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Microbiological and Physicochemical Quality of Honey in Minna Metropolis, Nigeria

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ABSTRACT

Honey is a naturally sweet dark golden liquid produced by honey bees. Ten (10) honey samples from different locations in Minna, Nigeria were evaluated for their microbiological and physicochemical quality. The samples were subjected to microbiological assessment using standard pour plate method. Results revealed that the physicochemical properties of the honey samples had an average pH of 3.94, total titratable acidity of 34.45meq/kg, electrical conductivity of 40.85µS/cm, moisture content of 17.07%, total solid of 82.93%, ash content of 0.25% and water activity of 0.56 which were within the acceptable standard limit for international and Nigerian honey. The results of the microbiological assessment showed that the total bacterial counts ranged from 0-$2.0x10^5$cfu/mL and total fungal counts ranged from 0-$7.0x10^4$cfu/mL. The data obtained from physicochemical assessment were subjected to one-way analysis of variance (ANOVA) ($P \leq 0.05$) which showed that there was no significant difference in the levels of pH, ash content and water activity, while there was significant difference in the levels of moisture content, conductivity, total titratable acidity and total solid. Microbiological assessment revealed significant difference in both the total bacterial counts and total fungal counts. The bacteria were identified as *Bacillus subtilis, Staphylococcus aureus* and *Pseudomonas aeruginosa,* while the fungus was *Aspergillus fumigatus.* This study shows that some honeys are contaminated with microorganisms that could be hazardous to human health. Hence, the need for routine hygienic practices necessary to avoid microbial contaminants.

Key words: Assessment; Honey; Microorganisms; Physicochemical; Quality.

INTRODUCTION

Honey is a mixture of sugars, water and other compounds (organic acid, formic acid, citric, succinic, latic, malic, gluconic acid and a number of aromatic acids). The specific composition of any batch of honey depends on the flowers available to the bees that produce the honey [1]. Honey has a density of about.36 kilograms per liter and 36% denser than water [2].

In view of the carbohydrates contents, honey is mainly fructose (about 38.5%) and glucose (about 31.0%) making it similar to the synthetically produced inverted sugar syrup which is approximately 48% fructose, 47% glucose, 5% sucrose and other complex carbohydrates [3]. Honey contains trace amounts of several vitamins and minerals [4]. As with all nutritive sweeteners, honey is mostly sugars containing vitamins or minerals in low amounts [5]. Honey also contains tiny amount of several compounds thought to function as antioxidants, including chrysin, pinobanksin,vitamins C, catalase, and pinocembrin [6]. Honey is produced by bees as a food source in cold weather. Bees use their stored honey as their source of energy [7].However, due to human benefit of honey; people have been able to semi-domesticate bee in artificial hives thus harvesting excess honey.

The average pH of honey is 3.9, but can range from 3.4 to 6.1. Honey contains many kinds of acids mainly amino acids and other organic acid. However the different types and their amounts vary considerably depending on the type of honey. These acids may be aromatic or aliphatic (non-aromatic). The aliphatic acids contribute greatly to the flavor of honey by interacting with the flavors of other ingredients. Gluconic acid, for instance is a flavor enhancer. The aromatic acids, such as malic acid, come mostly from the flowers, adding to the aroma and taste of the honey. Honey can contain up to 18 of the 20 amino acids. However amino acid content is almost negligible in honey accounting for only 0.05–0.1% of the composition. The main amino acid is proline [8].Organic acids comprise most of the acids in honey, accounting for 0.17–1.17% of the mixture. Gluconic acid which is the predominant organic acidis formed by the action of an enzyme called glucose oxidase. Other organic acids like formic, acetic, butyric, citric, lactic, malic, pyroglutamic, propionic, valeric, capronic, palmitic, and succinic are found in lesser amounts[9].

Honey is a natural product gotten from honey bees that contains some important nutritive and medicinal properties. However, as a result of its high demand, there is often adulteration of honey leading to its contamination by microorganisms.

Efforts have been towards studying the physicochemical properties of honey. There seem to be dearth of information on the microbiota of honey been documented proving that a well-developed understanding of these is needed. Therefore, this study represents one of the few studies in this area. This will provide an insight to the microbiological characteristics of honey so as to lay a foundation of combining microbiological and physiochemical aspects of honey in order to enhance better understanding of the microorganisms associated with honey particularly some pathogenic microbes that could cause health hazard and human diseases. Hence the study was designed particularly to determine the quality and microorganisms associated with honey in Minna, Niger state, Nigeria.

MATERIALS AND METHODS

Sample collection

Ten (10) samples of honey were purchased from different locations in Minna, Niger state. These included; Bosso, Mobile, Chanchanga, Kpakungu, Mekunkele, Tundufulani, Saukakahuta, Tunga, Maitumbi and Central market. They were transported immediately to the laboratory of Federal University of Technology, Minna, Niger state, Nigeria for microbiological and physic-chemical analysis. The honey samples were stored in the refrigerator until further use.

PHYSICOCHEMICAL ANALYSIS

pH

The pH of the honey samples were determined by carefully measuring out 10 mL of each sample into a clean beaker. The pH meter was then immersed into the honey sample, after which the honey sample was stirred with pH meter gently and waited until the display on the pH meter was stabilized. The pH value was recorded accordingly after the reading had been stabilized.

Titratable acidity (TTA)

The total titratable acidity was determined using the method of [8]. One milliliter (1mL) of each honey sample was measured into 5mL distilled water and titrated against 0.02M NaOH using phenol red as indicator.

Total titratable acid was calculated as follows:

$$\text{Total titratable acid} = \frac{X.20}{Y} \text{ Mmol/L} \qquad \text{Equation (1)}$$

Where X= Titre (mL) of alkali used

Y= Volume of samples

0.02 NaOH was determined to contain 20m Mol total titratable acid.

Electrical conductivity

Electrical conductivity of the honey samples were measured at 22℃ using a conductivity meter.

Moisture content

The moisture content of each sample was determined as follows:

Five gram (5g) of the sample was weighed and placed into a pre-weighed aluminum drying dish. The sample was dried to constant weight in an oven at 105℃ for 4 hours under vacuum [10].

$$\text{Moisture content} = \frac{M1-M2}{M1-M0} \qquad \text{Equation (2)}$$

Where:

Mo=Weight of the aluminum dish

M1=Weight of the fresh sample + dish

M2=Weight of the dried sample+ dish

Total solid

The percentage total solid of each sample was determined using the equation:

Total solids (%) = 100 −Moisture content Equation (3)

Ash content

Ash content was determined by weighing 5g of each honey sample separately into a porcelain crucible previously ignited and weighed organic matter was charred by igniting the sample on a hot plate in the fume cupboard. The crucible was then placed in the muffle furnace and maintained at 600℃ for 6 hours. They were then cooled in desiccators and weighed immediately [10].

The percentage ash was calculated as:

$$\text{Ash}\% = \frac{(\text{Weight of crucible+ash}) - (\text{Weight of empty crucible}) \times 100}{\text{Sample weight}} \quad \text{Equation (4)}$$

Water activity (Aw)

Water activity was determined using the equation below:

Water activity (Aw) can be calculated as;

$$\text{Aw} = \frac{(0.025 \times \text{gram water})}{(100\text{g honey})} + 0.13. \quad \text{Equation (5)}$$

MICROBIOLOGICAL ANALYSIS

Bacterial isolates

One milliliter (1mL) of the honey sample was aseptically introduced into 9mL of sterile distilled water in a test tube. This was shaken and serially diluted. One milliliter (1mL) from an appropriately serially diluted sample was introduced into a sterile Petri dish and molten nutrient agar was poured on it using the standard pour plate method described by [9] and mixed properly. It was then allowed to solidify and then incubated for 24 hours at 37℃ for bacterial growth.

Fungi isolates

Appropriate serially diluted honey sample were inoculated onto Sabouraud dextrose agar (SDA) to identify the fungal isolates. The plates were incubated at 28°C for 48-72 hours.

Characterization and identification of microbial isolates

Bacterial isolates

The bacterial isolates were characterized based on colonial morphology, cultural characteristics, Gram's reaction and biochemical tests as described by[11,12]. The bacterial isolates were identified by comparing their characteristics with those of identified species using the schemes of [13-15].The biochemical tests carried out on the bacterial isolate were catalase test, carbohydrate

fermentation test, citrate utilization test, coagulase test, indole test, methyl red test (MR), starch hydrolysis and Voges-proskauer test (VP).

Fungal isolates

Fungal identification was carried out using mycological atlas [16]. The fungi isolated were stained using lactophenol cotton blue solution and characterized based on the colour of the aerial and substrate hyphae, type of hyphae, shape and kind of asexual spore, sporangiophore and conidiophore and the characteristic of spore head. The isolates were identified by comparing their characteristics with those of known taxa using the schemes of [17].

RESULTS

The results from the research showed that the pH and total titratable acidity from all the locations ranged from 3.7-4.2 and 26.0-40.59 respectively (Table 1). There was no significant difference in the pH value for all the locations sampled, while there was significant difference in the values of the total titratable acidity for all the locations sampled.

The results from the investigations shows that the ash content and water activity from all the locations ranged from 0.16-0.36 and 0.53-0.59 respectively (Table 1).There was no significant differences in the ash content and water activity from all the locations sampled.

The results from the study shows that the conductivity, moisture content and total solid from all the locations ranged from 16.70-60.14, 11.60-21.35 and 78.65-88.40 respectively (Table 1).There was significant difference in the conductivity, moisture content and total solid from all the locations sampled.

Table 1: Physico-chemical parameters of honey samples from different locations

Locations	pH	Total titratable Acidity(meq/kg)	Conductivity ($\mu S/cm$)	Moisture Content (%)	Total solid (%)	Ash Content (%)	Water Activity
Mobile	4.1[a]	34.74[d]	24.55[h]	21.35[a]	78.65[g]	0.18[a]	0.53[a]
Saukakahuta	4.2 [a]	35.0[d]	16.70[j]	11.60[g]	88.40[a]	0.16[a]	0.55[a]
Kpankungu	4.1[a]	30.0[f]	22.40[i]	20.32[b]	79.68f	0.27[a]	0.57[a]
Tunga	3.8 [a]	26 .0[g]	33.40[g]	15.86[e]	84.14[c]	0.28[a]	0.54[a]
Maitumbi	4.0 [a]	37.5[c]	40.13[f]	17.03[d]	82.97[d]	0.19[a]	0.56a
Central Market	3.7 [a]	29.45[g]	55.26[c]	16.53[e]	83.47[c]	0.36[a]	0.59 [a]
Tundun Fulani	3.8 [a]	38.0[c]	47.48[e]	18.71[c]	81.29[e]	0.25[a]	0.55[a]
Chanchanga	4.0 [a]	39.50[b]	49.20[d]	16.53[e]	84.53[b]	0.33[a]	0.55[a]
Mekunkele	4.0[a]	40.59 [a]	60.14[a]	18.71[c]	83.24[d]	0.32[a]	0.56[a]
Bosso Market	3.7[a]	33.67[e]	59.20[b]	15.47[f]	82.93[d]	0.19[a]	0.54 [a]

Values (a, b, c, d, e, f, g, h, i, j) on the same column with different superscript are significantly different ($p<0.05$) while those with the same superscript are not significantly different ($p>0.05$).

It was revealed that Mobile, Kpankungu, Tundun-fulani, Mekunkele and Bosso market had total viable bacterial count of $2.0x10^5$, $1.5x10^5$, $1.8x10^5$,$1.0x10^5$ and $5.0x10^4$respectively, while Saukakahuta, Tunga, Maitumbi, Central market and Chanchanga had zero counts of bacteria growth (Table 2). There was significant difference in the total viable bacterial counts from all the locations sampled.

Table 2*:* Total viable bacterial counts from different locations

Locations	Total bacterial count (cfu/mL)
Mobile	$2.0x10^{5a}$
Saukakahuta	0^{e}
Kpankungu	$1.5x10^{5b}$
Tunga	0^{e}
Maitumbi	0^{e}
Central market	0^{e}
Tundun-fulani	$1.8x10^{5a}$
Chanchanga	0^{e}
Mekunkele	$1.0x10^{5c}$
Bosso market	$5.0x10^{4d}$

Values (a, b, c, d, e) on the same column with different superscript are significantly different ($p<0.05$) while those with the same superscript are not significantly different ($p>0.05$).

Results from Table 3 revealed that Chanchanga and Bosso market had total fungi count of 7.0 $x10^{4}$and 3.0 $x10^{4}$respectively, while Mobile, Saukakahuta, Kpankungu, Tunga, Maitumbi, Central market, Tundun-fulani and Mekunkele had zero counts of fungi growth. There was significant difference in the total fungi counts from all the locations sampled.

Table 3: Total fungi counts from different locations

Locations	Fungi count (cfu/mL)
Mobile	0^{c}
Saukakahuta	0^{c}
Kpankungu	0^{c}
Tunga	0^{c}
Maitumbi	0^{c}
Central market	0^{c}
Tundun-fulani	0^{c}
Chanchanga	$7.0x10^{4a}$
Mekunkele	0^{c}
Bosso market	$3.0x10^{4b}$

Values (a, b, c) on the same column with different superscript are significantly different ($p<0.05$) while those with the same superscript are not significantly different ($p>0.05$).

