An Assessment of effluent quality at Tobacco Processors Zimbabwe (TPZ)

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Abstract

An effluent quality study was conducted at Tobacco Processors Zimbabwe (Pvt) Ltd to ascertain the level of legal compliance for the effluent in terms of meeting the City of Harare and Zimbabwe National Water Authority (ZINWA) regulatory limits. In the course of this system evaluation, a total of 11 effluent streams were identified through a site survey, and after a critical review of the company's historical records on effluent quality, six sources were found to be significant. From each significant effluent stream, six weekly samples were collected and analyzed for pH, Total dissolved solids (TDS), Total suspended solids (TSS) and Chemical Oxygen Demand (COD). Compared to the other locations, the Boiler and Coalbunkers effluent streams were found to be the major wastewater streams of concern with regards to pH. They averaged 10.52 and 2.59 respectively and therefore fail to meet both legal limits for the City of Harare and ZINWA. It was also found out that the discharge of Humidifier effluent into the storm water drain is in violation of the Water Act and the new Environmental Management Act, which strongly prohibit the discharge of trade effluent into storm water systems. The study recommended the development of a relatively inexpensive and effective means of pH correction in the Boiler and Coal Bunker effluents through mixing the two streams and further dilution with groundwater.

Keywords

Effluent; wastewater; pH; Total Dissolved Solids; Total Suspended Solids; Chemical Oxygen Demand; Environmental Management Act; Standard Limit.

Introduction

Background to the Study

The world has witnessed an unprecedented rise in what can be termed global environmental consciousness. People worldwide are realizing that their activities have a measurable and significant impact on the world around them (Bekechi & Mercier, 2002). The impacts of such activities can be seen in dwindling supplies of fuel-wood in rural areas and, on a global scale, issues such as ozone depletion, biodiversity destruction, acid rain and global warming among other things. To curb this corporate onslaught of our natural environment, many governments have come up with a plethora of environmental laws and regulations. Emission and effluent standards are all part of a growing list of measures that have been taken to avert a possible "environmental crisis". Consequently, organizations are now being held responsible for the potential and actual environmental impacts associated with their activities. In response, organizations have started implementing environmental management systems (EMS) such as ISO 14001, which stresses the need for continuous improvement in striving to protect the environment not only for us but the future generation as well. There are three commitments at the core of ISO 14001: Compliance with environmental regulations, pollution prevention, and continual improvement.

In Zimbabwe the availability of water varies markedly across the country but in all areas it is considered to be a scarce and limiting resource (ZINWA, 2000*)* and therefore it is essential that industries discharge the highest quality of effluent that does not contaminate water resources. In the past, Zimbabwe did not have a comprehensive environmental policy and the associated legislation in place. Control of water pollution was based on the premise that prosecution would be effected and penalties charged on any organization found to be releasing any effluent that exceeded the stipulated limits unless that entity has been granted permission to do so through a permit. However, standards were rarely adhered to and the resultant penalties were inadequate. Companies would therefore find it much cheaper to pollute and pay fines rather than prevent pollution.

In full view of all negative impacts of poor quality effluent, much more strict legislation has been put in place to ensure that industries do not discharge 'bad' effluent into the environment. The recently introduced Environmental Management Act of 2002 seeks to make industries bear the full responsibility of the damage caused by their effluent or any other pollutant to the environment through the "Polluter Pays Principle." The Act also seeks to enforce the regulatory standards (awaiting the formulation of its own environmental quality standards) set out by the relevant regulatory authorities such as City Councils and ZINWA on sustainable levels of effluent parameters that are required in industrial discharges. Penalties of up to Z$5 million will be charged on companies whose effluent or any other environmental aspect fails to meet the legislative requirements. Companies are now under pressure to determine their compliance levels and where necessary, put in place environmental management systems that can effectively provide frameworks for managing their environmental impacts before the new Act comes in full force.

Company Profile

Tobacco Processors Zimbabwe, a member of the British American Tobacco (BAT) World Group of companies, is situated at corner Simon Mazorodze and Auckland Roads in the Southerton Industrial area of Harare. Its premises occupy a 4.8-hectare area of land. The company is one of the leading processors of Green Leaf Tobacco in Africa, providing storage, processing and packaging facilities and services to its clients who export their tobacco product overseas to markets in Asia, Middle East, the European Union (EU) and America.

