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Articles

Soft Clustering Technique on Academics Performance Evaluation

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Abstract: Clustering techniques are unsupervised learning methods of mining complex and multi-dimensional data sets such that observations in the same cluster are similar in some sense. The student academic performance evaluation problem can be considered as a clustering problem where clusters are formed on the basis of students intelligence. Choosing the right clustering technique for a given dataset is a research challenge. Therefore, intelligence-based grouping is essential for maintaining the homogeneity of the group; otherwise it would be difficult to provide good educational recommendation to the highly diverse student population. Homogenous grouping of students with similar result ranking into classes would further make student academic performance analysis detailed and sufficient for recommendation. Grouping of students using Fuzzy C-Means (FCM) techniques with the level of their degree of membership into different clusters allows for overlapping of boundaries and resolve sharp boundary problems as opposed to crisp-based method. FCM technique will reveal the degree of membership trend in the clusters which is the focus of this work. In this work, we implemented Soft clustering technique (Fuzzy C-Means) in C++ for student academic performance analysis. This will proffer recommendations that will enhance student performance.

Key words: K-means, Fuzzy-C- mean, Clustering algorithm, Performance evaluation

1.0 Introduction

Academic performance (AP) is the outcome of education, that is, the extent to which students has achieved in their educational goals. Academic performance have been linked to differences in intelligence. Students with higher mental ability tend to achieve highly in academic settings. AP has become the gatekeeper to institutions of higher education, shaping career paths and individual life trajectories(Stumm *et al.*, 2011). Student's academic performance is affected by numerous factor such as gender, age, teaching faculty etc. Many researchers conducted detailed studies about factors contributing the student performance at different levels. According to Minnesota (2007), the higher education performance is depending upon the academic performance of graduate students. Staffolani and Bratti (2002)

observed that the measurement of students previous educational outcomes are the most important indicators of students future performance which implies that as the higher previous appearance, the better the student's academic performance in future endeavours.

Students enrolled for a course in an institution have to complete the minimum number of courses required before graduating. These courses are only completed if they meet all requirements and pass with an acceptable grade. A student that fails a course earns no credit for that course.

The academic performance of a student is based on their GPA which is the average number of points the student attains in all their courses graded from A –F and this in turn determines the overall success of the student in their program of study.

Student academic performance can be seen as a clustering problem where each cluster is represented based on the intelligence of the student. This is needed especially in a diverse student population to ensure uniformity. This uniform grouping would make results more feasible and a basis for comparison can also be established. Using this clustering technique, the areas of strength and weakness of the student can be revealed so that proper monitoring can be established.

Grouping or clustering students using fuzzy-based techniques with the level of their degree of membership into different clusters may be a realistic approach as opposed to crisp-based methods (e.g. k-means). For example, a student with scores 30, 50, 60, and 70 will be in the region of good performance using k-means approach in Oyelade, *et al* (2010); but this FCM technique will reveal the degree of membership trend in the clusters which may not necessary be in good performance state.

2.0 Literature Review

Partitioning methods aim to find the best partition of data into k clusters in such a way that one criterion is optimized. The research work by Anand *et. al*., (2009) only provides Data Mining framework for Students' academic performance. The research by Varapron et al, (2003) used rough Set theory as a classification approach to analyze student data where the Rosetta toolkit was used to evaluate the student data to describe different dependencies between the attributes and the student status where the discovered patterns are explained in plain English. Oyelade, *et. al.*, (2010) applied k-means technique with deterministic approach to student's academic performance into different k clusters but fail to reveal each student's area of strength and weakness in different clusters with respect to the degree of membership to each cluster. Ramjeet and Ahmed (2012) proposed a dynamic fuzzy expert system to analyze and find modelling academic performance to improve on the quality of students and teachers

performance in academic domain but failed to reveal the degree of membership strength in difference clusters. In SajadinSembiring (2011), they applied Smooth Support Vector Machine (SSVM) classification and kernel k-means clustering algorithms by employing psychometric factors as variables predictors where their results showed a model of student academic performance predictors. Sharma (2013) presented a data mining techniques to process a dataset and identify the relevance of classification on the test data. Durairaj and Vijitha, (2014) used WEKA tool for prediction of student's performance in term of pass percentage and fail percentage using K-Means clustering algorithm.

In this work, we implemented fuzzy c-mean algorithm (Bezdek, 1981) in C++ for partitioning of students academic results with the level of their degree of membership into different clusters . In addition to the specification of the number of k clusters in the data set, the FCM method requires to choose m, which is the fuzziness parameter. There is little literature on the choice of this parameter (Bezdek, 1981; McBratney and Moore, 1985) but this is not the focus of this work.

3. Materials and Methods

We demonstrated our technique on student's result data set with nine courses offered in a semester from a private university in Nigeria. The total number of 79 students were considered and analyzed using FCM algorithm.

3.1 Development of FCM algorithm

The crisp clustering methods assign each object to one cluster only, unlike fuzzy clustering methods, it assigned each object to one or more cluster depending on the degree of membership in that cluster. The degree of membership has values ranging from 0 to 1. If the degree of membership of an object in a particular cluster is very close to 1, this indicate a very strong association of an object in that cluster and values close to 0 indicate weak or absent association with the cluster. The fuzzy c-means algorithm (FCM) (Bezdek, 1981) is one of the most widely used methods in fuzzy clustering which is based on the concept of fuzzy c-partition, introduced by Ruspini (1969) as follows.

Assume a set of n objects $X = \{x_1, x_2, ..., x_n\}$, where x_i is a d-dimensional point. A fuzzy clustering is a collection of k clusters C_1, C_2, ..., C_k and a partion matrix $U_{i,j} = u_{i,j} \in [0,1]$ for i = 1, ..., n and j = 1, ..., k, where each element $u_{i,j}$ is a weight that represents the degree of membership of object i in cluster C_j., all weight for a given point x_i must add up to 1. That is, $C_j = \dfrac{\sum_{i=1}^{n} u^m{}_{ij} x_i}{\sum_{i=1}^{n} u^m{}_{ij}}$

such that each cluster C_j contains non-zero weight, i.e. $0 < \sum_{i=1}^{n} u_{i,j} < n$.

Like k-means, FCM also attempts to minimize the sum of the squared error (SSE). That is,

In k-means:

$$SSE = \sum_{j=1}^{k} \sum_{x \in C_i} dist(C_i, x)^2$$

In FCM:

$$U_{ij} = \frac{(1/dist(x_i, C_j)^2)^{1/(m-1)}}{\sum_{q=1}^{k}((1/dist(x_i, C_q)^2)^{1/(m-1)})}$$

where m is the parameter that determines the influence of the weights and $m \in [1, ..., \infty]$.

For a cluster C_j, the corresponding centroid C_j is calculated as follows:

$$C_j = \frac{\sum_{i=1}^{n} u^m{}_{ij} x_i}{\sum_{i=1}^{n} u^m{}_{ij}}$$

This is an extension of the centroid in k-means. The difference here is that all points are considered and the contribution of each point to the centroid is weighted by its membership degree.

The fuzzy partition update can be obtained by minimizing the SSE subject to the constraint that the weights sum to 1. That is:

$$U_{ij} = \frac{(1/dist(x_i, C_j)^2)^{1/(m-1)}}{\sum_{q=1}^{k}((1/dist(x_i, C_q)^2)^{1/(m-1)})}$$

U_{ij} should be high if x_i is close to the centroid C_j, i.e. if $dist(x_i, C_j)$ is low.

The effect of parameter m in FCM is stated as follows:

- If m>2, then the exponent 1/(m-1) decrease the weight assigned to clusters that are close to the point.
- If $m \to \infty$, then the exponent $\to 0$. This implies that the weights $\to 1/k$.
- If m $\to 1$, the exponent increases the membership weights of points to which the cluster is close. As m $\to 1$, membership $\to 0$, for all the other clusters.

3.1.1 The algorithm steps

Given a dataset of n data points $X = \{x_1, x_2, ..., x_n\}$ such that each data point is in $\boldsymbol{R^n}$, the problem of finding the minimum J_m is given as:

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{c} u_{ij}^m \|x_i - c_j\|^2 \quad 1 \le m \le \infty \qquad (1)$$

- m is the fuzziness parameter which regulate the degree of membership in the clustering

process; for $m = 1$, the problem is the classical minimum sum of squares clustering and the partition is crisp. Therefore, m is any real number > 1;

- $U_{i,j}$ is the degree of membership of x_i in the cluster j;
- x_i is the $i-th$ the dimensional measured data.
- c_j is the dimensional center of cluster

Therefore, fuzzy partioning is carried out through iterative optimization of the objective function J_m depicted in equation 1 above, with the update membership $U_{i,j}$ and the cluster centers c_j described by:

$$U_{i,j} = \frac{1}{\sum_{j=1}^{c}\left(\frac{||x_i - c_j||}{||x_i - c_k||}\right)^{\frac{2}{m-1}}} \quad \text{and}$$

$$c_j = \frac{\sum_{i=1}^{N}(U_{i,j}^{m} x_i)}{\sum_{i=1}^{N} U_{i,j}^{m}}$$

This iteration will stop when:

$$max_{i,j} = \{|U_{i,j}(k+1) - U_{i,j}(k)|\} \leq \epsilon$$

where ϵ is the termination criterion between 0 and 1 and k is the iteration steps.

The algorithm steps is described as follows:

1. Initialize $U = [U_{i,j}]$ matrix. i.e. $U^{(0)}$
2. At k-steps:
   a. Calculate vector $C^k = [c_j]$ with U^k i.e.
   $$c_j = \frac{\sum_{i=1}^{N}(U_{i,j}^{m} x_i)}{\sum_{i=1}^{N} U_{i,j}^{m}}$$
3. Update:

$$U_{i,j} = \frac{1}{\sum_{j=1}^{c}\left(\frac{||x_i - c_j||}{||x_i - c_k||}\right)^{\frac{2}{m-1}}}$$

4. If $||U_{i,j}(k+1) - U_{i,j}(k)|| \leq \epsilon$ stop else return to step 2.

4. Results and Disscussion

From the fuzzy C means analysis we have 4 clusters (cluster 0 to 3) from the academic performance point of view each cluster representation is shown in Table 1

Table 1: Fuzzy Clusters academic performance representation

Cluster number	Grade performance	Linguistic performance	Class of Honour
Cluster 0	A & B	Good	2nd class upper and above
Cluster 1	F	Poor	Fail
Cluster 2	C	Average	2nd class lower
Cluster 3	D	Fair	3rd class

This can be represented in a fuzzy linguistic model such that the linguistic variable is student performance and the fuzzy sets are Good, Poor, Average and Fair:
Student Performance {Good, Poor, Average, Fair}
A sample data of 76 records with 9 attributes was used. Each record represents an instance of a student percentage quantitative performance in 9 core courses offered in a particular session. With fuzzy -c means analysis the system was able to cluster each student in their best performance cluster. Also, it reveals each record membership function in each cluster. The system assigns membership value to each data point (each record) corresponding to each cluster center on the basis of distance between the cluster and the data point. More the data is near to the cluster center more is its membership towards the particular cluster center. The summation of membership of each data point should be equal to one. This reveals each student strength distribution across the 4 categories of performances. For instance Table 2 shows an instance of the fuzzy-cC means analysis result. The percentage strength distribution for each data point in each cluster is shown in Table 3. Figure 1 shows a graphical distribution of the student's strength.

