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Environment & Earth Science

Water Pollution on Physiological

Clarias Gariepinus from Nile Delta

Highlights

Geo-accumulation & Ecological Risk

Anaerobic Co-Digestion of Municipal

Discovering Thoughts, Inventing Future

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Effect of Water Pollution on Physiological and Histological Alterations of African Catfish, Clarias Gariepinus from Nile Delta

By Ali A. Al-Halani, Ahmed E. Hagras, Sherif H. Abdeen, Abeer E. Abdrabbuh & MohamedI. Mashaly

Hajjah University, Yemen

Abstract- The present study aimed to assess the effect of water pollution on physiological and histological alterations of African catfish, Clarias gariepinus collected from spring 2015 to winter 2016, in two differing-quality aquatic ecosystems in Nile Delta, Egypt, namely Damietta Branch of River Nile and Ammar Drain. Results showed significant differences ($p \leq 0.001$) in all estimated physicochemical environmental factors in study areas. In addition, the results showed that the bad water quality in Ammar Drain due to pollution, the vast majority of the hematological parameters recorded lower levels in Ammar Drain than in River Nile. Because Ammar Drain receives greater agricultural, industrial and domestic wastes than the second one. Antioxidant enzyme activities were lower in fish from the contaminated site compared with fish from the reference site, suggesting a deficiency of the antioxidant system to overcome the oxidative stress. Lesions of histological deformations (skin, muscles, and gonads) were detected and analyzed to clarify the effect of water pollution on fish organs. The present study recommended treatment of the waste before being discharged into the waterways.

Keywords: *african catfish, pollution, nile delta, biomarkers, histopathology.*

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Effect of Water Pollution on Physiological and Histological Alterations of African Catfish, *Clarias Gariepinus* from Nile Delta

Ali A. Al-Halani[α], Ahmed E. Hagras[σ], Sherif H. Abdeen[ρ], Abeer E. Abdrabbuh[ω] & Mohamed I. Mashaly[¥]

Abstract- The present study aimed to assess the effect of water pollution on physiological and histological alterations of African catfish, Clarias gariepinus collected from spring 2015 to winter 2016, in two differing-quality aquatic ecosystems in Nile Delta, Egypt, namely Damietta Branch of River Nile and Ammar Drain. Results showed significant differences ($p \leq 0.001$) in all estimated physicochemical environmental factors in study areas. In addition, the results showed that the bad water quality in Ammar Drain due to pollution, the vast majority of the hematological parameters recorded lower levels in Ammar Drain than in River Nile. Because Ammar Drain receives greater agricultural, industrial and domestic wastes than the second one. Antioxidant enzyme activities were lower in fish from the contaminated site compared with fish from the reference site, suggesting a deficiency of the antioxidant system to overcome the oxidative stress. Lesions of histological deformations (skin, muscles, and gonads) were detected and analyzed to clarify the effect of water pollution on fish organs. The present study recommended treatment of the waste before being discharged into the waterways.

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I. Introduction

Fish spend their lifespan in water (from egg to adult), so, they are subjected to the full force of the aquatic environment, regarding physical, chemical and biological parameters. Successful survival of fish in fluctuating conditions of the aquatic ecosystem necessitates the possession of efficient hematological, physiological and immunological mechanisms to cope with the dramatic fluctuations of constituent elements of the ecosystem (Osman, 2010 & Ben Ameur et al., 2012). Point and non-point contamination sources affect water physicochemical features, natural ingredients of the sediment and biological components that in turn alter the quality and quantity of fish stocks (Mantovi et al., 2005 & Singh et al., 2006).

Field and experimental studies revealed that the buildup of pollutants in tissue is chiefly dependent on the amount of pollutant and duration of the exposure time. However, other physicochemical parameters such as temperature, hardness, pH and salinity can play an important role in the accumulation of pollutants in fish (Jeffree et al., 2006 & Has-Schon et al., 2007). Demonstration of the histopathology of the fish has been found to be a consistent bioindicator of the environmental stress (Elahee and Bhagwant, 2007), and a sensitive tool in demonstrating the interplay between the performance of fish and contamination of their natural habitats (Costa et al., 2009 (Evaluation of the biochemical and hematological profiles of fish has become a key indicator of the health and means of comprehending normal and pathological progressions, and toxicological influences (Saravanan et al., 2011). Fish represent one of the most nutritive and cheap sources of the animal protein. Fish contribute to about 6% of the world supply of protein and about 24% of the animal protein (El-Badry, 2010). African catfish, Clarias gariepinus (Burchell, 1822) are highly consumed by a large sector of Egyptians. These fish are more abundant throughout the year than much other Egyptian fish. They are important and cheap sources of the animal protein (Kime et al.,1996 & El-Badry, 2010). A promising development program of fish resources could solve the problem of animal protein deficiency at qualitative and quantitative levels (Nguyen, 2009). In this respect, the proper investigation of different aspects of the fish biology and ecology are strongly recommended (El-Etreby et al., 1993). The present study aimed at evaluating the effect of water pollution in Nile Delta on physiological and histological alterations of African catfish, Clarias gariepinus.

II. Materials and Methods

a) Study Area

Two different aquatic ecosystems were selected. Ammar Drain at Belqas city as a polluted environment and Damietta Branch of River Nile at Al-Tawailah village as a reference site50 km north Mansoura City and has the following coordinates: 31°22'46.4556" N 31°29'13.2432" E (Figure 1). The present study was conducted during the period spring March 2015 to winter 2016.

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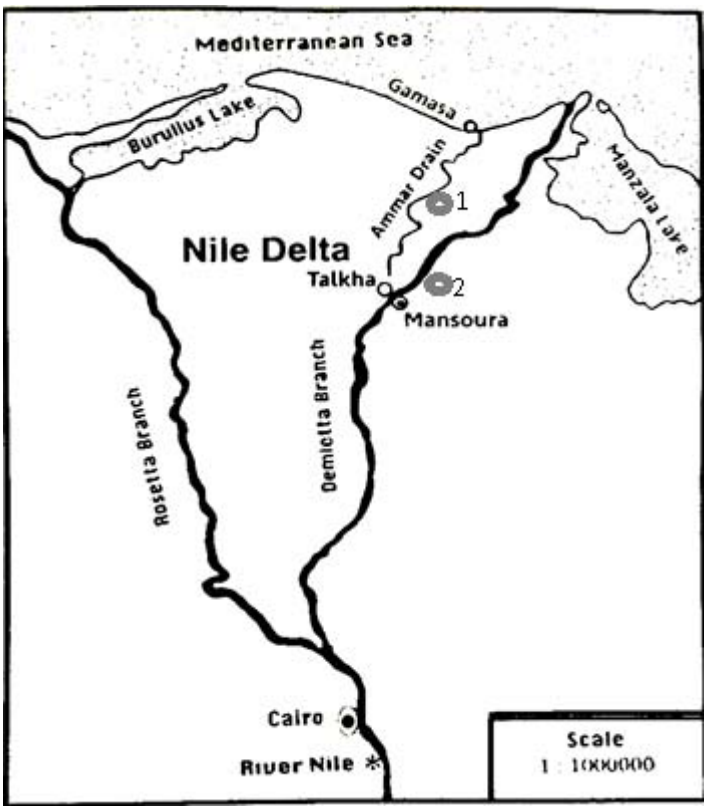

Fig 1: Map showing the study areas: Ammar Drain (1) and the River Nile (2)

b) Water and Fish Samples

For studying the physicochemical parameters in Damietta Branch of River Nile and Ammar drain, three sites were selected for each ecosystem with appropriate distances. However, ten water samples were collected monthly at each sampling site at 50-cm depth (from March 2015 to February 2016). In a one-liter plastic container, primary treatment of the samples was carried out in the field at the time of sampling. Concurrently, water samples were kept according to the protocol designed by El-Naggar et al. (2016)& Al-Halani et al. (2018) The procedures were implemented according to the standard methods (APHA, 1998).

About 20-30 samples of C. gariepinus were collected seasonally from each sampling site from River Nile and Ammar Drain. Fish samples were transported alive in aerated tanks with a plentiful amount of water to the laboratory for different investigations. Fish were placed in large plastic containers accommodating natural water to minimize stresses and injuries. Records were kept of the total body length, weight, and sex. Moreover, the gonads were weighed.

c) Fish Measurements

i. *Hematological and Biochemical Analysis*

Before fish dissection, blood samples were obtained from the caudal vein by a hypodermic syringe. Then, each sample was immediately divided into two portions; the first one used EDTA as an anticoagulant for measuring complete blood counts, while the second one was centrifugedat 3000 rpm for 10 minutes without anticoagulant. The collected sera were kept at -20 °C till analysis.

The whole blood was immediately used for the estimation of RBCs, and total WBCs counts under the light microscope using Brand count chamber (hemocytometer) following dilution of the blood in phosphate buffer at pH of 7.2 (Dacie and Lewis, 1984). Hemoglobin (Hb) content was determined colorimetrically by measuring the forming of cyanomethaemoglobin according to Van Kampen and Zijlstra (1961). Haematocrit (Ht) ratio was directly estimated after blood collection, by transferring a small amount of blood into a capillary tube and centrifuging them for 5 min in an ABX Micros 60 device, manufactured by HORIBA ABX SAS.

Levels of superoxide dismutase (SOD) enzyme were estimated with the aid of Cayman Kit (Biodiagnostic Company, Mansoura, Egypt), according to the method described by Nishikimi et al. (1972).Serum levels of catalase (CAT) activity were determined using Cayman Kit (Biodiagnostic Company, Mansoura, Egypt), according to the procedure estimated by Aebi (1984).

ii. *Histopathological Manifestations*

Following dissection, appropriate segments of fish muscles, gonads (testes and ovaries), and skin were preserved in 10% formaldehyde and processed for embedding paraffin, then sectioned at five µm thickness

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and stained in hematoxyl in and eosin according to Roberts (2012). Histological investigations were studied with the high aid power Leitz Labor Lux light microscope, and the imperative histological features were captured by a digital camera connected to the microscope.

d) Statistical Analysis

All values are given as (Mean ± SD). Data presenting monthly levels of the physicochemical parameters were analyzed using the Student's t-test to demonstrate whether the elements of the water quality are variant between the two investigated localities. On the other hand, the seasonal differences of the physicochemical parameters, blood parameters and water quality indices in each locality were tested using One-way ANOVA test. Furthermore, Tukey HSD was used as a post hoc test to detect significant differences between seasons at $P < 0.05$.