Founded in 1987, TPZ is owned by Export leaf Tobacco Company of Africa (Pvt) Ltd, Stancom Tobacco (Pvt) Ltd and Inter-Continental Leaf Tobacco Company Pvt) Ltd, the former (Export leaf tobacco) being the major shareholder. Depending on the scale of production, TPZ employs up to 1 000 employees, which consist of both seasonal and permanent workers. TPZ is responsible for the processing of over 47% of Zimbabwe's annual tobacco crop.

The company's Harare plant is one of the most modern and large leaf processing facilities in Africa. The equipment and facilities have a capacity of handling an average of 500 tonnes per day. Raw materials required for the company's operation include tobacco, electricity, water, coal and packaging material. The tobacco is acquired from indigenous and commercial farmers through various tobacco auction floors around Harare. The production process, known as Green Leaf Processing, involves the turning of cured tobacco received from farmers into a form that is usable by the cigarette factories. Assuring quality, uniformity and purity of the product, Green Leaf Processing occurs in three stages namely grading and blending, threshing and separating, and redrying and packing. The grading and blending involves the classification of tobacco bales and mixing according to type, achieving a uniform tobacco grade that is an essential building block to the blend of any future cigarette. Threshing and separation takes place when moistened leaves are mechanically threshed to remove hard midribs and leaf veins from the soft leaf tissue (lamina). The two components are separated with the aid of airflow. Redrying is whereby the tobacco strips from the threshing process are dried to a certain moisture level. Throughout the production process, wastewater is produced at the conditioning stage, prior to threshing and during redrying.

TPZ has shown a great deal of environmental responsibility. To this day, the organization has put in place measures to ensure that the environmental impact of its operations are kept minimal. In line with this, the company has implemented an Integrated Management System (IMS), which combines quality issues with environmental aspects. TPZ received its ISO certification for both ISO 9001:2000 and ISO 14001:1996 in August 2002 after being audited by Anglo-Japanese-American (AJA) of South Africa.

Statement of the Problem

The recent enactment of the Environmental Management Act (Chapter 20:25) could put organizations under heavy financial strain to comply. As a result, a growing number of companies are becoming aware that environmental performance can have a significant impact on business success and sustainability. Therefore organizations should establish their compliance status and effect corrective measures, which guarantee an effective and sufficient recognition of these, otherwise difficult, legislative requirements and guarantee compliance with them. Before the implementation of ISO 14001, TPZ was facing problems with its effluent which was always characterised by a high content of TSS, TDS, BOD, COD, high turbidity and unstable pH resulting in the company's effluent failing to meet both the City of Harare and ZINWA regulations.

Justification

With the punitive environmental legislation that now exist and is being continuously added in Zimbabwe, industrialists should seek code of practices, a set of rules and a formula to grant immunity from prosecution and heavy penalisation for non-compliance. With principles such as the "making the polluter pay" now in force, the cost of causing environmental damage or pollution is tremendous – far outweighing the actual clean-up costs of the original pollution. In March 2004, the Marondera City council was fined almost Z$20 million by the Zimbabwe National Water Authority for continued pollution of the town's catchment waters.

TPZ has already invested millions of dollars in ensuring its waste water discharges comply with the relevant legislation. However, the extent to which the investments have gone in improving the company's effluent situation has not been assessed. A detailed study is essential to justify the projects/programmes already implemented and pave the way for future initiatives.

Aim

To determine the regulatory compliance level for TPZ effluent.

Objectives

a) To identify sources of effluent discharges within TPZ premises.
b) To analyze the quality of effluent discharged from the sources identified and make comparisons against the City of Harare and ZINWA limits.

Methodology

Identification of Significant Parameters

A review of monitoring records regarding effluent samples and measurements according to applicable regulatory requirements for the years 2000, 2001 and 2002 was conducted. The four parameters which had been frequently above legal limits during the stated years were considered as significant to the research. The selection of the four parameters also took into consideration the fact that a strong correlation exist among different parameters such as TDS and COD, TSS and Turbidity, COD and BOD, and chlorides and conductivity (ZINWA, 2000). Therefore the level of one parameter would automatically reflect characteristics of the other.