Table 2: An instance of Fuzzy C means student performance analysis result with Data point cluster.

Record Number	Cluster 0 (Good)	Cluster 1 (Poor)	Cluster 2 (Average)	Cluster 3 (Fair)	**Record Cluster**
Data [2]	0.55	0.01	0.23	0.21	Cluster 0
Data [9]	0.79	0.01	0.10	0.10	Cluster 0
Data [57]	0.09	0.01	0.44	0.46	Cluster 3
Data [43]	0.23	0.02	0.38	0.37	Cluster 2
Data [73]	0.03	0.87	0.05	0.05	Cluster 1

Table 3: An instance of Fuzzy C means student performance analysis percentage strength distribution

Record Number	Cluster 0 (Good)	Cluster 1 (Poor)	Cluster 2 (Average)	Cluster 3 (Fair)
Data [2]	55%	1%	23%	21%
Data [9]	79%	1%	10%	10%
Data [57]	9%	1%	44%	46%
Data [43]	23%	2%	38%	37%
Data [73]	3%	87%	5%	5%

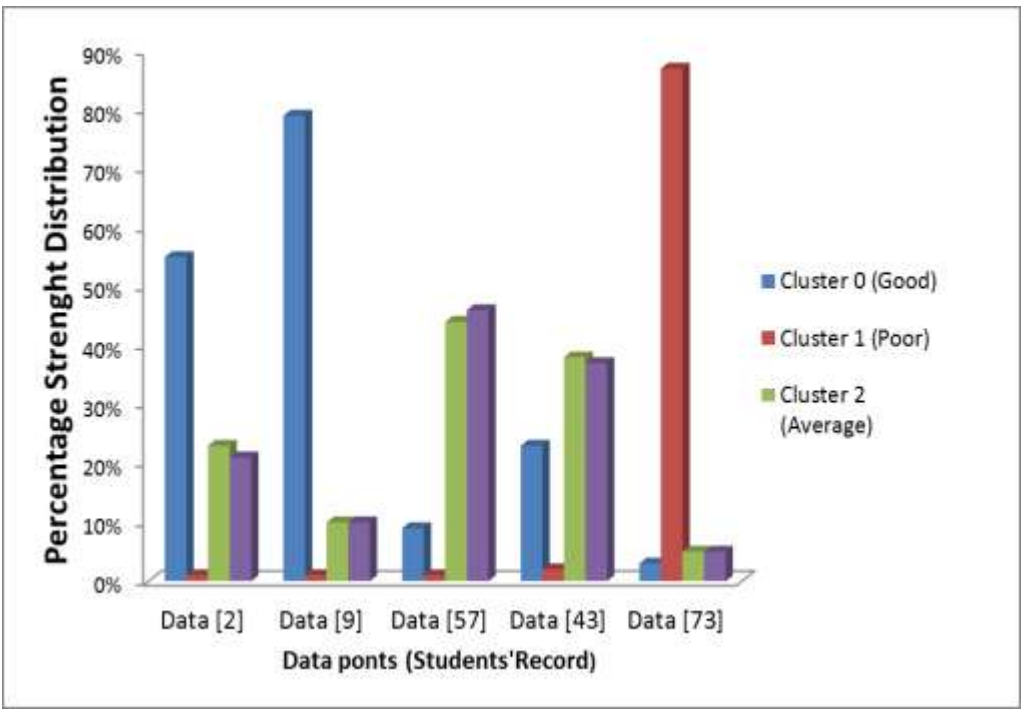

Figure 1: Graphical representation of Student's strength distribution

From the Table 2 Data[2] student has 55% of his strength in Cluster 0 which represents grade B-A ; good performance, 10 % in Cluster 1 which represents grade F; poor performance , 23% in cluster 2 of grade C; Average performance and 21% in cluster 3 which represents grade D; fair performance. These strength distributions show that this student is not a stable good student. He needs to improve his study capacity so as to strengthen his good performance ability; hence he may fall into average or below average performance category.

Data [9] student has 79% of his strength in cluster 0, of good performance, 1% in poor performance, 10% in average and fair performances. These show that the student is a stable good student. He just needs to maintain his performance. It might be difficult for him to move below average.

Data [59] student has 9% of his strength in good performance, 1% in poor, 44% in average and 46 % in fair performance. These show that this student is below average. Though he might not graduate with second class upper and above but if he works harder he can still increase his chances of second class lower, hence he might end up as a fair student of 3rd class.

Data [43] student has 23% of his strength in good, 2% in poor, 38% in average and 37% in fair. This reveals that this kind of student is above average but due to his carelessness his performance is fair. With proper monitoring and advice he can increase his good performance ability while he moves away from fair performance. Nevertheless, if care is not taking he might graduate with 3rd class.

Data [73] has 3% of his strength in good, 87% in poor, 5 % in average and fair performances. It is obvious that this student needs not to be promoted if after a session he has these strength distributions. He must have gathered enough carryovers, then he needs to be advised on time to change his course or withdraw without wasting time and resources.

Finally, the overall performance of this set of students is represented in Figure 2. It can be concluded that most of the students in this set are stable good students. Few of them, precisely 4 are poor students. Also, the graph reveals that those students that fall into average and fair performances have a thin line difference. The implication is that, if a student is in average performance this session under consideration, if care and diligent effort is not invested in the following sessions the student can easily fall into 3rd class category and also, if a student is in 3rd class, with little diligent effort this student can move to second class lower.

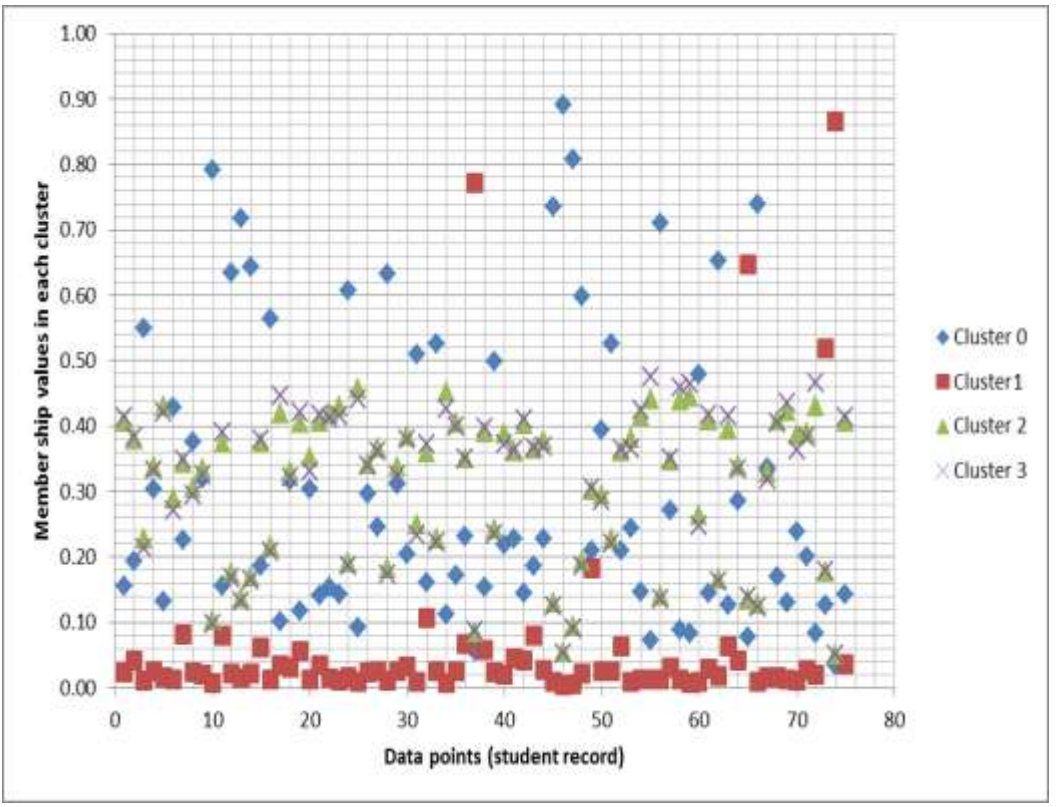

Figure 2: Student overall performance chart

5. Conclusion

In this paper, we implemented the qualitative power of FCM clustering algorithm in C++ to demonstrate the importance of degree of membership of student's performance in different clusters. This reveals each student's area of strength and weakness which the hard clustering technique (k-mean) fail to reveal (Oyelade, et. al., 2010). This model improved on some of the limitations of the existing methods. For example, the research work by Anand *et. al*., (2009) only provides Data Mining framework for Students' academic performance. The research by Varapron *et al* (2003) used rough Set theory as a classification approach to analyze student data where the Rosetta toolkit was used to evaluate the student data to describe different dependencies between the attributes and the student status where the discovered patterns are explained in plain English.

Therefore, FCM clustering algorithm serve as a good benchmark in monitoring the progress of students' performance in the institutions which enhances the decision making by academic planners by monitoring the candidates' performance semester by semester by improving on the future academic results in the subsequence academic session.

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Biochemical Oxygen Demand and Carbonaceous Oxygen Demand of the Covenant University Sewage Oxidation Pond

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Abstract: Biochemical Oxygen Demand (BOD) is a measure of the dissolved oxygen consumed by microorganisms during the oxidation of reduced substances in waters and wastewaters. It is often used ambiguously in relation to Carbonaceous Oxygen Demand (CBOD) which is the oxygen consumed during the oxidation of carbonaceous compounds to carbon dioxide (CO_2) and other oxidized end product. BOD is actually the sum of CBOD and NBOD where NBOD is the Nitrogenous Oxygen Demand which is the oxygen consumed during the oxidation of nitrogenous compounds (mainly NH_3) to nitrates with nitrites being an unstable intermediate. The major difference between CBOD and NBOD is that there are two classes of bacteria believed to be responsible for the oxidation of reduced nitrogen. The BOD_5 value of Sewage samples collected from Covenant University oxidation pond was therefore measured and the samples examined for the presence of *Escherichia coli*. The sewage samples collected from four points (starting point (A), two middle points (B, C), and end point (D) were inoculated on an Eosin Methylene Blue agar plates and the presence of *E. coli* was confirmed by the appearance of greenish metallic sheen colonies on the agar plates and biochemical Tests. The BOD of the effluent at the different points (A, B, C, D) respectively showed a reduction in microbial load. The ultimate CBOD was also estimated based on the BOD_5 value which is based upon the exponential (first-order) nature of oxygen demand. This research describes the formulations of CBOD breakdown using simplified oxidation kinetics.