The results from the microbial analysis revealed that the honey samples harbour different microorganisms which include *Bacillus subtilis, Staphylococcus aureus, Pseudomonas aeruginosa* and *Aspergillus fumigatus* (Table 4).Table 5 shows the biochemical tests carried out for bacteria isolates.

Table 4: Frequency of occurrence of bacteria and fungi isolates from honey

Microorganisms	**No of organisms isolated**	**Frequency of occurrence (%)**
Bacillus subtilis	2	28.57
Staphylococcus aureus	2	28.57
Pseudomonas aeruginosa	1	14.3
Aspergillus fumigatus	2	28.57
Total	7	100

DISCUSSION

The physicochemical properties of the different samples of honey are given in Table 1 above. The pH values of the honey samples ranged from 3.7-4.2. The pH values correlate and corroborate with the pH range of 3.2 - 4.5 as reported by [16] for international honey. The pH range obtained in the present study was however lower than the range of 4.31-6.0 reported by [18] for Nigerian honey from other locations. This may be due to adulteration of the honey with glucose solutions, dextrose, molasses, sugar syrup, invert sugar, flour, corn syrup, starch, or any other similar product, other than floral nectar or low-quality honeys with a high water content, because the honey has been taken from cells that are not properly covered with wax. The acidic pH of honey is desirable since acidification has been shown to promote healing by causing oxygen release from hemoglobin [19]. The pH of honey is low enough to prevent the growth of many species of bacteria.

Table 5: Biochemical tests for bacteria isolates

Locations	Gram Reaction	Cell shape	Catalase	Coagulase	Oxidase	Indole	Citrate utilization	H_2S production	Urease	MR	VP	Suspected Bacteria
Mobile	+	Rod	+	−	−	−	+	−	−	−	+	*Bacillus subtilis*
Bosso	+	Rod	+	−	−	−	+	−	−	−	+	*Bacillus subtilis*
Tundunfulani	+	Cocci	+	+	−	−	+	−	−	+	+	*Staphylococcus aureus*
Kpakungu	+	Cocci	+	+	−	−	+	−	−	+	+	*Staphylococcus aureus*
Mekunkele	−	Rod	+	−	+	−	+	−	−	−	−	*Pseudomonas aeruginosa*

+: Positive; **−:** Negative; MR: Methyl red; VP: Voges-proskauer.

The moisture content of the honey samples ranged from 11.60-21.35%. The moisture content of the samples falls within the range of 11.47 - 22.20 reported by [19] for international honey and by [20] for Nigerian honey from other locations. The variations in the moisture content of honey have been ascribed to the composition and flora origins of honey [19]. Moisture content is practically the most important quality parameter, since it affects storage life and processing characteristics. The strong interaction of sugar in honey with water molecules may decrease the water available for microorganisms. The low moisture content of honey also forms an important part of the system which protects the honey from attack by microorganisms.

The ash content of the honey samples ranged from 0.16-0.36% and it falls within the acceptable range of 0.10-0.36 reported by [22] for Nigerian honey from other locations and by [20] for international honey. The floral origin of honey has been reported responsible for the variability in ash content [22].The ash content is a measure of the mineral elements in honey.

The electrical conductivity values of the honey samples ranged from 16.70 - 60.14 $\mu S/cm$. These values fall within the range of 9.4 - 172.9 reported by [19] for Nigerian honey from other locations. Electrical conductivity measures all ionisable organic and inorganic substances present in honey. It has been related to the botanical origin of honey and very often used in routine honey control instead of ash content [21].

The total titratable acidity values ranged from 26.0-40.59meq/kg. The total titratable acidity values falls within the range of 40meq/kg reported by [18] for international honey and by [20] for Nigerian honey from other locations. The acidity of honey contributes to its stability against microorganisms and to flavour.

The values of the water activity varied from 0.53-0.59. These values fall within the range of 0.53 and 0.59 reported by [20] for international honey. The water activity of honey varies slightly. It is obviously related to the floral source of nectar. Honey is a supersaturated sugar solution with a low water activity, which means that there is insufficient water available to support the growth of bacteria and yeast. Although some yeast can survive in high water content causing spoilage of the honey.

Total solids in the present study varied from 78.65-88.40. The total solid is a measure of dissolved solids in the honey samples. A reduction or absence of total solids in honey samples is an indicator that further processing has been done on the honey samples. The total solids of honey samples obtained from this study falls within the acceptable range of 78.60 - 88.45 reported by [19] for Nigerian honey from other locations. The data obtained from physicochemical quality assessment were subjected to One Way Analysis of Variance (ANOVA) ($P \leq 0.05$) which showed that there were no significant differences in the levels of pH, ash content and water activity, while there was significant difference in the levels of total titrable acidity, moisture content, total solid and conductivity.

The results in the present study revealed that some of the honey samples purchased from different locations in Minna subjected to microbiological quality assessment were contaminated with pathogenic bacteria which include *Bacillus subtilis, Staphylococcus aureus* and *Pseudomonas aeruginosa.* Previous study carried out on honey revealed the presence of these bacteria [7].

The high counts of bacteria detected in honey may be due to contaminations such as the activities of personnel, equipment, containers, wind, dust, and the digestive tract of the honey bees and nectar, while the zero counts of bacteria may indicate proper handling and storage of the honey products. There were moulds in the honey samples from Chanchanga and Bosso identified as *Aspergillus fumigatus* but zero counts were detected in the other locations. This was however not surprising since [19] reported counts of less than 10 cfu/mL in Moroccan honey while some French honeys had zero counts of moulds and yeasts as reported by [25].The low counts of moulds and yeast may be due to the inhibitory properties of honey such as osmotic effect, hydrogen peroxide, acidity, phenolic compound that discourage the growth of many microorganisms [23, 24]. The data obtained from the microbiological quality assessment were subjected to One-Way Analysis of Variance (ANOVA) ($p \leq 0.05$) which revealed that there were significant difference in both the total viable bacterial counts and the total fungi counts.

CONCLUSION

The microbiological quality of honey in the present study has revealed that microorganisms are present in some honey purchased from different locations in Minna metropolis, Nigeria. Physicochemical quality assessment shows that some of the honeys were within the acceptable limits. Some of the microorganisms isolated from these samples are pathogenic and could be hazardous to human health. Hence, the need for routine hygienic practices necessary to avoid microbial contaminants.

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The histology of the proventriculus and gizzard of broilers fed wheat bran based diet supplemented with natuzyme and maxigrain

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Abstract This experiment was carried out to evaluate the effect of wheat bran based diet with or without commercial enzyme supplementation on the histology of proventriculus and gizzard of Arbor acres broilers. The design of the experiment was a completely randomized design (CRD) with four treatments: T1- wheat bran based diet without enzyme, T2- wheat bran based diet with Natuzyme, T3- wheat bran based diet with Maxigrain and T4- wheat bran based diet with Natuzyme and Maxigrain. One hundred and forty-four (144) one- day old unsexed Arbor Acre chicks were used for the trial. Experimental diet and water were supplied *ad-libitum* to the birds and the birds were subjected to the recommended vaccination programme. The birds were divided into 4 dietary treatments and replicated thrice. 12 birds were allocated into each replicate and the birds were fed the experimental diets for 49 days. Performance characteristics, carcass characteristics and histological observations were carried out. Total feed intake was determined and the FCR was calculated accordingly. The feed intake and slaughter weights of the birds were significantly affected ($p<0.05$) by the dietary treatments. Visceral weight, weight of filled gizzard and weight of empty gizzard were significantly affected ($p<0.05$). The histology of the proventriculi and gizzards of the birds showed different lesions indicating the level of reaction of the birds to the dietary treatments. Wheat bran with enzyme supplementation showed harmful effect on the proventriculi and the gizzards of the birds, which increases the susceptibility of the birds to infections.

Keywords Wheat bran, Natuzyme, Maxigrain, Histology, Proventriculus,Gizzard.

INTRODUCTION

Most unconventional feed resources which have emerged as potential feed resources are very high in fibre and non – starch polysaccharides. These fibrous and non-starch polysaccharides have placed a constraint on the use of these feed resources because of their high fibre, low energy, ether extract, protein and total digestible nutrient [1]. There is need to find ways and means to improve the utilization of these fibrous materials so that it can be incorporate these materials in the poultry feed without any adverse effect on their health and production [2].

The digestive system of any animal is important in converting the food the animal eats into the nutrients its body needs for growth, maintenance, and production. An animal's body breaks down food through both mechanical and chemical means. In many animals, mechanical action involves chewing; however, because birds do not have teeth, their bodies use other mechanical action such as grinding of feed particles by the gizzard. Chemical action includes the release of digestive enzymes and fluids from various parts of the digestive system as is the case of the proventriculus. In the gizzard the food is ground and mixed with the gastric juice. The muscular development of the gizzard is influenced primarily by diet. The level of fibre in broiler rations has an effect on the size of the gizzard [3].This

experiment was designed to investigate the effect of high fibrous wheat bran fed with or without commercial enzyme supplementation on the proventriculus and gizzard of broilers.

MATERIALS AND METHODS

This research work was carried out at the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara state, Nigeria. Omu Aran is located with geographical coordinates: 8°8' 0" North, 5° 6' 0" East and the ambient temperatures during the period of study were 25.6°C (morning), 31.1°C (afternoon) and 28.7°C (evening) with corresponding relative humidity of 69%, 40% and 51% respectively. The design of the experiment was a completely randomized design (CRD).One hundred and forty four (144) Arbor Acre one- day old broilers were used for the experiment. The birds were divided into four dietary treatments and replicated thrice. 12 birds were allocated into each replicate; the birds were fed the experimental diets for 49 days. Fresh water and feed were available to the birds ad libitum. All management practices were strictly observed and medications and vaccinations were administered appropriately as at when due.

Analytical and statistical analyses

The experimental diets were analysed for proximate composition using AOAC Official Methods of Analysis. The data collected were subjected to one-way analysis of variance (ANOVA) using SAS package and the means were separated using Duncan's multiple range test of the same software at 5% level of significance.

Determination of histological parameters

The birds were weighed weekly for their weight gain and their feed intake was also recorded; the feed conversion ratio (FCR) was calculated to determine the efficiency of feed utilization. At week seven (day 49), 2 birds per replicate (i.e. 6 birds per treatment) were randomly selected and fasted for about 18 hours to empty their gastro intestinal tract; individual live weight were taken after which they were slaughtered by slitting the jugular vein. Slaughtered weight, de-feathered weight, carcass and visceral weight were taken and recorded. The proventriculi and gizzards were harvested from the birds' viscera and preserved in samples plates with 10% formalin. Slide preparation and microscopy were carried out at the Department of Clinical Pathology, Faculty of Veterinary Medicine, and University of Ibadan, Nigeria.

RESULTS AND DISCUSSION

The effect of enzyme supplementation on the growth performance of broiler chicken was presented in Table 2 showing the differences in the feed intake, weight gain and the feed conversion ratio at the end of the experiment (day 49).

Table 1. Experimental Diet Composition

Ingredient	T1	T2	T3	T4
Maize	45	45	45	45
Wheat bran	15	15	15	15
Soy bean meal	30	30	30	30
Fish meal (65%)	5	5	5	5
Bone meal	2.25	2.25	2.25	2.25
Lime stone	1	1	1	1
Premix	0.5	0.5	0.5	0.5
Salt	0.25	0.25	0.25	0.25
Methionine	0.5	0.5	0.5	0.5
Lysine	0.5	0.5	0.5	0.5
Natuzyme	-	*	-	-
Maxigrain	-	-	**	-
Natuzyme + Maxigrain	-	-	-	***
Total	100	100100100		
Calculated feed composition				
Crude protein (%)	22.8	22.8	22.8	22.8
Metabolizable energy (kcal/kg)	2602.9	2602.9	2602.9	2602.9
Crude fibre (%)	4.74	4.74	4.74	4.74
Ether extract (%)	3.52	3.52	3.52	3.52
Calcium (%)	1.41	1.41	1.41	1.41
Phosphorus (%)	0.97	0.97	0.97	0.97
Lysine (%)	1.64	1.64	1.64	1.64
Methionine (%)	0.919	0.919	0.919	0.919

*=presence of natuzyme, **=presence of maxigrain, ***=combination of both enzymes (35g Natuzyme and 10g Maxigrain)Premix 0.5% providing per kg Vitamin A 12,000000IU, Vitamin D3 2,000000IU,Vitamin E7000IU, Vitamin B2 4000mg, Nicotinic acid 15,000mg, Calcium d-pentothenate 800mg, Biotin 40mg, Vitamin b12 10mg, Manganese 20,000mg, Iron 50,000mg, Zinc 100,000mg, Copper 10,000mg, Iodine 750mg, Cobalt 3000mg.