III. Results

a) Water Factors

Tables 1 and 2 show the seasonal fluctuations of water physicochemical parameters from River Nile and Ammar Drain, respectively. The results obtained from the analysis of water sampled from the two aquatic environments indicate that the quality of water varies greatly between the two study areas. From tables 1 and 2, it is clear that the pH of the River Nile and Ammar Drain was slightly alkaline. It ranged from 7.447 to 7.970 in the River Nile (Table 1) and from 7.093 to 7.557 in Ammar Drain (Table 2).

Tables 1 and 2 show seasonal variations of water temperature in the two investigated areas. The values of water temperature ranged between 17.70 °C in Ammar Drain during winter and 32.06 °C in River Nile during summer. From Figure 6, it, and is obvious that water temperature gradually increases in spring, reaching its maximum levels in summer.

Tables 1 and 2 show a very wide range of variation in water EC between River Nile and Ammar Drain. The EC values varied from 0.40 µs/cm in River Nile during winter to 2.49 µs/cm in Ammar Drain during spring. The highest EC values were estimated during spring in Ammar Drain, while the lowest value was recorded during winter in River Nile.

Seasonal fluctuations of TDS of water in the two study sites are recorded in Tables 1 and 2. The TDS values ranged between 246.720 mg/l in River Nile during spring and 1590.400 mg/l in Ammar Drain during the same season. From Figure 10, it is obvious that TDS reached its maximum value during spring in Ammar Drain; however, the minimum value was recorded during the same season in the River Nile.

Tables 1 and two show marked seasonal variation of bicarbonates values between River Nile and Ammar Drain. It varied from 90.28 mg/l in River Nile during summer to 356.607 mg/l in Ammar Drain during winter.

Seasonal changes of Cl contents of water are documented in Tables 1 and 2. The chloride content of water in Ammar Drain is higher than that in River Nile. The maximum value of the chloride content of water (578.413 mg/l) was recorded in Ammar Drain during winter; however, the minimum value was 32.260 mg/l and obtained in River Nile during the same season.

Seasonal differences of the sulfate content of water are shown in Tables 1 and 2 . The recorded values of sulphate varied from 9.28 mg/l at River Nile during autumn to 910.85 mg/l at Ammar Drain during spring.

Tables 1 and 2 document the seasonal changes of calcium, magnesium, sodium and potassium at River Nile and Ammar Drain. The concentrations of these minerals are generally lower in River Nile than Ammar Drain. The mineral calcium varied from 38.133 mg/l at River Nile during summer to 112.933 mg/l at Ammar Drain during winter. The concentration of magnesium varied from 6.257 mg/l in River Nile during autumn to 68.607 mg/l at Ammar Drain during winter. The concentration of sodium ranged between 1.820 mg/l at River Nile during winter and 442.165 mg/l at Ammar Drain during spring. The concentration of potassium ranged between 5.5 mg/l at River Nile during spring and 21.833 mg/l at Ammar Drain during autumn. From Tables 1 and 2, it can be seen that the concentrations of minerals have higher values in Ammar Drain during the study period.

Table 1 and 2 show the seasonal differences in nitrogen and phosphorous concentrations between River Nile and Ammar Drain. It is noticed that the concentration of these elements are generally lower in River Nile than Ammar Drain. Regarding the concentration of nitrogen, it varied from 3.15 mg/l at River Nile during spring to 10.5 mg/l at Ammar Drain during winter. On the other hand, the concentration of phosphorous varied from 0.107 mg/l at River Nile during summer to 0.16 mg/l at Ammar Drain during spring.

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Table 1: Seasonal changes of physicochemical parameters (Mean ± SD) of water sampled from River Nile.

Parameters	pH	Temp.°C	EC(µs/cm)	TDS	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	N	P
Season				(mg/l)									
Spring	7.447 ± 0.349	27.33 ±1.53	0.413 ±0.006	246.720 ±2.240	94.795 ±13.545	58.400 ±8.340	31.485 ±2.305	41.800 ±6.600	13.320 ±0.120	11.830 ±8.460	5.500 ±0.500	3.150 ±0.630	0.130 ±0.000
Summer	7.970 ±0.416	32.067 ±0.416	0.447 ±0.006	274.560 ±10.652	90.280 ±20.687	42.270 ±5.096	77.727 ±15.385	38.133 ±2.540	15.393 ±2.665	21.393 ±1.529	6.667 ±1.607	3.780 ±0.630	0.107 ±0.032
Autumn	7.800 ±0.191	22.133 ±3.544	0.463 ±0.006	282.027 ±29.254	180.560 ±20.687	44.493 ±5.102	9.277 ±8.758	68.933 ±14.144	6.257 ±4.098	4.990 ±1.866	8.667 ±0.577	7.560 ±1.890	0.127 ±0.018
Winter	7.500 ±0.027	22.033 ±1.779	0.403 ±0.023	257.920 ±17.209	176.047 ±13.545	32.260 ±0.096	11.297 ±12.002	48.400 ±11.641	16.273 ±4.671	1.820 ±1.210	6.833 ±1.258	9.450 ±1.890	0.127 ±0.015

pH = Hydrogen ion conc. TDS= Total dissolved solids
SO_4^{2-} = Sulphates Na^+ = Sodium P= Phosphorous
HCO_3^- = Bicarbonates Ca^{2+} = Calcium K^+
N = Nitrogen EC = Electric conductivity Cl^-= Chlorides = Potassium
Mg^{2+} = Magnesium

Table 2: Seasonal changes of physicochemical parameters (Mean ± SD) of water sampled from Ammar Drain.

Parameters / Season	pH	Temp.°C	EC(µs/cm)	TDS	HCO_3^-	Cl−	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	N	P
				(mg/l)									
Spring	7.093	25.750	2.490	1590.400	162.503	91.765	910.845	83.600	15.120	442.165	7.250	4.290	0.160
	±0.340	±1.750	±0.300	±277.200	±13.545	±5.005	±194.880	±22.00	±3.600	±63.105	±0.250	±0.750	±0.02
Summer	7.557	31.933	2.313	1420.803	162.503	78.977	830.943	60.427	27.617	384.260	6.667	6.090	0.127
	±0.197	±0.757	±0.335	±214.091	±13.545	±13.489	±184.876	±7.113	±7.743	±62.880	±1.041	±0.962	±0.015
Autumn	7.410	22.533	2.333	1339.400	334.037	493.873	66.177	85.067	35.743	289.453	21.833	8.820	0.156
	±0.062	±2.363	±0.199	±174.274	±61.065	±105.947	±69.838	±17.782	±16.954	±71.764	±3.055	±1.667	±0.038
Winter	7.300	17.700	2.377	1521.067	356.607	578.413	78.110	112.933	68.607	355.967	8.833	10.500	0.140
	±0.121	±1.652	±0.618	±395.577	±47.556	±222.188	±24.335	±26.522	±17.264	±169.951	±2.255	±0.962	±0.01

pH = Hydrogen ion conc. TDS= Total dissolved solids
SO_4^{2-} = Sulphates Na^+ = Sodium P= Phosphorous
HCO_3^- = Bicarbonates Ca^{2+} = Calcium K^+ = Potassium
N = Nitrogen EC = Electric conductivity Cl^-= Chlorides
Mg^{2+} = Magnesium

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Statistical analysis (Independent samples t-Test on SPSS package version 20) indicated a very highly significant difference of the electrical conductivity, total dissolved solids, bicarbonate content, calcium content and sodium between the two investigated areas ($p \leq 0.001$). Independent samples t-There was a high significant difference in the hydrogen ion concentration, chloride content, sulfates content, magnesium content and dissolved oxygen between the River Nile and Ammar Drain ($p \leq 0.01$). The minerals potassium and phosphorous showed significant differences between the two investigated areas ($p \leq 0.05$). Other physicochemical environmental parameters showed non-significant differences between the Nile River and Ammar Drain ($p > 0.05$).

b) Hematological Parameters

Table 3 represents seasonal values of Hb content in fish inhabiting the two study areas. Significant variability in Hb content was observed between the two investigated areas, especially in winter. From Table 3, it is clear that the highest Hb level (17.33 g/dl) was detected during winter in fish sampled from River Nile, while the lowest value (7.13 g/dl) was recorded during summer in those sampled from Ammar Drain.

The seasonal changes of RBCs collected from C. gariepinus inhabiting River Nile and Ammar Drain. This blood parameter attained higher levels in River Nile than Ammar drain (Table 3). From Table 3, it is obvious that the highest RBCs count (2.87 106/µL) was recorded during winter in River Nile, while the lowest level (1.73 106/µL) was counted summer in, Ammar Drain.

Table 3 represents the seasonal values of Hct collected from C. gariepinus inhabiting River Nile and Ammar Drain. This blood parameter showed marked variations between the two study sites. From Table 3, it can be noticed that the highest Hct level (38.33 %) was measured during autumn in River Nile, whereas the lowest value (24.03 %) was recorded in summer during Ammar Drain.

Table 3 represents the seasonal variations of WBCs count of C. gariepinus sampled from the two investigated areas. Marked variability in WBCs was detected between River Nile and Ammar drain. From Table 3, it is clear that the highest WBCs value (214.13 103/µL) was recorded during autumn in Ammar drain, while the lowest value (161.23 103/µL) was counted in winter in River Nile.

Statistical analysis (Independent samples t-Test on SPSS package version 20) indicated the hemoglobin and RBCs content of the blood of catfish varied significantly between both sites ($p \leq 0.05$). A high significant difference in Hct values was observed in catfish between River Nile and Ammar Drain ($p \leq 0.01$). Marked variability in WBCs was detected between the two investigated areas. The WBCs count of C. gariepinus varied significantly between River Nile and Ammar Drain ($p \leq 0.05$).

Table 3: Seasonal changes in the blood parameters (Mean ± SD) of C. gariepinus sampled from River Nile and Ammar Drain.