Keywords: Biochemical Oxygen Demand; Carbonaceous Oxygen Demand; *Escherichia coli*; Wastewater

Introduction

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period (Manyuchi and Ketiwa , 2013). The BOD value is most commonly

expressed in milligrams of oxygen consumed per litre of sample over five days of incubation at 20 °C and it is often used as a robust surrogate of the degree of organic pollution of water (Virendra *et al.*, 2013). BOD can be used to gauge the effectiveness of wastewater treatment plants (Penn *et al*., 2013). Chemical Oxygen Demand (COD) is a measurement of the oxygen depletion capacity of a water sample contaminated with organic waste matter. It is similar in function to Biochemical Oxygen Demand (BOD) because they both measure the amount of organic compounds in water and they are the most commonly used parameters for the characterization of wastewaters (Abdalla and Hamman, 2014). COD also used to estimate BOD because a strong correlation exists between them, however COD is a much faster and more accurate test but it is less specific, since it measures everything that can be chemically oxidized, rather than just levels of biologically active organic matter (Sawyer *et al*., 2003). The conventional standard method for the determination of BOD measures the microorganisms' oxygen consumption or respiration over a period of 5 days and it is reported as BOD_5 (Liu *et al*., 2014). The BOD measurement is a good indicator of the concentration of organic pollutants in water but it is extremely slow hence not suitable for process control (Chen *et al*., 2002) but it is essential to obtain a correlation between BOD_5 and COD for various wastewater treatment plants to help in the design and operation of treatment plants (Abdalla and Hamman, 2014). However, BOD is often used ambiguously in relation to Carbonaceous Oxygen Demand (CBOD) which is the oxygen consumed during the oxidation of carbonaceous compounds to carbon dioxide (CO_2) and other oxidized end product (Penn *et al.*, 2009). BOD is actually the sum of CBOD and NBOD where NBOD is the Nitrogenous Oxygen Demand which is the oxygen consumed during the oxidation of nitrogenous compounds (mainly NH_3) to nitrates with nitrites being an unstable intermediate (Yudianto and Yuebo, 2008). *Escherichia coli* is an index organism used for the determination of faecal contamination it can be used to measure the effectiveness of the disposal mechanisms or treatment plants in ensuring that the effluents are environmental friendly (Naidoo and Olaniran, 2014). This research work was therefore carried out to isolate *Escherichia coli* from the Covenant University Oxidation pond, evaluate the BOD of the oxidation pond and determine the CBOD based on the BOD_5 values.

Materials and Methods

Collection of Samples

Four sewage water samples were obtained from four different point

of the Covenant University Oxidation pond. The samples were collected with the aid of sterile sampling bottles and a long rope tied around the neck of each bottle was allowed to gradually sink into the sewage to fill the bottles. The bottles were covered aseptically and transported to the Microbiology Laboratory of the Department of Biological Sciences, Covenant University, Ota. The samples were analyzed immediately.

Cultivation of *Escherichia coli*

Ten milliliter (10ml) of water sample was dispensed into three test tubes containing ten milliliters of double strength McConkey broth (10ml), one milliliter of the water sample was dispensed into single strength McConkey broth (10ml) in each of three test tubes and 0.1ml of the water sample into another set of three test tubes containing single strength McConkey broth (10ml). The inoculated broths were incubated at 37^{o}C for 24 - 48h and they were monitored for acid and gas production. The pour plate method was used for the presence of *E.coli*. One milliliter of each sample was aseptically transferred into a sterile petridish to which about fifteen milliliter of cooled molten agar was poured. The organisms were subcultured on EMB to obtain pure cultures and they were thereafter streaked on nutrient agar slant and incubated at 37^{o}C for 24h and stored as stock cultures.

Measurement of Dissolved Oxygen of the Covenant University Oxidation Pond

The dissolved oxygen of the samples collected at the four points was measured using the MW600 Dissolved Oxygen Meter. The device was calibrated according to manufacturer's specification. The probe was verified to be polarized and probe meter calibrated. The tip of the probe was immersed in the samples (A, B, C, D) respectively. For accurate Dissolved Oxygen (DO) measurements a minimal water movement of 0.3m/sec was required and each sample was dispensed into a sterile beaker and placed upon a stirrer. To check if the water speed was sufficient, a waiting period was observed for the reading to stabilize and move the DO probe.

Measurement of Biochemical Oxygen Demand of the Covenant University Oxidation Pond

The Biochemical Oxygen Demand of the samples was carried out according to the methods described in UGA extension (2013) whereby a DO meter was used to measure the initial dissolved oxygen concentration in the sample bottle collected from point D of the oxidation pond and the bottle was placed in a dark incubator at 20^{o}C for five days. After five days, the DO meter was used to measure a final dissolved oxygen concentration. The Final DO reading is then subtracted from the initial DO reading and the result is the BOD concentration.

$[BOD_5] = [DO]_{Final} - [DO]_{Initial}$

Mathematical Determination of CBOD

This was determined according to the method described by Penn *et al*. (2009) whereby the equation for the determination of CBOD is:

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O \quad (1)$$

$$2H_3^+ + O_2^- = 2H_2O + 2H^+ \quad (2)$$

$$[BOD_5] = [DO]_{Final} - [DO]_{Initial} \quad (3)$$

$$d[DO]/dt = d[CBOD]/dt = -K[CBOD] \quad (4)$$

The BOD exerted (Oxygen Demand) increases with time, therefore,

$$[CBOD] = [CBOD]_o \times e^{-kt} \quad (5)$$

Where K = First-order reaction rate constant

T = Time in days

$[CBOD]_o$ = initial CBOD concentration

Ultimate CBOD using the approximation of the BOD_5 which is based on using the exponential (first-order) nature of oxygen demand is therefore,

$$\text{Ultimate-CBOD} = BOD_5 \times (1-e^{kt})^{-1} \quad (6)$$

$$\text{Ultimate} - [CBOD] = [BOD_5] \times (1-e^{kt})^{-1}$$

Where (BOD_5) = the Biochemical Oxygen Demand exerted over the five day period

Results

***Escherichia coli* strains obtained from the Covenant University Sewage pond**

All the samples from the sewage oxidation pond investigated revealed the presence of *E.coli* as shown by the Most Probable Number (MPN) test whereby all the samples showed gas production (Table. 1). The appearance of greenish metallic sheen colonies on Eosin Methylene Blue agar further confirms the presence of *E.coli* (Table. 2). The biochemical characteristics of the *E. coli* isolates (Table. 3) revealed that the *E.coli* were Indole positive, Methyl red positive, Catalase positive and Voges Proskauer negative, Starch hydrolysis negative, Urease negative and Citrate negative. They appeared as Gram-negative rods under the microscope.

Determination of Dissolved Oxygen at points of collection

The Dissolved oxygen measurement for samples taken at four random points along the oxidation pond decreased from a value of 10.1 mg/l to 7.9 mg/l from point A to point D respectively (Fig. 1).

Determination of Biochemical Oxygen Demand

The BOD values obtained is as follows:

$[BOD_5] = [DO]$ Final – $[DO]$ Initial

$[BOD_5] = 39.5mg/l - 7.9mg/l$

$[BOD_5] = 31.6$ mg/l

Mathematical Determination of Ultimate Carbonaceous Biochemical Oxygen Demand

This was determined using the following:

DO final =39.5 mg/l

DO Initial =7.9 mg/l
Time in Days = Five Days; 5 x 24=120h
K = ranging from 0.3 to 0.7

Ultimate [CBOD] = [BOD5] x (1–e-kt)-1
Ultimate CBOD = 31.6mg/1 for K= 0.3 and K= 0.7

Table 1: The Most Probable Number of Organisms from the Covenant University Oxidation Pond

Sample Zones	Combinations	MPN Index per g/ml
A	3-3-1	4.6
B	3-2-2	2.1
C	3-3-3	>11
D	3-2-2	2.1

Table 2: Growth of *Escherichia coli* on Eosin Methylene Blue Agar

Samples	**Growth on EMB**	**Presence of *E.coli***
A	+	+
B	+	+
C	+	+
D	+	+

Keys

+ indicates a positive test
- Indicates a negative test

Table 3: Biochemical Characterization of *Escherichia coli* strains isolated from Covenant University Oxidation Pond

Sample	**Oxidase Test**	**Catalase Test**	**Urease test**	**Citrate Test**	**Voges Proskauer**	**Methyl Red**	**Indole Test**	**Starch Hydrolysis test**	**Gram Staining Reaction**
A	-	+	-	-	-	+	+	-	Negative Rods
B	-	+	-	-	-	+	+	-	Negative Rods
C	-	+	-	-	-	+	+	-	Negative Rods
D	-	+	-	-	-	+	+	-	Negative Rods

Key

+ indicates a positive result
- indicates a negative result

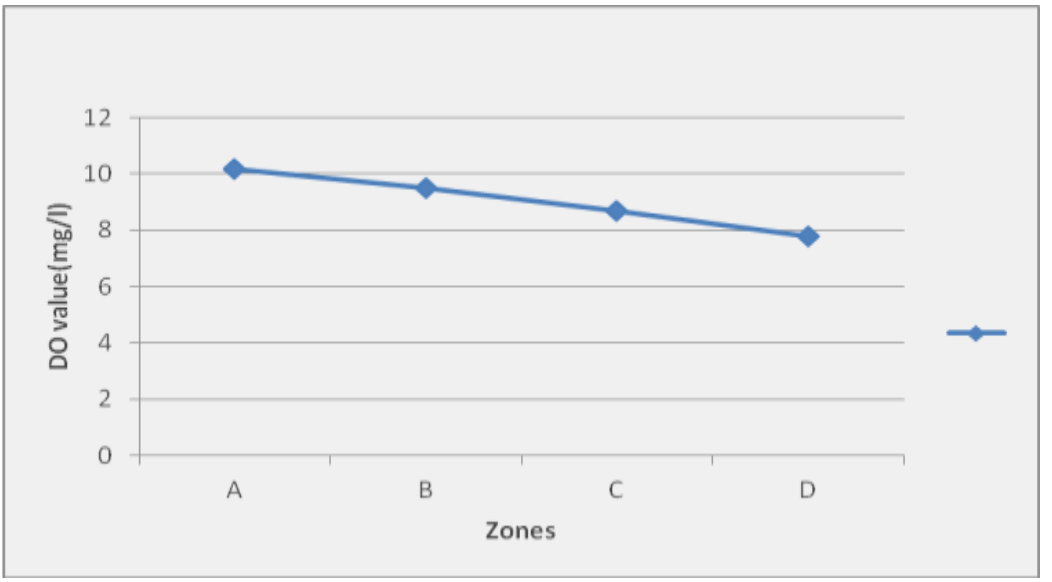

Fig 1: Dissolved Oxygen at the various points (A-D) of the Covenant University Oxidation Pond

Discussion

The results of this investigation revealed that the Biochemical Oygen Demand was employed as a parameter to define the strenght and examine the efficiency of the Covenant University Oxidation Pond. The goal of wastewater treatment is to protect and maintain healthy rivers and oceans which is the aim of evaluating the BOD_5 and COD of waste water (Abdalla and Hamman, 2014). If pollutants in wastewater are not removed, they flow directly into our waterways and this can threaten public health, fisheries, wildlife habitat, recreation opportunities and ultimately, our quality of life (Metro Vancouver, 2013). Two of the important components of wastewater addressed through treatment are: Total Suspended Solids (TSS) and the Biochemical Oxygen Demand. The amount of total suspended solids and biochemical oxygen demand removed from wastewater is used to gauge the effectiveness of wastewater treatment plants (Penn *et al*., 2009).

