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- Mr. Kamizhi (Plant Manager-KSTP)
- Mr. Kasengele, J. (S/Technician-Geochemical lab, UNZA)
- Mrs.Sichilima, L. (Analyst-Geochemical lab, UNZA)

PROJECT TEAM

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1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

The Kafue River is one of the largest rivers in Zambia. It is located inside Zambian territory and contributes an estimated 12% of basin flow at its confluence with the Zambezi River. By virtue of it's location and course that is, where all major industrial towns and centers are located, the river has become the most important and most economically utilized river basin in the country. For this reason, the Kafue River deserves to be protected from pollution.

As there are several industries operating in the area, AREZM's important mandate is to help prevent this potential source of pollution and make as many stake holders as possible aware of the current situation and the consequences of any pollution occurrence. In this case AREZM is also focusing on the exacerbated degradation of the KRB's ecological system and water quality, which is threatening both human and other forms of life. This is being done with prior knowledge that pollution of water deprives people of their human right of access to clean water and sanitation.

Suggested possible means to try and evaluate the extent of pollution of the KRB will be apart from chemical analysis of possible pollutants, community based self-monitoring and enforcement strategies. In so doing, the level of environmental consciousness of the community is being assessed.

The criterion for justifying and pointing out the acceptable level of effluent discharge by these industries is their compliance to Environmental Council of Zambia set standards.

1.2 ECZ REGULATIONS

In Zambia, the discharge of effluent and wastewater into the aquatic environment is regulated by The Water Pollution Control (effluent and waste water) Regulations, 1993 (ECZ Regulations) issued through Statutory Instrument No. 72 of 1993. According to these regulations, aquatic environment has been defined as all surface and ground water, but does not include water in installations and facilities for industrial effluent, sewage collection and treatment. The third schedule (Regulations 5(2)) of these regulations gives the Table of Standards (Limits) for the Effluents and Waste Water. These standards give the acceptable quality of effluents and wastewater to be discharged into aquatic environments like the Kafue River.

1.3 DESCRIPTION OF THE STUDY AREA

In this survey, only the industrial area of Kafue town is under consideration. The Kafue industrial area is located in the central part of the town and comprises such industries as those out lined in the table below. In the table, a particular industry's location and products are listed:

NAME OF INDUSTRY	LOCATION	MAJOR PRODUCTS
Nitrogen chemicals of Zambia	Kafue Industrial Estate	Ammonium Nitrate (sold to Lee Yeast). Ammonium Sulphate and compound fertilizer (N, P, K), Nitric Acid, Sulphuric Acid, Liquid Ammonia, Carbon Dioxide and Methanol.
Bata Leather Tannery	Kafue Industrial Estate	Finished Leather for sale
National Breweries of Zambia	Kafue Industrial Estate	Opaque beer (shake shake), Drags (Husks used as stock feed) and compound Yeast
Lee Yeast	Kafue Industrial Estate	Yeast
Kafue Textiles of Zambia	Kafue Industrial Estate	Cotton and different types of clothes
Kafue Sewage Treatment Plant		
Kafue Chemicals of Zambia	Kafue Industrial Estate	Sodium Silicate, Sodium Sulphate and Hydrochloric Acid.

2.0 OBJECTIVES OF THE CURRENT WORK

The objectives of AREZM's present study were to

- Collect and review work done in the KRB
- Undertake on the spot checks at industries and institutions discharging effluents into the KRB.
- Hold consultation with the KRB communities, industries, institutions etc.
- Collect data on composition of effluents and concentration of each component at some selected operating companies.
- Collect data on the flow rates of the discharged effluent into the KRB.
- Advise the industries concerned of the findings and request for remediation.

3.0 METHODOLOGY

In order to ensure that the above objectives are realized, a field program was made which comprised several activities. These activities include literature review on publications done on similar work, plant familiarization of each industry, sample collection, laboratory analysis of the samples, data treatment and follow-up interviews with company and council officials.

4.0 LITERATURE REVIEW

A number of publications were consulted to get the feel of the work at hand and to have a general picture of what was expected. These included published material on similar work done in the past, Industrial manuals as well as scientific books which served as references for certain concepts. The following activities were generally found to be the major sources of pollutants to the Kafue River:

4.1 Agriculture

Agricultural activities are either point or non-point sources of nutrients. Kaleya smallholders, Garner farms, Nakambala sugar estates, cere farms and Nanga farms located in the upstream section contribute nutrients to the Kafue River. Nutrient-rich run off waters from the farms find their way into the Kafue River through ground water canals and streams or floods. Nakambala estates are the largest contributor.

4.2 Industry

Discharges from industrial activities are both point and non-point sources. In the Kafue area effluents from industries enter Kafue River through Chilumba stream. During the rainy season, the local people use up the effluents to water their vegetable gardens that are located between the industries and the river. During the rainy season, the nutrients reach the KR through Chilumba stream and other low-lying channels.

4.3 Municipal services

The municipal activity identified as the major contributor of nutrients in the Kafue River is the Kafue Sewage Treatment plant. With 20,000 of wastewater received per day, the facility is estimated to be discharging to the river about 12 Tones of Ammonia, 140 Tones of nitrates and 12 Tones of phosphorous per year through Surface water. Visual inspection of the discharge points as well on-site analysis using test strips suggest an abundance of nutrients at the site. The water hyacinth mats in the area surrounding the discharge point are composed of healthy looking plants.

4.4 Kafue fisheries

The concentration of nutrients along the KR generally increases between the stations located up stream of the site and the down stream station. The appearance of water hyacinth on the fisheries suggests an abundance of nutrients. The plants are generally healthy and form dense mats. (Source: ECZ-KRNL, Summary Report Volume1, 2000: P 54). And the following are the problems associated with area of interest in the Kafue river Basin:

(1) **Eutrophication** of the river through industrial waste such as well as sewerage disposal, are said to cause a decline in fish population. During an interview with the local people, the people complained about the observed decline of fish population and the apparent change of taste of the fish. The people went on further and mentioned that there

was an epidermal colour change of the fish. From this observation, people are skeptical about eating the fish they catch from Kafue River.

On this basis, we concluded that any factors responsible for reported decline in the fish population should have more to do with chemical than social ones. By social, we mean that over catching of fish by the local people can also contribute to the same decline of fish population especially if not regulated.

(2) The Kafue weed (Sylvania Molester) rich in Nitrogen, Phosphorous and Potassium affect water quality, aquatic life, accelerated sedimentation, posses a danger to the generation of electricity, economic livelihoods of the surrounding communities and the survival of animals in the natural reserves.

(3) During the rollback malaria survey, it was discovered that cases of malaria were on the increase especially in this part of the town.