Identification of Effluent Sources

A walk through of the premises was carried out to identify all points of continuous and periodic discharges into either the sewer system or storm water drains for all processes resulting from TPZ's operations. The findings were authenticated by use of a drainage map for TPZ. Finally the sources identified were matched against the sources recorded in the TPZ register of environmental impacts for effluent. From all the sources identified, the six most significant were considered for the study.

Coal Bunker

This effluent arises from water that is occasionally sprinkled over the coal under storage to capture coal dust and minimize chances of spontaneous ignition. This water seeps through the coal and seepage collects at the bottom of the bunker and is released as wastewater. Because there were no proper drainage facilities (though a settling tank was under construction at the time of study), the waste water found its way into the storm water drain.

Boiler blow down

Blowdown effluent results from the discharge of boiler water when it has deteriorated in quality. Blow down is done almost every four hours depending on the quality of the feed water coming in. The effluent goes into the municipal sewer system via a sedimentation tank.

Battery Charging Area

This is an area where fork lift batteries are charged. Effluent from this section arises from floor washings. Since a lot of acidic salts accumulate on the battery terminals, the pH of the effluent is always low (acidic).As a result effluent collects in a drain which runs across the room and is conveyed into a pH neutralization sump situated at the lower end of the drain. The sump allows for alkali dosage. 500g of Bicarbonate of soda is added to correct the pH before the release valve is opened as an outlet to the sewer. Effluent from the Battery section is discharged once a week or as and when the neutralization sump is filled up.

Humidifiers

Humidifiers help to keep occupational dust and temperature low in the factory. Tape water from the municipality is vaporized or converted into fine mist by the humidifiers. All the water that fails to vaporize collects in the pipe below the humidifiers into the gutters and finally discharged into the storm water drain.

Redriers

The effluent arises from water in form of steam, mist water and manual water that is added to the tobacco with the aim of maintaining the required moisture level. There are four Redriers, one for each production line. Each Redrier's discharge outlet produces a continuous stream of wastewater.

Quantitative Measurement of Effluent Quality from Each Source

This involved the collection of samples from the six significant sources of effluent identified during the early stages of the study. Samples were collected on a weekly basis from the 1st of November 2003 to the 4th of December 2003. The following sampling points were identified; Coal Bunker, Boiler Blowdown, Battery section, Humidifiers, Redriers and the Washbay.

Sampling Points/Positions

The sampling points were chosen with the help of drainage maps and physical site study. Samples were collected from the points of discharge for each identified source once a week for a period of six (6) weeks.

Method of Sample Collection

Four grab samples were collected at the points of discharge of each source, at an hourly interval of time, over a period of 4hrs using 500 ml polyethylene plastic bottles. The four hourly samples from one source were mixed to form a 2 litre composite sample for analysis. The sample containers were closed tightly immediately after the sampling was completed to avoid pollutant loss by volatization in case of Volatile Organic Compounds and external contamination (Hess, 1996).

pH was measured on individual hourly samples at the time of sampling using a glass electrode coupled to a pH meter (American Public Health Association, 1992).

Sample Storage

Prior to analysis, samples were kept refrigerated at a temperature of 4^0C. The aim was to slow down bacterial activities on organic components of the sample (which constituted the main focus of the study) and ensure that the samples would not freeze thereby losing their homogeneity (ZINWA, 2000). The advantage of using refrigeration as sample preservation method is that the method does not interfere with any analytical method to be used later in the analysis of samples since it does not affect sample composition the whilst pH control, chemical addition and other sample preservation methods do (American Public Health Association, 1992).

Methods of sample analysis

Solid Analysis

All samples were analyzed for TSS and TDS. A blank solution (purely distilled water) was first run to find the error band of the system. This was followed by an Analytical Quality Control Solution (100mg/l NaCl) to check on the accuracy of the method for TDS. Finally the samples collected from the effluent sources were run.

c) <u>Procedure</u>

i) <u>Preparation of the Analytical Quality Control (AQC) Solution</u>

1.64843g NaCl was dissolved in 200ml water and diluted to 1 litre (1000mg/l). 50ml of the solution were poured into a 500ml flask and diluted to the mark to make a 100mg/l NaCl AQC solution (ZINWA, 2000).