The Dissolved oxygen values of the water samples obtained from the Covenant University oxidation pond decreased in value from the first point of collection from 10.1mg/l to 7.9mg/l respectively for four random collection points. This shows that the water is in a healthy condition and is fit for aquatic life. It also reveals that the Covenant University treatment plant is effective. Nester *et al*. (2001) reported that when there is excessive BOD, there will be deficiency of DO and water will be in anaerobic condition resulting in mortality of

living aquatic organisms; release of ammonia, methane, CO_2 in the absence of oxygen, anaerobic bacteria becomes active. CBOD is a method defined test which is measured by the depletion of dissolved oxygen by biological organisms in a body of H_2O in which the contribution from nitrogenous bacteria has been suppressed (Penn *et al*., 2009). It is used as an indicator of the pollutant removal from wastewater.

The results of this investigation revealed the presence of *Escherichia coli* in the four sewage samples obtained. The strains of *E.coli* isolated were found to be urease positive with the exception of the strains isolated from the last collection point (D). Also, the strains were found to be indole positive, Methyl red positive, Catalase positive fermenting Glucose, Lactose, Maltose and Sucrose, with exception of the strain from the third collection point(C). *E.coli* has been used as an indicator for water pollution since it is entirely foreign to water (Akande *et al*., 2011; Health Canada, 2012). *E.coli* is a facultative anaerobe, mixed acid fermenter, able to convert formic acid to hydrogen and carbondioxide, lactose fermenter and unable to utilize citrate as the sole carbon source (Holt *et al*., 1994). The presence of *E.coli* in water samples such as sewage implies faecal contamination and strongly suggests the possible presence of enteric pathogenic bacteria, enteric viruses and protozoans (Feng *et al.*, 2002). Apart from being an indicator of faecal pollution of water, *E.coli* has been implicated in diseases, although most strains are harmless (Nataro *et al*., 1998). The Ultimate CBOD has the same value as BOD_5 for K = 0.3 and K = 0.7 when calculated mathematically with the time for five days recorded in hours but an undefined result was obtained for the time calculated in seconds. This is probably due to the exponential function. The importance of the oxygen demand of wastewater for a healthy living condition cannot be overemphasized for two major related purposes which are: To provide an indirect measure of the total amount of organic matter in the wastewater and to provide a basis for assessing the effects of the natural water receiving it. CBOD is sometimes advantageous when compared with BOD because it measures just the oxygen demand exerted by organic (carbonaceous) compounds, excluding the oxygen demand exerted by the nitrogenous compounds. The CBOD accomplishes this by inhibiting the nitrifying organisms from using oxygen by the addition of a nitrification inhibitor to the samples (Acton, 2012).

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Microbiological Safety Evaluation of Ready to Eat Shrimps and Snails Sold Along Lagos-Shagamu Expressway, Nigeria

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Abstract: Vending of ready-to-eat foods (RTFs) along the high ways is a common practice associated to youth unemployment in Nigeria as in some other countries of the world. RTFs sold on streets have been implicated in foodborne illnesses and its attendant economic loses. The microbial quality of ready to eat shrimps (*Penaeus monodon*) and snails (*Achatina maginata*) was investigated in three vending sites along Lagos – Shagamu express road. Sixty samples (30 each of shrimps and snails) were analyzed for microbial counts and for organisms of public health importance. The mean total aerobic plate count cfu/g samples ranged from 1.3×10^4 - $3.5 \times 10^4$and 3.8×10^4 - 5.6×10^5 in abdomen and capitulum of shrimps and 5.6×10^5 - 7.5×10^5 in snails. The samples were contaminated with coliforms and fungi at counts ranging from 1.0×10^2 – 2.3×10^2 and 2.0×10^2 – 8.3×10^3. The microbial isolates identified included species of *Bacillus* (31%), *Staphylococcus aureus* (18%), *Klebsiella* (13%), *Escherichia coli* (6%), *Salmonellae* (2%). Fungal species included *Aspergillus, Mucor, Geotrichum, Fusarium, Paecilomyces, Rhizopus* and *Cladosporium.* The presence of coliforms which are indicator organisms of feacal contamination and *Salmonellae* which are enteric pathogens is a reflection of the sanitary quality of the processing of these food products. This result is informative with respect to public health hazard and calls for urgent improvement in hygiene practices by food processors and vendors. Adoption of hazard analysis and critical control point (HACCP) principles in seafood preparation should be encouraged to prevent possible foodborne illnesses and outbreaks.

***Key words*:** Ready-to-eat foods; foodborne illnesses; coliform; enteric pathogens; HACCP

Introduction

All edible aquatic life may be referred to as seafood. Seafood contributes a significant proportion to the world's food supply and income. Over 70 million tons of seafood is harvested world-wide annually and estimates report consumption averages of 13 kg per person per annum for fish and shellfish [1]. The shrimp landing in Nigeria was estimated at 4,500 to 5,000 tons with annual export earnings of US$29.6M – 50M [2; 3]. Seafood is a good source of protein, it accounts for 14–16% of the animal protein consumed world-wide and over one billion people rely on seafood as their primary source of animal protein [4].

Research has shown that the nutrients and minerals in sea foods can make improvements in brain

development and reproduction and has highlighted the role for seafood in the functions of the human body [5; 6]. According to the U.S. Food and Drug Administration, certain varieties of seafood are excellent sources of vitamins A, C, D and E, calcium, iron and potassium. Eating seafood offers many health benefits, reduces risk of stroke or heart attack largely due to the effects of Omega-3 fatty acids, potentially lower the risk for colon, breast or prostate cancer, and pregnant women can benefit from the high levels of protein, zinc, iodine and iron found in seafood [7; 8; 9].

Seafood is a part of a healthy diet but its consumption is not risk free. Seafood allergy in sensitized individuals could be life threatening [10] and it is responsible for an important proportion of most food-borne illnesses and outbreaks [11-14]. Seafood-associated infections are caused by a variety of bacteria, viruses, and parasites that might have gotten into the food from different sources ranging from rearing or harvesting, processing, transport to food handlers including the consumer. These agents are acquired from three sources: (1) mainly fecal pollution of the aquatic environment, (2) to a lesser extent, the natural aquatic environment, and (3) industry, retail, restaurant, or home processing and preparation [15].

Iwamoto *et al*. [11] reported that 188 outbreaks, 4020 illnesses, 161 hospitalizations and 11 deaths in the United States, from 1973 to 2006 were caused by bacterial, viral or parasitic agents in which seafood was identified as the single food vehicle. Microorganisms implicated in foodborne illness associated with seafood included but not limited to species of *Vibrio*, *Salmonella*, *Shigella*, *Campylobacter*, *Listeria* and pathogenic *E. coli*, *Norovirus/ Norwalk virus*, *Rotavirus*, *Hepatitis* E and A viruses, *Cryptosporidium*, *Cyclospora cayetanensis*, *Giardia lamblia*, *Entamoeba histolytica* and some fungal species [11-14; 16-18].

Foodborne illness associated with seafood can be prevented by using safe food handling practices including washing hands, utensils, and cooking surfaces often, cooking seafood to a minimum of 145°F for 15 seconds, keeping raw and cooked seafood separate to avoid cross-contamination, storing seafood in the refrigerator below 40°F or in the freezer below 0°F; all and more of these measures are enshrined in the application of the Hazard Analysis and Critical Control Points (HACCP) system which is one of the most effective tools in food safety, it is a simple and efficient way to ensure food safety, predict, resist and prevent food borne illnesses before they occur [15; 19; 20]. This work was designed to determine the microbial load of ready to eat shrimps and snails sold along the

busy Lagos- Shagamu expressway and thus, create awareness for consumers on safety of these RTE seafood purchased along the expressway.

Materials and Methods

Sample sources and collection

Three stop-over terminals for travelers along the Lagos- Shagamu expressway and popularly known for the ready to eat foods (RTFs) vending activities were chosen for sample collection. These spots/ terminals included Berger, on the Lagos axis, Ibafo on the midway and Mowe on the Shagamu end of the highway.

Thirty samples each of ready to eat shrimps and snails were collected (ten samples of each food were randomly purchased from each vending site). The samples were collected as packaged for customers and aseptically placed in sterile polyethylene packs and transported to the laboratory in cold packs for further analyses. Samples were collected and analyzed between January and April, 2014.

Sample analysis

The shrimps were aseptically dissected into capitulum and abdomen with the aid of a sterile scalpel. The capitulum and the abdomen were cultured separately. Twenty five grams of each food sample (capitulum of shrimps, abdomen of shrimps and snails) were blended in Stomacher lab blender and homogenized in 225mL of sterile peptone water (Oxoid, England).

Serial dilutions of the homogenates were made to 10^{-4} and 0.2mL of each dilution was spread inoculated onto triplicate media plates of Nutrient agar (for total aerobic plate count)**,** Sabouraud Dextrose agar (for fungal count), Mannitol Salt agar (for isolation of *S. aureus*), Eosin Methylene blue agar (for coliform count), *B. cereus* medium and Salmonella Shigella agar (for isolation of salmonellae and Shigella following 24h sample pre-enrichment in Selenite-F broth) (all the media were from Oxoid, England). EMB broth (Sigma-Aldrich, USA) in capped test tubes with inverted Durham tubes was inoculated with a gram of samples for coliform test. The culture plates and tubes were incubated for 24 to 48 h at 37°C. A plate of the EMB cultures was however, incubated at 44°C for faecal coliform *E. coli* isolation, while the Sabouraud Dextrose agar (SDA) plates were incubated at laboratory room temperature 28±2°C for 3 to 5 days. Colony counts were made from plates of appropriate dilutions at the end of incubation periods. Cultural characteristics of the colonies were also recorded to aid identification.