(4) The by-pass (untreated sewage) and the discharge from blocked sewer lines which flow straight into the Kafue river contains high levels of heavy metals, toxic chemicals and silt. When there is high concentration of calcium, there is a corresponding increase in snail's population. This is a very serious cause for bilharzias. It also contributes to high levels of total water hardness.

(5) In the present survey, attention will paid to the contribution by Industrial and municipal activities to the above mentioned problems.

5.0 PLANT FAMILIARIZATION

This was a deliberate program, which lasted a maximum of three days in each industry. It was intended to enable AREZM staff to know more about a particular industry's operations and to identify the best sampling points. Having had gone through the industrial manuals, this period gave us an opportunity to see what we read from manuals being put in practice.

5.1 SAMPLING AND ON-SITE TESTING PROCEDURES

All the effluent from the industries under consideration is either directly discharged or finds its way into the nearby Chilumba stream. The Chilumba stream directly leads to the Kafue River. For this reason, points of discharge of effluent from each industry were of great significance. Samples were taken immediately upon discharge from the industry's effluent plant and just before entry into the Chilumba stream.

A total of eleven (11) samples were collected from strategic points around the area under consideration. Though Lee yeast was not fully under AREZM's present consideration, three (3) samples were collected from one discharge point from Lee yeast. This point was considered to be significant in that there is need to check the contribution made by the industry to the total effluent discharged from the industries since the effluent from all the industries mixes at some point along the Chilumba stream.

Results obtained from the samples have been reported. Three samples were taken in order to a more representative result. Six sampling points were identified from Bata Tannery. These were two outlet points from the lagoons 3 and 4, the sludge drying beds as well as the three evaporation lagoons. The sludge drying bed was analyzed for Chromium. Considering the large volume of the sample bodies, four samples from each of these sampling points were taken. Therefore, from an estimated 1500 liters of effluent, four liters of sample were obtained from discharged effluent daily for a period of one week. This was done to ensure that a representative sample was obtained and ensure confidence in the results obtained.

Only on-site measurements were taken at Kafue Chemicals. These included volume flow rate, colour and turbidity. At Kafue Sewerage Treatment plant (KSTP), four sampling points were identified: Discharge from both Old and New treatment plants, Combined (old and new) treatment plant effluent and the discharge into the Kafue river from the last oxidation pond. Here, the sample volume and volume flow rate was of paramount importance. This is because a high volume flow rate of sample requires frequent sampling. Therefore, two samples were obtained daily for period of two weeks spent at the plant from each of the sampling points identified. Half-liter samples were taken from the treatment plant discharge while ¾ liter sample volume was obtained from the discharge into the Kafue River. This was so because of the high flow rate of effluent.

5.2 ACTUAL ON-SITE TESTING

Using test strips, certain parameters like nitrates and metals (Copper, Zinc, Lead and Nickel) were read off at the sampling sites. This was done to avoid deviations commonly encountered as a result of contamination of the samples. It was also done to form a comparative ground for laboratory results. The procedure for using test strips is as out lined below:

Five (5 ml) of the test sample was prepared and acidified with nitric acid. Then two test strips of nickel, copper or nitrate were prepared and the reaction zone of each test strip was immersed in the test sample acidified with nitric acid. The excess liquid was then shaken off from the strips and then the strips were allowed to stand for 30s. There after, the colour change of the reaction zone of the strips was compared with the colour scale on the surface of the strip container.

The colour coinciding with that on the reaction zone was read off and it’s value noted. However, the procedure for analyzing lead and zinc was slightly different. The test tube was firstly rinsed with the solution to be tested. As before, 5 ml of a testing sample was prepared then acidified by a few drops of concentrated nitric acid. Ten drops of either lead or zinc testing reagent was added and swirled carefully. The test strips of zinc and lead were then prepared and their reaction zones were immersed in the sample for 1s. The excess liquid was shaken off from the strips. After two minutes, the colour change on the reaction zone was compared with that of the colour scale on the surface of lead/zinc strip container.

It should be noted that two strips of each analyte were used in order to obtain a representative reading.

6.0 OVERVIEW OF THE INDUSTRIES UNDER CONSIDERATION

6.1 BATA TANNERY

Tanning is the process by which animal hides are converted into leather. The hides, after removal of flesh and fat, are treated with chemicals, which cross-link the microscopic collage fibers to form a stable durable material. Bata Tannery is located west of Kafue town opposite Kafue textile of Zambia. The industry was established in 1974. The Tannery produces leather from animal hides by the process known as tanning. The tanning mechanism involves a number of processes. The main processes include; Soaking, Liming, Deliming, Degreasing, Pickling, Chrome splitting, Shaving, Retuning (fat liquoring), Drying, Batting (trimming) and Finishing.

Further processes include trimming, drying, butting and surface coating. From these processes, some wastes will arise from surplus, spent or washed–out chemicals. Some of the chemicals used in the tannery plant in order to realize their products include: Sodium Sulphide, Calcium hydroxide, Hydrochloric acid, Ammonium Sulphate, Sodium bisulphate, Sodium chloride, Calcium formate, Sulphuric acid, Sodium carbonate, Sodium sulphite, Chrome salts, bates, bactericides, syntans, fat liquors, dyeing, auxiliaries, dyes and finishers. Some organic chemicals are also used during leather finishing. These include: Butanol, Ethyl acetate, Butyl acetate, Isobutyl acetate, Formic acid, MonoChloro Benzene, Cyclo hexane, Di-isobutyl Ketone, Ethyl Benzene, Ethylmercaptan, Ethylene glycol, Methyl butyl ketone, Methyl ketone, Perchloro Ethylene, Toluene, Trichloro ethylene and Xylene. Some of these chemical constituents may be powerful pollutants in water and on soil. The release of volatile Sulphides gives rise to obnoxious (and toxic) odours. Certain solvent vapours can have adverse health effect s after pronged exposure.

Animal residues also result from such operations as mentioned above (Cleaning, Splitting and Trimming). Each of these generates waste products, which must be disposed of or re-used. Solid waste products of animals are powerful pollutants in water and they also produce bad odours when they decompose in their solid forms.

6.2 TREATMENT OF EFFLUENT BY THE BATA TANNERY

The effluent treatment plant receives the effluent from mainly the wet blue stage and the liming stage. This is collected in the main receiving tank. The effluent from this tank is then pumped into the hydro sieve by means of a pump. The hydro sieve screen removes the suspended materials and large waste materials. From the hydroseive screen the effluent gravitates into the equalization and primary aerator.