Table2. Performance Characteristics

Parameters	T1	T2	T3	T4	SEM
Total feed intake/kg/bird	5.70^{ab}	5.54^{c}	5.60^{c}	5.87^{a}	0.06
Total weight gain/kg/bird	2.09^{c}	2.09^{c}	2.15^{b}	2.31^{a}	0.04
Feed conversion ratio	2.73^{a}	2.65^{b}	2.61^{b}	2.55^{b}	0.03

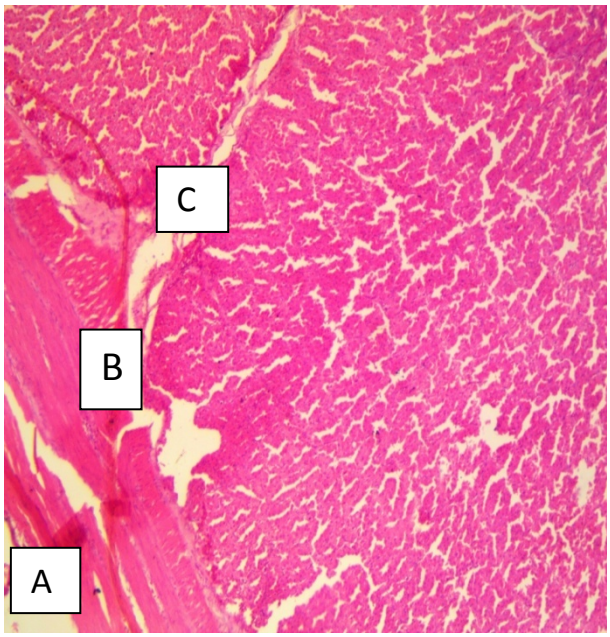
Means with different superscript (a, b and c) in the same row are significantly different at ($p<0.05$).
The feed intake tends to increase among the dietary treatments and was significantly ($p<0.05$) highest in T4.

Table 3. Carcass Analysis

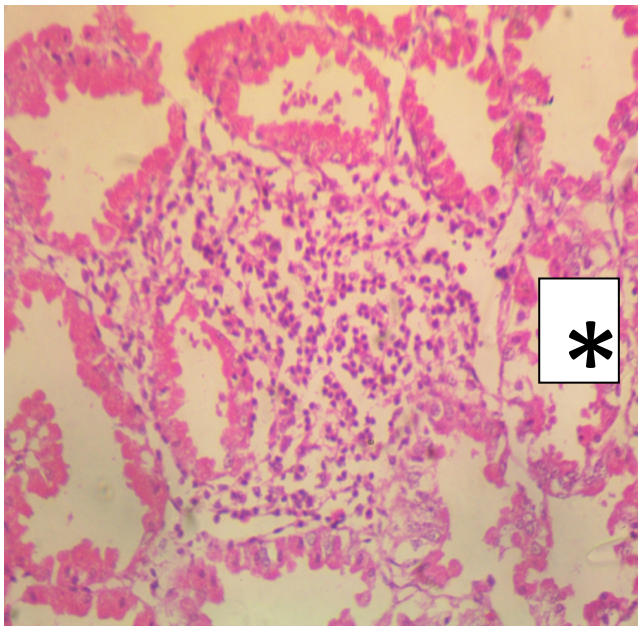
Parameters	T1	T2	T3	T4	SEM
Live_w	2.39	2.30	2.33	2.43	0.02
Sl_w	2.13[b]	2.21[ab]	2.23[ab]	2.33[a]	0.04
Df_w	2.07	2.07	2.11	2.24	0.04
Dr_w	1.64	1.59	1.66	1.70	0.02
Vis_w	0.28	0.32	0.30	0.28	0.01
Wfg	65.70[a]	66.12[a]	61.75[b]	61.59[b]	1.06
Weg	46.20[a]	47.28[a]	44.44[b]	43.38[b]	0.76

Means with different superscript in the same row are significantly different at $p<0.05$. Live_w=live weight, Sl_w=slaughtered weight, Df_w=de-feathered weight, Dr_w=dressed weight, Vis_w=visceral weight, Wfg=weight of filled gizzard, Weg=weight of empty gizzard.

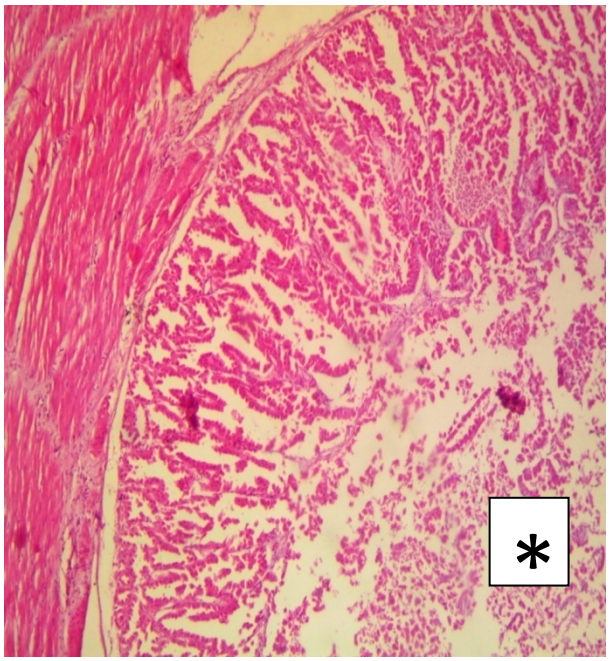
Figure 2. Microphages of the Proventriculus



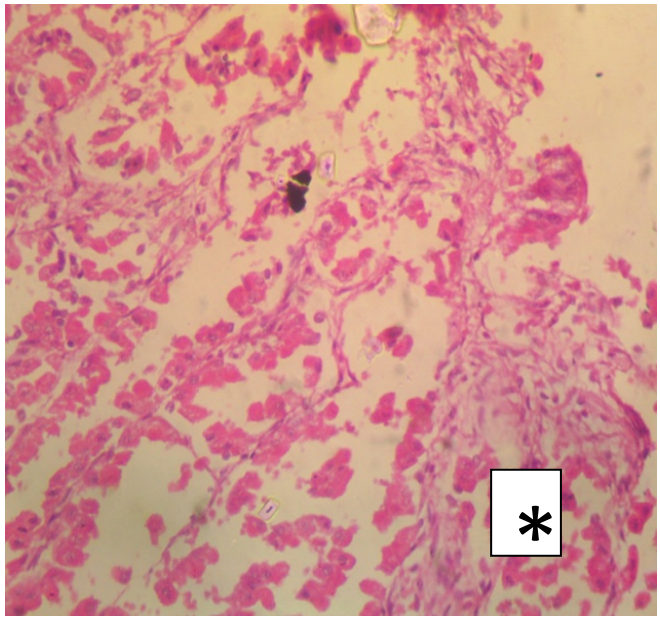
T1: Normal proventricular glands lying on the external muscular layer [left of photomicrograph]; with no visible lesion.



T2: Moderate necrosis of the proventricular simple tubular glands [right of photomicrograph]; a few foci of moderate aggregates of inflammatory cells (heterophils) between the glands.

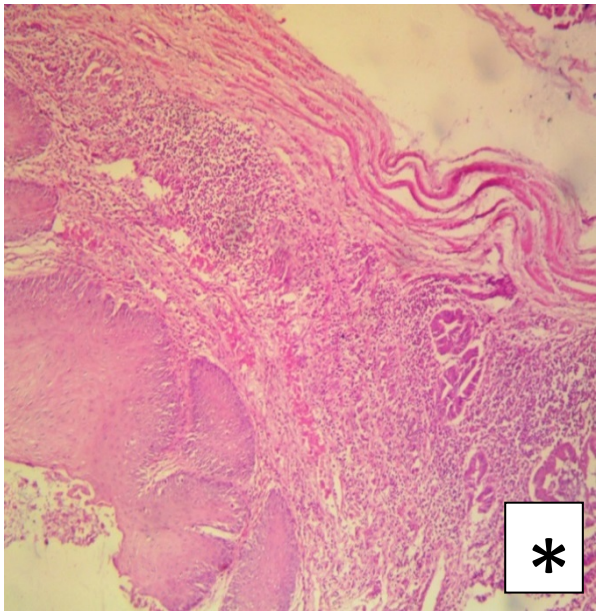


T3: moderate sloughing off of tips of proventricular tubular glands.
[Right of photomicrograph].

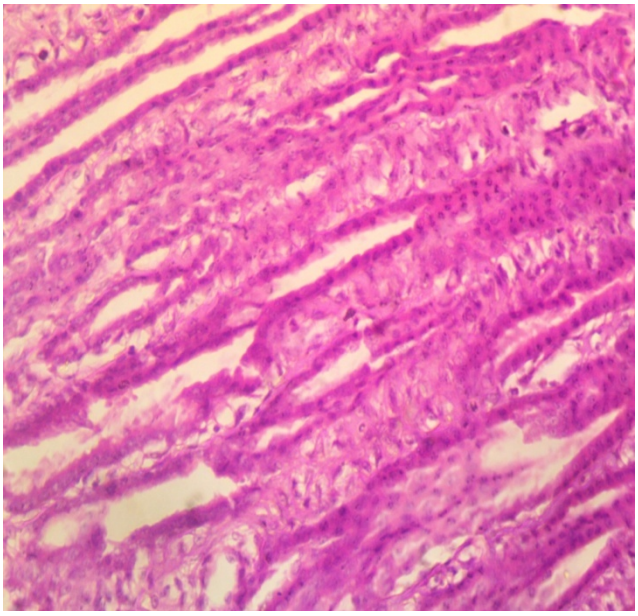


T4: Mild sloughing off/necrosis of proventricular glands

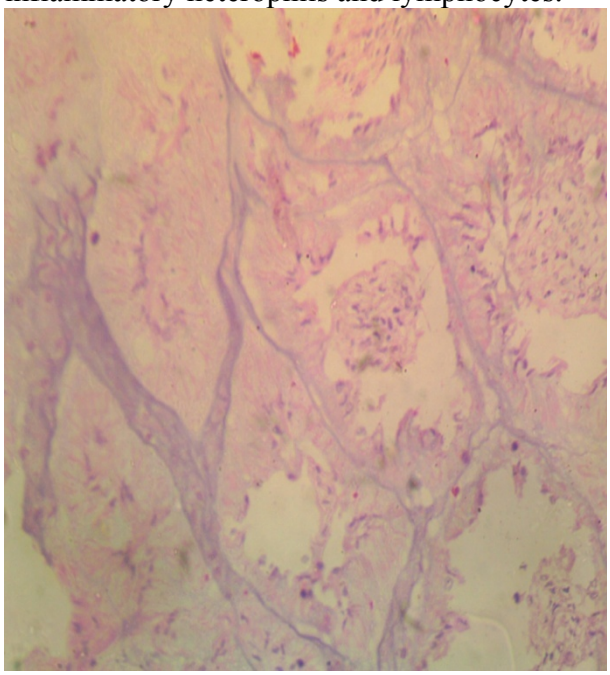
Figure 3. Microphages of the Gizzard



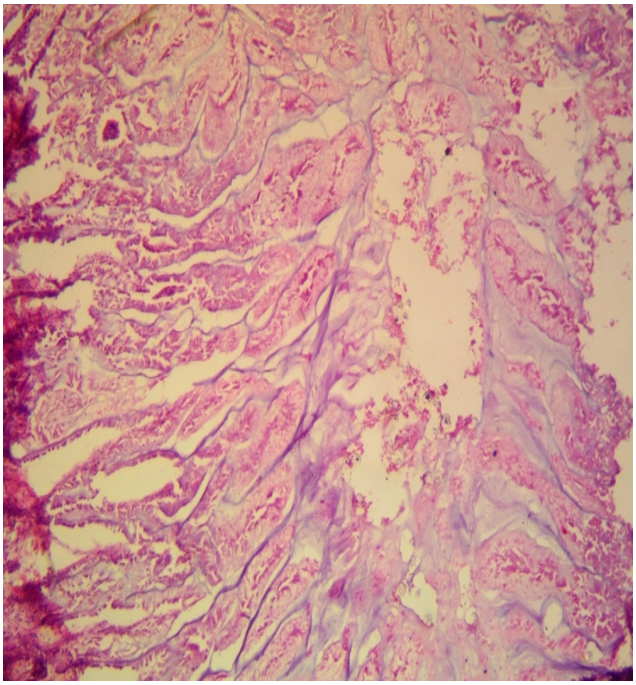
T1: Locally extensive necrosis of subcuticular glands [bottom right] and associated marked aggregates of numerous inflammatory heterophils and lymphocytes.



T2: No visible lesion: thick cuticle.



T3: Marked degeneration of subcuticular region.



T4: Poor section; degenerate subcuticular region

The average feed intake was depressed in birds fed wheat bran based diet without enzyme supplementation; this result is in accordance with some authors [4; 5; 6; 7;8] who reported decrease in feed intake with addition of fibrous diet. Increment in the feed intake from T 1 to T 4 respectively this could be as a result of the different action of the enzyme on the fibre content of the feed. Fibre affects feed intake and energy utilization of birds. The primary factor in the voluntary feed intake of chicks appears to be the need for energy; birds will ordinarily eat to satisfy their energy requirement. The inclusion of fibre in feed dilutes energy concentration of diets. Hence, for birds to keep a constant energy level they have to change their feed intake as the energy density of the feed changes, consequently the need for increase in feed intake.