StudyAreas	River Nile				Ammar Drain			
Parameters	Hb (g/dl)	RBCs ($\times 10^6$/µL)	Hct (%)	WBCs ($\times 10^3$/µL)	Hb (g/dl)	RBCs ($\times 10^6$/µL)	Hct (%)	WBCs ($\times 10^3$/µL)
Season								
Spring	9.93±3.42	2.21±0.74	34.37±8.87	207.13±27.39	9.73±0.40	2.06±0.02	28.47±2.25	209.43±20.59
Summer	9.83±1.79	2.34±0.28	30.33±5.15	179.77±16.54	7.13±2.14	1.73±0.48	24.03±6.38	201.63±13.68
Autumn	11.43±0.46	2.63±0.14	38.33±4.47	187.23±25.99	9.40±1.75	1.91±0.82	26.13±7.52	214.13±2.30
Winter	17.33±3.26	2.87±0.61	35.28±7.38	161.23±32.35	9.50±1.56	2.16±0.40	26.93±3.54	204.00±11.53

Hb = Hemoglobin
RBCs = Red blood cells
Hct = Hematocrit
WBCs = white blood cells

Table 4 shows the seasonal levels of SOD enzyme in blood samples of fish inhabiting River Nile and Ammar Drain. This parameter varied obviously between the two water environments. From Table 4, it can be seen that the highest SOD value (341.50 u/ml) was recorded during winter in River Nile, while the lowest level (137.50 u/ml) was detected in spring in the same environment.

Table 4 shows the seasonal variations of CAT enzyme in the blood collected from fish inhabiting River

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Nile and Ammar Drain. This parameter showed marked variations in CAT activity between the two study areas. From Table 4, the highest CAT value (869.10 u/l) was recorded during spring in Ammar Drain, while the lowest value (109.10 u/l) was recorded during winter in the same locality.

Statistical analysis revealed the significant variation of SOD value of catfish between River Nile and Ammar Drain ($p \leq 0.05$). There was no significant variation in the CAT levels of catfish between River Nile and Ammar Drain ($p > 0.05$). Seasonally, differences in CAT activity of catfish were very highly significant either in River Nile or Ammar Drain ($p \leq 0.001$ respectively).

Table 4: Seasonal changes in the serum parameters (Mean ± SD) of C. gariepinus at River Nile and Ammar Drain.

Study Areas	River Nile		Ammar Drain	
Parameters	SOD (u/ml)	CAT (u/l)	SOD(u/ml)	CAT (u/l)
Season				
Spring	137.50±57.28	422.67±32.13	175.00±78.06	869.10±137.04
Summer	270.73±36.08	150.60±33.90	145.76±95.43	115.27±55.33
Autumn	267.04±20.61	610.31±77.56	144.14±52.03	363.81±13.92
Winter	341.50±14.50	148.80±15.21	245.72±25.93	109.10±82.75

SOD = Superoxide dismutase enzyme
CAT = Catalase enzyme

c) Histopathological Investigations

i. *Sections of skin*

The normal architecture of the fish skin is illustrated in Figure 2 (A, B, and C). The skin comprises three main layers, namely the epidermis, dermis, and hypodermis (Figure 2 A, B and C). The epidermis is formed of the superficial, middle and inner layers. The superficial layer includes the stratified squamous epithelium that is arranged in some rows of polygonal cells (Figure 2 A, B, and C) and unicellular, oval to circular goblet (mucus-producing) cells (Figure 2 A, B, and C). As shown in Figure 2 (A, B, and C), each goblet cell possesses a storing vacuole and a small, flattened basal nucleus. The goblet cell evacuates on the outer surface through a terminal opening. The middle layer of the epidermis comprises the club cells (Leydig or alarm cells) (Figure 2 A, B, and C). This cell type is large in size, irregular in shape and is supported by epidermal cells. There is a pale pink cytoplasm in the club cells. The inner epidermal layer is formed of a single layer of cuboidal or columnar cells held on a thin basement membrane (Figure 2 A, B and C).

The corresponding histopathological changes of the skin of fish caught from Ammar Drain are shown in Figure 2 (D). It can be noticed that there is a reduction in the number of mucus-producing cells and Leydig cells. The basement membrane is two or three times thicker than normal. Moreover, the number of pigment cells is reduced. Regarding the inner epidermal histological features, there is a marked proliferation of the cuboidal cells. Furthermore, no lymphocytic cells were recognized among the constituent elements of the skin.

ii. *Sections of fish muscles*

Figure 3 (A and B) shows the normal histology of muscles fibers of C. gariepinus dwelling River Nile. It can be observed that the muscle bundles are polygonal, well–organized and formed of closely–packed units (Figure 3 A and B), during winter and summer, respectively. In contrast, the muscles bundles of C. gariepinus from Ammar drain (the polluted site) showed marked deformation; the muscles bundles are loosened and widely–spaced (Figure 3 C and D). A typical inflammatory response could be recognized around a likely parasitic form in Figure (3 C and D). Clumps of inflammatory cells (granulomas) and marked degeneration of the muscular tissue bordering the pathogen and encapsulating granuloma are evident (Figure 3 C and D).

iii. *Sections of the fish ovary*

The normal histology of the ovary of fish inhabiting River Nile is illustrated in Figure 4 (A and B). The oocytes are full– formed and the stages of gonadal development were completed (previtellogenic, postvitellogenic, and vitellogenic stages). The oocytes are loaded with vitellogenic cells and surrounded by stroma (Figure 4 A and B). As shown in Figure 4 (B), there is a greater number of follicles compared to the winter harvest, however, they are smaller in size and relatively irregular in shape. At Ammar Drain, there is a marked alteration of the gonadal development is recognized (Figure 4 C and D). There are a marked

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degeneration and resorption of oocytes at any point in development (Figure 4 C and D). The vitellogenin mass inside the mature oocytes and obvious patchiness dominates the ovarian tissues (Figure 4 D). From Figure 4 (C and D), it is clear that the summer preparations of the ovarian tissues are more adversely influenced than winter samples.

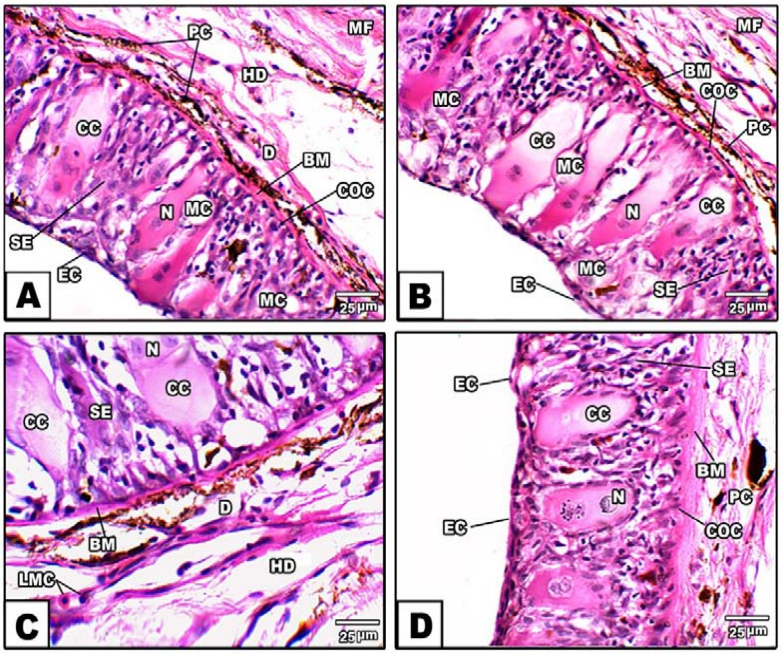

Fig. 2: Photomicrograph showing the normal histological features of the skin of *C. gariepinus* (A, B and C) inhabiting River Nile in comparison with the corresponding histopathological changes of the skin of catfish, (D) inhabiting Ammar Drain. Scale bar = 25 µm. BM, basement membrane; CC, club cell; COC, columnar cell; D, dermis; EC, epithelial cell; HD, hypodermis; LMC, lymphocytic cell; MC, mucus cell; MF, muscle fiber; N, nucleus; PC, pigment cell; SE, stratified squamous epithelium. (H & E X 400)

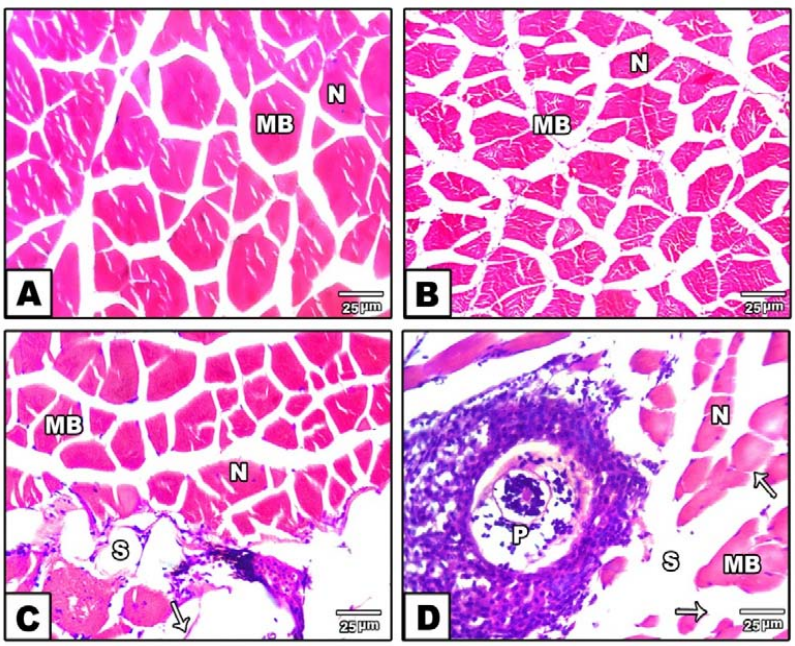

Fig. 3: Photomicrograph showing the histological features of muscles fibers of *C. gariepinus* inhabiting River Nile (A and B) and Ammar Drain (C and D), during winter and summer, respectively. Scale bar = 25 µm. MB, muscles bundles; S, spaces between muscle bundles; N, the nucleus of muscle bundle; P, parasitic cyst; arrow, degenerated fibers. (H & E x 400)

