are usually present because of the process of oxidation of nitrite and Sulphite, respectively. The nitrate concentration varied (decreased) (Table 2 and or 3) with distance in a river downstream from the industry discharging wastewater with very high nitrate level of 140 ppm, except for sampling point 1 which is up stream of the damping area. The high nitrate level detected at sampling point 1 (starting point) of 0.49 ppm could have been a contribution from agricultural activities in the catchment, where fertilizers are used (Fig. 7).



Note: Nitrate leve for sampling point 4 is coloured black

Fig. 7. Levels of nitrate across the sampling points, excluding sampling point 6

However, on average the nitrate level detected in the receiving waters is below the suggested maximum allowable limit of 100 mg/1 (Boyd, 1984). Hence, the concentration levels of N0-3 within the area of study is within the tolerable limit for the growth of fish including other aquatic organisms and plants.

Nitrogen and phosphorous are the nutrients that plants most often run out of first, and are therefore called limiting nutrients though they can also be toxic to plant, and especially to animals, when they are present at high levels of concentration. In this study, the phosphorous levels detected cannot give problems to aquatic life because the detected levels are within the acceptable limit.

Again, there are certain organic nitrogen molecules that are rare in aquatic systems; the most toxic is ammonia, which is present in the area under study. Ammonia and less toxic ammonium are in an equilibrium that depends on pH. The more acidic the water is, the more free hydrogen ions that are present, the more the equilibrium shift from NH_3 to NH_4^+. But in this case, it is the other way round because the waters observed are not that acidic (Table 2). As a result, ammonia observed can be toxic to fish for short-term exposure. Even the levels detected for ammonia are generally ranging between the suggested toxic concentration of 0.6 and 2 mg/l, for most of the species in water (Smith and Piper, 1975).

Temperature readings were considerably stable in all sample sites where mean values ranged from 24.267 to 27.510°C (Table 2 and 3).

Secchi disk visibility within the lake was generally higher at sampling point 3 than 4, implying that turbidity was higher on sampling distance 3 than 4. This imply the direction of water movement as indicated by the movement of the orange, which was put in the lake; thus the water generally flows southward, hence it causes considerable amount of turbulence on sampling point 3 than 4. Again, it could be because sampling point 3 is near the disposal point for Dwangwa Sugar Cooperation in the lake. Even the concentration levels of the selected pollutants are indicating to be generally higher than on sampling point 4 (Table 2 and 3).

The data obtained on alkalinity (Table 2), comparing with what Landau (1992) reported shows that this water is hard. The alkalinity obtained in terms of calcium carbonate is above the required minimum limit of at least 20ppm (Pillay, 1995). Hence, the water quality condition for alkalinity, necessary to maintain fish health is acceptable.

5.0. CONCLUSION.

According to the findings of this study, the levels of pollutants in the receiving waters decreases towards the lake and their concentration levels are still below the hazard limits. However, the disposed ethanol effluents are highly toxic because they contains unrecommended concentration levels of pollutants, for effluent that will be in contact with any water body. Therefore continuous disposal of such effluents may lead to high levels in the receiving waters over time, which could be widely toxic to plants and aquatic biota that later may affect human life through feeding levels. It is therefore seductively easier to accommodate them by simple disposal means, with a continuous monitoring, essential to check on their levels.

Besides, common people's observations about fish quality may be reflected; that is, how direct or indirect are the people to the problems. As of now, the people around the area can continue using the water normally as before because the results in the receiving waters indicate that the water quality is still good for both people and all aquatic life including fish, though with a little more care when using water, especially in Dwangwa river near the disposal site (downstream). For instance, drinking water should be boiled. But no one should use the water from the effluent ponds since the concentration levels of all the pollutants analysed in the effluent are discovered to be toxic to life (toxic to human and all aquatic life, including fish). Therefore, the Company should take precautions as indicated in the recommendation below to avoid polluting the water. Otherwise, if the prevailing conditions of disposing the effluent continue then with time the receiving waters will be polluted.