The interaction effect of dietary crude fibre levels, enzyme supplementation on performance as well as carcass yield has been evaluated by many researchers and the inclusion of enzyme in high fibre diet (6.5%) was found to significantly increased body weight and live weight gain of broilers [9]. Carcass characteristics of birds fed wheat bran supplement with enzyme were significantly different ($P<0.05$) from those fed control diet, resulting in high carcass yield. Significant differences ($p<0.05$) was only recorded in the slaughtered weight of the birds, T4 had the highest slaughtered weight while the lowest weight was recorded in T1; this result is in agreement with [10] who reported a variation in the slaughter weight of broilers fed *Moringaoleifera* leaf meal. The visceral weight and the gizzard weight were not affected by the dietary treatment as no significant difference ($p<0.05$) was recorded among the treatments. The weights of filled and empty gizzard were statistically not significant, but the highest mean value for both weight of filled gizzard and weight of empty gizzard were recorded in treatment 2. The increase in the size of the gizzard in the supplemented group may not be unconnected with the level of fibre in the diets. This organ might have enlarged in order to facilitate the grinding function of the fibre as reported by [7]. The result obtained from the organ is similar to the findings of [5] who reported no significant difference ($p>0.05$) in the gizzard of broilers fed mucuna bean based diet and[11] who also reported that there were no significant differences ($p>0.05$)in relative weights of digestive organs such as crop, proventriculi and gizzards of birds fed different dietary treatments.

The result obtained in the weight of the organs also correlate with that of [12] who reported that there lative sizes of proventriculi, gizzards, and intestine were not affected by dietary metabolizable energy level or enzyme supplementation; on the contrary, it differs from that obtained by [8] who reported a significant difference ($p<0.05$) in the weight of the proventriculi and the gizzards of broilers fed enzyme supplemented rice husk, it also disagree with that of higher gizzard weights of laying hens which could be achieved when feeding 40 % of whole wheat grain to laying bird. This could be as result of the variation in the fibre content of the both feed ingredients used by the previous researchers compared to wheat bran used in this research. The insignificance values ($p>0.05$) in the weight is also not in line with that of [13] who also reported that birds fed diets containing Rice Hull Meal had heavier gizzards than birds fed the control diet.

Histology of the Proventriculus

The micrographs of the proventriculi which is the glandular stomach and site of enzymatic secretion and action showed difference among the treatment, no visible lesion was recorded among the birds fed T1, the proventricular glands were normal lying on the external muscular layer; there was moderate necrosis of the proventricular simple tubular glands and few foci of moderate aggregate of inflammatory cells (heterophils) between the glands among birds fed

T2. Sloughing off of the tips of the proventricular tubular glands was moderate for T3, while mild sloughing off and necrosis of the proventricular glands was observed for T4.The result obtained in the histology of the proventriculi is in line with the previous result as obtained by [14] who reported changes in the histology of the proventriculi of African ostriches fed vitamin A furnished feed; it is also in line with the findings of [15] who reported an alteration in the histology of the proventriculi of quails in adaptation to their food habitats. The changes in the histology of the proventriculi of the birds with enzyme supplementation could not be traceable to the fibre content of the feed as treatment 1remained normal, but to the reaction of the exogenous enzymes on the non-starch polysaccharides (NSPs) such as arabinoxylan which increases intestinal viscosity leading to poor digestibility of the nutrients in the feed. This findings is in accordance with the previous result as obtained by [8] who reported that to adapt to these changes, the activities of the intestinal secreting mechanism may be enhanced possibly leading to hypertrophy of the digestive organs. It was also reported that since the proventriculus is the main site of endogenous enzyme secretion such as the hydrochloric acid and the pepsin, there could be an alteration in the concentration due to the interaction between the endogenous and the exogenous enzymes resulting into the presence of heterophils noticed in T2 and the sloughing off of the cells in T3, though the visible lesions is moderate. This findings is in line with the previous findings of [5] who reported that significant pulmonary congestions, intestinal villus collapse and cardiac degeneration of birds fed high mucuna diet indicates the poor health of the bird and their susceptibility to secondary infections.

Histology of the Gizzard

The micrographs of the gizzard (figure 3) showed differences among treatments; T1 showed locally extensive necrosis of subcuticular glands with associated marked aggregates of numerous inflammatory cells (heterophils) and lymphocytes, T2 showed no visible lesion but thick cuticles which is necessary for the birds for proper breaking down of feed particles; the birds in T3 showed marked degeneration of the subcurticular region; and a degenerate poor curticular region of the gizzard was observed among the birds in T4. The changes in the gizzards of the birds could be as a result of the difficulty encountered in grinding the feed as a result of the high fibre content of the feed; this finding is in agreement with that of [8] who reported that increase in the gizzard size was due to the need for more grinding activities resulting in increased musculature consequent on increased fibre content of the rice husk based diet; it is also in correlation with the past result of [16], who reported that the birds fed enzyme supplemented diets had heavier and larger duodenums and larger overall size and weight of their small intestines than those of birds fed enzyme un-supplemented diets. This was possibly due to the fact that the enzymes accelerated the process of digestion in the digestive tract, particularly in the gizzard. He also reported that the relative gizzard weight of birds fed the enzyme supplemented diets were also significantly lower this may indicates increased muscular activity of the gizzards and therefore enhanced development of the organ in the birds fed crumbled copra meal diets without enzyme supplementation. Although for birds fed T2, visible lesions were not observed but thick cuticles, which showed the adaptability of the gizzard to the fibre, content of the feed.

The result obtained is in line with the findings of [10], who reported changes in the liver of birds fed aluminium phosphide treated maize based diet, it is also in accordance with previous findings of [4] who reported a distortion in the histological structures of the organs such as the liver, the kidney, the pancreas, the lungs and the heart of broilers fed kidney beans. The changes observed in the proventriculus and the gizzard also align with the findings of [17] who concluded that, differences existed in the body weight, GIT and pH

values of the indigenous Venda and broiler chickens when compared together under normal conditions.

CONCLUSION

The result of this study shows that birds fed enzyme supplemented and un-supplemented fibrous feed had degenerative lesions both in their proventriculi and their gizzards. The supplementation with enzymes could not hamper against this changes resulting from the rigorous activities of these organs in the digestion process of the feed. From the result obtained from this study, feeding of high level of wheat bran with enzyme supplementation showed harmful effect on the proventriculi and the gizzards of the birds that increases the susceptibility of the birds to infections on the long run.

RECOMMENDATION

Based on the findings of this study caution should be taken while feeding bird with wheat bran supplemented with enzyme based feed as this could make the birds susceptible to various infections especially in the organs investigated in this experiment.

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Heavy Metal Accumulation in Haruan *(Channa striatus)* from Sungai Sabai at Hulu Selangor and the Associated Health Risks

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Abstract

This study was conducted to evaluate the levels of selected heavy metals in river water and self-caught haruan fish from Sungai Sabai in Hulu Selangor, Malaysia. The heavy metal content was determined by flame atomic absorption spectrophotometry. Results obtained showed that river water had the highest concentration of lead followed by zinc, copper, manganese and chromium. The quality of the river water complied with the Class III, Interim National Water Quality Standard for Malaysia, INWQS, 1985. There were significant differences in the concentrations of heavy metals determined in the liver, bones and muscles of haruan (*Channa striatus*) from Sungai Sabai. Concentrations of all metals were highest in the liver followed by muscle then bone. The concentration of heavy metals in fish muscle ranged from 0.68-1.25, 27.59-34.56, 28-232, 0-0.07 and 0.42-0.84 mg/kg for lead, copper, zinc, chromium and manganese, respectively. The order of the heavy metal concentrations in muscle were Zn>Cu>Pb>Mn>Cr, and exceeded the guidelines set by the Food and Agriculture Organisation (1999) for copper, lead and zinc. A health risk analysis based on the mean target hazard quotient for individual metals yielded values more than 1 for copper when consumed more than five times a week. The total target hazard quotient which is the aggregate risk due to heavy metal uptake via consumption of *C. striatus* was 0.499, 0.997 and 2.498 for consumption of haruan fish once, twice and five times a week respectively. This suggests that haruan from Sungai Sabai is not safe for consumption if consumed more than twice a week and there is potential for metal toxicity to occur to the consumer.
Key words: metals, fish, hazard quotient, risk estimation

INTRODUCTION

The pollution of water bodies by heavy metals has become a major environmental problem, due to the release of these contaminants from natural and anthropogenic activities [1]. There is a growing threat by toxic heavy metals contamination in the aquatic environment due to their non-biodegradable nature and accumulative properties [1]. The specific problem associated between heavy metal and aquatic environments is the accumulation of heavy metal through the food chain [2]; and since fish are situated relatively at the top of the aquatic food chain therefore accumulation of heavy metals from food, water and sediments occur [3, 4]. Accumulation of heavy metals in fish is influenced by the concentration of the metal,

exposure time, way of metal uptake and also environmental conditions such as temperature, pH, hardness and salinity of the water [4]. Additionally, internal factors including the age, sex, size, and reproductive cycle, feeding behaviour and swimming patterns also influence the accumulation process [5, 6]. The levels of contaminants in fish are of particular interest because of the potential effects of such substances on the fish itself and on the organisms that consume them, including humans [7].

Sungai Sabai although located in a rural area without much development, receives discharge from the Kalumpang Landfill located in Kalumpang, Hulu Selangor. This landfill was built and is operated without proper monitoring facilities such as liner materials, groundwater monitoring wells, methane gas ventilation pipes, leachate collection and treatment ponds. However, since it started operation prior to 1989 it was not subjected to the requirement of environmental impact assessment (EIA) [8]. Untreated leachate from this landfill flows directly into the waterways of Sungai Sabai. Heavy metals such as iron, zinc, lead, copper, chromium and manganese have been reported in landfill leachate [9, 10]. The accumulation of metals in fish sourced from such rivers may affect humans as consumers of those fish. Due to the potential health risk from contaminants in fish, several countries have responded by issuing consumption advisories, however little attention has been directed toward self-caught fish [11]. The common snakehead, locally known as haruan, is caught from Sungai Sabai by local fishermen and individuals for self-consumption, and is a common food fish among the local populace. Consumption of contaminated fish with heavy metals can result in hazardous effects on human health. Zn, Mn and Cu toxicity is rare as they are classified as essential elements and play a biochemical role in the life processes of all aquatic plants and animals. However, in higher concentrations copper may induce toxicity characterized by symptoms of irritability, muscular stiffness and pain loss of appetite, and nausea [12]. In contrast lead has been classified as one of the most toxic heavy metals inducing delayed embryonic development, suppressed reproduction and inhalation of growth, increased mucous formation, neurological problems, enzyme inhalation and kidney dysfunction [13]. This makes it important to estimate the potential health risk from eating haruan, which is a dominant fish at the above site. Hence this study sought to determine the concentration of chromium (Cr), copper (Cu), lead (Pb), manganese (Mn) and zinc (Zn) in river water and its accumulation in three body parts (liver, bone and muscle) of the haruan caught from Sungai Sabai. Additionally, an evaluation of the health risk from consuming the edible parts (muscles) of the fish was carried out.

MATERIALS AND METHODS

Water and Fish Sampling

Water samples (n=5) were collected 20cm below the surface on a sunny day, using polypropylene bottles pre-treated with nitric acid. Water samples were transported to the laboratory and stored at 4^{o}C until sample preparation. Haruan samples *(Channa striatus)* were randomly collected from individual fisherman using cast nets along Sungai Sabai. The total length of fish collected ranged between 20 and 30 cm, and was measured from the most anterior part of the fish to the tip of the longest caudal fin ray. The fish (n=45) were washed

using deionized water, placed in clean isolated polyethylene bags with ice and immediately taken to the laboratory, where the samples were deep frozen at -20^{o}C until further analysis.

Sample Preparation and Analysis

Water samples were allowed to regulate at room temperature and acid digested by the USEPA Method 3010A. The fish samples were thawed to room temperature, dissected and various tissue samples taken (liver, bone and muscle) and homogenized. Individual samples were oven-dried at 110^{0}C for 24 hours to constant weight. Samples were processed in duplicate where 1 gram of dried sample was ashed in the furnace at 450^{0}C for approximately 4 hours, until a white or grey ash was obtained. This residue was dissolved in 5 ml of HNO_3 (25% v/v) and heated slowly on hot plate. The samples were cooled to room temperature and 2ml of hydrogen peroxide was added. The solution was again heated in a digester until brown fumes were expelled, tissues dissolved completely and a colourless solution was obtained. The mixture was filtered through 0.45 µm Whatman filter paper, transferred to a 25 ml volumetric flask and made up to volume with 1% HNO_3 [14,15]. AA Analyst 400 Perkin Elmer Atomic Absorption Spectrometer (AAS) was used for the analysis of heavy metals in fish body parts which included chromium (Cr), copper(Cu), lead (Pb), manganese (Mn) and zinc (Zn).

Quality Control and Assurance

A recovery study of the total analytical procedure was carried out for metals in selected samples by spiking analysed samples with different concentrations of aliquots of a multi-element standard solution. All determinations were replicated three times. In order to determine the reliability of instruments, a blank and known standard were run after every 10 samples. Acceptable recoveries for the metals were 81.4% Cr, 89.5% copper, 105.1% for Pb; 92.4% for Mn and 107.1% for Zn.