Coliform test

Samples with gas formation indicated by the Durham tubes and/ or colour change of dye in the medium were reported as positive for presumptive coliform test.

Confirmatory coliform test was carried out by plating out positive presumptive test cultures on EMB agar plates and incubating overnight at 37°C. The presence of characteristic greenish metallic sheen black colonies typical of *E. coli* or brown mucoid colonies characteristics of *E. aerogenes* and which are Gram negative non-spore forming was considered a positive confirmatory test. The colonial growths were treated for completed test and stored at 4°C for further characterization.

Microbial Colony Count and Identification of Isolates

At the end of incubation time, colonies were enumerated using colony counter (Gallenkamp, England), total counts were expressed as colony forming units per gram of sample (cfu/g). Pure cultures of isolates for characterization were obtained by repeated subculture on appropriate medium. Preliminary identification of bacterial isolates was based on morphological characteristics of colonies, microscopy and biochemical tests including catalase production, indole test, methyl red, Voges-Proskauer, citrate utilization, coagulase, oxidase and urease production, gelatin liquefaction, starch hydrolysis, fermentation of sugars, temperature and salt tolerance tests and motility test. The Biomerieux© sa API system with reference to standard identification manuals was employed in the further identification of the bacterial isolates [21; 22]. Fungal isolates were identified based on morphological characteristics and microscopy with reference to standard identification keys and atlas [23-25].

Statistical Analysis

All data from colony counts are presented as mean and standard deviation. The level of significance in differences of means was determined by DMR test using SPSS 20.0 software for windows

Results

The mean microbial population for total aerobic plate count, coliform count, and fungal count of the shrimps and snails food samples from the three vending sites reveals that TAPC of snails are significantly different from the TAPC obtained from capitulum and abdomen of shrimps. Similarly, TAPC of samples of snails from Ibafo terminal were significantly different from counts of samples from other sampling terminals (Table 1). The table 1 also shows that coliform counts from shrimp capitulum obtained from Ibafo were significantly different from that of shrimp abdomen and snails from Mowe and Berger. The fungal counts from the capitulum of shrimp samples were significantly different from that of snails and samples of shrimp abdomen. Similarly, fungal counts of shrimps from Ibafo and Mowe were significantly higher than counts from Berger sampling site.

Table 2 shows the counts for *Staphylococcus* and *Salmonellae* in samples from the three terminals. The table revealed that the *S. aureus* from samples of snail obtained from Ibafo were significantly higher than *S. aureus* counts from other samples. The capitulum of shrimp has significant higher *S. aureus* and *Salmonellae* counts compared to samples of shrimp abdomen and snails.

Fig.1 presents the percentage occurrences of bacterial and fungal isolates from all the food samples. It shows that species of *Bacillus, Staphylococcus* and *Klebsiellae* are the predominant bacteria isolates while *Aspergillus, Geotrichum* and *Mucor have* the highest percentage of occurrences as fungi.

Discussion

All the samples analyzed in this study had microbial loads below 10^6, with a TAPC ranging from 10^4 to 10^5 $cfug^{-1}$ of samples, but for some samples with salmonellae and coliforms, it could be said that most of the ready-to-eat shrimps and snails (sea foods) sold along Lagos-Shagamu expressway are of acceptable microbial quality. The ICMSF [26], Microbiological quality guide for ready-to-eat foods [27] states that ready-to-eat foods with heterotrophic plate counts of 10^3 are acceptable and 10^5 are of tolerable microbial quality. Although in some countries zero (0) bacteria $25g^{-1}$ of sample is the acceptable microbiological level in cooked crustaceans [28].

The aerobic plate counts could be contaminants from foods own flora that escaped destruction by processing techniques or post process contaminants from processing environment, water, utensils, and food personnel [15; 29; 30].

The presence of coliforms in some of the shrimp and snail samples could be explained to mean possible contamination of products by animals or human faecal materials. Coliforms are indicator organisms connoting that their presence could imply possible presence of other enteric pathogens. Contamination with coliforms could be from the personnel (food processors and vendors) as the samples are often packed and arranged with bare hands in white cellophane or hawked in small bowls for customers to select with toothpicks or fork. The water for processing and utensils could be a source for sample contamination with coliforms [31; 32]. The environment of the food vending terminals (Berger, Ibafo and Mowe) could contribute to coliform contamination [30], animals in their flocks is a common scene as cattle, goat, ram, sheep, donkey, chicken, etc. are moved through these terminals to nearby markets for sale. The growth of coliforms at 44-45°C incubation indicates that some of the coliforms are of feacal rather than environmental origin. Effective

application of good manufacturing practices and HACCP is necessary to prevent coliform contamination.

Bacillus and fungal species are known to be spore formers and common environmental contaminants; this could explain their presence in the shrimp and snail samples. *B. cereus,* a common food borne pathogen, was not isolated from the samples analyzed. Majority of *Bacillus* and fungal species are food spoilage organisms or opportunistic pathogens, thus, in the absence of known pathogens like *B. cereus* and *B. anthracis* the presence of other *Bacillus* species must be controlled to reduce possible spoilage activities. Fungi such as *Aspergillus* and *Fusarium* species are known to produce deleterious mycotoxins under favourable conditions, their presence in RTE shrimps and snails must not be treated with levity considering the fact that some of the products (shrimps and snails) are hawked for days until they are sold and these products are nutritionally rich to support the proliferation of these fungi in growth and possible mycotoxin(s) production. Some species of *Rhizopus* and *Mucor* have been implicated as opportunistic agents of infections, specifically, in the immunocompromised [33].

Staphylococcus aureus and *S. epidermidis* are normal flora of human; this could explain the possible contamination of the samples from personnel. Cross contamination from equipment and food contact surfaces are likely avenues through which shrimp and snail samples could have been contaminated. Enterotoxin producing strains of *S. aureus* are known to cause food poisoning [34-38], there is therefore need to control RTEFs from S. *aureus* contamination.

The presence of *Salmonellae, Klebsiella, E. coli* and other enterobacteria is an indication of faecal contamination of some of the samples [39]. *Salmonellae* are causative agents in salmonellosis often associated with consumption of contaminated foods and drinks [13; 16; 17]. Pathogenic strains of *E. coli,* specifically, *E. coli* O157: H7 have been implicated in food borne infection outbreaks [40]. *Klebsiellae, Proteus, Pseudomonas* and some other enterobacteria have been implicated as opportunistic pathogens specifically in the immunocompromised [41; 42]. The presence of these enterobacteria in some of the RTE shrimps and snails is a cause for concern. Education and training of the personnel, effective application of GMP and HACCP are imperative to making these products completely safe for human consumption.

The capitulum of shrimps had significantly higher levels of contamination compared to the abdomen; this could be attributed to the organism's feeding mode of straining out small particles including bacteria from water [26].

Though the counts recorded for the samples in this study are generally $<10^6$ $cfug^{-1}$ of samples, the presence of more *salmonellae, S. aureus* and coliforms in the capitulum suggest that it might be safer to consume only abdomen of shrimps while the capitulum be channeled for other useful products [43-45].

Conclusion

Ready-to-eat shrimps and snails sold along the highway had microbial counts $<10^6$ indicating safe level of contaminants for human consumption. However, the presence of coliforms, *Salmonellae*, *S. aureus*, and some other enterobacteria signify faecal contamination of some samples and thus they are not fit for human consumption. Food safety enlightenment campaigns for the vendors and processors of RTEFs is necessary, the consumers should demand for better handling and packaging of product, by so doing these personnel will improve on hygiene measures in dealing with the products and thus make it safe for consumption.

Table 1: Mean microbial counts of RTE shrimps and snails ($cfug^{-1}$) sample

Sample Site	Capitulum of shrimps			Abdomen of shrimps			Snail		
	TAPC	Coliform count	Fungal count	TAPC	Coliform count	Fungal count	TAPC	Coliform count	Fungal count
Berger	3.8×10^{4a}	1.0×10^{2a}	6.5×10^{2a}	1.3×10^{4b}	7.0×10^{1a}	2.0×10^{2b}	5.9×10^{5c}	1.2×10^{2a}	2.0×10^{2b}
Mowe	3.9×10^{4a}	1.3×10^{2a}	8.0×10^{2c}	1.5×10^{4b}	NG	5.5×10^{2d}	5.6×10^{5c}	1.3×10^{2a}	2.8×10^{2b}
Ibafo	5.6×10^{5c}	2.3×10^{3b}	8.3×10^{3e}	5.3×10^{4d}	1.2×10^{2a}	5.6×10^{2d}	7.5×10^{5e}	1.2×10^{2a}	2.7×10^{2b}

abcde: Values with different alphabet superscript down the column and across the row for same count are significantly different

Table 2: Mean *S. aureus* and *salmonellae* counts of RTE shrimps and snails ($cfug^{-1}$) sample.

Sample Site	Capitulum of shrimps		Abdomen of shrimps		Snails	
	Staphylococcal count	*Salmonellae* count	Staphylococcal count	*Salmonellae* count	Staphylococcal count	*Salmonellae* count
Berger	2.9×10^{3a}	1×10^{1a}	4.0×10^{1b}	NG	3.8×10^{2c}	NG
Mowe	1.8×10^{2d}	1×10^{1a}	1.6×10^{3e}	NG	1.7×10^{2d}	NG
Ibafo	5.7×10^{2f}	1.1×10^{2b}	2.9×10^{2g}	1.1×10^{1a}	3.6×10^{3h}	1.0×10^{1a}

abcdefgh: Values with same alphabet superscript down the column and across the row for same count are not significantly different