ii) <u>Total Suspended Solids (TSS)</u>

A filter paper was dried at 105^0C for 1 hour in an oven to drive out all the moisture and kill microorganisms, as these would distort the initial filter paper weight. The paper was then weighed on a balance and the weight was recorded as the initial filter weight, W_1. A blank solution (distilled water) was shaken vigorously in order to attain sample homogeneity before 100ml were drawn up and filtered using a filter pump. Residues (filterable solids) remained on the filter paper whilst the filtrate collected in a conical flask. The filter paper, together with the residue was removed and oven-baked for 1 hour at 105^oC until a constant mass was achieved. This mass was recorded as the final filter paper weight, W_2. The difference between the final filter weight, W_2 and the initial weight, W_1 was taken as the mass of TSS in the 100ml sample. The mass of TSS in the 100ml sample was multiplied by 10 get the concentration, in mg/l, of TSS from the effluent source where the sample was collected.

<u>Calculations</u>

TSS in 100ml sample = $(W_2 – W_1)$ mg

$$\text{TSS in mg/l} = (W_2 - W_1) \times \frac{1000ml}{100ml} = (W_2 - W_1) \times 10$$

iii) <u>Total Dissolved Solids (TDS)</u>

An evaporating dish was prepared by first cleaning with distilled water and rinsing in alcohol. The dish was oven dried for 10 minutes before being cooled, weighed and stored in a dessicator until required for use. The weight obtained here became the initial basin weight, $BW_{1.}$ The filtrate collected from TSS analysis above was filled in the evaporating dish and evaporated to dryness in an oven at a temperature of 105^oC until a constant mass was achieved. This mass was recorded as the final basin weight, BW_2.

The difference between the final basin weight, BW_2 and the initial basin weight, BW_1 was taken as weight of TDS in the 100ml sample. The weight of TDS in the 100ml sample was then multiplied by 10 to get the concentration of TDS in the sample in mg/l.

<u>Calculations</u>

Weight (mg) of TDS 100ml = $(BW_2 - BW_1)$ mg

$$\text{TDS in mg/l} = (BW_2 – BW_1) \times \frac{1000ml}{100ml} = (BW_2 – BW_1) \times 10$$

Determination of pH

pH was measured for each hourly sample. The four hourly readings were then averaged to get the weekly reading. The pH meter was calibrated using buffer solutions of pH 4, 7 and 10 before the commencement of each sampling day. This was to ensure that the readings obtained for effluent sample are as accurate as possible (ZINWA, 2000).

Apparatus

- A pH sensitive glass electrode coupled to a pH meter
- Buffer solutions of pH 4, 7 and 10

Procedure

The glass electrode was immersed into each hourly waste water sample. The reading was only recorded after the reading on the pH meter had stabilized. After each reading the electrode was washed in distilled water. The pH readings obtained from each hourly sample were averaged to get the final reading for the week. The glass electrode was kept in distilled water between measurements.

Chemical Oxygen Demand (COD) Analysis

COD of a sample is the amount of oxygen required by one litre of the sample to oxidize all the organic and inorganic matter in the sample to carbon dioxide and water. In the analysis potassium dichromate ($K_2Cr_2O_7$), in the presence of sulphuric acid (H_2SO_4), is added to the sample to provide this oxygen and it is reduced to Cr^{3+} as follows:

$$Cr_2O_7^{2-} + 14\,H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

The sample is left to react with dichromate by refluxing for 2 hours. This is followed by the determination of the amount of oxygen consumed by the sample during the oxidation process through titrating the sample with ferrous ammonium sulphate which reacts with residual dichromate as follows:

$$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$$

Ferroin is used as the indicator.

Procedure

The sample was diluted 1:10 using a volumetric flask to make a 100ml sample. Clear effluents were not diluted. 20ml were pipetted (in duplicates) from the 100ml into the refluxing sample and 400ml of concentrated sulphuric acid was added followed by a few glass beads. A blank was prepared using 20ml of distilled water. The mixture was refluxed on the plate for 2 hours at 350^oC. The mixture was allowed to cool before being titrated against standard 0.025M ferrous ammonium sulphate using Ferroin indicator (2 drops). The colour changes that occurred are:

Green → Blue → Reddish brown (end point)

The COD level is determined using the following formula:

$$\left(\frac{(A-B)xM800mg/l}{samplevolume}\right)$$

Where

B - ml of ferrous ammonium sulphate used for blank titration

A - ml of ferrous ammonium sulphate used for sample titration

(A-B) - proportional to the amount of dichromate consumed by sample

M - molarity of ferrous ammonium sulphate

= (Volume 0.0417 M $K_2Cr_2O_7$ solution titrated, ml) x 0.25/ Volume ferrous ammonium sulphate used in titration.