Risk Assessment

The estimation of non-carcinogenic health hazards from the consumption of haruan was determined by the equation provided in the United States EPA Region III Risk based concentration table [16].

The target health quotient (HQ) is:

$$HQ = \frac{EFr \times ED \times IR \times C \times 10^{-3}}{RfD \times BW \times AT} \quad Eq.1$$

Where EFr is exposure frequency (365 days/year); ED is the exposure duration 70 years (average lifetime); IR is the food ingestion rate (g/day); C is the heavy metal concentration in fish (µg/g); RfD is the oral reference dose (mg/kg/day); BW is the average adult body weight (60 kg); and AT is the averaging exposure time for non-carcinogens (365 days/year × number of exposure years). The applied RfD for chromium, copper, lead, manganese and zinc was 0.0015, 0.04, 0.004, 0.14 and 0.3 mg/kg/d, respectively [17]. Exposure to multiple pollutants may cause interactive or additive effect; hence, the total target hazard quotient (THQ) was calculated as the sum of each individual metal HQ. A THQ <1 means that the exposed population is assumed to be safe; however when the THQ is between 1 and 5 there is a potential risk related to the studied metal in the exposed population [18].

Statistical analysis

Inter-tissue comparisons were carried out to test for significant differences in the concentration of the heavy metals in the fish samples using parametric analysis of variance (ANOVA).

RESULTS

Metal concentration in water and fish

The concentration of metals in the river water were 0.24±0.01, 0.04±0.01, 0.52±0.03, 0.15±0.01 and 0.32±0.01 mg/L for Cu, Cr, Pb, Mn and Zn respectively, and are shown in Figure 1. The concentrations of metals in fish showed variation between metals and different body parts. Copper and zinc concentrations were much higher than the other metal concentrations and ranged between 18.80 - 38.50 mg/kg and 20 - 232 mg/kg, respectively. Chromium was not detected in the bone and liver of all samples, however was detected in the muscle at a mean concentration of 0.05±0.07 mg/kg. In general, the liver contained the highest levels of all studied metals, followed by the muscle, whereas the lowest levels were observed in the bone. The metals characterized in the muscle, liver and bone of haruan fish are summarized in Figure 2. The relative mean concentrations in the muscle, liver and bone of haruan fish were Zn<Cu<Pb<Mn<Cr for all body parts respectively. All metal concentration showed significant difference ($p<0.05$) between type of tissues analysed. The metal concentration in the edible muscle portion of the body was compared against the national standard, the Malaysian Food Regulations [19], and internationals guidelines by the Food and Agricultural Organization [20]. The concentration of lead in the edible part of the fish was not in violation of the Malaysian standards which sets the limit for lead at 1 mg/kg. The Malaysian legislation does not provide for the concentration of copper, chromium, manganese or zinc in fish. The metals characterized in the edible portion of the fish samples are summarized in Table 1.

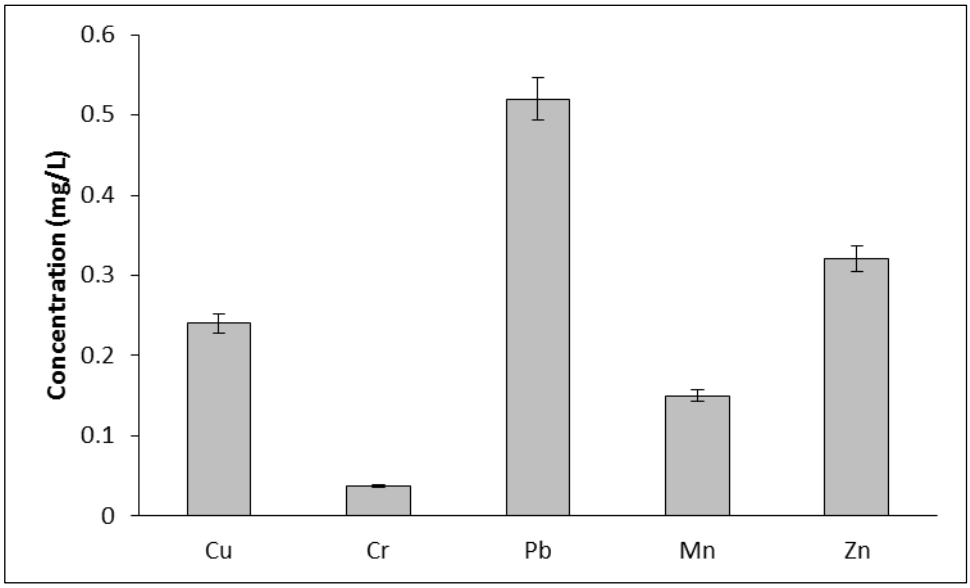

Figure 1 Mean concentration (mg/L) of metals in river water

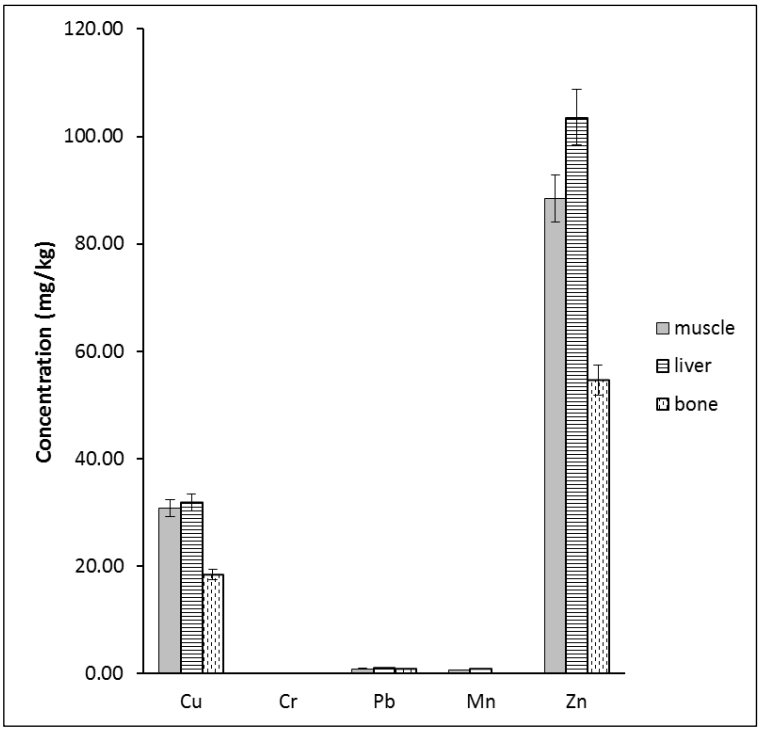

Figure 2 Mean concentrations (mg/kg) of metals in fish body parts

Table 1 Mean concentration of metals in edible muscle and standard comparison

Metal	Mean±SD	Permissible limits	
	mg/kg	Malaysia*	FAO/WHO**
Copper	30.76 ± 2.43	-	30.0
Chromium	0.05 ± 0.07	1.0	-
Lead	0.86 ± 0.20	1.0	0.2
Manganese	0.63 ± 0.14	-	-
Zinc	88.40 ± 72.93	-	30.0

* Malaysian Food Regulation [17]
**FAO/WHO [19]

Estimation of potential health risk

Evaluation of the potential health risk to local people in the study area was carried out by using data on the consumption of haruan fish and the data from the concentration of metals in muscle samples. The average Malaysian fish consumption rate is 160g/meal/person/week [21, 22] and calculations were made by assuming that the maximum consumption of haruan fish is five times per week. The target hazard quotient (HQ) values for all individual metals in haruan muscle were below 1 and ranged from 0.002 to 0.583 for citizens who consume haruan once, twice or 5 times a week except for copper. The HQ of copper if fish haruan were consumed 5 times a week was 1.461 and poses a human health risk. HQs of the five studied metals from consuming fish are depicted in Table 2. The total target heath quotient (THQ) values for consuming haruan fish twice a week was 0.997 and is a cause for concern (Figure 3).

DISCUSSION

In this study the mean concentrations of lead was the highest compared to the other metals. The high lead load recorded may be a result of effluent discharge from anthropogenic activities and warrants further investigation. Furthermore, this stream receives leachate discharge from the Kalumpang Landfill which is categorized as a class I non-sanitary landfill [8]. The concentrations of metals in the water followed the order of Pb<Zn<Cu<Mn<Cr. The water of Sungai Sabai is classified as Class III according to the Malaysia Interim National Water Quality Standards based on the parameters measured (data not shown). Water classified at this quality requires extensive treatment before it can be used for human consumption however it can be used for livestock drinking and fisheries of common and tolerant species with economic value [23]. Sungai Sabai flows into Sungai Kerling further downstream and is mostly used as irrigation and fisheries by the local people.

Table 2 Target hazard quotients (HQ) of individual metals and total target hazard quotient (THQ) by consuming haruan fish once, twice and five times a week.

Consumption Frequency	Target hazard quotient (HQ)					THQ
	Copper	Chromium	Lead	Manganese	Zinc	
Once a week	0.292	0.012	0.082	0.002	0.112	0.499
Twice a week	0.583	0.024	0.163	0.003	0.223	0.997
5 times a week	1.461	0.061	0.408	0.009	0.559	2.498

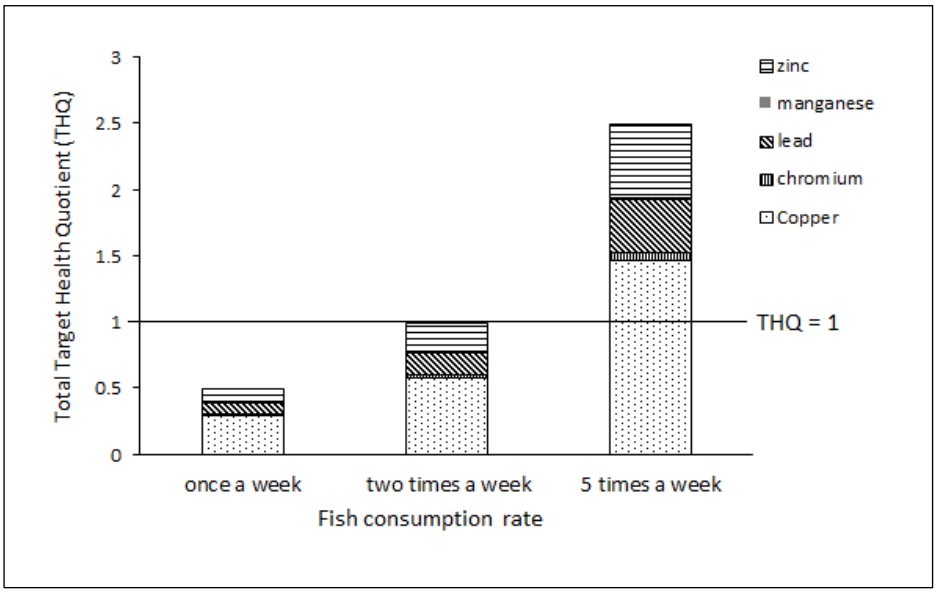

Figure 3 Total target hazard quotients (THQ) of exposed consumers by consuming haruan fish once a week, twice a week and 5 times a week. The population will experience health risk if the THQ is equal or greater than 1.

In the fish samples, there was a significant variation between metal accumulations among body parts. Metals are accumulated in different tissues/organs of the fish in varying amounts which is directly influenced by metal concentration in the aquatic environment, the different affinity of metals to fish tissues, uptake, deposition and excretion rates [24, 25]. Heavy metal accumulation in fish is also related with salinity, temperature, hardness and pH of water [26, 27]. In the present study, livers of the haruan fish accumulated higher concentrations of metals when compared to other body parts. The liver plays an important role in the detoxification of heavy metals whereby metallothioneine proteins (metal binding proteins) are produced to bind and detoxify metals that are absorbed into the body [28] hence this process concentrates metals in the liver [29, 30]. The fish muscles which are also the edible part contained less heavy metal than the liver but more than the bones. The muscle or flesh of

the fish is the most important part of a fish in terms of contamination. Individual metal concentrations in muscle were significantly different and were in the order Zn<Cu<Pb<Mn<Cr. The fish gills, liver and kidneys are known to accumulate heavy metals in higher concentration in comparison to muscles, which exhibit lowest levels of metals accumulation [31]. Data from the existing literature shows that the heavy metal concentrations in the muscles of fish vary widely; however it should be emphasized that the concentration of metals in fish muscle does not represent the actual impact on fish [32].

Consumption of fish contaminated with heavy metals may result in hazardous effects on human health. Potential health risk occurs when a hazard quotient (HQ) exceeds 1.0 [33]. The HQ calculated for Cr, Pb, Mn and Zn were below 1 for all frequencies of fish consumption thus poses no potential health risks to the consumers. However, there is a potential health risk associated with consumption of haruan fish five days per week where the HQ values of Cu exceeded 1. Although copper is an essential element for normal processes in the human body, high and long-term exposure can be harmful [34]. Despite no apparent risk for each metal analysed individually except for copper the potential risk could be multiplied when considering the presence of all heavy metals. Therefore, the total hazard quotient (THQ) is reliably helpful to assess and compare their combined risks [35]. The THQ for consuming haruan twice and five times a week was 0.997 and 2.498, respectively. This presents a relative cause for concern as regular consumption of haruan fish may cause deleterious effects during a lifetime. Therefore, it would be pertinent to conduct more detailed studies on the water quality of the river and the quality and quantity of leachate discharged in to the river. A sanitary survey conducted along the river would also elucidate the sources of metals and pollution to the river.