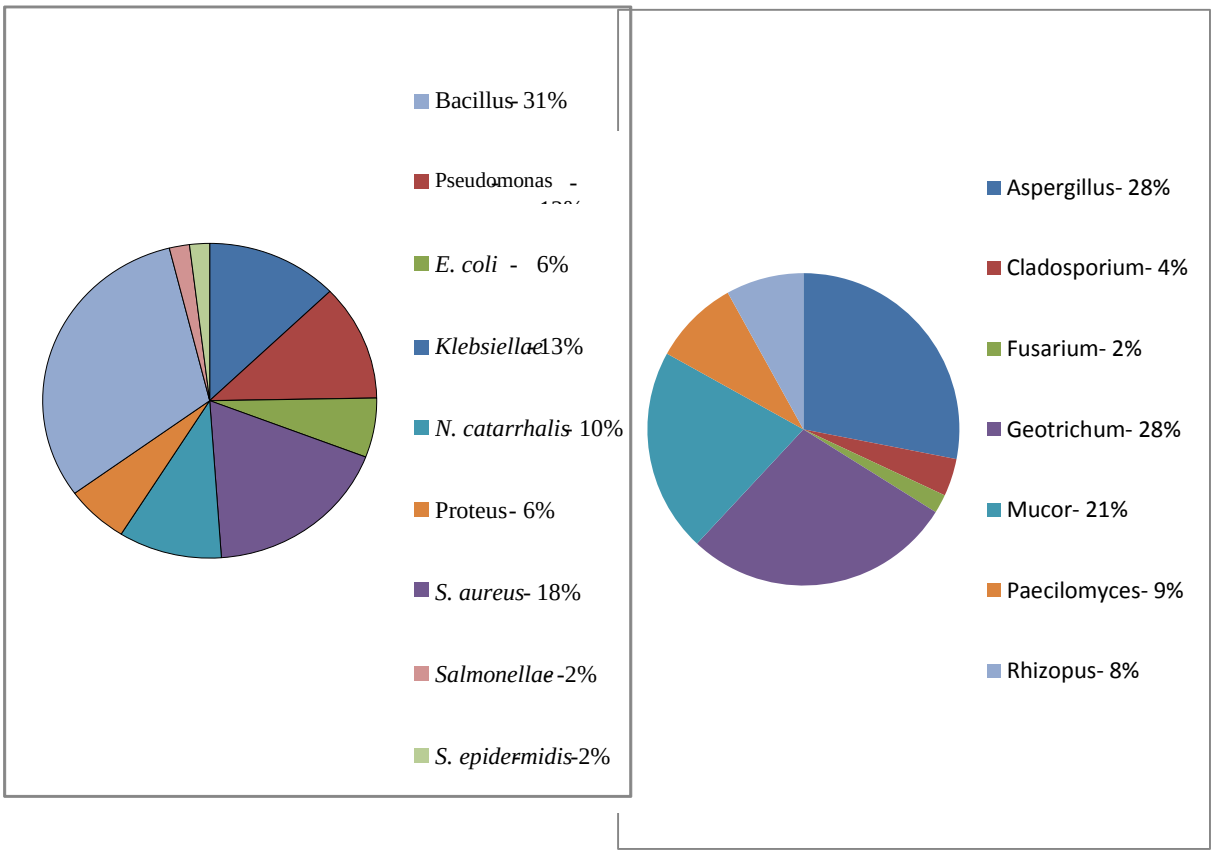

Figure1: Percentage occurrences of Bacterial and Fungal isolates from shrimp and snail samples

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Variations of time derivatives of the horizontal geomagnetic field and horizontal geomagnetic field along 96-degree magnetic meridian

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Abstract: The Energetic particles are released from the Sun by solar flares or eruptive ejections interaction with geomagnetic field producing geomagnetic storms and more ionization in the ionosphere. The geomagnetic substorms are classified as one of major factor that influence geomagnetically induced currents (GIC) that affect the operation of technological system through the geomagnetic field variations. The direct representation of GIC is the time derivative of the horizontal geomagnetic field. 138 substorms onset events were obtained from IMAGE magnetometer data from Northern Europe, using Dst (Disturbance storm time) to determine the substorm events of varying strengths, for five stations (Addis Ababa, Abisko, Bangui Hermanus and Nurmijarvi). The data used in this study covers the periods from 1999 to 2001. Positive high correlation exhibited between the maximum value of time derivatives of the horizontal geomagnetic field (dH/dt_{max}) and maximum value of horizontal geomagnetic field (max H). Also, Monthly variations of the maximum value of time derivatives of the horizontal geomagnetic field (dH/dt_{max}) and maximum value of the horizontal geomagnetic field (max H) were also investigated.

Keywords: Substorms, Geomagnetically induced current, Disturbance storm time, Time derivatives of the horizontal geomagnetic field and Horizontal geomagnetic field.

1.0 Introduction

Sun releases energetic particles that interact with the magnetic field of the Earth. This interaction produces geomagnetic storms and increase ionization in the ionosphere [1] (Stauning, 2013). Literatures revealed the geomagnetic disturbance posed by a coronal mass ejection (CME) generated geomagnetically induced currents (GICs) on the operation of technological systems such as power grids, communication cables, oil pipelines and human health [2-4] (Tom, 2002; Watari et al., 2009 and Pulkkinen et al., 2010). All these are manifestations of the ground effect of space weather at high geomagnetic latitude, which are known to cause problems. The GICs flowing along electric power-transmission systems are produced by a naturally induced geo-electric field during geomagnetic disturbances. Whenever a current flowing through neutral point, the operating point of transformer shift from the optimum point, resulting in transformer loss in form of the over

heating or harmonic being produced that may affect the protective relay leading to malfunctioning of the transformer.

The auroral electrojet, ionospheric and magnetospheric current systems, are considered to be the major causes of geomagnetic disturbances which manifest to GIC. During the geomagnetic disturbances of the Earth's magnetic field, varying electrical currents in the ionosphere and magnetosphere induced electric fields in the Earth's surface. GIC can be obtained if the spatiotemporal behaviour of ionospheric currents is known and the Earth's conductivity is available. Then the horizontal geoelectric field which drives GICs can be computed. The GIC are considered as factors of time derivative of the geomagnetic field, the electric resistivity of the Earth and resistances of the power grid. [5-8] established that GIC also occurs at mid and low latitudes even at Africa and South Africa.

Based on the fundamental of Faraday's law, linking temporal changes of the magnetic flux to the electromotive force, the geoelectric field is associated varying geomagnetic field, indicating that the time derivatives of the geomagnetic field provide direct representation for GIC activity, especially with the horizontal component (dH/dt) [9-10]. The geoelectric field could be obtained from the measured geomagnetic field as statistical estimation of the GIC occurrence in a particular location. The major driver for GIC is the horizontal electric field induced at the Earth's surface as a result of time-varying ionospheric current systems. In the creation of GIC, substorms play significant role [11-14].

Several studies of geomagnetic field variations focused on higher latitude regions investigating on time derivative of the horizontal geomagnetic field (dH/dt). High values of dH/dt appear during the main phase expansion of geomagnetic storm using the International Monitor for Auroral Geomagnetic Effects (IMAGE) network. Increase in max dH/dt with increasing latitude equatorward of the auroral oval and decrease at the poleward were observed [15]. [16] compared the storm time substorms and non storm time substorms, the size of max dH/dt can be doubled by storm time substorms at all latitudes. The electrojet has great influence on the horizontal geomagnetic field (H), dH/dt is more liable to be influenced by smaller scale of ionospheric features [17].

In this paper, the hourly and monthly variations of the time derivatives of the horizontal geomagnetic field (dH/dt) and horizontal geomagnetic field (H) were analyzed. Also the relationship between the dH/dt and H during geomagnetic activity from 1999-2001 were also investigated. In this work, d*H*/d*t* is a direct representation of geomagnetically induced current (GIC).

2.0 **Material and Methods**.

The data used in this research includes Dst values (Disturbance storm time) and horizontal geomagnetic field component *H* for three years from 1999-2001. The substorm onsets are divided into those that occur during storm time conditions (Dst<−40 nT) were considered and this activity level defines substorm events. The *Dst* index data were provided by the World Data Center for Geomagnetism at Kyoto University (WDC). 138 substorms events were obtained from IMAGE magnetometer data from Northern Europe, using Dst to determine the substorm events of varying strengths for five stations (Addis Ababa, Abisko, Bangui Hermanus and Nurmijarvi). The time derivatives of the horizontal geomagnetic field were calculated to obtain a good measure of the GIC. The idea of local time (LT) was engaged throughout in the study using the concept of [18-19]. Coordinates of the stations engaged in this work are shown in Table 1.

Table 1: Geographic and geomagnetic coordinates of magnetic observatories

Stations	Codes	Geographic Latitudes	Geographic Longitudes	Geomagnetic Latitudes	Geomagnetic Longitudes
Addis Ababa	AA	9.030	38.770	0.16	110.47
Abisko	AB	68.356	18.824	65.11	102.31
Bangui	BAN	4.333	18.566	-5.27	90.13
Hermanus	HER	-34.425	19.225	-42.35	82.15
Nurmijarvi	NUR	60.580	24.655	56.82	102.50

2.1 Correlation between the dH/dt and H

In section 2.1 we obtained regression analysis of both hourly time derivatives of the horizontal geomagnetic field (dH/dt) and horizontal geomagnetic field (H) components. Tables 2 presents the regression analysis performed to test the relationship between max time derivatives of the horizontal geomagnetic field (dH/dt_{max}) and max horizontal geomagnetic field (max H) at different latitudes, recorded at five stations in the period of 1999-2001 for substorm storm-time. The correlation coefficient between dH/dt_{max} and max H are quite high for the three years. The difference in correlation clearly reflects the geographical orientation of the stations. This indicates that the (substorm) mechanism behind the relation between max H and dH/dt_{max} may be independent of storm conditions as suggested by

[20]. The GIC has a good relationship with the geomagnetic field variations due to the underground conductivity.The geoelectric field is always associated with varying geomagnetic field [21].

Table2: Shows regression analysis of max H and max dH/dt for 1999, 2000 and 2001

Stations	r (1999)	r (2000)	r (2001)
Addis Ababa	0.7068	-	0.6812
Abisko	0.8238	0.6875	0.6956
Bangui	0.7234	0.9331	0.6722
Hermanus	0.6456	0.6462	0.7765
Nurmijarvi	0.7079	0.8365	0.8108

Despite the differences, the hourly value of dH/dt_{max} is always a good indicator for the hourly amplitude of GIC. The results involving the time derivatives also have good correlation coefficients in all stations.

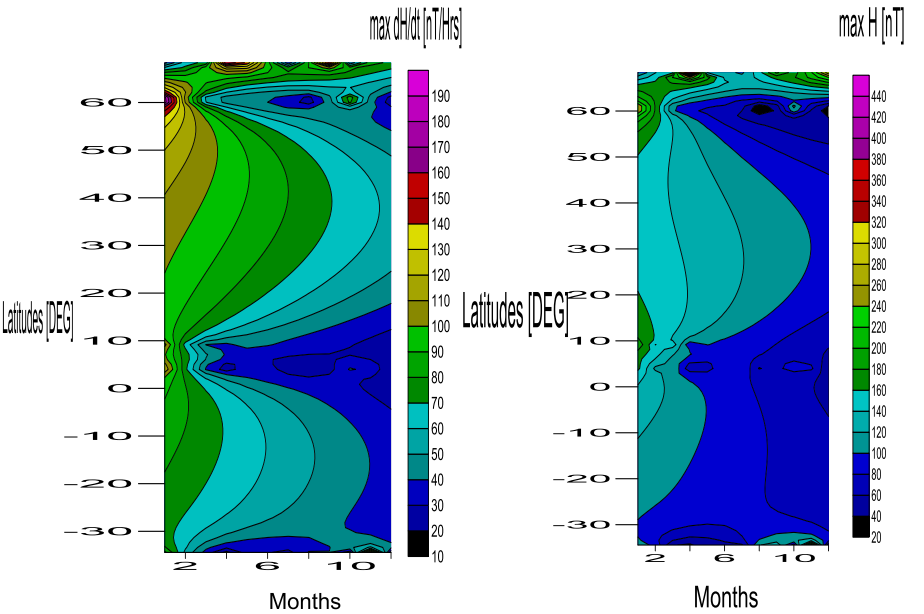
2.2 Monthly variation of max time derivatives of horizontal geomagnetic field (dH/dt_{max}**) & max horizontal component of geomagnetic field (max H).**

Monthly occurrence of dH/dt_{max} and max H are illustrated in Figures 1(a and b) to 3(a and b). Figures 1 (a and b) indicate that there is high activity of dH/dt_{max} and max H during the months of March in Abisko. In Bangui and Nurmijarvi both max H and dH/dt_{max} were noticed in September, also in Hermanus both dH/dt_{max} and max H were observed in the month of October and November. While high activity is also noticed in January at Addis Ababa. During these substorms, dH/dt_{max} was larger in the auroral region and the sub auroral region than lower region. The substorm onset for 1999 is in agreement with the general increase in geomagnetic activity observed near the equinoxes.