6.3 EQUALIZATION AND PRIMARY AERATION TANK

This tank has the capacity of 3500 m^3. When the effluent goes into this tank it is aerated by means of a pump, which makes the effluent get stirred up by the rising of fluid itself through small openings in the pipe that run along the tank. Normally, the effluent stays in this tank for 24 hours before it is pumped into the next tank. The control of PH is also done in the tank. The mixing of the low PH effluent from wet blue stage and a high PH from liming stage is only PH control measure that they have put in place. Thereafter, half the volume of the solution is pumped to the next tank, which is the secondary aerator. The main purpose of this stage is that it is the first stage where aeration is performed to allow the effluent to undergo biological oxidation using the oxygen being provided from the atmosphere. At this stage also, manganese Sulphate is added which acts as a catalyst in liberating toxic hydrogen Sulphide gas.

6.4 SECONDARY AERATOR TANK.

The secondary aerator tank has almost the same capacity has the primary aerator tank. In here most of the oxidation takes place i.e., chromium compounds are oxidized to less toxic compounds. At this stage, the aeration is done by the submerged air tubes, which are mechanically operated. This kind of aeration enriches the tank with oxygen necessary for oxidation. It is at this stage that Aluminium Sulphate must be added. Again the detention period is 24 hours. From here, the solution gravitates into the sedimentation columns. This stage is important because here, extensive complex formation and complete oxidation of most deleterious pollutants take place.

6.5 SEDIMENTATION COLUMNS

Together there are 12 sedimentation columns. There main purpose is to separate the suspended solids from the solution by allowing them to settle down or sediment. This usually is given an allowance of 3 months before they can be checked, removed and put on drying beds for them to completely dry up as sludge. For the liquid part the detention period is 24 hours before they are finally discharged into the lagoons. It is at this stage where the polyelectrolytes and the flocculants must be added. The sedimentation stage is important because at this stage, the sludge is separated from the effluent. The sludge is pumped to the drying beds while the effluent is pumped to lagoons for further biological treatment.

6.6 LAGOONS

There are four lagoons altogether. The solution from the sedimentation columns gravitates into the first lagoon. After several months detention period the effluent is allowed to go into the next lagoon, which after sometime discharges into the third lagoon until the effluent is finally discharged into the Chilumba stream and in the long run into the Kafue River. Green algae are utilized to purify the pollutant found in tanner effluents. The specific type is a spirulina algae. This is found naturally in salt lakes and in the sea. Spirulina algae utilize carbon dioxide and nitrogen nutrients found in tanner effluents. This act as a feed source and after feeding the algae produces oxygen as a by-product. Other nutrients like phosphates and potassium present in the effluents water are utilized.

6.7 THE DRYING BEDS

There are three drying beds lying opposite to the aerator tanks. The sediments removed from the sedimentation columns are deposited here in order to allow them dry up. These are collected as sludge aft

7.0 PARAMETERS OF IMPORTANCE CONSIDERED DURING TESTING

From all the industrial samples, the following parameters were analyzed or were found to be of importance.

7.1 BIOLOGICAL OXYGEN DEMAND (BOD)

This refers to the amount of oxygen that would be consumed if bacteria and protozoa oxidized all the organics in one liter of water. When aerobic bacteria consume much of the available oxygen, the bacteria robes of other aquatic organisms of the oxygen they need to live. In other words, BOD is a measure of the oxygen used by micro-organisms to decompose this waste. If there is a large amount of organic waste in the water supply, there will also be a lot of bacteria present working to decompose this waste thereby making the demand for oxygen to be very high.

The first step in measuring oxygen demand is to obtain equal volumes of water from the area to be tested and dilute each specimen with a known volume of distilled water, which has been thoroughly shaken to ensure oxygen saturation. After this, an oxygen meter is used to determine the concentration of oxygen within one of the vials. The remaining vial is then sealed and placed in darkness to be tested five days later. BOD is then deter\mined by subtracting the second meter reading from the first.

7.2 CHEMICAL OXYGEN DEMAND (COD)

This also measures the amount of oxygen depletion in the river due to pollution except that this is long-term effect. By definition, COD is the amount of oxygen required to degrade the organic compounds of wastewater. The bigger the COD value of wastewater, the more oxygen the discharges demand from water bodies. COD is a vital test for assessing the quality of effluents and wastewaters prior to discharge. The COD test predicts the oxygen requirement of the effluent and is used for the monitoring and control of discharges and in this survey, for assessing the Kafue Sewage Treatment Plant Performance. A short description on other parameters is given below;

pH - measures the degree of acidity or alkalinity of a particular solution. A pH of 7.0 is ideal for animal consumption.

SULPHIDES (S) – Characteristic of toxic H_2S gas.

AMMONIA -Toxic to fish and stimulates growth of plants and weeds.

NITRATE - This is an oxidized form of nitrogen which posses health problems (eutrophication). Also, the Nitrates are said to cause what is commonly known as the *Blue- Baby Syndrome* in infants.

PHOSPHATE –Though not toxic, it stimulates the growth of weed and other plants.

FAECAL COLIFORMS –These are intestinal bacteria, which are usually incurred from contamination by manure or sewage.

LEAD – This causes retardation of mind growth in infants.

CHROMIUM –This is a persistent heavy metal in the river (hexavalent form is said to be more toxic than trivalent form).

COLOUR- from tanning and dyes filters out light needed by plants for photosynthesis (planktons)

SULPHATES – accelerates corrosion of concrete sewers.

CHLORIDES – In high concentration damage plants.

ENVIRONMENTAL CONSIDERATIONS

As much as we appreciate the economic significance of the Tannery industry, the environmental impact of its by-products must be under constant check. The equalization and primary aerator there was no aeration-taking place due to the fact that the pump was down at the time of visitation. This means that there was no oxidation taking place, which led to the inefficiency of the operation. Again, bad odours resulting from toxic hydrogen Sulphide gas are released from the same tank. The odours emanating from this tank are environmentally unfriendly. If only something could be done to curb this problem, it will be of great help to both the workers as well as people visiting the plant.

The control of PH in the primary aerator tank is not adequate as one cannot just depend upon fixing of effluents in order to tell whether a neutral PH is reached or not. Otherwise a proper monitoring system must be put in place.

The manganese Sulphate added to the primary aerator as a catalyst is at no point recovered. This means that in the final effluent there is a possibility of one finding high levels of manganese compounds. This eventually contributes to the historical problem of extensive sedimentation in the Kafue River. The sediments at the river bed is said to contain very high levels of metallic elements.

During the secondary aeration, in the secondary or main oxidation tank aluminum Sulphate $Al_2 (SO_4)_3$ must be added to mark the first step of water treatment but this is nonexistent at the Kafue Bata Tannery Effluent Treatment Plant.

The secondary aerator is aerated by means of submerged tubes that are pressure operated. At the time of visitation these tubes where not operating, otherwise they where just operated when we insisted. The tubes are designed to be running throughout the operation. Such irregularities lead to inefficient treatment of effluent, as the oxidation process is inadequate.