CONCLUSION

In conclusion, the investigated haruan fish varied widely in their copper, chromium, lead, manganese and zinc concentrations within the various body parts. The THQ values calculated were less than 1 when fish is consumed weekly indicating no adverse effects are expected. However, the consumption of haruan from Sungai Sabai twice a week yields a THQ value of 0.997 and is a cause for concern. It should also be noted that the exposure to metals from other food sources have not been taken into consideration hence these inputs are crucial to provide information for minimizing the potential health risk in the population.

Conflict of interest statement – The authors declare that there are no conflicts of interest.

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Estimation of Dispersion of Carbon Monoxide (CO), Nitrogen Dioxides (NO_2), and Carbon Dioxide (CO_2) From Port Klang - KLIA Road

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ABSTRACT

Criteria pollutants and greenhouse gases such as carbon monoxide (CO), nitrogen dioxides (NO_2), and carbon dioxide (CO_2) are usually the main gases monitored in air quality measurement. The increase of their concentrations year by year has become a source of concern. The main sources of these gases identified by Department of Environment (DOE) are due to mobile sources or the transportation sector contributing more than half of the total percentage of emission load. The purpose of this study is to estimate the concentration of CO, NOx and CO_2 from the mobile sources by using fuel-based methods estimation and Gaussian line source dispersion equation. The 64-km stretch of road from Port Klang to KLIA, Selangor was chosen as a case study. Three-day traffic volume composition study was also conducted. Finally, the estimated results were then compared with ambient concentration data from two nearest monitoring stations at Shah Alam and Petaling Jaya, Selangor, Malaysia.

Keywords: Carbon Monoxide (CO), Nitrogen Dioxides (NOx), Carbon Dioxide (CO_2), Gaussian Line-Source Dispersion Model

INTRODUCTION

In Malaysia, rapid increase in population in urbanized areas has triggered the development phase as well, in order to meet the current demand, thus enhancing the economic growth together with the living standard of the urban community. Modern society is highly dependent on motorized transportation such as cars, trucks, and railways. Movement of people and goods require energy which relies mostly on burning of fossil fuels, thus causing emissions with adverse local and global effects. The emission emitted from various kinds of vehicles comprises many major predominant gases that will contribute to the air pollution either locally or globally. Carbon dioxide is the most significant gas produced from the transportation activities and the effect brought by it is attributed to the global warming phenomenon if adequate controls or mitigation measures are not taken.

The significant increase of vehicles movement in Malaysia has contributed to an increase of Green-House Gases. There has been an increase in the level of environmental impact that has contributed to the unstable pattern of weather around the globe and variations in the natural phenomena such as floods, droughts and the disappearance of glaciers. Malaysia has itself released of GHG 37.2 tonnes of CO_2 in 2000 and there has been noticeable change in weather pattern, for example, the flood event in Johore in December-January 2007.

GREEN-HOUSE GASES

Green house gases are gases in the atmosphere that absorb radiation within the thermal infrared range causing the greenhouse effect. Carbon dioxides and nitrous oxides are known as principal greenhouse gases. Even though carbon monoxide is not classified under green house gases, it is one of major criteria pollutants that is generated from transportation sector .Moreover it is formed when carbonaceous fuels are burned under less than ideal condition resulting in CO instead of CO_2 (Gilbert M.M, 2008). Complete fuel combustion produces CO_2 while incomplete fuel combustion will produce CO. The use of catalytic converters in motor vehicles however generates CO_2.

Nitrogen oxides form when fuel is burned at high temperatures, as in the combustion process of the internal combustion engine. One member of the NOx group, nitrous oxide, is a greenhouse gas. It accumulates in the atmosphere with other greenhouse gasses causing a gradual rise in the earth's temperature, a phenomenon known as global warming (Jamal, 2004).

Malaysia's emission of greenhouse gases (GHG) totalled 144 million tonnes of CO2 in 1994. Net emissions, after accounting for sinks, totalled 76 million tonnes. On a per capita basis, the net emissions were equivalent to 3.7 tonnes. The CO_2 emissions from final energy use (excluding electricity) by various activities of the economy indicate that transportation contributed 49 per cent, industries, 41 per cent, residential and commercial activities, 7 per cent, and agriculture, 3 per cent of the overall emissions.

FIELD STUDY

The KLIA-Port Klang road was selected for the field study, being one of the busiest roads and considered to be generating GHG from a heavy traffic. The availability of the DOE monitoring stations within the catchment can help in providing essential information on the ambient air conditions. This 64-km stretch of road will be therefore be used as a representative of a typical road connecting a marine port and air port, heavily dominated by freight transports over a 24-hour period 7 days a week.

ROAD DESCRIPTION

The route, Jalan Klang-Banting which connects KLIA to Port Klang is chosen as a case study. The total distance of this road is 64 km. This Port Klang – KLIA route is a double carriageway with two lanes at each roadway with exception at some intersections where the numbers of lanes for the roadway are between 3 to 6 lanes. From the observation that had been made, towards the freight movement, most logistics companies used this route to travel from Port Klang to KLIA for delivery/supplying goods to KLIA. In addition, other motor vehicles are plying this road as well because of its preferred short distance causing this route to be congested at most times.

This route is the most preferable for the traffic as it had the shortest distance to KLIA from North Port or South Port. The high traffic movement is directly proportional to the tremendous release of pollutants to the surrounding environment. Moreover, this road has been upgraded to cater the growth and expansion of urbanisation and the logistics sector. The map below shows the route from Port Klang to KLIA.

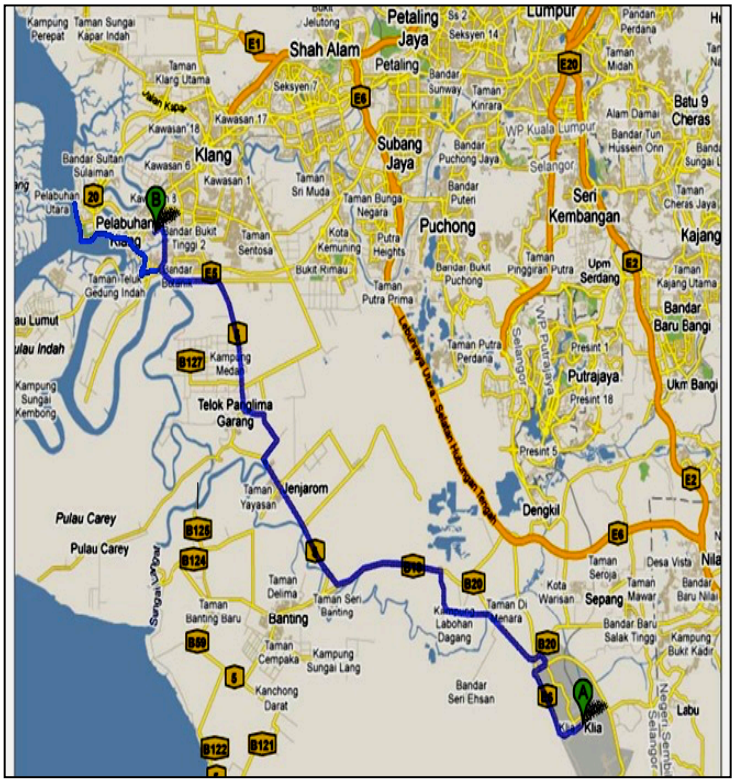

Figure 3.0: Port Klang- KLIA Map

VEHICLE VOLUMETRIC STUDIES

For the purpose of emission prediction from vehicles, a 3- days traffic volume study was carried out at the convergence junction between Northport and Westport. Traffic counting included mainly "Tally Sheet" model to ensure every surveyor recorded 3 types of vehicles at the same time.

Field motor vehicles counts were continuously monitored for different categories of vehicles (i.e. passenger cars, vans, lorries and heavy trucks) for each direction. Every surveyor was provided with a manual counter (mechanical hand tally counter), field data forms and a stopwatch. Traffic counting data are used for prediction of emissions released from the motor vehicle, which was carried out by fuel-based methods. Table 3.1 below is the composition of vehicles by days.

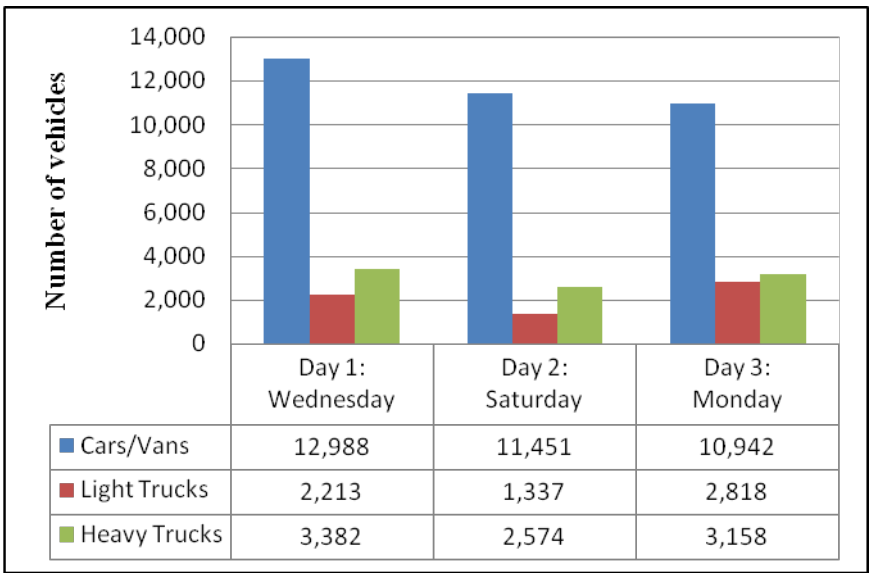

Figure 3.1: *Graph* of *number of vehicles composition by day*

SOURCES OF GREEN HOUSE GASES (GHG)

Greenhouse gas emissions from industry, transportation and agriculture are very likely the main cause of recently observed global warming. In 2008, it was estimated that the combined pollutant emission load for carbon monoxide (CO) and nitrogen oxides (NOx) were 1,451,746 metric tonnes and 409,972 metric tonnes, respectively. From this overall emission load, the highest contributor of CO and NOx was motor vehicles 97.1% and 49%, respectively (DOE, 2008).The estimation of the emissions loading are made by fuel-based method whereby the consumption of fuel by different types of vehicles for every kilometre is used for estimation. The emissions predictions are carried out by multiplying the emissions rates per unit vehicles with the volume of traffic in accordance to types of vehicles and with the stretch of 64 km of the distance covered for the study that is from Port Klang to KLIA.

The emission rate for each pollutant is calculated based on US EPA emission rate for each category of vehicle. The amount of CO, NOx and CO_2 emitted along the 64 km stretch by different types of vehicles are shown in *Table 3.0(a), Table 3.0(b), and Table 3.0(c)*.

Table 3.0(a): Average emissions and Fuel Consumption for Cars and Vans

Components	Emission Rate and Fuel Consumption		Kilometres Travel (km)	Calculation	Emissions Per unit vehicles (lb)	Emissions (lb)		
	Per mile*	Per Km				Traffic Volume		
						Day 1	Day 2	Day
Carbon Monoxide	20.90g	12.98g	64	12.98g/km X 64km X 1lb/454g	1.829	23,755.05	20,943.88	20,01
Oxides of Nitrogen	1.39g	0.86g	64	0.86g/km X 64km X 1 lb/454g	0.121	1,571.55	1,385.57	1,323
Carbon Dioxide	0.916lb	0.569lb	64	0.569Ib X 64km	36.416	472,971.00	416,999.62	398,46

Source : USEPA, National Vehicle and Fuel Emissions Laboratory

Table 3.0 (b): Average emissions and Fuel Consumption for Light Trucks

Components	Emission Rate and Fuel Consumption		Kilometres Travel (km)	Calculation	Emissions Per unit vehicles (lb)	Emissions (lb)		
	Per mile*	Per Km				Traffic Volume		
						Day 1	Day 2	Day
Carbon Monoxide	27.70g	17.21g	64	17.21g/km X 64km X 1 lb/454g	2.426	5,368.74	3,243.56	6,836
Oxides of Nitrogen	1.81g	1.12g	64	1.12g/km X 64km X 1 lb/454g	0.158	349.65	211.25	445.
Carbon Dioxide	1.15lb	0.715lb	64	0.715Ib X 64km	45.76	101,266.88	61,181.12	128,95

Source : USEPA, National Vehicle and Fuel Emissions Laboratory

Table 3.0(c): Average emissions and Fuel Consumption for Heavy Trucks

Components	Emission Rate and Fuel Consumption		Kilometres Travel (km)	Calculation	Emissions Per unit vehicles (lb)	Emissions (lb)		
	Per mile*	Per Km				Traffic Volume		
						Day 1	Day 2	Day
Carbon Monoxide	19.78g	12.29g	64	12.29g/km X 64km X 1 lb/454g	1.733	5,861.00	4,460.74	5,472
Oxides of Nitrogen	11.22g	6.972g	64	6.972g/km X 64km X 1 lb/454g	0.983	3,324.51	2,530.24	3,104
Carbon Dioxide	3.262lb	2.027lb	64	2.027Ib X 64km	129.73	438,746.86	333,925.02	409,68

Source: International Fall Fuel and Lubricant

MONITORING STATIONS

Ambient air pollutants concentration recorded at two nearest stations, which is Shah Alam, and Petaling Jaya stations were used as a comparison with the emission prediction along the road.