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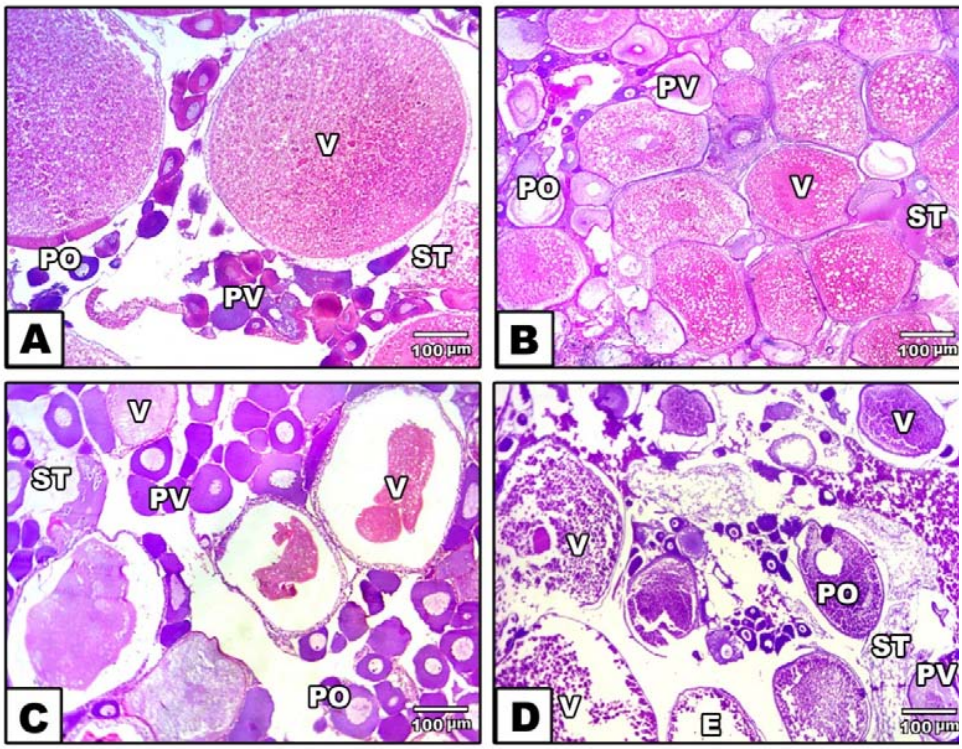

Fig. 4: Photomicrograph showing the histological features of the ovary of *C. gariepinus* dwelling River Nile during winter (A) and summer (B), and the histopathological features of some fish from Ammar Drain during winter (C) and summer (D). Scale bar = 100 µm. E, empty follicle; PO, postvitellogenic stages; PV, previtellogenic stages; ST, stroma; V, vitellogenic stages. (H & E X 100).

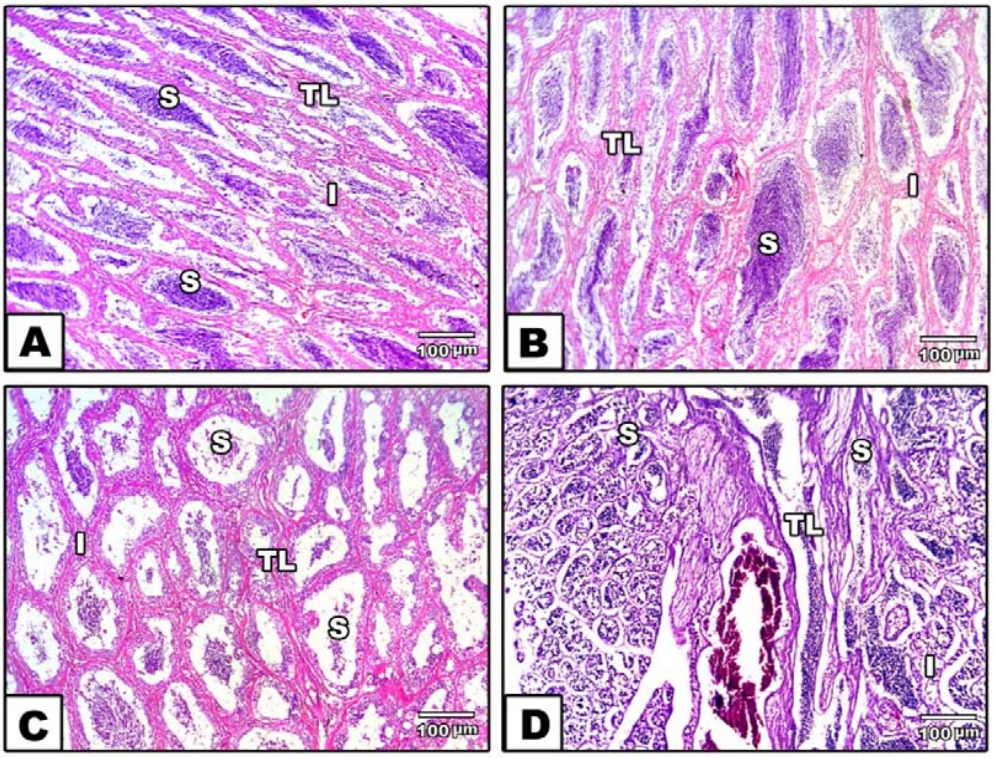

Fig. 5: Photomicrograph showing the histological features of the testis of *C. gariepinus* dwelling River Nile during winter (A) and summer (B), and the histopathological features of some fish from Ammar Drain during winter (C) and summer (D). Scale bar = 100 µm. TL, testicular lobule; S, spermatozoa; I, interstitium. (H & E X 100)

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iv. *Sections of the testis*

Regarding the normal testis (Figure 5 A, and B) of C. gariepinus inhabiting River Nile, the distended testicular lobules showed high variation in their shapes and sizes. They are surrounded by interstitium (Figure 5 A, and B). Spermatozoa are centrally located and tubules are surrounded by blood vessels. In affected areas during winter (Figure 5 C), the testicular lobules showed different activity where most of lobules were distended with spermatozoa and some the lobules appeared empty as they discharged their spermatozoa. Spermatozoa were scattered in the testes in an eccentric location. During the summer season, effects were less evident (Figure 5 D), where other lobules appeared partially empty or empty from spermatozoa.

IV. Discussion

The Damietta Branch of the River Nile is regarded as a control or lightly polluted ecosystem. However, Ammar Drain is considered as a stressed ecosystem as it accommodates huge amounts of agricultural and domestic discharges. The water body of Ammar Drain is rich in its chemical nature, where it incorporated higher levels of total dissolved solids, electrical conductivity, bicarbonates, chlorides, sulfates, calcium, magnesium, and sodium.

The acceptable pH for fish culture ranges between 6.5 and 8.0 (Meade, 1998). The study found that the pH values of all sampling sites were within the standard limit, indicating that the two aquatic ecosystems are valid for aquatic life. The pH limit of protection between 6 and ten was adopted for fisheries and aquatic life by the European Community (Chapman, 1993). Elevation of the water temperature affects the amounts of dissolved oxygen in the water column where DO is inversely proportional to the thermal regime (Adeogun, 2012). Evans et al. (1965) found that fish can produce an immune response at temperatures from 5 to 8oC.The relative increase in the water temperature of Ammar Drain in some seasonals had potential implications on the oxygen retention capacity of water (UNEP, 2006). The electrical conductivity (EC) reflects the number of dissolved salts in water samples(Moore et al.,2008). EC in the present investigation showed a very wide range of variation between the River Nile and Ammar Drain. The electrical conductivity lied within the non-desirable scale at Ammar Drain. The high conductivity values recorded in Ammar Drain suggested possible sources of run-off from adjacent landscapes and strongly implicates agricultural and sewage sources.

The levels of the total dissolved solids showed significant variation between the two investigated areas. The water of the River Nile showed lower levels of TDS than Ammar Drain. This might be due to variations in agricultural activities or drainage water. TDS comprise primarily chlorides, bicarbonates, phosphates, sulfates and conceivably nitrates of magnesium, potassium, sodium, calcium, in addition to hints of manganese, iron and further ingredients (Akan et al.,2012). The total dissolved solids recorded in Ammar Drain were above the WHO guideline of 1000 mg/l for the protection of fisheries and aquatic life, and for domestic water supply (WHO, 2004).

Water pollution is one of the most crucial environmental problems and public health concerns in the River Nile (Mohamed et al.,2013; El-Amier et al.,2015). The highest mean value of total dissolved solids, bicarbonates, chlorides and sulfates was recorded in Ammar Drain. This could be attributed to drainage water in this area, and the decomposition of the organic matter or may be due to the effect of the interconnecting drains which increase sulfates in this area. Chloride concentrations higher than 200 mg/l are considered to be a risk for human health (Versari et al.,2002). However, sulfates in high levels cause water hardening. The present data indicated that sulfates in Ammar Drain exceeded the WHO permissible limit which is 200 mg/l (WHO, 1993).

The concentration of the monovalent cations (sodium and potassium) and the divalent cations (calcium and magnesium) were evaluated. The results showed that the levels of these minerals were generally higher in Ammar Drain than the River Nile. El-Amier et al., (2015) found that the cations of water take the following sequence; Na+> Ca+2> Mg+2> K+.Sodium is the most abundant among other cations and this could be attributed to the drainage water from different agricultural and cultivated lands (Arain et al.,2008).

Exposure to interactive effects of the multisource pollutants leads to negative impacts on the hematological indices (Vutukuru, 2005).The present study showed that all hematological parameters of African catfish sampled from Ammar Drain were lower than those sampled from River Nile. This could be a reflection of fish response to environmental pollution (El-Naggaret al.,2016 and Tayel et al.,2007). The decreases of these parameters go in line with elevation in the levels of chemical parameters studied such as nitrogen and phosphorous, DO depletion and the increase in TOC as a result of pollution stress in that area (Al-Halani et al., 2018)

There was a positive correlation between DO and RBCs, Hb, Hct values in African catfish. Under oxygen depletion condition, the liver probably revives erythropoiesis to recompense the desire by elevated oxygen transportation to marginal tissues (Rifkind et al.,1980). Singh (2008) suggested that different water pollutants are the possible chief source of the

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physiological disorders of fish. The decrease in RBCs, Hb and Hct values in fish dwelling Ammar drain may be related to water pollution.