It is quite clear from Figures 2a and 2b substorms onset for 2000 that auroral regions (Nurmijarvi and Abisko) have the highest value of dH/dt_{max} noticed in the month of February, April, August, September, October and November. In Hermanus, dH/dt_{max} was observed in the month of August with another peak in February, October, November and December. At low latitude (Bangui), dH/dt_{max} is high in the month of April and July. While max H also follow the same trend at auroral regions and lower latitude.

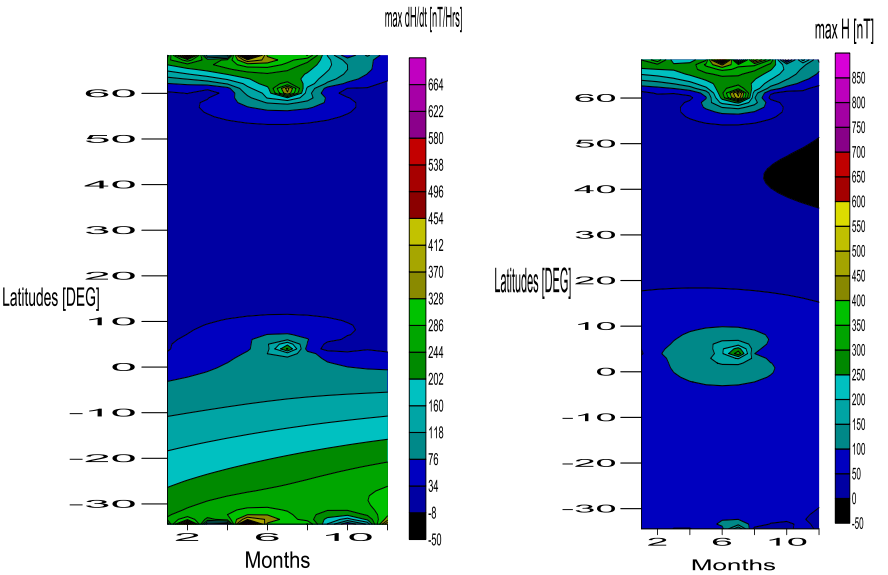
Figures 3a and 3b substorms onset for 2001 shows the distribution pattern of dH/dt_{max} and max H varies strongly in the auroral region. The dH/dt_{max} and max H occurs in the month of March, April, October and November at Abisko, Nurmijarvi, Bangui, Hermanus and Addis Ababa.

1a **b.**



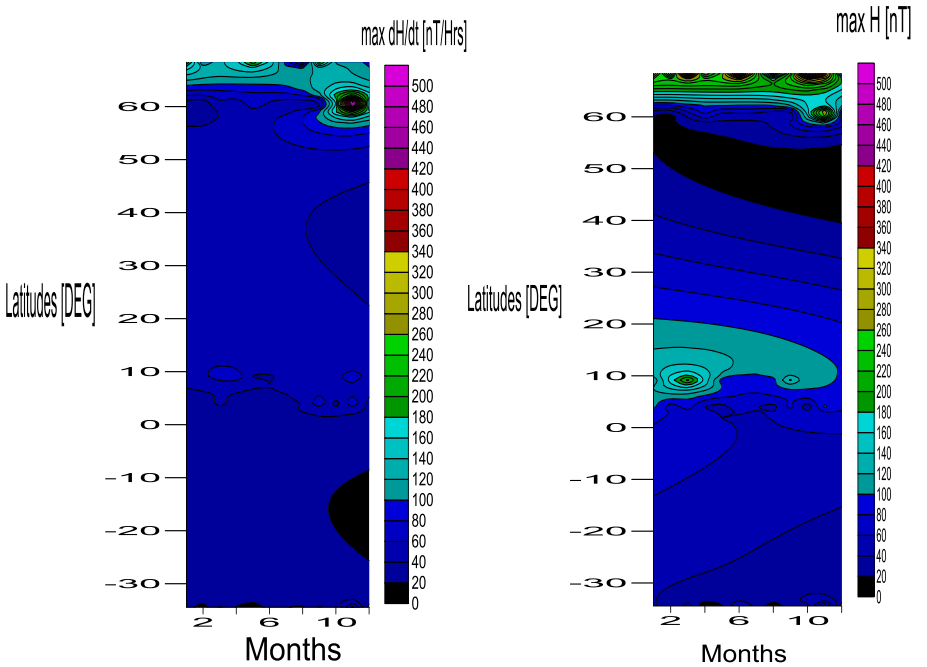
Figures 1 (a and b): Monthly variation of dH/dt_{max} and max H for 1999.

2a. **b.**



Figures 2 (a and b): Monthly variation of dH/dt_{max} and max H for 2000

3a. **b.**



Figures 3 (a and b): Monthly variation of dH/dt_{max} and max H for 2001.

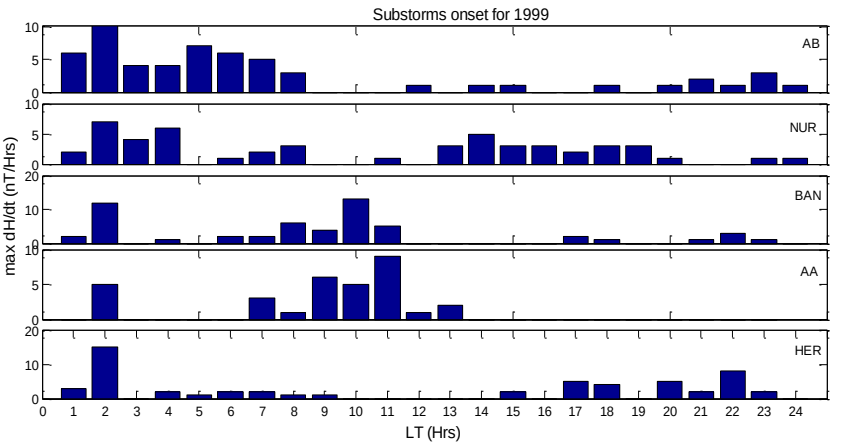
The monthly distribution of dH/dt_{max} and max H may be as a result of sudden pulse noticed during the commencement of the magnetic storm and variation of the geomagnetic field during storm [22]. It was also confirmed that large GIC events occur most frequently at high latitudes in the vicinity of auroral electrojets and other dynamic ionospheric current systems [23-24].

2.3. Time occurrence of dH/dt_{max} and max H for substorms onset

Figure 4 (a-c) illustrates the hourly occurrence of dH/dt_{max} from 1999 to 2001. Figure 4a shows dH/dt_{max} around the early morning hours, and nearly vanishes during noon time at Abisko in 1999. The occurrence of large dH/dt_{max} has two daily maxima, one around the afternoon and another in the morning at Nurmijarvi. In Bangui, the maximum values of occurrence were noticed in the morning time. In Addis Ababa, during the daytime dH/dt_{max} shows a large enhancement over the equatorial zone while during the nighttime the amplitude has decreased monotonously. It collaborates with the electrojet strength. In Hermanus, dH/dt_{max} was noticed during morning time and nighttime. In 2000 (Figure 4b), it can be seen that the variation patterns are quite the same in early morning time for all the stations. The amplitude of the dH/dt_{max} variation at the stations in the morning is generally much higher than the afternoon time. But AA has no data for 2000. In 2001, dH/dt_{max} shows nearly the same variation forms with a slight

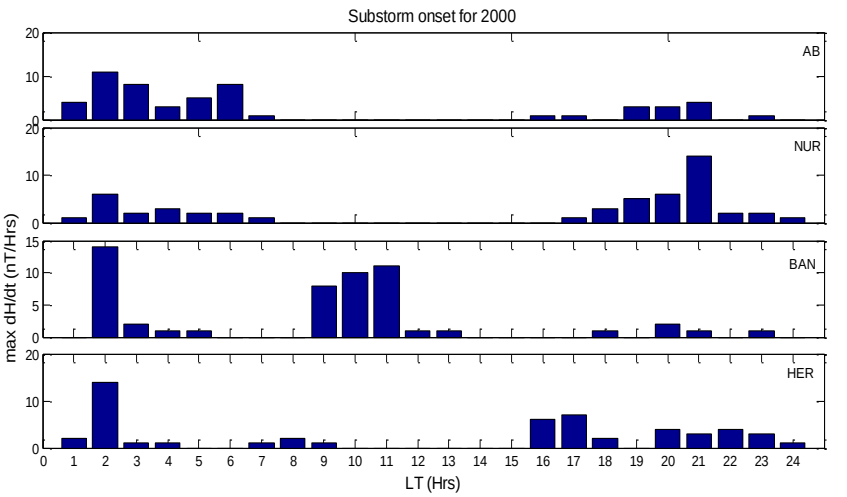
difference in the morning and afternoon due to a diurnal pattern in AB and NUR. Addis Ababa (AA) and Bangui (BAN), dH/dt_{max} on the magnetic equator shows the maximum value around the local noon period. In HER, the dH/dt_{max} varies in the morning and nighttime (Figure 4c).

4a.