6.0. RECOMMENDATIONS.

Effluent from ethanol distilleries is a potential hazardous pollutant if left to enter large bodies of water, mostly because of its high oxidation demand. Therefore, ethanol effluent needs to be treated or handled downstream carefully to avoid polluting the environment. The company can avoid polluting the environment by using the effluents economically as follows:

l. Fertiliser substitutes.

a. The effluents can be used as a direct fertilizer, so long it is diluted with copious amount of water (ratios of 40:l, water: effluent) and use it for irrigation, though it should be used with precautions of avoiding clogging the soil. For example, at the time of sampling it was observed that Ethanol Company was sending its effluents into the sugar fields (by diluting the effluent). However, over long use, the high TSS in the effluent will clog the soil and starve it of oxygen.

b. Extraction of potassium sulphate (K_2SO_4) from the ash for possible sale to Optichem or other firms producing mixed fertilizers. K_2SO_4 can be made from ethanol effluent sludge as follows (Fig. 8):

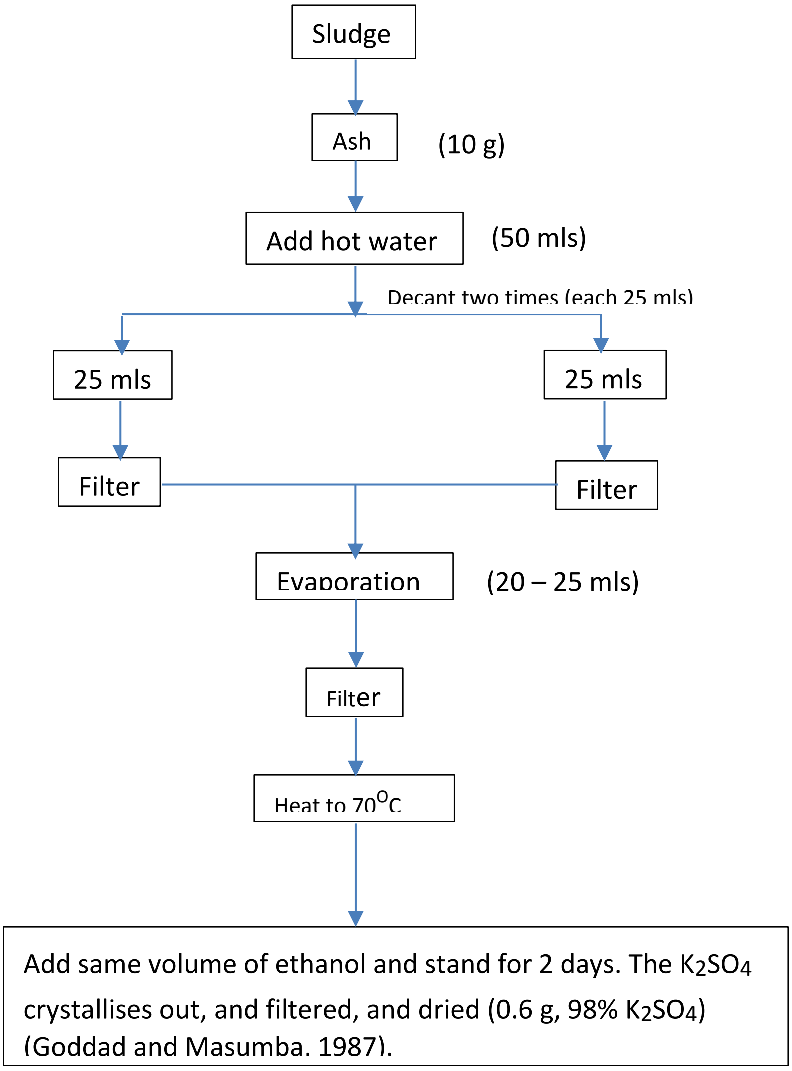


Fig. 8. A diagram illustrating K_2S0_4 extraction from ethanol effluent sludge.

This will help to reduce problems on the fertiliser market.

2. Livestock feed

   Distillery effluent from fermented molasses can be used as animal feed. For instance rumivite can be made and sold to cattle farmers. Therefore, this can boost livestock industry in Malawi.

3. Fuel

Ethanol effluent can be used as a fuel. For example, making of pellet, (It has high calorific value) and used as fuel in boilers just the same way coal is used. This can reduce costs, therefore economical for the company. See illustrations on pellet formation below, (Fig. 9).