The WBCs are the regulator of the immune system; its count was elevated in the blood of African catfish sampled from Ammar drain. This could be attributed to the exposure to chronic sewage and domestic discharges, and agricultural wastes. This is in agreement with the results of Gaber et al. (2013) who suggested that the increase of WBCs in the blood of fish caught from El-Rahawy Drain could be a result of exposure to chronic sewage. In the present study, the increase of WBCs count may be attributed to a general immune response to pollution (Nussey et al., 2002). According toEl-Sayed et al.(2007), increased WBCs count in fish subjected to pollutants indicates leukocytosis or an increase in the total WBCs value over the normal range. Fish sampled from River Nile was found to be healthier than those from Ammar Drain. Fish sampled from Ammar drain seemed darker and unhealthy in appearance. This might be due to the high pollution level in Ammar Drain compared to River Nile.

Oxidative stress biomarkers such as SOD and CAT enzymes are commonly employed for environmental hazard impacts assessment (Livingstone, 2001& Tsangaris et al.,2011). The present work revealed lower SOD and CAT activities in the blood of African catfish sampled from Ammar Drain compared to those from River Nile. The changes of Oxidative stress biomarkers in Ammar drain can be interpreted due to water pollution. Different water pollutants are the possible main source of the physiological disorders in fish (Adams et al.,2001& Viarengo et al.,2007). In the present investigation, decreased oxidative stress enzyme activity in fish sampled from Ammar Drain can be correlated to the deficiency to recompense for imbalance of the release of free radicals and oxidative defense mechanisms, probably a consequence of intense pollutant gradient. Owing to the present findings, the levels of SOD and CAT activities were lower in fish sampled from Ammar Drain than those of River Nile. The drop in those enzyme activities may be correlated to long-term exposure of fish to environmental contaminants. Similar response patterns were documented in previous studies (Lenartova et al.,1997). Previous studies in sea bass, Dicentrarchus labrax and grey mullet, M. cephalus revealed low SOD and CAT actions in fish dwelling polluted water (Ben Ameur at el., 2012).

The histopathological changes of the skin of African catfish caught from Ammar Drain included a reduction in the number of mucus-producing cells, Leydig (alarm) cells and the pigment cells. The basement membrane appeared thicker than that illustrated in the normal skin of the catfish inhabiting River Nile. The skin is an outer wrapper of fish; hence, it is in-full-force of environmental fluctuations. As a consequence, the skin plays a key role as the first line of defense in physical and chemical means (Vernerey and Barthelat, 2014). Concerning the inner epidermis, there was a marked proliferation of the cuboidal cells. Moreover, no lymphocytic cells were observed in the histological preparations of the skin of African catfish inhabiting Ammar Drain. The epidermis is a fragile layer, which is regularly sloughed off and regenerated. The scales covering the skin of African catfish act as an additional, physical barrier separating the skin and underlying tissues from the flowing water currents (Helfman et al.,2009). The dermis lies beneath the epidermis. This layer contains blood vessels, nerves, connective tissues and sense organs. The dermis is well supplied by blood vessels; hence, it also provides nourishment to the epidermis.

The present study revealed that fish inhabiting Ammar Drain exhibited some histopathological signs where their muscles bundles were obviously loosened and showed marked spacing. The tissues changes in fish sampled from Ammar Drain can be contributed to water pollution. The current study illustrated that histopathological changes of fish muscles may be due to uptake of pollutants coming from sediment and its surrounding environment (Jeffree et al., 2006). Thophon et al. (2003) and Kaoud and El-Dahshan (2010) found that fish exposed to pollutants may undergo histological alterations in the form of degeneration of muscles bundles with certain focal areas of necrosis. Similar results were described by Kaoud and El-Dahshan (2010) who observed that fish exposed to pollutants show degeneration of muscles bundles with atrophy and splitting of muscles fibers.

In the present study, histological preparations indicated alterations in the oogenesis or spermatogenesis of fish exposed to pollutants where the development cycles of gametes were incomplete and some stages were malformed. Histopathological changes in testis and ovary of African catfish collected from Ammar Drain may be due to their exposure to sewage, domestic, and agricultural wastes as recorded by Tayel et al. (2007). Similar histopathological changes (lesions) have been reported in fish exposed to pollutants (Gaber et al., 2013).

In female fish, the mean oocytes number is considered as an important criterion for assessment of the reproductive performance in fish (Gaber, 2000& Gaber et al., 2013). In the present study, the mean oocytes number of fish was affected by the polluted environment. Mohamed (2001&2003) recognized histopathological alterations in fish testis and ovary suggesting that this may reduce the ability of fish to reproduce. It is well known that water pollution has a serious inhibitory effect on fish reproduction (Mohamed, 2001&2003) resulting in a decrease in their abundance and, consequently, a decline in fish species diversity. In the present study, pollution effects appeared as

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disruption in gonadal development. It comes in agreement with other studies for fish inhabiting polluted water (Balch et al., 2000). Also, oogenesis and spermatogenesis were influenced by exposure to sewage effluents (Kiparissis et al., 2003).

V. Conclusion

The bad water quality of Ammar Drain has induced changes or modification in the blood profile and alterations in the muscles, gonads and skin histological features of African catfish, C. gariepinus. The present findings indicate also that Ammar Drain represents a potential environmental disaster threatening the human health, deteriorating aquatic life and degrading the ecosystem as a whole. The bad water quality of Ammar Drain may cause massive fish kills and induce chronic health problems such as renal failure and hepatic dysfunction, in addition to its deleterious impacts on the soil.

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Keywords: anaerobic digestion, bio-energy, codigestion, sludge, sewage sludge digestion, sludge treatment, and reuse.

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Shaikh Mahfuzur Rahman [α], Fatema Sultana[σ] & Tushar Chowhan[ρ]

Abstract- A large amount of sewage sludge is produced through the sewerage system in Bangladesh. A laboratory scale research work was carried out to find the potential of sewage sludge as a source of renewable Bio-Energy. This paper presents the output results of the research work which was carried out to find out the appropriate technology for biogas generation from co-digestion of sewage sludge & cow dung. The study deals with usage of different proportion of sewage sludge, cow dung and domestic sewage for four trials carrying 6% total solid concentration. For all the experiments, sewage and domestic sludge were mixed in 1:1 ratio. Anaerobic digestion was performed for 60 days at room temperature 30±4 ºC. The pH of the slurry was maintained by the system itself. The inoculum was familiarized with cow dung in the same atmosphere taken for the study and sufficient active biomass was present. It was observed in the research that, when sewage sludge mixed with other co-substrate, the significant increase in gas yield was remarkable. The performances of the reactors were analyzed on the basis of gas yield and methane yield. On the basis of the analysis of the performance of the reactors, it was found that; Trial-2 reactor containing 25% cow dung and 75% municipal sewage sludge and domestic sewage, on total solid (6% TS) of slurry gives optimum result in terms of total gas yield and methane yield (72%). Standards of Trial-2 might choose as an optimum condition for gas generation from municipal sewage sludge.

Keywords: anaerobic digestion, bio-energy, co-digestion, sludge, sewage sludge digestion, sludge treatment, and reuse.

I. Introduction

Sewage sludge contains considerable amounts of various contaminants. If it is not properly handled and disposed of, it may produce large-scale hazards to health and the environment. Anaerobic digestion is a biochemical technology for the treatment of organic residues and wastes. In this treatment process, it is used for the production of biogas, which can be used as a fuel or co-generation of electricity. The main purpose of this research work is to find out the appropriate technology for biogas generation from municipal sewage sludge through a laboratory scale experiment. Experimental result indicates that municipal sewage sludge contains a significant amount of volatile solid responsive for biodegradation. Because of low C\N ratio; municipal sewage sludge alone is not suitable as a substrate for anaerobic digestion. Therefore, different proportion of cow dung and domestic sewage were put to use as co-substrate to achieve an optimum result. The study was carried out using a different proportion of sewage sludge, cow dung and domestic sewage for four trials carrying 6% total solids (TS) concentration. For all trials, sewage sludge and domestic sewage were mixed in 1:1 ratio. Anaerobic Digestion (AD) was performed for 60 days at room temperature 30±4°C. The inoculum was adjusted with cow dung in the certain environmental condition and the presence of an adequate amount of active organic matter was detected. Thus start-up of the trials was achieved easily. It was observed that, when sewage sludge mixed with other co-substrate, the significant increase in gas yield was remarkable. The performances of the reactors were analyzed on the basis of gas yield and methane yield. In this study potentiality of biogas production from Sewage Sludge has been investigated using a mixture of cow dung and sludge at a different ratio.

II. Methodology

The methodology of this research work can be divided into some parts. The first part was investigating the current situation of sewage sludge treatment system & collection samples. The second part was the preparation of substrate followed by the experimental setup of the AD. Sludge used as substrates was less than 6 mm diameter in size. Domestic sewage was added in the different ratio as a diluent to keep the sludge in suspension to achieve the desired level of flowability in each reactor. Domestic sewage also serves as a source of various microbes which is required for the anaerobic co-digestion process. The domestic sewage was collected from the Jatrabari residential area. Cow dung was also used in different proportion as a co-substrate to maintain the optimum C/N ratio. Predigested residue from earlier AD containing all the essential microorganisms; was used as inoculum for early startup of the biomethanation process [1]. The inoculum was synthesized using cow dung by 6% TS concentration in the laboratory. For our research work, the predigested residue was used as inoculum.

In order to measure biogas, yield from municipal sludge through anaerobic digestion; a simple laboratory-scale methanogenic test procedure was followed with some modification according to technical limitations & resources available in the local market [2].