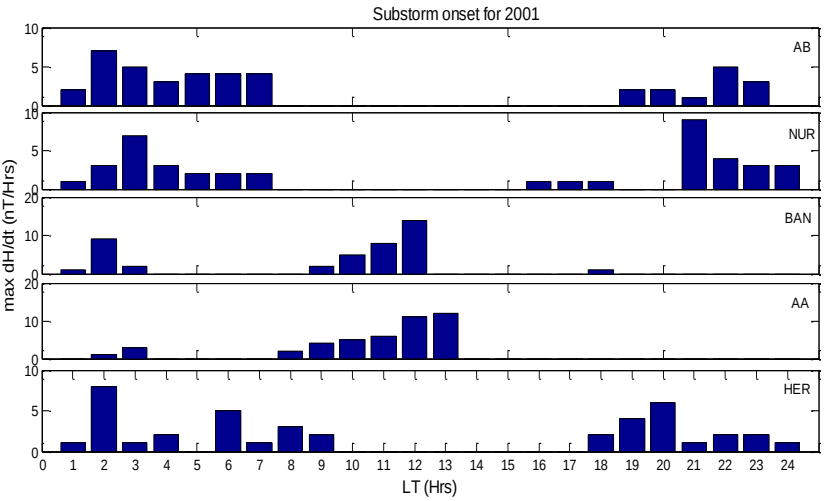
Figures 4a: Shows the hourly occurrence of dH/dt_{max} for 1999

b



Figures 4b: Shows the hourly occurrence of dH/dt_{max} for 2000

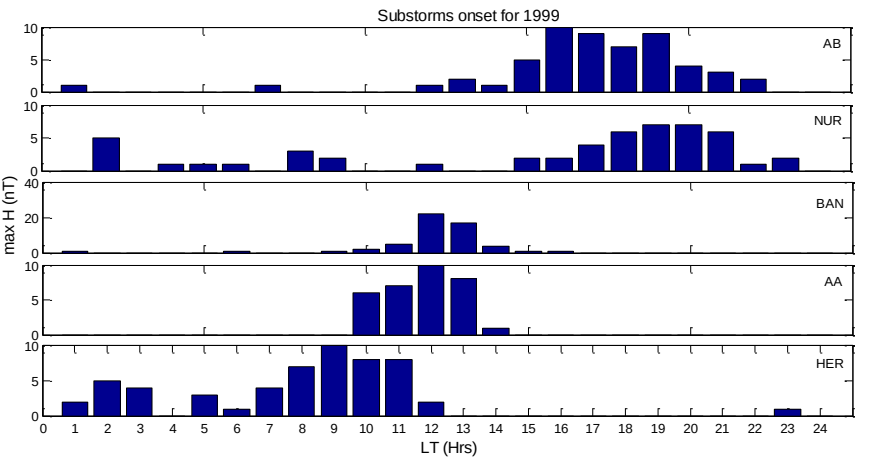
c.



Figures 4c: Shows the hourly occurrence of dH/dt_{max} for 2001.

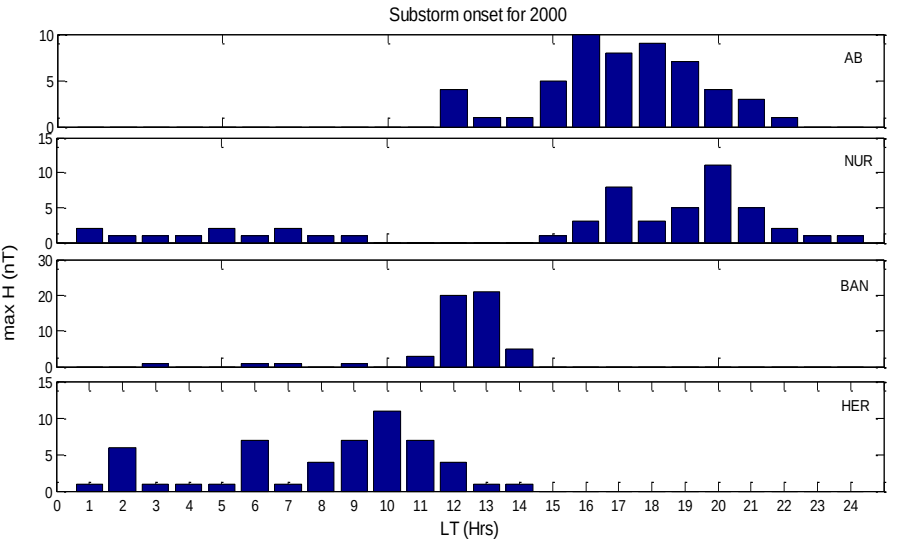
Figures 5 (a-c) illustrates the hourly occurrence of max H, for the period of 1999, 2000 and 2001 the night time max H are generally greater than the day time magnitudes for AB, NUR and BAN for hourly variation. The variation of max H appeared to be showing a maximum around 12:00 noon at AA in 1999 and 2000 due to the electrojet current. In HER, max H was noticed from morning time attaining peak magnitude in the early morning at 2:00 LT and gradually decrease to night time value after sunset.

5a.



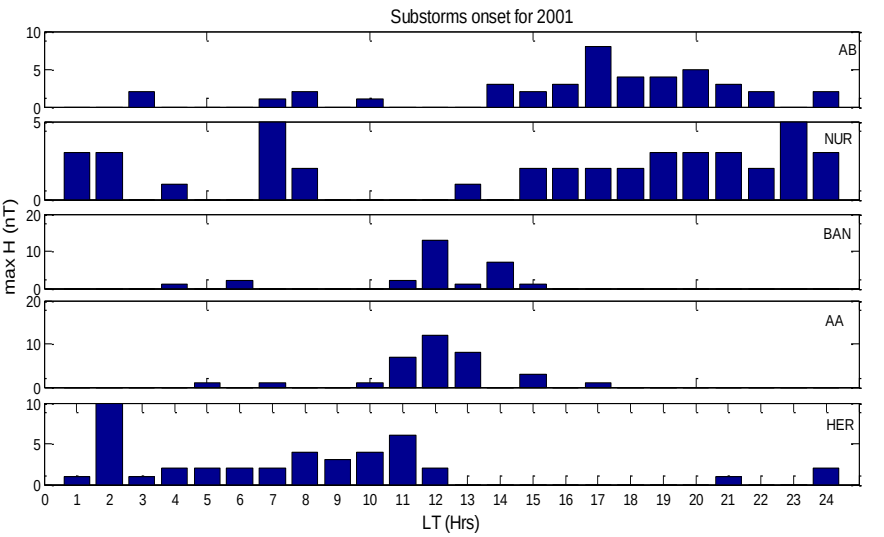
Figures 5a: shows the hourly occurrence of max H for 1999.

b.



Figures 5b: shows the hourly occurrence of max H for 2000.

c.



Figures 5c: shows the hourly occurrence of max H for 2001.

3.0 Results and discussion

The solar wind and the Earth magnetic field interactions affect the physical process in the magnetosphere and ionosphere, the result of this interaction is observed

as variation of geomagnetic and geoelectric fields. Table 2 contains summaries of events used in this study, the correlations between the dH/dt_{max} and max H are given by the correlation coefficients which varies from one station to another station from 1999 to 2001.

Generally, correlation coefficients are high for all the stations. This indicates a strong relationship between the dH/dt_{max} and max H. For relations tested values 0.8238-0.6456, 0.9331– 0.6462 and 0.8108-0.6722 are high for all the stations in Table 2. These numbers shows that the variation may be associated with high latitude disturbance driven by electrojet intensifications which produce large differences in geoelectric field response for these disturbance years. The variation in ground observation of dH/dt changes with respect to intensity, location, and orientation of the aurora electrojet [25].

The contour plot in Figures 1 (a and b), 2 (a and b) and 3 (a and b) shows the dH/dt_{max} and max H increases with latitude for substorms onsets. The value of dH/dt_{max} increases with increasing latitude at the auroral and decreases at toward the equator. The dH/dt_{max} and max H events occur most frequently at high latitudes in the vicinity of auroral electrojets. It was also observed from Figures 1(a and b) to 3(a and b) that Autumn and Spring have the highest values of dH/dt_{max} and max H. This implies that more storms occur during Autumn and Spring, as a result of increase in the energy input by solar wind magnetosphere coupling. Max H is noticed at Addis Ababa (AA) as a result of equatorial electrojet activity stronger in AA as it is closer to the magnetic dip equator.

Figures 4 (a-c) illustrates the time occurrence of dH/dt_{max} effect. In Figure 4a it is obvious that maximum time derivatives of the horizontal geomagnetic field (dH/dt_{max}) effect exist in early morning with negligible occurrence during the day time and slight occurrence at the night time in AB. The dH/dt_{max} is more noticeable in the early morning time and turns weak during the nighttime at NUR. The dH/dt_{max} was seen around the noon time. It means that equatorial enhancement is much higher during the daytime than the night time at AA and BAN. At mid latitude (HER), the variability occurrence of dH/dt_{max} was dawn to dusk phenomena and observed in the daytime and turns very strong during the nighttime. Figures 4b and 4c have similar pattern with Figure 4a. It have long been established that ionospheric current flows at the dip equator with high current intensities during the daytime. The field aligned current generated in the boundary regions between the Earth magnetosphere and the solar wind have influence on the ionospheric current at the morning time and evening time of high latitudes. At nighttime the intense ionospheric

current at high latitudes are driven by field aligned current from substorm processes in the unstable magnetospheric tail region. The dH/dt_{max} occurs during night-time events may be governed by westward ionospheric currents.

The max H is illustrated in Figures 5(a-c), the day to day variability peaks were noticed during the daytime after the local noon time and the nighttime at AB and NUR respectively from 1999 to 2001. Various reasons were suggested to be responsible for these nighttime variations amongst include asymmetric ring currents in the magnetospheric currents, magnetospheric effects like the westward ring current even during fairly quiet periods, also variations due to disturbances suggesting possible non-ionospheric origin. The occurrence of max H was noticeable during daytime at local noon of AA and BAN for the years. AA and BAN stations are located in the equatorial regions. Also, AA (0.18 dip latitude) is station within equatorial electrojet zone with high amplitude in 1999 and 2001. This is eastward band of electric currents in the ionosphere called Equatorial Electrojet current suggested by [26]. The variation of max H at HER shows a maximum variation morning time before noon and decrease towards the nighttime. The day time variability noticed may be attributed to ionospheric electric field mainly controlled by the E-region dynamo process and the tidal forces from the lower atmosphere [27].

4.0 Conclusions

The monthly and hourly variations of maximum value of time derivatives of the horizontal geomagnetic field (dH/dt_{max}) and maximum value of the horizontal geomagnetic field (max H) were investigated between 1999 and 2001. From our results the following conclusions are drawn.

During the monthly variation, dH/dt_{max} activity increases with increasing latitudes at the auroral region and decreases toward the equator. dH/dt_{max} and Max H is high during the Spring and Autumn. This implies more storms occur during these two seasons. dH/dt_{max} activity is high around the early morning hour and night time hour, vanishes around noon time at high attitudes (Abisko and Nurmijarvi). While max H occurrence for substorm onset occur during the nighttime at Abisko and Nurmijarvi. dH/dt_{max} and Max H activity is high around the noon time at Addis Ababa and Bangui due to an eastward electric current in the ionosphere which is known as Equatorial Electrojet.

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