There is sudden change in color as the effluent discharges into the secondary aerator tank from the primary aerator from grayish to reddish. The Manager of the plant (Mr. Mutale) however, could not tell exactly the reason for that sudden color change in the effluent. Nevertheless, it is alleged that the effluent should have the presence of chrome (vi), which shows variation in colors as it is oxidized.

Previous, evaluation and analysis carried out by ECZ on sludge showed the presence of chromium (vi), which is a toxic substance (Mr. Mutale Plant Manager- personal interview).

The following are the prominent characteristics of inefficiently treated effluent from a tannery factory:

- High Oxygen Demand
- High salt contents
- Strongly Alkaline (PH >7)
- High Chrome Content

EFFLUENT TREATMENT IN THE TANNERY INDUSTRY

The following processes are required to be performed for effective effluent treatment: High performance aeration, nitrification / denitrification (usually biological), high efficiency filtration, carbon filtration to remove pesticides and other organics, reverse osmosis and evaporation to separate salt, dewatering and sludge handling. How ever, only the under lined processes are performed at Bata Tannery.

OVERVIEW

Aeration is supposed to be done 24 hours a day as mentioned above but at the Bata tannery plant bubbling is only done for an average of six hours per day. Efficiency of denitrification only depends on the reproduction of the spirulina algae (not reliable), which may take quite a long time to multiply (typical of a biological process) and some times its growth might be affected by other factors.

High efficiency filtration is done, though the filtration process depends on the Hydro sieve machine, which is quite old. Carbon filtration has never been done before; therefore, we suspected a high level of organic matter in the effluents (COD Value) as the previous investigations have repeatedly shown.

Reverse Osmosis is also never done-Otherwise the concentration of some of the toxic soluble substances such as sodium Sulphide, Sodium Chloride, Aluminium salts e.t.c could be reduced considerably.

Physical evaporation is never done. In order to maintain the effluent levels in the ponds, they depend on natural evaporation by help of the sun.

Dewatering and sludge handling is quite effectively done. Though there is fear of contamination of ground water by the draining of the sludge material into the ground by rainwater. Results in the past have shown gross contamination of ground water by this scenario and this is likely to be a direct hazard especially to the local people who draw untreated water from the wells.

SAMPLE RESULTS

PARAMETER	ECZ STANDARDS	DETERMINED VALUES	
		SAMPLE 1	SAMPLE 2
S.Solids	100	-	-
Chlorides	800mg/l	3330	9110
Sulphates	1500mg/l	1.30	1.30
Phosphates	1.0mg/l	91.0	72.8
Ammonia-N	10mg/l	64.94	42.50
Nitrate	50mg/l	3.72	5.64
Chrome	0.1mg/l	<0.006	<0.006
Zinc	>250mg/l	-	-
Copper	-	-	-
Nickel	-	-	-
Lead	-	-	-
Ph	6-9	8.45	7.20

ANALYSIS OF RESULTS

From the results above, it has been seen that Chloride levels exceeded the ECZ standards by far. Results from Sample one which is a discharge from lagoon number 3 exceeded by 2530 mg/l, whilst sample two which is a discharge from Lagoon number 4 exceed the ECZ standard value by 8310 mg/l. Phosphates which are one of the deleterious pollutants exceeded the ECZ standards by 71.8 mg/l and 90 mg/l in lagoon 4 and lagoon 3 discharges respectively. This has been proved by the results obtained from the out let to the lagoons, which were sampled over the period of two weeks and the results averaged. From these results, we can see that phosphate values exceed the ECZ standard values close to 90 times. The concentration of Sulphates in Lagoon 4 discharge as well as that of Nitrates from both lagoons fell below the ECZ standard, while the levels of ammonia nitrogen in both lagoons exceeded the ECZ standard by 54.96 and 32.50 mg/l respectively. Total chrome level in the effluent was very low in accordance with the ECZ standard. However, despite the fact that the fourth lagoon chrome value fell within the ECZ regulation, the third lagoon, which also acts as a discharge point, had the chrome value exceeding the ECZ standard. For the first lagoon, even though the chrome value exceeded the ECZ standard value, it's not so much of a concern because the effluent at this stage is still in the process of treatment. PH values for both discharges fell within the acceptable range. Chloride values abnormally exceeded the ECZ standard values.

RESULTS FROM TANNERY LAGOONS

PARAMETER	RESULTS FROM LAGOONS (mg/l)			ECZ STD. VALUES (mg/l)
	FIRST	THIRD	FOURTH	
PH	7.74	8.06	8.28	6-9
Phosphate	66.9	72.8	91.0	1.0
Nitrate	4.93	5.64	3.72	50
Chromium	0.31	0.29	0.09	0.1
Chloride	3430	9110	3330	800
S.S.	0.30	0.16	0.37	100
TDS	353.2	484.4	889.2	
Lead	-	-	-	-
Zinc	> 250	> 250	>250	-
Copper	Nil	Nil	Nil	-
Nickel	Nil	Nil	Nil	-

EFFECTIVENESS OF EFFLUENT TREATMENT AT THE TANNERY PLANT

From the above analysis, it can be concluded that the effluent treatment at the Tannery is not effectively done. Reasons for this are summarized below:

- Aeration is inadequate
- Excess salt (Sodium Chloride) used in the industrial process is never recovered at any point. This leads to excess levels of chlorides in the discharged effluent.
- Insufficient treatment of effluent to remove hydrogen Sulphide gas which is one of the deleterious pollutants allowed to escape into the atmosphere unchecked. To neutralize this poisonous gas, manganese Sulphate should be added as a catalyst to liberate this gas.
- No internal analysis of possible pollutants is done. If this was being done, it would regulate the amount of deleterious pollutants to be discharged.
- Sludge drying beds should be lined with a material, which cannot allow leaching of pollutants in sludge into the ground thereby contaminating the ground water.

RECOMMENDATIONS

Use of a mixture of tanning agents (e.g. Chrome + Titanium) not only can minimize toxicity levels but also overcome some of the problems of leather quality. Vegetable agents can also be used in tanning.

Though Aluminium gives a weaker chemical bond with collagen fibers (reported in Technical report series no 4; *Tanneries and the environment)* than does chromium, producing flat hard leather with a whitish colour. It can be used alone or in combination with traditional tanning agents (chrome) and this can be useful especially as preliminary tannage. This can then be followed by a second step using traditional materials that give the leather its desired physical qualities.