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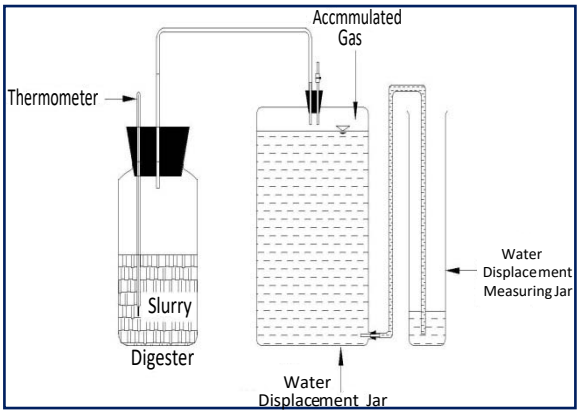

Figure 1: Technical Outline for Experimental Setup

A known amount (6% solids) of the substrate; containing a mixture of organic waste was transformed into a 2-liter capacity conical flux bottle. All conical fluxes were sealed by rubber corks and the other bottle which was filled up with water to collect gas equipped with rubber tubes for gas collection. Solid and moisture content of samples were found out through laboratory experiment.

Organic waste was mixed and added to each conical flux bottle in different proportion to obtain a working volume of 1 liter for all digester. All the reactors contained 6% solid concentration gives optimum biogas yield [3]. The municipal sludge and sewage were mixed by 1:1 basis in all the reactors. Combinations of Waste in different Trial are as follows:

Trial-1: Waste (6% Solid) *[Cow dung (50%) + Municipal Sludge & Municipal Sewage (50%)]* + Inoculum (100 ml) + Water (amount required to be filled up 1000 mL)

Table 1: Slurry Composition on Trial 1

	6% Solid					
	1.5%	1.5%	3%			
Trial-1	Municipal Sludge	Municipal Sewage	Cow dung	Inoculums	Tap Water	Volume of Slurry
	gm	*mL*	*gm*	*mL*	*mL*	*mL*
	82.83	385	192.31	100	395	1000

Trial-2: Waste (6% Solid) *[Cow dung (25%) + Municipal Sludge & Municipal Sewage (75%)]* + Inoculum (100 ml) + Water (amount required to be filled up 1000 mL)

Table 2: Slurry Composition on Trial 2

	6% Solid					
	2.25 %	2.25 %	1.5 %			
Trial-2	Municipal Sludge	Municipal Sewage	Cow dung	Inoculums	Tap Water	Volume of Slurry
	gm	*mL*	*gm*	*mL*	*mL*	*mL*
	124.24	580	96.15	100	165	1000

Trial-3: Waste (6% Solid) *[Cow dung (12.50%) + Municipal Sludge & Municipal Sewage (87.5%)]* + Inoculum (100 ml) + Water (amount required to be filled up 1000 mL)

Table 3: Slurry Composition on Trial 3

	6% Solid					
	2.625 %	2.625 %	0.75 %			
Trial-3	Municipal Sludge	Municipal Sewage	Cow dung	Inoculums	Tap Water	Volume of Slurry
	gm	*mL*	*gm*	*mL*	*mL*	*mL*
	138.74	770	42.61	100	25	1000

Trial-4: Waste (6% Solid) *[Cow dung (0%) + Municipal Sludge & Municipal Sewage (100%)]* + Inoculum (100 ml) + Water (amount required to be filled up 1000 mL)

Table 4: Slurry Composition on Trial 4

	6% Solid					
	3.0%	3.0%	0%			
Trial-4	Municipal Sludge	Municipal Sewage	Cow dung	Inoculums	Tap Water	Volume of Slurry
	gm	*mL*	*gm*	*mL*	*mL*	*mL*
	158.56	870	0.00	100	10	1000

Biogas production was measured by partial water displacement measure and recorded at every 24-hour interval. After daily gas measurement; a slurry of the conical flux (i.e. digester) was mixed manually. All trials were carried out at a temperature of 30±4 °C for 60 days.

Frequently used anaerobic digestion process parameters included pH, Chemical Oxygen Demand (COD), Volatile Fatty Acid (VFA) concentration, Volatile Solid (VS) destruction, biogas production & composition.

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Due to the lack of lab facility; pH, Gas composition & Temperature was measured.

Characteristics of different substrates (solid content, water content, and pH) were determined through laboratory work. Solid and moisture content was measured according to the *standard method for the examination of water & wastewater* [4]. Electronic digital pH meter was used for the determination of pH of the slurry. A buffer solution *(pH water)* containing pH 7 was used to calibrate the digital pH meter. For temperature measurement; a thermometer of range 0~110 ^{o}C having an accuracy ±0.5 ^{o}C was used. Parameters mention above was checked periodically for 60 days. Daily biogas production of each reactor was monitored using water displacement on a daily basis. The volume of water displaced from the bottle was equivalent to the volume of gas generated at the temperature and pressure that conquered during the study period.

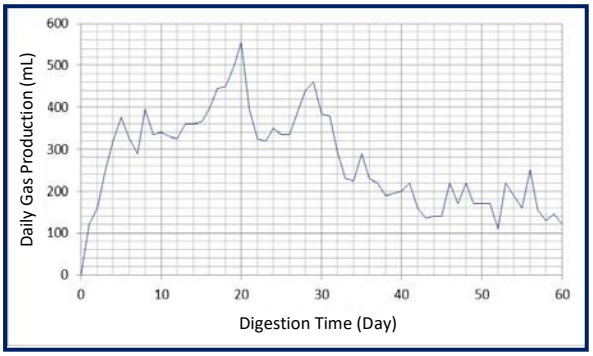
Very concentrated freshly produced KOH solution used to separate carbon dioxide from biogas mixture. The rest amount of gas is considered methane.

Figure 2: Biogas Unit Setup in the Laboratory.

Each digester was loaded with both solid and liquid waste respectively according to Table 1, Table 2, Table 3 and Table 4; after evaluating the substrate composition. Thus the test reactors for four organic loading were constructed. Gas composition and pH was measured weekly. The total amount of gas production and the temperature was measured daily. Biogas composition was measured on every ten days' interval.

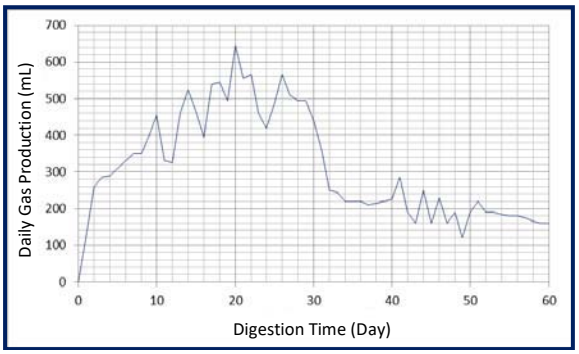
III. Data analysis & Observation

The Graph 1 To 4 represent the volumes of daily gas accumulation with varying amount of sewage sludge in different reactors.



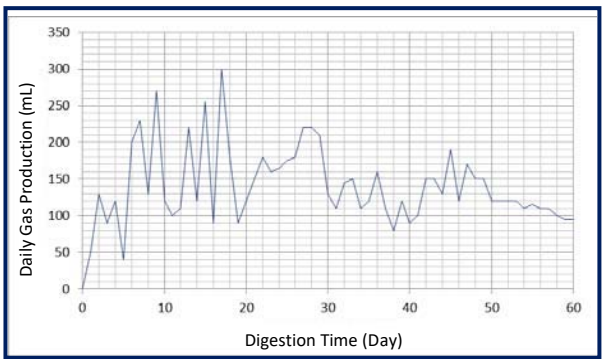
Graph 1: Daily Gas Production Vs. Time Graph for Trial-1

Belt shape trend of daily gas generation for Trial-1 where sludge and domestic sewage was 50% on 6% solids of the slurry, is shown in Graph 1. It was observed that gas generation started at the very next day of charging the digesters with the slurry. The rate of gas generation gradually increased with increasing of the digestion period. In this reactor, the highest gas production of 555 mL was observed on the 20th day. It was observed that; gas production rate considerably declined after 32nd day.



Graph 2: Daily Gas Production Vs. Time Graph for Trial-2

Considering the amount of daily gas generation for Trial-2 which contains 75% of sludge and domestic sewage is shown in Graph 2. In this trial, the generation of gas started from the next day after recharging the reactor with slurry. The highest gas production of 645 ml was observed on the 20th day.



Graph 3: Daily Gas Production Vs. Time Graph for Trial-3

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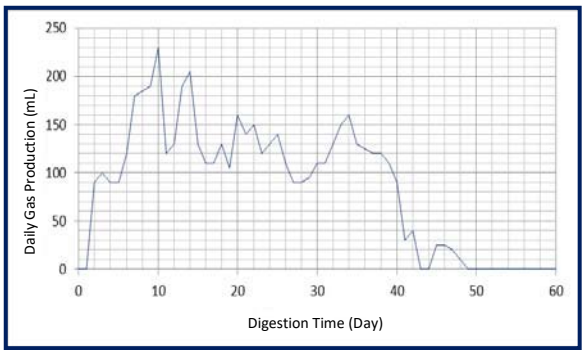
The daily gas production amount in Trial-3 is shown in Graph 3. Trial-3 contains 87.5% sludge and domestic sewage of the total solids of the slurry. The peak gas production was 300 mL; observed at 17th day.

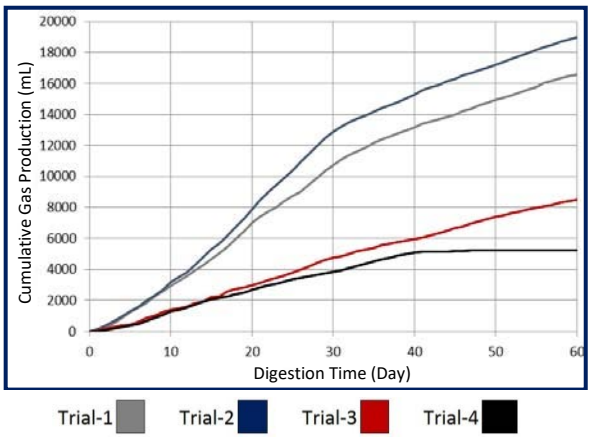


Graph 4: Daily Gas Production Vs. Time Graph for Trial-4

Graph 4 represents the daily gas production for Trial-4, which contains 100% sludge and sewage on 6% total solids. This shows a lower range of gas production. As there is no cow dung in the slurry and the inoculum was used in the slurry originate from cow dung based biogas unit so that in the other reactor. In this trial, the generation of gas started from the second day after recharging the reactor with slurry. The peak gas generation was 230 mL which was observed on the 10th day. Gas production almost ceased at the 42nd day of digestion period.