Hypothesis Testing

The hypothesis testing was carried out to check whether there was a significant difference between the measured effluent parameter concentrations and their corresponding regulatory limits. It was performed using a computer-based statistical program known as Crunch, developed by S4i Limited of the United Kingdom. Crunch is developed on Microsoft Excel and can easily perform a *1-sample student t-test,* giving feedback on the significance of the difference between the concentrations of the parameters over the six weeks and the reference value i.e. the legal limits. The researcher chose the student *t*-test as the most suitable method because the number of samples, n was less than 30 (Rees, 1989).

Results

Table 1: Results from effluent analysis

COAL BUNKER								
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	**Average**	**Limit**
pH	2.54	2.49	3.24	2.45	2.49	2.34	***2.59***	**6.8-9.0**
TDS (mg/l)	19521	1930	11675	17160	10895	28870	***15008.50***	**2000**
TSS (mg/l)	763	4100	854	270	270	275	***1088.67***	**150**
COD((mg/l)	580	150	380	1750	202	640	***617.00***	**200**

BOILER EFFLUENT

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	**Average**	**Limit**
pH	10.33	10.12	10.35	10.22	10.57	11.55	***10.52***	**6.8-9.0**
TDS (mg/l)	1288	3800	2027	1286	1537	5121	***2509.83***	**2000**
TSS (mg/l)	18	250	49	85	115	29	***91.00***	**600**
COD (mg/l)	95	105	123	73	104	180	***113.33***	**3000**

BATTERY SECTION

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	**Average**	**Limit**
pH	6.67	6.87	7.87	7.96	7.79	8.17	***7.56***	**6.8-9.0**
TDS (mg/l)	1450	70	2206	5020	3190	2430	***2394.33***	**2000**
TSS (mg/l)	5290	29	258	3140	500	330	***1591.17***	**600**
COD (mg/l)	9200	2300	57	5200	470	521	***2958.00***	**3000**

HUMIDIFIERS

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	**Average**	**Limit**
pH	7.36	7.99	7.59	7.68	7.77	7.97	***7.73***	**6.8-9.0**
TDS (mg/l)	246	301	281	286	537	250	***316.83***	**2000**
TSS (mg/l)	1	2	7	15	11	5	***6.83***	**150**
COD (mg/l)	43	30	123	45	54	168	***77.17***	**200**

REDRIERS

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	**Average**	**Limit**
pH	6.39	6.08	6.43	6.56	7.14	6.94	***5.43***	**6.8-9.0**
TDS (mg/l)	620	1420	374	406	300	404	***587.33***	**2000**
TSS (mg/l)	500	200	24	59	86	165	***172.33***	**600**
COD (mg/l)	1350	580	600	693	265	740	***704.67***	**3000**

CAR WASHBAY

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	**Average**	**Limit**
pH	7.26	6.97	7.21	8.95	6.89	7.03	***7.39***	**6.8-9.0**
TDS (mg/l)	432	920	433	714	360	300	***526.50***	**2000**
TSS (mg/l)	44	50	28	90	115	70	***66.17***	**600**
COD (mg/l)	560	136	172	460	316	203	***307.83***	**3000**