Additionally, titanium if used alone though imparts slightly different properties; its wastewater properties are non-toxic (non-toxic salts are produced). For example, titanium dioxide is completely inert and safe to handle in sludge form. From an environmental standpoint, AREZ is proposing that it is a good alternative to chromium. From the findings obtained from the industry, Mr. Mutale, the plant manager admitted the excessive use of salts and acids in their operations. The former is used in the soaking, bating and pickling stages there by resulting in high levels of Chlorides in effluents. Chlorides in higher concentration, damages plants. These include aquatic plants, which serve as food to fish. The later results in increased levels of nitrates and phosphates, which also contribute greatly to excessive eutrophication. In an attempt to campaign against the alleged reduction of fish population in Kafue River, the first step we are taking is to campaign against careless discharge of effluents rich in Chlorides, Phosphates and Nitrates. The fact that these parameters are high signifies in efficiency of effluent treatment. The laboratory results below show the levels of these parameters in the samples taken from different parts of the Tannery Plant.

KAFUE SEWAGE TREATMENT PLANT.

The Kafue sewage treatment plant is a biological treatment plant. This plant receives raw sewage of about 20 000m^3 from Kafue estates and other parts of Kafue town (personal communication, Mr. Kamijhi, foreman, Kafue Sewage Treatment Plant). The raw sewage firstly passes through the trommel screens, which removes some suspended materials (rags and stones) which otherwise would damage the pumps to be used at some point. The sewage then under goes through the process of aeration and clarification after which between 45-50% sludge is removed.

The sludge goes through secondary aerators and is finally sent to drying beds. The dry material is used as fertilizers. The clarified water resulting from the processes of aeration and clarification go through four oxidation ponds before being discharged from the last pond through a pipe that goes directly into the Kafue River.

ENVIRONMENTAL CONSIDERATIONS.

On the aspect of effluent treatment, it is always necessary that sewage material pass through the treatment plant so as to minimize the concentration of some of the common biological pollutants. Conditions for the safe discharge of affluent depend on the nature of the receiving water. BOD, Nitrate, Ammonia and Phosphate levels in the sewage effluent are unacceptable. From the survey conducted by AREZ at Kafue Sewage Treatment Plant, it was discovered that the New Sewage Treatment Plant was non-operational. This meant that the effluent meant for the new plant was a by-pass (un treated). Un treated sewage material contains high levels of Nitrogen, Phosphates, BOD, COD and other nutrients. Nitrates and Phosphates in a water body can contribute to high BOD levels. Nitrates and phosphates are plant nutrients and can cause plant life and algae to grow quickly. When plants grow quickly, they also die quickly. This contributes to the organic waste in the water, which is then decomposed by bacteria. This results in a high BOD level. From the sewage oxidation ponds, this effluent high in BOD, Nitrogen and Phosphorous goes straight into the Kafue River there-by increasing the BOD of the Kafue River as well. Looking at the analytical results from the laboratory, the above scenario has been confirmed. Indeed from the tables below especially from the results of the by-pass, it can be seen that levels of Ammonia-Nitrogen and Phosphates are so high that they exceed ECZ standards by several tens. No matter how these effluents are made to stay in the ponds for additional treatment (removal of some nutrients, which are a nuisance) the desired extent of removal of these nutrients is not achieved because in the first place they are loaded in very high amounts.

When BOD levels are high, dissolved oxygen (DO) levels decrease because the bacteria are consuming the oxygen that is available in the water. Since less dissolved oxygen is available in the water, fish and other aquatic organisms may not survive.
From the sewage oxidation ponds, it was discovered that there was an over growth of weed and this is due to the careless loading of untreated effluent into the ponds. This is likely to contribute to the above scenario of increasing the BOD of the water in the river, as earlier pointed out. This is because when organic matter such as leaves, dead plants, grass clippings, these mixed with manure and sewage discharge is present in a water body, will cause the bacteria to begin the process of breaking down this waste. When this happens, aerobic bacteria, robbing other aquatic organisms of the oxygen they need to live, consume much of the available oxygen.

How ever, it is worth mentioning that though growth of weeds is necessary because they help remove some of the deleterious pollutants from the effluent ready to be discharged into the Kafue River, these ponds were found to be ideal and conducive breeding ground for the mosquitoes, which are the vectors for malaria parasites which cause malaria-the number one killer disease in sub-Sahara Africa.

In 2003, AREZ conducted a follow-up to the 2002 malaria survey in order to build a very strong compelling case to have the weeds cleared as a matter of urgency and to restore effective sewer effluent treatment process. This was carried out among the local communities living in the vicinity of the sewage plant. A random household sample survey of approximately 50 families was carried over for the period of November/December and January/February. Average households comprise 6 – 12 members of the family. The respondents were unanimous in stating that sewerage ponds were breeding grounds for mosquitoes and that on average each member of the respondents households suffered from Malaria more than 3 times every year. In some instances, deaths have been noted from the malaria related diseases.

Another aspect was that malaria was prevalent the whole year as opposed to the rainy seasonal peaks generally experienced in other areas. The health personnel interviewed at the local health center also echoed the need to address the malaria problems in the area by first clearing the weed in the oxidation ponds. A laboratory analysis of some of the deleterious pollutants of interest revealed the extent to which these pollutants are discharged into the Kafue River. Worse enough, as can be seen from the tables of results below, most of these parameters exceeded the ECZ standard values by far. Also, comparing these results with ECZ Regulations provides an objective standard of judging the effectiveness of the effluent treatment at the KSTP.

TABLES OF RESULTS

KSTP 1: Discharge From Old Treatment Plant

PARAMETER	RESULTS MG/L	ECZ STD VALUES
PH	8.44	6-9
PHOSPHATE	42.8	1.0
NITRATE	3.96	50
AMMONIA-N	29.12	10

KSTP2: By pass from New Treatment Plant

PARAMETER	RESULTS mg/l	ECZ STD VALUES mg/l
PH	7.94	6-9
PHOSPHATE	94.7	1.0
NITRATE	3.92	50
AMMONIA-N	89.6	10

FLOW RATE = 159 m^3/h

KSTP3: Discharge to Oxidation Ponds

PARAMETER	RESULTS (mg/l)	ECZ STANDARDS
PH	8.81	6-9
PHOSPHATE	96.0	1.0
NITRATE	7.44	50
AMMONIA-N	53.76	10

KSTP4: Discharge to Kafue River

PARAMETER	RESULTS (mg/l)	ECZ STANDARDS
PH	8.0	6-9
PHOSPHATE	88.0	1.0
NITRATE	12.04	50
AMMONIA-N	42.56	10

SAMPLE FLOW RATE = 151m^3/h

INTERPRETATION OF RESULTS

The obtained results can be interpreted as follows:

- The values of the different parameters decrease on treatment.
- The nutrient level of the by-pass from the new treatment plant exceeded that of the old treatment plant, which is treated.
- The levels of nutrients in the discharge to the river exceed the acceptable levels by the ECZ despite passing through different stages of the treatment plant.
- The reported results are an average of the results obtained during the period of study. This implies that at some point in time the amount of deleterious pollutants go higher than the reported values.
- The values of nitrates and ammonia were analyzed separately to determine the composition contribution to total nitrogen in the effluent.