The cumulative biogas production on test reactors operating at a various organic loading of sewage sludge, domestic sewage, and cow dung; was measured. Calculated data of cumulative gas production for each trial are shown in Graph 5.

Graph 5 shows that highest gas generated for Trial-2 and in most of the digestion period gas generation rate was higher than the others. Even though Trial-2 contained lesser amounts of cow dung then Trial-1, there also a gas generation rate was higher.



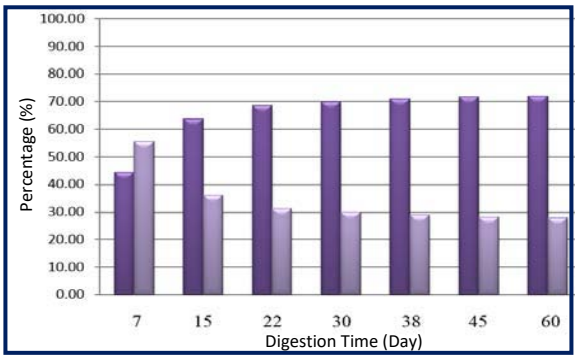
Graph 5: Cumulative Gas Production in Different Trial.

PH is a very important process monitoring parameter for anaerobic digestion. According to Rahman and Muyeed [5], the desirable pH range is between 6.5~8.0 for anaerobic digestion. The highest gas yield was observed by Chengdu Research Institute for 7.5 to 8.0 pH range. PH on each trial on a weekly basis is listed in Table 5.

Table 5: Slurry pH During Anaerobic Digestion Period

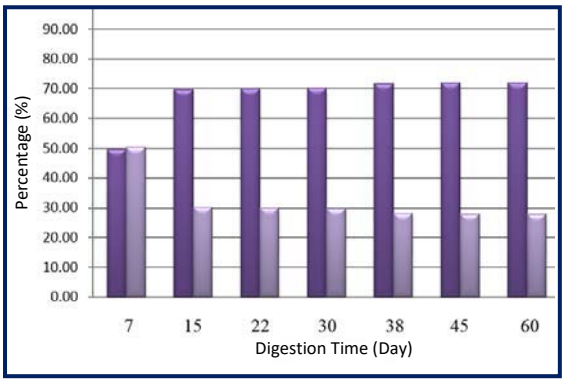
Day	pH			
	Trial-1	Trial-2	Trial-3	Trial-4
(Initial) 0	7.19	7.15	7.46	7.86
6	7.14	7.02	7.44	7.85
12	6.94	6.88	7.38	7.61
18	7.22	7.18	7.04	7.30
24	7.44	7.38	7.12	7.30
30	7.49	7.39	7.00	7.45
36	7.49	7.41	7.42	7.44
42	7.42	7.43	7.38	7.33
48	7.45	7.45	7.30	7.45
54	7.45	7.47	7.32	7.40
60	7.46	7.47	7.32	7.43

Biogas produced from AD usually contains 60% CH_4, 30~35% CO_2 and a little percentage of trace elements, generally H_2S. The composition of produced gas for all trial is shown in Graph 6 to 9.



Graph 6: Variation of Gas Composition with time for Trial-1

Graph 6 shows the percentage of methane and carbon dioxide content for Trial-1. Methane content for Trial-1 was 44.4% to 71.98%.



Graph 7: Variation of Gas Composition with time for Trial-2

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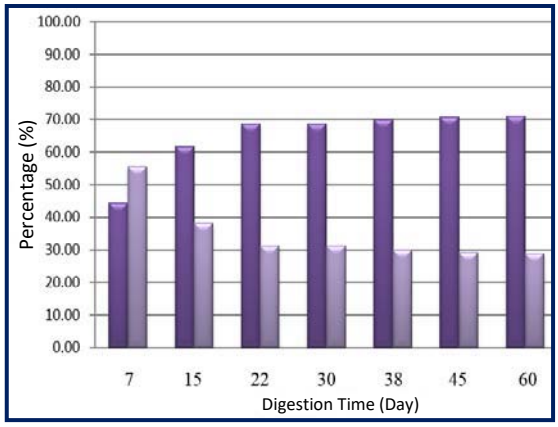
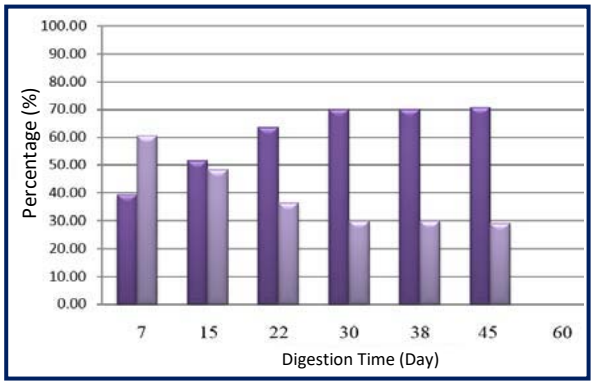
Graph 7 shows the percentage of methane and carbon dioxide content for Trial-2. Methane content for Trial-2 was 49.66% to 72.08%.



Graph 8: Variation of Gas Composition with time for Trial-3

Graph 8 shows the percentage of methane and carbon dioxide content for Trial-3. Methane content for Trial-3 was 44.44% to 70.81%.



Graph 9: Variation of Gas Composition with time for Trial-4

Graph 9 shows the percentage of methane and carbon dioxide content for Trial-4. Methane content for Trial-4 was 39.4% to 71.98%.

Summary of the Observation

- Sewage sludge with cow dung and sewage is a highly potential substrate for biogas generation.
- Among four trials, maximum gas was produced by Trial-2 on which 75% of the TS of the slurry were municipal sludge and domestic sewage. Domestic sewage and sludge were mixed in a 1:1 ratio.
- Municipal sludge with a certain amount of cow dung is potential enough for gas generation than using more cow dung.
- P^H ranges were the favorable range for an AD for all trials. The highest gas production was for the pH ranges from 6.88 to 7.47 for Trial-2.

IV. Conclusion & Recommendations

From the above observation we have concluded:

- Municipal sewage sludge with cow dung and domestic sewage is a very prospective substrate of biogas generation by anaerobic digestion.
- Even Trial-4 which contains only sewage sludge and domestic sewage on the total solids of the slurry has been shown considerable results. Methane content in biogas generated from different reactors varied from 71% to 72%.
- For optimum gas generation from sewage sludge; all the criteria for Trial-2 reactors can be adopted as it has been given the best performance.
- The optimum conditions for biogas generation from sewage are: 6% total solid concentration, pH 6.88 to 7.47 and temperature 30°±4 °C cow dung and domestic sewage will need to be used as co-substrate. 25% of the total solids of the slurry will be cow dung and 75% will be sewage sludge and domestic sewage in the ratio of 1:1. Water needs to be added to maintain the described volume of the slurry.

Recommendation for further study

- Only one solid concentration was taken into account in this study, various solid concentrations can be studied.
- Only one percent of inoculums was used in this research. Using various proportions of inoculums, reactors can be set up for finding the optimum result.
- COD, VFA, VS, C/N ratio measurement of waste is recommended for future study.
- For gas composition measurement, using a modern gas analyzer (Orsat gas analyzer) is recommended.
- Special arrangement to maintain the optimum temperature of 35 °C for gas generation is recommended.
- A pilot-scale field research on the basis of the output of this paper is recommended.

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By Dibofori-Orji, A. N & Edori, O. S.

Abstract- Samples from roadside dust collected from different stations in Forces Avenue, Old GRA, Port Harcourt, Rivers State, Nigeria were digested (mineralized) and subsequently analyzed for heavy metals concentration. The result of the investigation showed that Iron (Fe) was the most abundant metal detected in the roadside. The highest value of Fe was obtained in station 2, which was 81.40±8.12 mg/Kg. The order of concentration of the metals was iron (Fe) >zinc (Zn) > nickel (Ni) > copper (Cu) > lead (Pb) >cadmium (Cd) > chromium (Cr). The mean concentrations of the heavy metals from the various stations was: Fe (71.08±5.38), Zn (47.34±6.05), Ni (25.27±0.99), Cu (18.08±0.93), Pb (0.54±0.05), Cd (0.36±0.03) and Cr (0.18±0.05) mg/Kg. Contamination factor analysis showed that the Forces Avenue area is within contamination category, but not yet polluted with heavy metals. Geo-accumulation index and ecological risk assessment interpretations showed that the concentration of heavy metals in the environment arose from natural factors and pose no ecological risk to the environment. However, adequate care and control should be put in place to put the environment under check to avert possible rise in the concentrations of the metals especially Zn, Ni and Cu.

Keywords: heavy metals, roadside dust, geo-accumulation, ecological risk, contamination factor, assessment.

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GEOACCUMULATIONANDECOLOGICALRISKASSESSMENTOFHEAVYMETALSFROMROADSIDEDUSTAROUNDFORCESAVENUEOLDGRAPORTHARCOURTNIGERIA

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I. Introduction

The continuous and ever increasing growth in population and expanse of cities is worldwide issue. In order to take care of the population geometric growth, there is a rise in urban drift and which is consequent on the need to build more industries. The building and functioning of industries have led to the continuous release or emission of heavy metals into both terrestrial and aquatic environment (Yiran *et al*., 2013).Heavy metals are known to portend serious health threat to humans and animals. The presence of heavy metals in any environment reveals the underlying contamination levels of that place. Moreover, metals are not easily degraded and as such has the capacity to accumulate to levels that are detrimental to human health and wellbeing, especially when their concentrations have exceeded threshold levels (Censi *et al*., 2006; Ubwa *et al*., 2013).

Dust from the Roadside is considered to be one of the main contributors of metal contamination in an urban settlement. Chronic exposure or contact with dust that has been polluted can cause chronic damage to vital organs or tissues of living organisms. Contact with contaminated dust can come through different ways such as inhalation, ingestion, and dermal or skin contact (Mafuyai et al., 2015).