Table 2: Hypothesis testing results

Parameter	Mean Discharge, x	Standard Limit, *u*	Conclusion
Coal bunkers			
pH	2.59	6.8 – 9.0	Significantly below the lower limit.
TDS (mg/l)	15008.50	2000	Significantly greater than the standards.
TSS (mg/l)	1088.67	150	Not significantly greater than the standards
COD(mg/l)	617.00	200	Not significantly greater than the standards
Boiler Blowdown			
pH	10.52	6.8 - 9.0	Significantly above the upper limit.
TDS (mg/l)	2509.83	2000	Not significantly greater than the standards
TSS (mg/l)	91.00	600	Significantly below the limit
COD(mg/l)	113.33	3000	Significantly below the limit
Battery Section			
pH	7.56	6.8- 9.0	Significantly within the standards.
TDS (mg/l)	2394.33	2000	Not significantly greater than the standard
TSS (mg/l)	1591.18	600	Not significantly greater than the standards
COD(mg/l)	2958	3000	Not significantly greater than the standards
Humidifiers			
pH	7.73	6.8 – 9.0	Significantly above the lower the limit of 6.8 but significantly below the upper limit
TDS (mg/l)	316.83	2000	Significantly below the limit
TSS (mg/l)	6.83	150	Significantly below the limit
COD(mg/l)	77.17	200	Significantly below the limit
Redriers			
pH	5.43	6.8 - 9.0	Not significantly below the lower limit but significantly below the upper limit.
TDS (mg/l)	587.33	2000	Significantly below the limit
TSS (mg/l)	172.33	600	Significantly below the limit
COD(mg/l)	704.67	3000	Significantly below the limit
Washbay			
pH	7..39	6.8 - 9.0	Significantly above the lower limit of 6.8 but significantly below the upper limit
TDS (mg/l)	526.50	2000	Significantly below the limit
TSS (mg/l)	66.17	600	Significantly below the limit
COD(mg/l)	307.83	3000	Significantly below the limit

Discussion

pH

Generally, pH is failed to meet the ZINWA and City of Harare requirements at three of the six sampling stations, namely Coal Bunkers, Boiler Blow down and Redriers. The other three stations (Washbay, Battery section and Humidifiers) had pH levels within the range of established standards.

All the six weekly samples of effluent from the Coal Bunkers were significantly below the ZINWA lower limit for pH as revealed by the hypothesis test conducted. The effluent is characterized by extremely low pH (acidic), averaging 2.59. This pH impairment could be due to acid mine drainage (AMD). The pH of the Boiler effluent was highly alkaline, with all the six samples collected falling within the range of 10.12- 11.55 which is above the upper limit (9.0) for Harare City council. This is supported statistically in the hypothesis testing. The high pH is due to the fact that wastewater coming out of the boilers as blowdown is already alkaline as regulations for boiler maintenance recommend that the pH inside the boilers be maintained at between 10 and 12. In order to counter typical boiler problems such as scale formation and corrosion in boiler internals, feed water and condensate systems, boiler water is maintained with a high concentration of hydroxyl ions, OH^- (alkalinity) (ProchemTech International,2003). This is because low pH is presumed to aid the prevalence of these boiler problems. A high pH is also required by the carbonate and phosphate scale control chemistry to properly form the scale preventing precipitates. These inherent limitations in the control of boiler chemistry (due to the fact that boiler water should be maintained above a specific pH) make it difficult to control the pH at source. Further, the unavailabity of a pH balance tank to neutralise or, at least bring down the pH level to within permissible limits result in the discharge of the alkaline effluent into the sewer system.

The pH for the battery section, averaging 7.56, was in compliance with the limits as indicated in the statistical test. This is due to the chemical treatment that is being applied. In the chemical treatment process, the acidity is buffered by the addition of an alkaline chemical, sodium bicarbonate. This chemical raises the pH to acceptable levels in an acid-base reaction. The following reaction illustrates the neutralisation process:

$$NaHCO_{3\,(s)} + H^+_{(aq)} \quad Na^+_{(aq)} + CO_{2\,(g)} + H_2O_{(l)}$$

The pH level within the Humidifier effluent for the entire six sampling weeks are well within the ZINWA requirements, ranging 7.36- 7.99 and averaging 7.73. The reason for meeting the limits for this effluent is that the water used in this area is not altered either physically nor chemically as no additives are put in. It is merely pure municipal water.

Only two out of the six weekly samples collected from the Redriers managed to meet the city of Harare standards for pH. The rest were fluctuating below the lower limit of 6.8. However statistical inference indicate that, despite these low measurements, the average pH level of effluent from the Redriers (5.43) is not significantly different from the standard. The most probable cause for this slightly low pH is the temperature of the effluent. pH is temperature dependent i.e. it decreases (becomes acidic) with increasing temperature (Droste, 1997). This means that upon cooling or mixing with other low temperature effluents, there is likely to be pH self-correction bringing the level to neutral hence permissible levels.