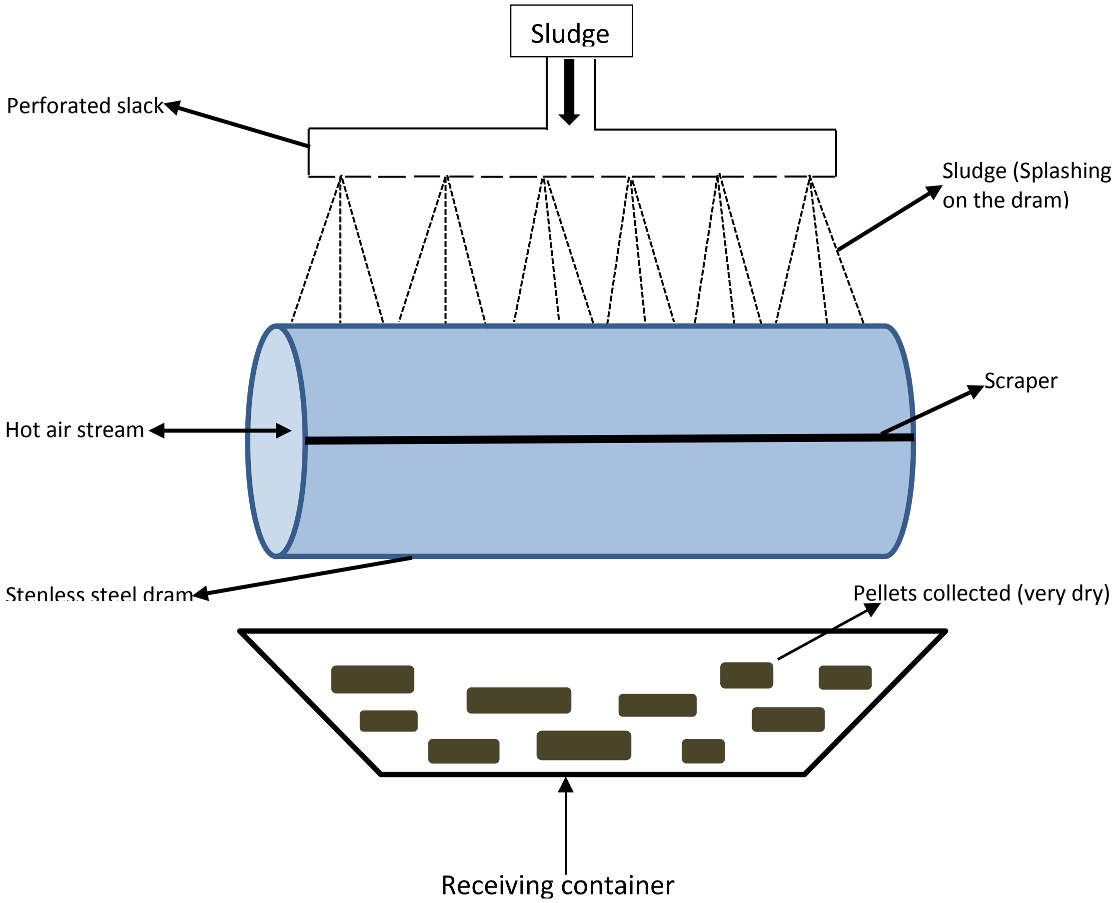


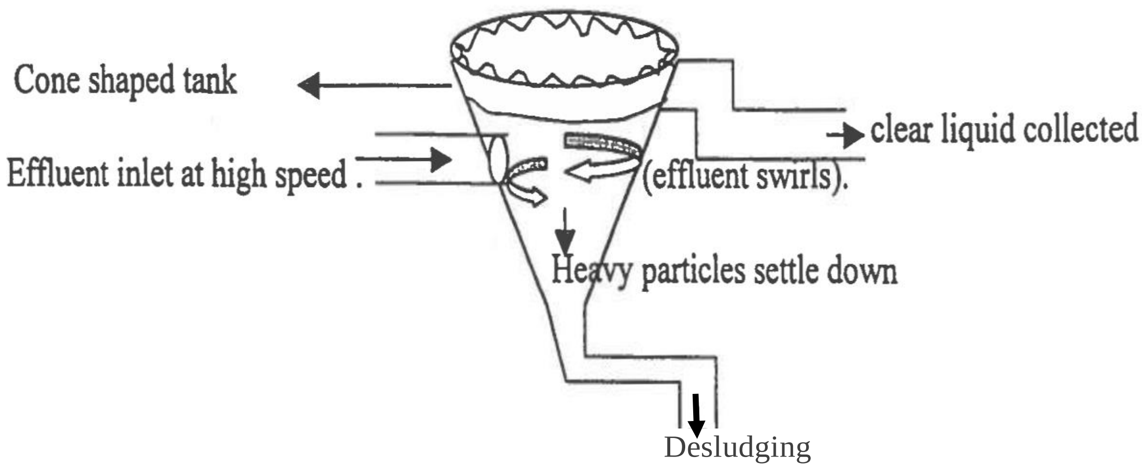
Fig. 9. A diagram illustrating pellet formation for fuel

4. Dust reduction and binding

Effluents can be used as dust suppressant on earth or gravel roads and because of the ash and glycerol in the effluent, not only does it suppress the dust, but also bind the loose gravel together giving the road a false bitumen look – if compaction is done properly. However, this should be done with careful measures because of ethanol effluent's acidic pH, since it can corrode metal parts of the cars or during rainy season, they may flow into the lakes or rivers and may cause pollution.