Table 3.1: Average CO and NOx concentrations at Shah Alam and Petaling Jaya stations

Parameters	Station	Average 1-hr concentration (ppm)
Carbon Monoxide (CO)	Shah Alam	1.002
	Petaling Jaya	1.853
Nitrogen Oxides (NO_2)	Shah Alam	0.019
	Petaling Jaya	0.033

Source: S.Z. Azmi et. al (2010)

Higher concentration of CO was recorded at Petaling Jaya with a mean value of 1.853 ppm compared with Shah Alam (1.002 ppm).The other gas which was also recorded at a very high concentration at Petaling Jaya is NO_2, which had an average concentration of 0.033 ppm compared with Shah Alam (0.019 ppm).

GAUSSIAN DISPERSION MODEL

Gaussian dispersion model defines the amount of pollutants that might reach a receptor/ person if the person is standing x distance from the line source. The prediction of emissions is carried in this manner are for control. A line-source dispersion model was used for calculate the emission concentration of every pollutants. The ground –level concentration of pollutant at perpendicular distance x from the line source can be described by the following:

$$C(x) = \frac{2q}{(\sqrt{2\pi})\,\sigma_z u}$$

Where,
q =emissions rate per unit of distance along the line (g/ms)
σ_z = vertical dispersion coefficient (m)
u = wind perpendicular to line source (m/s)

The calculation is based on stability class D (overcast conditions, regardless of wind speed) and vertical dispersion co-efficient, σ_z is determined from Table I and II (*Appendix A*).

Table 4.0: Concentration of pollutants (ppm)

Distance, x (km)	$C(x) = 2q / (\sqrt{2\pi})\ \sigma_z u$ (ppm)								
	Carbon Monoxide(CO)			Nitrogen Oxides (NOx)			Carbon Dioxides (CO_2)		
	Cars & Van	Light Trucks	Heavy Trucks	Cars & Van	Light Trucks	Heavy Trucks	Cars & Van	Light Trucks	Heavy Trucks
0.2	0.813	1.077	0.770	0.033	0.043	0.266	10.27	12.900	36.584
0.4	0.488	0.646	0.462	0.020	0.026	0.161	6.162	7.739	21.951
0.6	0.348	0.461	0.330	0.014	0.018	0.114	4.402	5.528	15.679
0.8	0.271	0.359	0.257	0.011	0.014	0.089	3.423	4.299	12.195
1.0	0.235	0.312	0.223	0.010	0.012	0.077	2.982	3.744	10.621

Figure 4.0 represents contour iso concentration line of CO from cars and van. From the line source (vehicle on the roadway), at distances 200m, 400m, 600m, 800m and 1000m, the estimated concentration of CO by using Gaussian dispersion model, are 0.813 ppm, 0.488ppm, 0.348 ppm, 0.271ppm and 0.235 ppm, respectively.

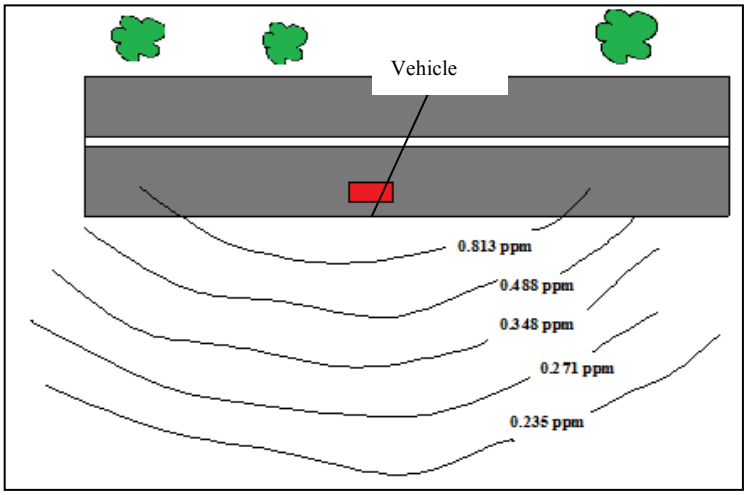

Figure 4.0: *Representative Contour for Iso Concentration line of CO from cars and van*

DISCUSSION

From the sources (*Table 3.0*), emission is calculated based on emission rate and fuel base per mile, which resulted in high amount of emission because they are directly from the vehicles' exhausts. The calculated values for cars and vans, for example ranged from 20,000 – 23,337 lbs. The amount of emission is spread over the entire region at some distances from the road under study. The calculated values from the Gaussian model stipulated a range of 0.813 ppm to 0.235 ppm over distances of 200 to 1000 m.

The concentration of CO calculated by using Gaussian dispersion model shows a lower amount compared with monitoring stations. From figure 4.0, it can be seen that the concentration of CO is getting lower as the distance increase. The monitoring stations are located quite a distance from the source and it did not directly measure the emission from the vehicle itself. The ambient concentration of CO and NOx recorded at the stations are comparatively in the same scale and concentrations. The sources can be a combination of other non-point as well as point sources in the region.

CONCLUSION

From the sources types, it can be concluded that cars and vans emitted more emission compared with trucks. This is because the number of cars and vans is higher than trucks on the under study road for the three days. But if looking at single vehicle emission, trucks produced more emission by fuel consumption.

As proven in Table 3.0, the most polluting source is carbon dioxide (CO_2). The CO_2 emitted by cars and vans along the 64 km is the highest (398,463.87 lb - 472,971.00 lb). However, CO_2 emitted by heavy trucks (333,925.02 lb - 438,746.86 lb) is nearly similar to that from cars and vans. This shows that heavy trucks produced high emission of CO_2 since the number of them on road is approximately 70% lesser than cars and vans.

There are several uncertainties in this study for instance the exact volume of vehicles on the road since the traffic volume was carried out at one sampling point only. There might be a possibility that not all vehicles went along the 64 km stretch of the road. In view of the fact that this is a preliminary finding, further study will be carried out with the assistance of satellite use, more air monitoring devices and instruments, together with air modeling software (CALINE-4) to provide more accurate and better representation of concentration of pollutants derived from mobile sources.

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APPENDIX A

Table I: Atmospheric Stability Classifications

Surface Windspeed[a](m/s)	Day solar insolation			Night Cloudiness[e]	
	Strong[b]	Moderate[c]	Slight[d]	Cloudy (>4/8)	Clear (<3/8)
<2	A	A-B	B	E	F
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

[a] Surface windspeed is measured at 10 m above the ground.
[b]Corresponds to clear summer day with the sun higher than 60 above the horizon.
[c]Corresponds to a summer day with a few broken clouds, or a clear day with sun 35-60 above the horizon.
[d]Corresponds to a fall afternoon, or a cloudy summer day, or clear summer day with the sun 15-35 above the horizon.
[e]Cloudiness is defined as the fraction of sky covered by clouds.
[f]For A-B, B-C, or C-D conditions, average the values obtained for each.
Note: A, Very unstable; B, moderately unstable; C,slightly unstable; D, neutral; E,slightly stable; F, stable. **Regardless of windspeed, class D should be assumed for overcast conditions, day or night.**
Source: Turner,1970

Table II: Dispersion coefficients (m) for selected distances downwind (km)

Distance x (km)	Stability Class and σ_y						Stability Class and σ_z					
	A	B	C	D	E	F	A	B	C	D	E	F
0.2	51	37	25	16	12	8	29	20	14	9	6	4
0.4	94	69	46	30	22	15	84	40	26	15	11	7
0.6	135	99	66	43	32	22	173	63	38	21	15	9
0.8	174	128	85	56	41	28	295	86	50	27	18	12
1	213	156	104	68	50	34	450	110	61	31	22	14
2	396	290	193	126	94	63	1953	234	115	51	34	22
4	736	539	359	235	174	117		498	216	78	51	32
8	1367	1001	667	436	324	218		1063	406	117	70	42
16	2540	1860	1240	811	602	405		2274	763	173	95	55
20	3101	2271	1514	990	735	495		2904	934	196	104	59

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Development of a Structural Gross Pollutant Trap Model

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ABSTRACT

Stormwater runoff is responsible for transporting many of the pollutants, which are degrading our waterways and rivers. The common pollutants from urban sources are sediments, nutrients, heavy metals, litter and debris, oil and surfactants and many more. The control of storm water pollution is an integral part of the Urban Storm water Management for Malaysia (MSMA). A structural gross pollutant trap model was developed in the aims of controlling the pollutant at source before it gets to nearby ponds, rivers and or waterways.

Keywords: Gross pollutant trap model, Pollutant and Stormwater runoff

INTRODUCTION

Pollutant removal has been a hectic task for the local councils and any other maintenance bodies in any part of our country. For example, more than 60 tonnes of rubbish is being cleaned and removed from our famous Klang River daily and in addition to this, we have 'choked' drainage system caused by heavy pollutants and the latter leading towards flash floods. The need to develop domestically manufactured gross pollutant trap arises to overcome the above problem.

Objectives

a) The prime objective of this project is to assess and further develop a structural Prototype engineering model of Gross Pollutant Trap (GPT), which could function mechanically to capture pollutants in the piped or concrete drainage network.
b) To study the maximum load conditions above the GPT structure.
c) To study the type of pollutants and removal efficiencies displayed by the new prototype model.

Significance of Project

This project is very essential for the enhancement of our river quality, such that all the pollutants can be captured at – source before it enters into the river bodies. The application of

structural GPT may lead to a cleaner environment as in current practice; all the pollutants are washed away into the drains and rivers during any storm event. Nevertheless, Malaysians, not all, but most still litter the drains without care.

Methodology

The research methodology is as described below;

Surveying, Sketching and Brainstorming

Basically the idea of a GPT structure needs a thorough understanding of the design criteria and some basic underlying principles, as such, field survey on the conventional GPT are studied and further discussed within the team members to have an idea of developing a Structural GPT. This allows information sharing and some basic parameters to be adopted in the design.

Pollutant Sampling

To identify the most common pollutants in the rivers and or drainage systems. This allows for the design of mesh screening to be identified in the prototype model**.**

Model Development

Upon gathering the necessary information, the prototype model is constructed from transparent high density plastic. This includes the internal frame for the deposition of pollutants and also the by pass channel to route the excessive water in a higher storm event. The model will also encased with an inflow and outflow pipe for the water to flow and a submersible pump will assist in the generation of water form an underground bucket.

LITERATURE REVIEW

Gross Pollutant Traps, or GPT's, are devices used to remove large debris from polluting the waterways. These devices are primarily used in stormwater drains, industrial plants, urban ponds and wetlands. Generally these GPT's collect larger items from the water, such as containers, cans, twigs, leaves, bottles and plastic bags. Smaller pollutants such as dirt, chemicals and heavy metals are not collected directly by the GPT's but since the water flow is attenuated in the GPT, then these particles tend to settled and thus retaining it under the collection chamber of the GPT's.A number of definitions of gross solids are currently used in the industry most of which center around the definition of the size of these solids. Allison et *al.* (1998) defines gross solids as any solids that are larger than 5 mm. Essentially gross pollutant traps combine the mechanisms of gross solid interception and retention. The main mechanism of treatment being the process of settling and interception, the fundamental features of most GPT's are the utilization of a energy dissipation device (to facilitate settlement of coarse sediment and non-floatable objects), a sedimentation basin to retain

settled material and trash racks to intercept gross solids. GPT's would typically be comprised of a concrete lined wet basin and a trash rack with provision for maintenance and cleaning of the basin. Gross Pollutant Traps may be used as the pretreatment for flow into a pond or wetland to confine the area of deposition of coarse sediments. This facilitates the eventual removal of finer sediments. Traps may also be used to keep coarse sediment out of ponds, protecting the vegetation at the head of the pond from the smothering effects of sediment. Traps may also be used to remove coarse sediment before the flow enters an infiltration device or filtration device, which would otherwise clog up prematurely. GPTs may also serve the purpose of capturing floatable oil, provided that they are designed appropriately. The traps provide little, if any, flow attenuation. Most GPTs will also provide some reduction in other pollutants. For example, trapping of coarse sediment may also provide:

- Removal of particulate nutrients;
- Trace metal removal;
- Oil and grease removal;
- Reduction in bacteria; and
- Reduction in dissolved oxygen demanding substances.

All of the above substances can be partly bound to sediments, and will be removed along with the trapped sediment. There are now a number of devices (including the conventional and the proprietary GPTs that will be discussed further in this chapter) for the trapping of gross pollutants that are based on initially diverting stormwater to a separation and retention chamber in which these pollutants are subjected to the mechanisms of interception and sedimentation. The diversion device allows stormwater to by-pass the separation chamber in the event of blockage of the chamber due to excessive accumulation of gross pollutants and during above-design events.