Car Washbay effluent's pH, averaging 7.39, meets the Harare City Council regulations. This is supported by results from the hypothesis testing, which indicate that the pH is still statistically well within the statutory limits. The effluent from car washings can be acidic (as a result of battery acids used as electrolytes) or alkaline due to soaps (Droste, 1997) and soda solutions used to wash battery terminals. The availability of an oil separator for this effluent allows for the equalisation of the effluent such that the acidic effluent is allowed to thoroughly mix with the alkaline hence the effluent becomes neutral through self pH correction.

Total Dissolved Solids (TDS)

The TDS standard requirement for ZINWA is a maximum of 2000mg/l whilst no limit has been set for the same parameter by City of Harare Trade Effluent Control Regulations. This effectively implies that, in terms of dissolved solids, TPZ is obliged to ensure regulatory compliance for effluents from the Coal Bunkers and Humidifiers which are regulated by ZINWA. However, in order to keep the levels of TDS under control for best practice purposes, it is only reasonable and therefore advisable to compare all effluent sources at TPZ against the ZINWA limit for the dissolved solids.

TDS in the Coal Bunker effluent are too high, averaging 15008mg/l. Statistical inference shows that the level is significantly above the ZINWA limit hence do not comply with the statute requirement of 2000mg/l. High TDS in the coal effluent are likely to be de to dissolved metals whose solubility increases at low pH. The metals stay dissolved in solution until the pH rises to a level where precipitation occurs. Since this effluent was not treated to correct the acidity, precipitation of the dissolved metal could not occur hence their concentration remained high. Another contributory factor to high TDS could be the excessive use of water (in terms of volume) to dampen the coal. This has resulted in the dissolving of most of the soluble constituents of coal resulting in high content of TDS in the waste water. High TDS can also be attributed to the quality of the coal. Poor quality coal tends to have a high content of sulphur, chlorides and heavy metals which become the critical components of TDS.

The level of TDS in the Boiler wastewater is also exceeding the legal limit; averaging about 2509mg/l although the difference from the standard is not statistically significant. TDS are a result of ions such as calcium, magnesium and their carbonates in the boiler water which are concentrated during steam production. In an effort to conserve water and minimal use of boiler water treatment chemical, these are only blown down when their levels are between 2500mg/l and 3500mg/l. However the minimum TDS level (2500mg/l) for blowdown to take place would have already exceeded the legal limit (2000mg/) hence the failure to comply with the standard.

TDS in the Battery effluent are exceeding the ZINWA limits, having an average discharge of 2394mg/l. The difference from the limit is however insignificant according to the hypothesis testing results. TDS in the Battery effluent are attributed to the electrolytes in the cells of the batteries and the salts formed in the acid-base neutralization reaction between sodium bicarbonate that is added to correct the pH. Components of the electrolytes include zinc, lead, iron and chlorides. The electrolytes react to form solid salts which tend to accumulate on the terminal of the batteries. Upon charging, the salts are scrapped off the terminals and disposed off into the Battery room drain where they dissolve in the waste water.

Total Suspended Solids (TSS)

The level of TSS generally complies with the relevant statute requirements except for effluents from the Battery section and Coal Bunkers which were averaging 1591mg/l and 1089mg/l respectively. The ZINWA limit for discharge into storm water drains is 150mg/l whilst City of Harare's threshold is 600mg/l.

The Coal bunkers exceeded the ZINWA limit throughout the sampling period due to the dusty nature of coal and the fact that the canal which ran from the bunkers is an open channel (allowing dust into the waste water). Boiler effluent's TSS level (averaging 91mg/l) is significantly below the statutory requirement of the City of Harare as proven by the hypothesis test performed. Compliance for this wastewater with regard to TSS can be accredited to the availability of a settling tank which holds the effluent and allow for the sedimentation of most of the suspended solids before discharge into the sewage system. The high value of 250mg/l recorded during Week 2 might have been caused by an increase in flow rate of effluent due to increased frequency of blowdown. This might have resulted in the effluent not being given sufficient time to settle out the solid. The flow rate of the water body is a primary factor in TSS concentrations. Fast running effluents can carry more particles and larger-sized sediment. A reduction in flow rate of waste water can significantly lower the TSS levels in the effluent because the particulate matter is allowed to settle. However particulate matter from bottom sediments may be resuspended at an increased effluent flow speed (http://h2osparc.wq.ncsu.edu/).