HOW EFFECTIVE IS THE EFFLUENT TREATMENT AT THE PLANT?

Over the yeas, untreated sewage has been one of the chief contributors to the high concentration of deleterious pollutants in vital water bodies. High concentrations of Phosphate, Nitrates, Ammonia and Chlorides act as one of the indicators of in efficient sewage effluent handling.

From the survey, it has been concluded that the effluent treatment at the KSTP is not effective. As seen from the results above, there is careless discharge of nutrients resulting from the untreated sewage. Examples of these are Total nitrogen and the Phosphates, which have exceeded the ECZ standard values by large amounts.

The old treatment plant lacks maintenance. Since the plant was opened maintenance has never been consistent if not that it has never been done. The plant manager Mr. Kamiji was not sure what had actually gone wrong but he however attributed the problem to lack of finances faced by the council.

A number of electrical faults faced by the pumps and other electrical equipment render the treatment ineffective. This is because every now and then, the pumps are reported as non operational. During the period this survey was being done, only two out of five pumps were operational. Therefore the process is very slow as regard the amount of sewage the plant has to handle. Because of this accumulation of sewage waiting to be treated, the area around the plant experiences an irritating odour resulting from the plant. This odour is environmentally unfriendly especially that there are houses belonging to some of the plant personnel within a radius of 20m from the plant. During a personal communication with the plant foreman, he assured us that some thing will be done to restore the pumps as soon as the funds are available.

As pointed out earlier on, the over growth of the weeds in the oxidation ponds observed, which extensively contribute to the outbreak of malaria (Rollback malaria survey findings) is an indication of the excessive pollutants leaving the treatment plant. Under normal circumstances where the plant is performing effectively, the pollutant's level of deleterious pollutants should meet the ECZ regulations.

There are at the moment no proper laboratories to monitor the effectiveness of the treatment plant. At the time of the visitation, it was found that a small room that in the past used to be the laboratory is no longer in use because all the equipment is down and there is no money to either repair the existing equipment or buy new ones. This has had a negative effect on the operations of the plant.

If the plant personnel were given an opportunity to monitor some of the simple parameters like PH, BOD, COD, e.t.c right there at the plant, relevant adjustments could easily be made instantly instead of waiting for physical indicators and outbreaks of diseases like Malaria. We would to under take an emergence campaign to lobby for more funds for the plant so that effective treatment of effluent can be achieved.

Further, the plant effluent has a very high flow rate as the results above show. High flow rates cause sewage treatment system to react differently from its normal pattern as designed for municipal sewage. The un equalized or un proportioned industrial flow observed is especially troublesome in that they accelerate the effects of un treated sewage pointed out above.

The oxidation ponds inhabit crocodiles, which threaten the nearby farmers and employees of KSTP. This has contributed so much to the delaying of the work on the oxidation ponds. ARE suggested to the council secretary that they should find ways and means as soon as possible of driving away or killing these crocodiles, which are jeopardizing people's lives.
In order to monitor the levels of different parameters the plant is discharging out either into the oxidation ponds or into the Kafue River itself, there is need to re- stalk the small laboratory at the plant. The laboratory is non-operational at the moment and this was attributed to lack of funding to the plant (Personal communication with Mr. Kamizhi, the plant foreman)

GENERAL DISCUSSION

Water is life and all members of the KRB communities should have access to fresh water resources, which is the source of life. Water is a basic ingredient for development; the more the development, the higher the water demand. It is for this reason that the KRB water resources should be protected from pollution. During this short survey, it was found that industrial activities are a major source of pollutants to the KRB. Therefore, the survival of the KRB ecological system and biodiversity depends on the extent to which the degradation and pollution is controlled. Nonetheless, it is clear going by the country's economic development policies and strategies that more new industries and agricultural schemes will be developed. The KRB seems likely to be the target for these new industries and agricultural schemes due to its strategic geographical locality and the abundance of water. The time to act is now!

Three industries were under consideration during this survey, namely: Kafue Chemicals, Bata Tannery, Lee Yeast and the Kafue Sewage Treatment Plant. These industries, among others, were found to be the chief source of deleterious pollutants, which contribute adversely to the degradation of the KRB. In order to form a basis for justifying this fact, a laboratory analysis was conducted for some selected parameters in the samples obtained at selected points in each of these industries. The following were the laboratory findings:

a) The sample obtained from the discharge coming from Lee Yeast was found to contain the highest level of Phosphates and Nitrates. This was attributed to the possible use of both phosphate and nitrogen containing compounds during the manufacturing process. These pollutants are discharged without proper pre-treatment.

b) The Bata Tannery effluent was found to contain high levels of Chlorides, which was attributed to the use of excess salt in the industrial process.

c) The discharge from the Kafue Sewerage Treatment Plant was found to contain very high levels of these parameters. This was because of the fact that the effluent meant for the New Sewerage Treatment Plant was never treated and therefore allowed to go into the oxidation ponds and eventually into the Kafue River with an acceptable amount of pollutants. The effluent was found to contain extremely high levels of Phosphates, Ammonia nitrogen and nitrates. These pollutants are said to contribute to very high levels of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD).

d) It was also found that the sewer pipes which passes just in front of the Bata Tannery Industry, was blocked and it's constituents were allowed to go into the nearby stream which eventually ended up into the Kafue River.

e) The sampling with the test strips indicated fluctuating quantities of nutrients load. In some cases the test strips indicate undetectable values. Occasionally the nutrients loads were very high largely due to inefficient treatment process. One of the main problems is attributed to infrastructure breakdowns and lack of re-capitalization in the maintenance of the sewer system.

WAY FORWARD

Constant monitoring and analysis of different industrial effluents will continue. From time to time during the year, ARE will follow-up the effluent treatment process in each industry. Work on other areas which are potential pollutants other than those looked at in this report, will continue. ARE has scheduled a sewerage remediation meeting where ARE will table reports and offer options to effective sewerage system.

ARE has compiled reports and will soon circulate them to relevant stakeholders for action-highlighting gaps in the effective industrial effluent environmental controls. ARE will also target working to have remediation discussions/meetings with the various managements.

APPENDIX 1

SELECTED REGISLATIONS RELEVANT TO THE ENVIRONMENT

(Adapted from NEAP, 1994).