5. Recycleration, that is moving towards zero discharge

During production of ethanol, molasses need to be diluted using fresh water from the lake (raw water) with its pH set at 4.5 by using Sulphuric acid. Therefore, decanted fluid (after clarifying it) can be used, instead of using raw water for dilution. This can be very economical because the decanted water is already or close to pH 4.5 as a result little or no need to add acid for acidifying the water to pH 4.5 (bacteria is suppressed at. pH 4.5, therefore yeast grows best, no competition). See illustrations on how to recover water (clear decanted fluid) for dilution of molasses (Fig. 10).



(Sludge collected for making either fertilizer, livestock feed, or for fuel, as indicated above).

Fig. 10. A conical shaped tank illustrating how to recover water.

6. Biogas (methane) production

It can also be helpful if the Company can re embark on biogas production from the effluent should money be available though it was discontinued. This is a good idea because it is one way of pretreating the effluent before disposal into water streams. For instance, - pH increases, that is, can increase from 4.5 to 8.

- Reduction of COD and BOD

With biogas effluent, there would be little or no need of diluting it for irrigating fields.

Therefore, to avoid effluent from affecting the water quality of the receiving waters; the management at Ethanol company responsible for effluent disposal should take into account such recommendations as outlined above and enhance on how to improve the ways of disposing effluent. Otherwise, in the near future, if such effluents continue to be in contact with water bodies, the aquatic environment in the receiving waters will be polluted.

However, I would also recommend that more research that is extensive be carried out in the future, but now it should be done together with the Ethanol Company. That is, the Company should make sure effluents do not spill out as they dispose them and they should renovate there ponds or mend them now and then, just to make sure there is no migration of effluents to the water. Besides, the factory should follow the way of disposing their effluents as originally planned. Filling of the ponds should be done on a rotation basis whereby pipes are routed to another when one is full and so forth, by the time the last pond is being filled the first few are already dry -ready for cycle 2. For obvious reasons, this technique can only be effective during the dry season; thus, the Company should make it a point of producing only during dry season (operating season). This can also give time to service the operating machines and do all the necessary maintenance required for effective production every year. This research can be more conclusive if the second phase can be done. It can be my research work during masters and the results of this study could be used to ascertain if the recommended ways of reducing pollution by ethanol effluent would be of any help to effectively support the aquatic life in the receiving waters of Lake Malawi.

REFERENCE.

Boyd C.E., *Water Quality in Warm Water Fish Ponds*. 1984, Aubum, Alabama: University of Agricultural experiment station.

Corbitt R.A., *Standard Handbook of Environmental Engineering*. 2nd ed. 1999, New York: McGraw-Hill Professional.

Edward A.L., *Aquatic Pollution*. 2nd ed. 1993, Honolulu, Hawaii: University of Hawaii.

Erichsen J.J.R., *Fish and River Pollution*. 1st ed. 1964, London: Butterworth.

Home A.J. & Goldman C.R., *Limnology*. 2nd ed. 1994, New York: McGraw-Hill Professional.

Henry J.F., Talib, A. & Ford k., *Hand Book of Biomass Conversion Technologies for Developing Countries,* USA: ONUDI.

Keating M., *The Earth Summit's Agenda 21, Agenda for change*. 2nd ed. 1994, Geneva, Switzerland: Center for our common future.

Jobling M., *Environmental Biology of Fish*. Fish and Fisheries Series Vol. 16. 1995, London: Chapman & Hall.

Maree J.P., Dafana D., Mbonjani D., Van Tonder G.J. & Millard P., *Development of a limestone process to neutralise acid effluents originating from a phosphate fertilizer manufacturer*. In: Conference proceeding, Biennial Water Institute of South Africa (WISA), Vol. 1, pp. 1 – 10.

Pillay T.V.R., *Aquaculture development: progress and prospects*. 1994, Great Britain, Cambridge: University of Press.

Pillay T.V.R., *Aquaculture Principles and Practices*. 1st ed. 1995, Oxford: Blackwell publishing.