There are limited definitive guidelines for the design of gross pollutant traps with the most amount of research work being carried out in the area of sedimentation basin design. Issues related to the size of trash rack, design flows, operation under above design conditions and optimal dimensions for the trap are often dealt with in a cursory manner. There are many individually designed GPTs currently in use, most of which have been designed to promote the key mechanisms of gross solid interception and retention. In this chapter, a broad overview of some of the common GPTs in use is presented to provide the reader with an appreciation of the key features of these devices to enable the reader to select and design desirable features applicable to their individual requirements.

SBTR' type GPTs

SBTR traps combine the functions of a Sedimentation Basin and a fixed Trash Rack. The device is named after the initial of the two components. 'SBTR' type traps have previously been referred to in some literature as GPT's. The difficulties in and de-silting the sedimentation basins in Canberra led, in 1979, to the construction of the first major SBTR trap in Canberra, Australia. The trap was a major concrete lined basin that was designed to intercept litter, debris and coarse sediment during storm flows and to act as an efficient retarding basin. This trap drew on the previous experience of sedimentation basins but also

incorporated additional features to intercept trash and debris. It marked the commencement of the development and refinement of gross pollutant traps in Australia.

The on-going development of SBTR type traps in Australia has focused on improving these facilities for ease of maintenance and simplifying the design elements to reduce capital costs.

Major SBTR (Type 1) traps are typically located in major channels and engineered waterways to intercept medium to high stormwater flows from large urban catchments. They are visually unattractive and generally should be placed away from residential areas, or screened (see Figure 2.1).

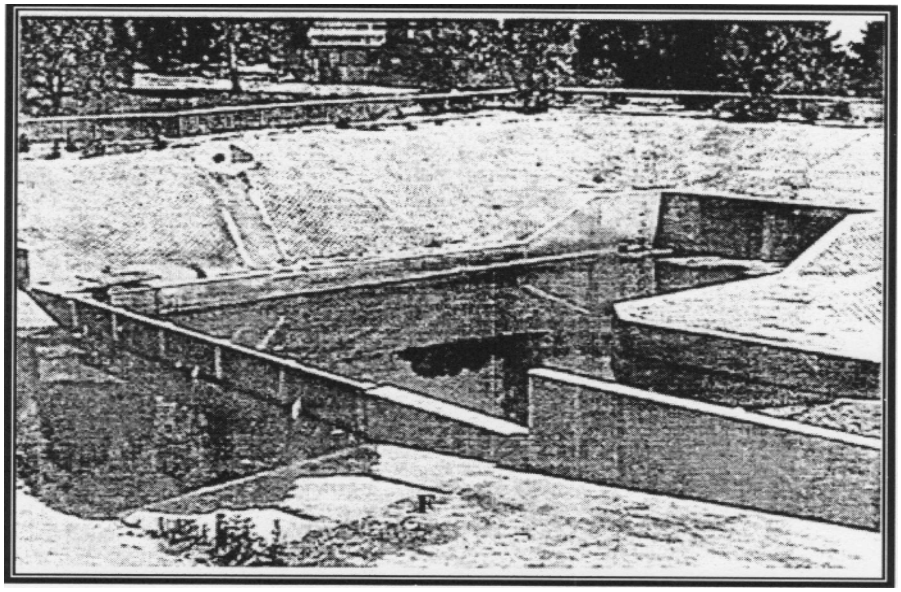

Figure 2.1: Type 1 SBTR trap

Covered in-ground (Type 2) traps are used at the downstream end of pipe or open drains. They are less visually intrusive and hence are more suitable for residential or urban areas. Due to the cost of the structure they are usually smaller in size than Type I traps and are only suitable for treating small catchments areas, mainly on pipe drains.

Indicative 'standard' arrangements for Type 1 and Type 2 SBTR traps are given in Figures 2.6 and 2.7, respectively. Many design variations are possible to suit site conditions.

ECOSOL RSF 4000 In-Line/End-Of-Line

The **RSF 4000** in-line or end-of-line unit is designed to remove solid pollutants, free oils, greases and fine sediments from piped stormwater flows, although the units can be modified to accept flows from open channels. The unit can be fitted 'to any sized or shaped pipe and consists of two parallel channels and a filtration/collection silo contained within a pre-cast concrete unit. It has no moving parts and minimal head hydraulic loss.

Solid pollutants, as well as oil and grease, and sediment enter from the drainage system into the filtration/collection unit. Through a series of apertures the filtration unit separates, collects, and retains more than 95% of gross pollutants down to at least 3mm, with a significant part of the collected pollutants (approx. 80%) smaller than 3.

Independent tests have shown that the unit collects more than 86% of sediments with a median diameter of 0.25mm. Free oils and grease are retained in the outer channels by the use of two baffles. The filtered water passes through the mesh on both sides of the filtration unit and into either of the two overflow/by-pass channels located on each side of the filtration/collection unit. The **RSF 4000's** design forces the water back upstream against its

main directional flow, entering the inlet across the face of the bypass/overflow area and creating the unique *hydraulically driven barrier.*

While the filtration unit is filling with pollutants, this barrier directs the incoming water and solid pollutants into the filtration/collection unit. When tile collection unit is full, the water no longer passes through the mesh and the *hydraulically driven barrier* can no longer be formed. Concurrently, the pollutants form a barrier across the mouth of the filtration unit, directing most of the incoming water into either of the two overflow/by-pass channels. Under these conditions, stormwater and pollutants will continue to be directed into either of the overflow/by-pass channels until the system is cleaned.

The RSF *4000* is designed to handle all flows within the specified Treatable Flow Rate (TFR), in the manner described above. However, in critical-flows above the TFR, the *hydraulically-driven barrier* no longer prevents the water, and the pollutants, from passing into the overflow by-pass channels. In these circumstances, tile collection unit functions primarily as a retention device until the storm event passes. This virtually eliminates the risk of blockage from critical flow conditions whilst still effectively maintaining the unit's function as a solid pollutant trap.

Conventional GPTs BANDALONG*TM*

Concept

It has a unique swinging gate at the throat of the entry of the trap. The water comes down the waterways and is entrapped in this litter trap. The gate with paddles on the outside will ensure it is closes and keeps the litter trapped inside whenever there is a change of the flow of the water. (Tony Welsh, 1997)

Description

Bandalong^{TM} trap is a type of floating litter trap that sits on top of the waterways for collected litter and debris being transported in rivers, streams and estuaries. The trap is typically moored to the bank of a river, stream or canal. It is made out of two polyethylene black pipes running parallel to each other and tapering towards the front and with two boom pipes at the rear. In plan view the trap is "fish" shaped (figure 2.2) with floating lifter and debris being funneled (via the tail) into the main body of the trap where it is caught.

Figure 2.2 Bandalong trap

3 HYPOTHESES AND RESEARCH METHODOLOGY

Hypotheses

1. The designed GPT will be able to retain pollutants with gross sizes more than the mesh size of 3mm .
2. The designed GPT will treat the first flush stormwater based on 3 month ARI for a catchment area of 2 hectares.
3. The designed GPT is targeted to retro-fit the current conventional drainage system in Malaysia and a primary treatment before stormwater discharges into the wetlands and or pond.
4. High trapping efficiencies.
5. Captures more than 98% of gross pollutants > 3mm.
6. No remobilization or overtopping of captured pollutants.
7. Can be sized to suite wide range of flows, gradients, and pipe sizes in future designs as currently the designed GPT has controlled parameters.
8. Cover Slabs in the GPT are designed for traffic loading

Theoretical / Modeling basis

Model

The model of GPT that will be designed is by considering the design criteria's outlined in the Urban Stormwater Management For Malaysia(MASMA), volume 13.

Parameters

The proposed GPT will have fixed parameters as follows;

1. Area of catchment is 2 ha.
2. Gradient of GPT is 1/230 or 1 percent slope.
3. Inlet/Outlet pipe are 600 mm.
4. Trap volume is 7.44 m^3.

Theories

Theories extracted from the Manual Saliran Mesra Alam Malaysia (MASMA) by Department of Irrigation and Drainage Malaysia.

Methods for determining model parameters

Before the design of GPT, the characteristics below should be considered:

Determination of required % removal,

$$\eta = \frac{\text{AMC proposed}}{\text{AMC existing}}$$

AMC = annual mean concentration

Calculation of discharges, Q , by Mannings

Roughness,

$$Q = 1/n \, . \, (A^{2/3} / P^{2/3}) . \, S_o^{1/2}$$

Where

n = 0.012 to 0.017 (concrete), typical value = 0.013, A is area of pipe , P is wetted parameter, S_o = Slope of pipe

Calculation velocity of flow,

$$V = 1/n \, . \, R^{2/3} . \, S_o^{1/2}$$

Where

R = A/P where A is area of pipe and P is wetted parameter, S_o = Slope of pipe

Determination of K value,

$K = A^{5/3} / n.P^{2/3}$

Headloss,

$$h = P/\rho g$$

Where

$P = \rho gh$ Internal flow in straight circular pipe of constant diameter,$Re = \rho Vd / \mu < 1 \text{ X } 10^3$ laminar $> 2 \text{ X } 10^3$ turbulent

OR $$h = P/\rho g + V^2/2g + Z$$

EXPERIMENTAL RESULTS

The open gate valve was used to control the flow rate and the sieve collected particles that passed through the filter. The flow rate was determined using a standard 90° V-notch weir. Constant flow of water was assured with the pump running continuously. Particle pollutants were represented with plastic beads with two different specific gravities , i.e floating beads(SG=0.90) and sinking beads(SG=1.2). These quantities were computed using glass measuring cylinders.

The proposed gross pollutant trap has a high percentage on trapping the pollutants. The maximum volume of the pollutants in the capture silo is about 7.44 m^3 and captured 96

percent of pollutants. This clearly illustrates that the proposed gross pollutant trap meet the demand of capturing pollutants in competitive with other available systems. The pollutants with size about 3 mm and above will trap in the capture silo and at the same time fine sediments will dissolved on the floor of the structure.

Removing oils and grease

The gross pollutant trap can trap the oil and grease effectively by the using of baffle plates that have been placed at the both sides of the unit parallel to the inlet and outlet of the unit.

Effective catchments area

The designed structural GPT has an effective catchment area of about 2.0 ha per unit. All the design is based on normal overland flow of stormwater into the drainage network. In the event of other restricted conditions , the designed GPT should take in consideration the obstacles and to properly cater to capture the required pollutants. In placing a GPT , other important consideration such as the intensity of pollutants should also be looked at. Such as of this condition is the placement of GPT in an outlet of a drainage pipe in a open wet market compared to the placement of GPT in a housing areas. With the variable intensity of pollutants of this two places, the engineer should take in deep consideration before designing an appropriate GPT.

Cost effectiveness

The proposed structural gross pollutant trap is comparatively economy than the other available gross pollutant trap, thus the fabrication of GPT locally is to reduce the cost of construction and minimize the logistic and other time related factors during the construction. In addition, the materials are easily available and are comparatively cheap compared to the imported ones.

CONCLUSION

Capture efficiencies

The design of the proposed gross pollutant trap model is a “guinea pig” start as a proprietary system in the urban stormwater management in Malaysia. Though, in the development of the model only one inlet sizing is available, much information on the pollutant behavior has been understood. Lighter density pollutants tend to merge at the corner of the mesh compartment while the heavier density pollutants distribute in a manner of a decreasing slope from the initial mesh compartment to the latter parts. This is phenomena is primarily due to the velocity of the inlet water which dissipated the pollutants in such a manner.

If the model is constructed in the actual site, it is expected that the capture efficiency of the pollutants are very much higher and can be ranged above 96%. Maintenance of the GPT after post installation is also a contributing factor for the efficiency and performance. Periodic supervision is required to gather data before a complete cycle of cleaning record is

developed. The actual capture pollutants are approximately 7.44 m^3. This figure is based on the computation from the scale model of 1:6. Further research is required to gather important information on pollutants and also to develop various types of GPT with variable sizing of inlet pipes.

Cost effectiveness

Since cost plays vital role in client's decision to revert to GPT's, locally manufactured GPT system will be an added advantage to the regulators and engineers as cost of importing products can be minimized and further improve locally based research in the area of GPT.

Easy to maintain

The term easy to maintain refers to the ability of a suction truck to insert the hose and clean. It is pre assumed that the service of educator truck in Malaysia is limited and can be costly, but recent development in Putrajaya, the use of educator truck to clean rubbish is seen as very effective. With this system a clean surrounding and less odors can be experienced as no pollutants will be taken out and dumped into a rubbish collector truck as being done in the conventional style. This type of service is very economy in the long run and if many proprietary GPT's are installed in one vicinity.

Suitable use for Malaysia pollutant condition

The gross pollutant trap can be retro fitted or installed at the pipe or drainage network where high percentage of pollutants loading are conveyed, mainly drainages linking to rivers, i.e. Klang river, Gombak river and etc. Furthermore, with all these systems in place less pollutants will be choking the rivers and prevent the occurrence of flash floods.

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