Although the average TSS discharge level is above the legal limit, four out of the six samples collected from the Battery section managed to meet the established standard. High values recorded in the 1st and 4th weeks (of 5290mg/l and 3140mg/l respectively) are responsible for the high average. The most probable cause for these high readings might be the discharge procedure that was employed when the effluent was released into the sewer system. After alkali dosage in the Battery sump, the wastewater was agitated vigorously to thoroughly mix the alkaline additive with the acidic media. The release valve was opened as soon as the agitation was complete. Because agitation re-suspend the already settled solids, the effluent was not given sufficient time to re-settle out the solids hence the high concentration of TSS.

The level of TSS in the Humidifier effluent, averaging 6.83mg/l, is insignificant when compared with the ZINWA limit of 150mg/l. The fact that this water is purely municipal water explains the low TSS levels.

The construction of the dust plant with ductings which suck virtually all the dust at different points along the processing lines might have led indirectly to a reduction in TSS, TDS and COD levels of the waste water. TSS in the Washbay effluent are very low (66.17mg/l) as a result of the oil separator which also serves the purpose of settling out most of the suspended solids.

Chemical Oxygen Demand

The ZINWA standard for COD is 200mg/l. City of Harare requires a maximum of 3000mg/l. According to the results, the effluent is complying with the regulatory limits at four of the six sources. These are boilers (113.13mg/l), Humidifiers (77.17mg/l), Redriers (704.67) and Car Washbay (307.83mg/l). Compliance has been proved statistically in the hypothesis testing against the corresponding standards. Wastewater from the Coal Bunkers and Battery section do not meet the statutory limits. It can be clearly noted that the level of COD in all the effluents is following the trend of TSS, that is, where TSS are high, COD is also high and vice versa.

The impact of the Battery effluent can be insignificant considering the volumetric contribution of such effluent to the company's final discharge and the non-continuity of the flow (usually once a week). Because the volume is small, the battery effluent can be readily diluted into other complying effluents resulting in legislation compliances for the final effluent. It is also hoped that the situation at the Coal bunker may soon be rectified with the commissioning of the new settling tank which was under construction during the time of study. The settling tank allows the suspended solids to settle down, at the same time precipitating the dissolved solids. The construction of the Coal bunker Settling Tank will also see the waste water being re-directed into the Municipal Sewer system from the public stormwater drains which will immediately prompt for a change in regulatory limits from the more strict ZINWA limits to the less stringent Harare Trade effluent control standards.

Conclusion and Recommendations

Conclusion

The study has revealed that the effluent streams of higher significance are the Boiler blowdown, Coal Bunkers, Redriers, Battery section, Humidifiers and Car Washbay. Effluent from these sources generally complies with the relevant regulatory standards in terms of TSS, TDS and COD. However, two wastewater streams, the Boiler Blowdown and seepage from Coal Bunkers, have been found to be of major concern, as their effluents do not comply with legislation with regards to pH. pH for the blowdown is highly alkaline (10.52) whilst that of the Coal bunkers is too acidic (2.59). Extreme pH levels are corrosive to pipes, increase the demand for water treatment chemicals and can be detrimental to the aquatic life especially fish (Droste, 1997).

The study also found out that the method of disposal for the Humidifier effluent does not comply with the provisions of the new Environmental Management Act of 2002, section 59 which prohibitively states that trade effluent should be discharged only into the sewage system.

General Recommendation

- There is need to incorporate the servicing of all water pollution control equipments (settling tanks and oil separators) into the maintenance programme so that they are cleaned or de-sludged frequently to ensure effective functioning.
- Efforts should be made to ensure that all effluents at TPZ go into the sewage system in terms of section 59 of the Environmental Management Act, which restricts the discharge of trade effluent only into the sewage system. Currently the humidifier and Basement water effluent is being discharged into the storm drains.
- Facilities to measure and quantify effluent being discharged from the company need to be put in place. This information can be demanded, at any point in time, by the Environmental Management Board (section 58, Environmental Management Act).
- Currently, Tobacco Processors Zimbabwe does not have the licence to discharge its effluent. Section 60 (2) of the Environmental Management Act requires every operator of an industrial undertaking that discharge effluent to be in possession of that discharge permit issued by the Environmental Management Board. As of now, the Board has not yet started issuing out these licences.
- Effluent quality records should be consistent and more parameters should be included in the monitoring exercise.

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