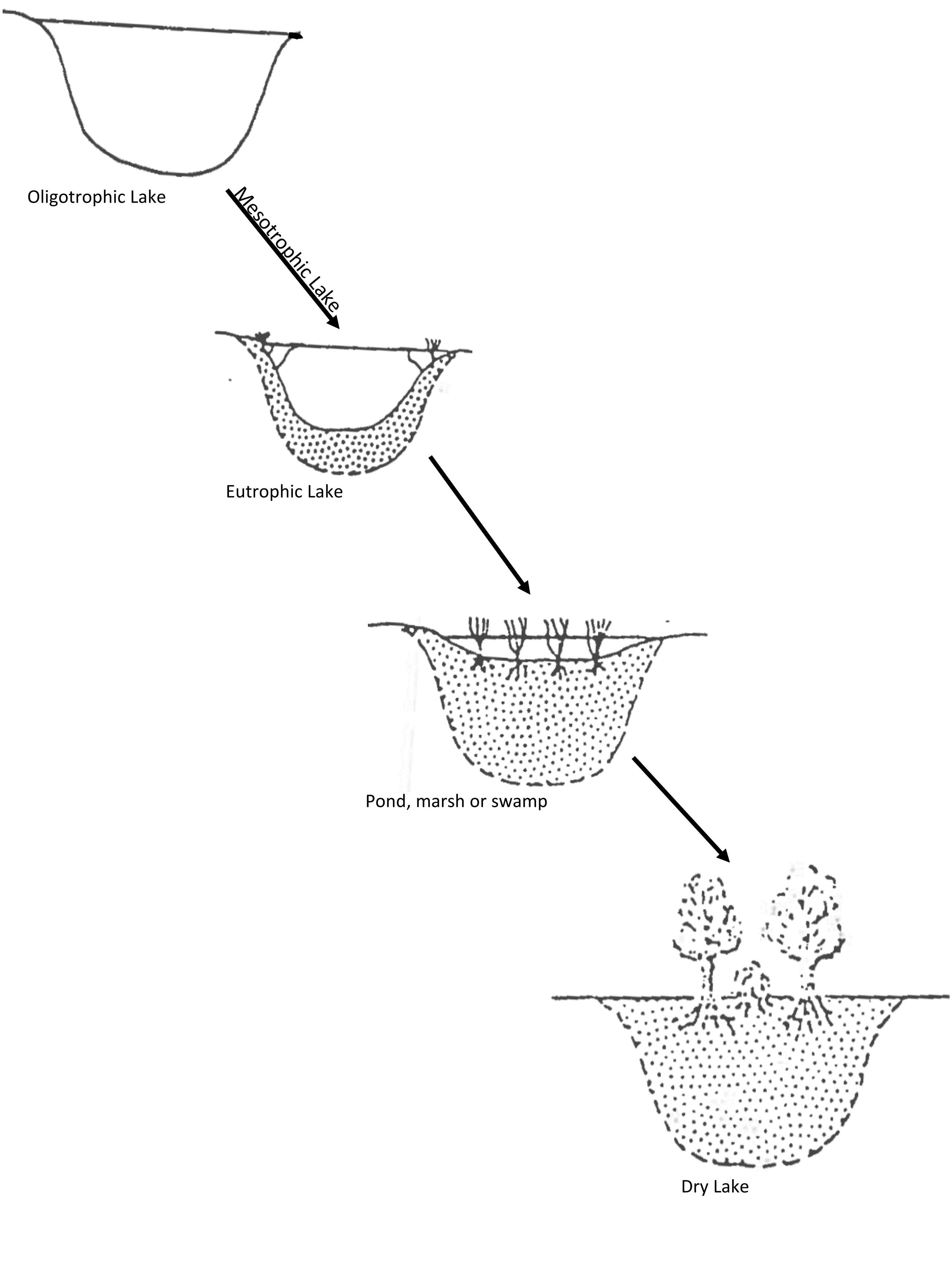
Piper R.G., McElwain I.B., Orme L.E., McCraren J.P., Fowler L.G. & Leonard J.R., *Fish Hatchery Management*. 1982, Washington, D.C: United States Department of the Interior, Fish and Wildlife Service.

Ramalho R.S., *Introduction to Wastewater Treatment Processes*. 1977, New York: Academic Press.

South African Sugar Technologists' Association, *Laboratory Manual for South African Sugar Factories Including the Official Methods*. 3rd ed. 1985, Interpark Natal, Pietermaritzburg: Mount Edgecombe.

Tchobanoglous G. & Schroeder E.D., *Water Quality: characteristics, modeling, modification*. Water quality management Vol. 1. 1985, Reading, Mass: Adison-Wesley.

Appendix 1: Aging of the Lake



Appendix 2: Map showing area of study