MINISTRY	LEGISLATION	PROVISIONS
Agriculture, Food and Fisheries	Agriculture Lands Act of 1960, Cap 26	Legal basis of agricultural management
	The Agriculture (Fertilizers and Feed) Act, Cap 351 of 1990	Regulates and controls the manufacture, processing and importation and sale of agricultural fertilizers and feed, and establishes minimum standards and purity.
	The fisheries Act, Cap 314 of 1974	Provides for commercial fishing and registration of fishermen
Environment and Natural Resources	Environmental Protection and Pollution control No. 12 of 1990	Regulates the law relating to the protection of the environment and control all forms of pollution.
	Forest Act, Cap 314	Provides for forest management, conservation and protection of forests and trees, and licensing and sale of forestry produce**.**
	Natural Resources Conservation Act 315 of 1970	Control the management and use of natural resources outside forest reserves and national parks.
Energy and Water Development	The Water Act, Cap 312 of 1949	Provides for the control, ownership and use of water excluding water that is part of the international boundaries. The Act also established water board, which is administered by a water officer.

APPENDIX 2

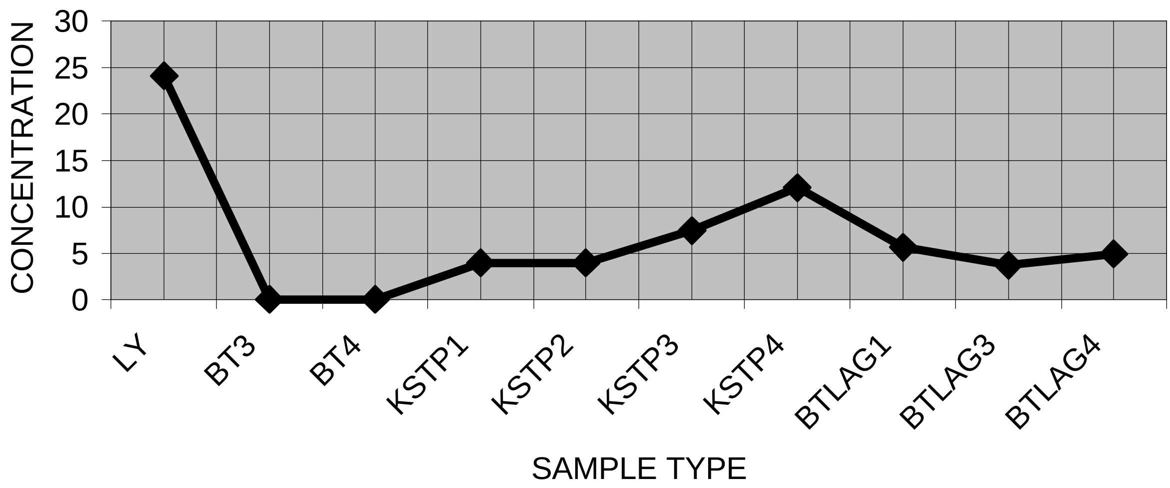
SOME USEFUL ANALYTICAL METHODS AND DETECTION LIMITS

PARAMETER	ANALYTICAL METHOD	REFERENCE METHOD	DETECTION LIMIT (mg/l)
Total-N	Kjedahl	4500-N	.001
Ammonia	Nessler	4500-NO3-D	.01
Nitrates	Ion selective	4500-P-C	.01
Total Phosphates	Molybdate Analysis	3500-K-B	.01
Potassium	AAS	3500-Ca-D	.01
Calcium	AAS	3500-Ca-D	.01
Magnesium	AAS	3500-Fe-D	.01
Iron	AAS	5210-B	.01
COD	Winkler	5221-C	1
BOD	Titrimetric		2

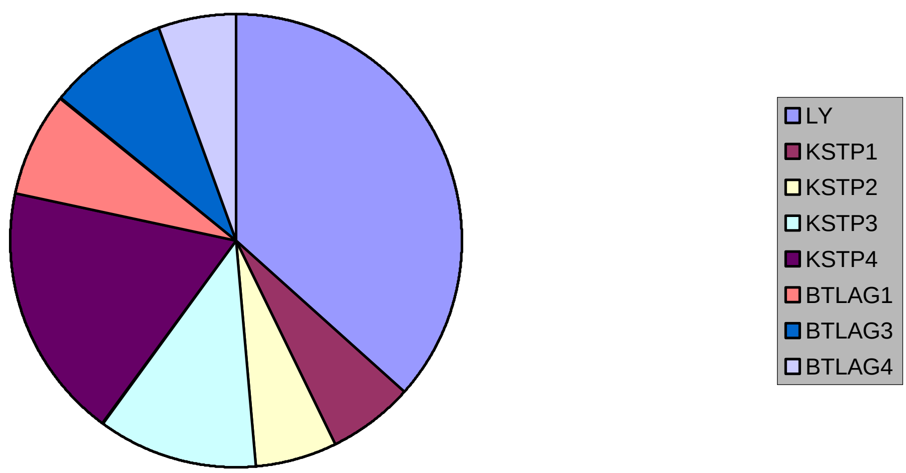
APPENDIX 3

GRAPHICAL REPRESENTATION OF RESULTS

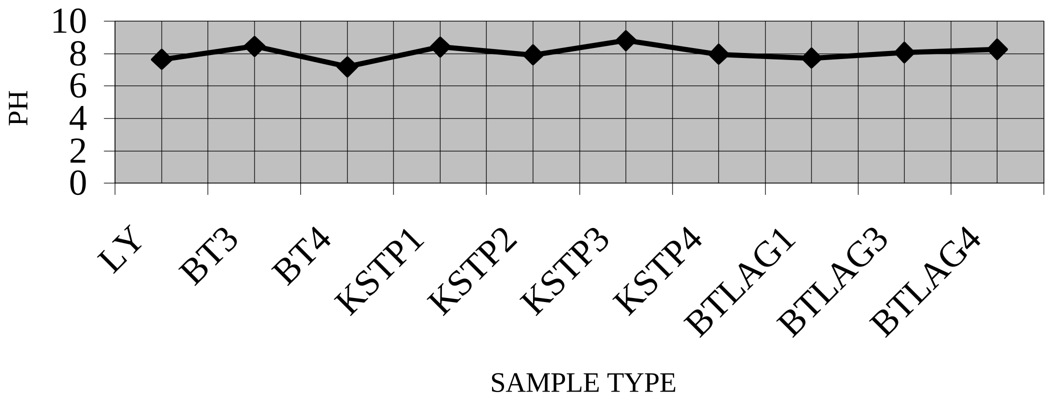
GRAPH 1: NITRATES



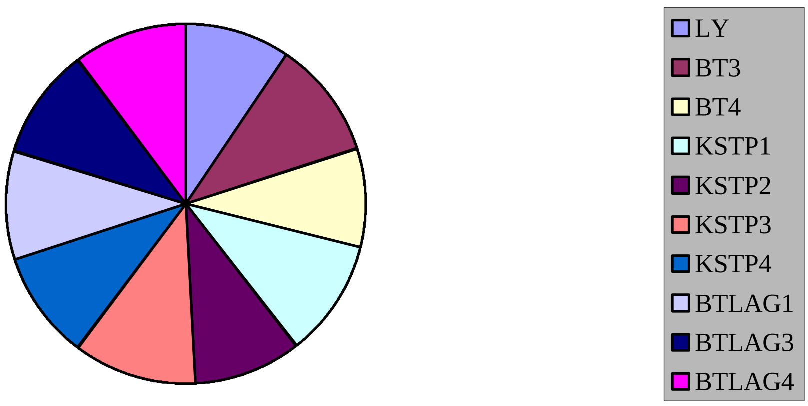
PIE CHART REPRESENTATION OF NITRATE LABORATORY RESULTS



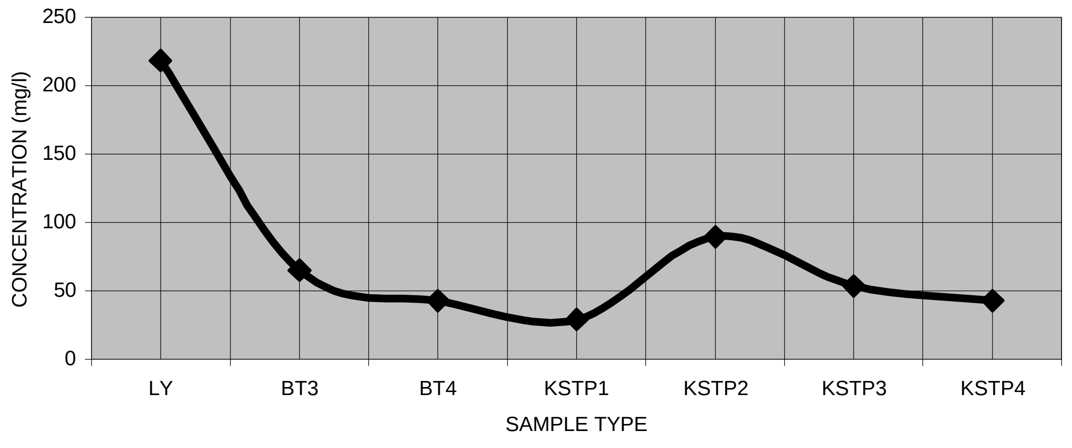
GRAPH 2: PH RESULTS



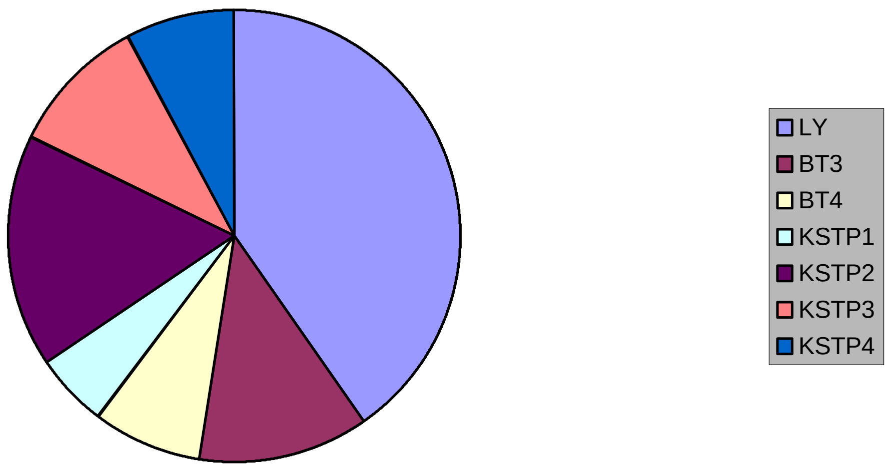
PIE CHART REPRESENTATION OF PH LABORATORY RESULTS



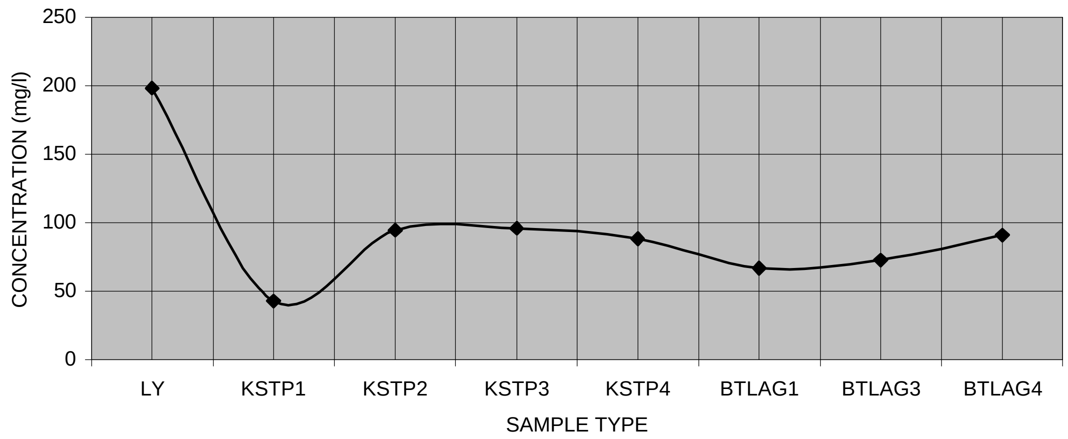
GRAPH 3: LAB. RESULTS FOR NITROGEN AMMONIA



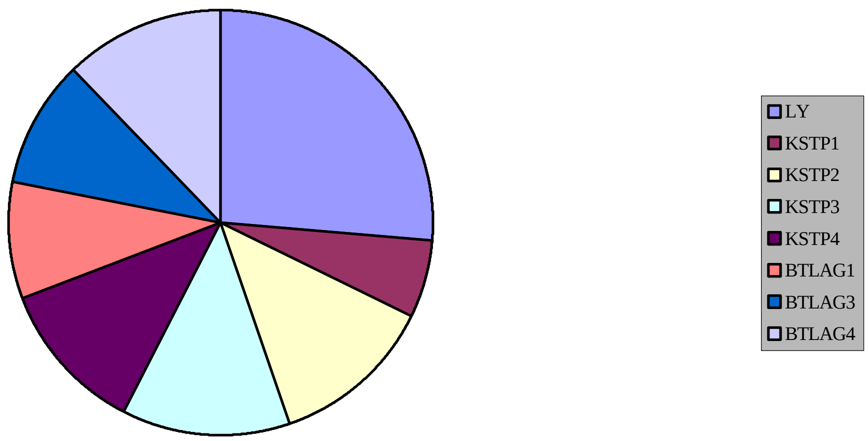
PIE CHART REPRESENTATION OF LABORATORY RESULTS ON NITROGEN AMMONIA



GRAPH 4:LAB RESULTS FOR PHOSPHATES



PIE CHART REPRESENTATION OF LABORATORY RESULTS ON PHOSPHATE CONCENTRATION



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