The discharge of heavy metals is of utmost substantial environmental problem, which is caused by anthropogenic activities namely; construction of roads and bridges, mining and excavations, agricultural practices, waste burnings, disposal of sewage, forest and bush burnings, exhausts gases exhuming from vehicles, industrial effluents, lubricating oil, wear and tear from automobile parts, corrosion and disintegration of building materials, deposition from atmospheric drifts and particulate emission(Ho and Tai,1988; Sutherland, *et al*., 2000; Adriano, 2001).

The toxicity of majority of the heavy metals to living organisms cannot be overemphasized. Despite the fact that some of them are essential micronutrient, yet at some concentrations a bit higher than required also become toxic. Important biochemical processes are damaged by heavy metal and as such constitute threat or hazard to human well-being, plant life and animal welfare (Silva *et al*., 2005).This research was therefore conducted to evaluate the geochemical and ecological assessment of heavy metal contamination of Roadside dust around Forces Avenue, GRA I in Port Harcourt.

II. Materials and Methods

Roadside dusts were collected with plastic trowel around the Forces Avenue of Old GRA at six different points and transferred into polythene bags. The soil samples were taken to the Chemistry Research Laboratory of the Department of Chemistry, Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Rivers State. The samples were air dried for two weeks to constant weight in the laboratory.

The samples were powdered and sieved with a 2mm mesh. The samples were digested using aqua regia mixture (HNO_3: HCl) in the ratio of 1:3 using digestion vials. The temperature for digestion was maintained at a 100 –105 °C. At the end of the digestion, the vials were spun or centrifuged and the digest

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decanted into plastic sample containers (Akbar *et al*., 2006).

The digests were analyzed for heavy metals with Atomic absorption spectrophotometer (AAS). Triplicate determination of each metal was done and the result obtained validated.

The data obtained from the heavy metals were then examined with three model indices. They are:

$Contamination\ factor\ (Cf) = \frac{Cm}{Cb}$, where Cm is the measured concentration and Cb is the standard value (Lacatusu, 2000).

$Geo - accumulation\ (I - geo) = \log 2 \frac{Cm}{1.5\ Bn}$, where Cm is the measured concentration, Bn is the background value and 1.5 is a value added to correct lithological differences (Muller, 1969).

$Ecological\ risk\ Index\ (Er) = Tr\ x\ Cf$, where Tr is the toxic response factor of the individual metal and Cf is the contamination factor of the corresponding metal (Hakanson, 1980).

III. Results and Discussion

The concentrations of the heavy metals obtained in the Forces Avenue locations is given in Table 1. Iron (Fe) was observed to be the most concentrated metal in the area, which was followed by zinc (Zn), then nickel (Ni) and copper (Cu). The metal with the lowest concentration in the dust by the roadside was chromium, followed by the value obtained for cadmium (Cd) and then lead (Pb).

Lead: The concentrations of lead (Pb) varied from 0.48 ± 0.00 – 0.61 ± 0.05 mg/Kg, with a mean value of 0.54 ± 0.05 mg/Kg in the sample locations. The value observed for Pb in this work is lower than values obtained by Mafuyai *et al*., (2015) along busy highways in Jos; Popoola *et al*., (2012) in selected classroom dust in different areas in Lagos metropolis and Ogundele *et al*., (2015) along highways in North Central Nigeria. The low values of Pb observed in this work is attributable to the complete absence of industries within the area, the soil type and free flow of traffic which would have caused deposition due to vehicular emissions.

Cadmium: The concentration of cadmium (Cd) ranged from 0.31 ± 0.00 - 0.40 ± 0.02 mg/Kg. These were lower than the ones obtained in Katsina, Nigeria from selected major roads (Lawal *et al*., 2017) and those observed by Inuwa *et al.,* (2007) in parts of North West Nigeria, but higher than those observed by Ogundele *et al*., (2015) in some traffic roads in North Central Nigeria. Cadmium sources include cadmium-nickel battery production, paints, stabilizer in plastic fabrications and deterioration of tyres. Chronic exposure to Cd toxicity can result in different disease conditions (Lee, *et al*., 2005).

Chromium (Cr): The values obtained for Cr ranged from 0.11±0.02 – 0.25 ± 0.01 mg/Kg. These values are lower than the values observed by other authors (Wei and Yang, 2010; Popoola *et al*., 2012; Ogundele *et al*., 2015).The growth of industries in any environment usually increases the concentration of Cr. This is mostly observed in places where chemical and tanning industries predominate. Roadside Cr can also result from decomposition or decay of vehicular components (Lu *et al*., 2009).

Iron (Fe): The values obtained for Fe varied from 63.46±4.67 - 81.40±8.12 mg/Kg. the concentration of Fe observed in this work is either lower or higher than those observed by Mafuyai *et al*., (2015), but lower than the values obtained by Lawal *et al*., (2017).Iron (Fe) is a natural component of the earth's crust. However, its concentration in any soil environment is dependent on the nature of the soil and other environmental considerations such as human inputs. Sources of Fe in the environment are industrial activities and decomposition or decay of metal parts.

Zinc (Zn): The concentrations of Zn in the sampled locations varied between 39.96 ± 4.22 - 55.55 ± 5.01 mg/Kg. These values were about four times lower than the values obtained in a study by Wei and Yang, (2010) in urban soils, urban roadside soils and agricultural soils in different urban Cities of China and also about four to eight times lower than the values recorded by Yiran *et al*., (2013) from different parks in Beijing, China. Zinc (Zn) in the environment can originate from deteriorated or worn out tyre, electrical materials, brake linings and from fuel containers (Dolan *et al*., 2006).

Nickel (Ni): The concentrations of Ni in the present study varied from 23.98 ± 3.08 - 27.27 ± 3.12 mg/Kg. The values of Ni observed in the present study were higher than those obtained by Marcus *et al*., (2017) in leachate contaminated soils within Port Harcourt, Rivers State, Nigeria and those observed by Edori and Kpee, (2017) in selected abattoirs in Port Harcourt, Rivers State, Nigeria.

Copper (Cu): The concentration of Cu in the sampled stations varied from 16.49 ± 2.06 – 19.05 ± 1.67 mg/Kg. The level of Cu observed in this work is lower than those observed in a similar study in roadside soils in Northern England (Akbar, 2006) and those observed by Mafuyai *et al*., (2015) in Jos, Nigeria roadside dust, but either lower or higher than those observed by Ogundele *et al*., (2015) along traffic roads in North Central Nigeria.

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Table 1: Concentrations of Heavy Metals in Roadside Dust at Different Location in Forces Avenue

Sample location	Concentrations of Heavy Metals (mg/Kg)						
	Pb	Cd	Cr	Fe	Zn	Ni	Cu
1	0.61±0.04	0.31±0.00	0.25±0.01	70.32±6.33	45.60±4.35	25.14±2.98	19.05±1.67
2	0.49±0.01	0.40±0.02	0.18±0.03	81.40±8.12	39.96±4.22	27.27±3.12	17.96±2.03
3	0.52±0.03	0.36±0.01	0.24±0.00	68.50±5.38	44.65±3.85	24.91±3.33	17.36±3.76
4	0.56±0.04	0.38±0.00	0.15±0.00	63.46±4.67	55.55±5.01	25.01±2.18	16.49±2.06
5	0.60±0.10	0.37±0.03	0.16±0.05	72.29±2.45	42.78±2.66	23.98±3.08	19.04±3.76
6	0.48±0.00	0.35±0.02	0.11±0.02	70.52±5.13	55.52±6.25	25.33±3.26	18.56±2.66
Mean±SD	0.54±0.05	0.36±0.03	0.18±0.05	71.08±5.38	47.34±6.05	25.27±0.99	18.08±0.93

The contamination factor values obtained from this work is shown in Table 2. The values of contamination factor obtained in this work when compared with the values given for comparison as proposed by Lacatusu (2000) indicated that the stations are uncontaminated with Pb, Cr and Fe. The stations are moderately contaminated with Cd and Zn, severe or moderate contamination with Cu and severely – very severe contamination with Ni. However, the values of contamination factor were lower than those observed by Marcus *et al.*, (2017) in soils contaminated with leachates from dumpsites within Port Harcourt, but higher than those observed by Edori and Kpee (2017) in abattoirs in Port Harcourt.

Table 2: Contamination Factor of Heavy Metals in Roadside Dust at Different Locations in Forces Avenue

Sample location	Contamination Index of Heavy Metals						
	Pb	Cd	Cr	Fe	Zn	Ni	Cu
1	0.0072	0.388	0.0025	0.00185	0.326	0.718	0.529
2	0.0058	0.500	0.0018	0.00214	0.285	0.779	0.499
3	0.0061	0.450	0.0024	0.00180	0.319	0.712	0.482
4	0.0066	0.475	0.0015	0.00167	0.397	0.715	0.458
5	0.0071	0.463	0.0016	0.00190	0.306	0.685	0.529
6	0.0056	0.438	0.0011	0.00186	0.397	0.724	0.515

The geo-accumulation index of heavy metals from the various stations is given in Table 3. The result of geo-accumulation from this work when compared to I-geo pollution assessment index as proposed by Muller (1969) indicated that all the sample stations were pollution free. The stations are practically uncontaminated with Pb, Cr, and Fe, but may have little contamination tendencies of Ni, Cu, Cd and probably Zn. Geo-accumulation index revealed that these metal concentrations observed in the area (Forces Avenue, Old GRA) have not been influenced by anthropogenic activities, but rather of natural factors.

Table 3: Geo-accumulation Index of Heavy Metals in Roadside Dust at Different Locations in Forces Avenue

Sample location	Geo-accumulation Index of Heavy Metals						
	Pb	Cd	Cr	Fe	Zn	Ni	Cu
1	0.00144	0.0777	0.00050	0.0004	0.065	0.144	0.106
2	0.00116	0.100	0.00036	0.00043	0.057	0.156	0.100
3	0.00123	0.090	0.00048	0.00120	0.064	0.143	0.097
4	0.00132	0.095	0.00032	0.00036	0.079	0.143	0.092
5	0.00142	0.093	0.00032	0.00038	0.061	0.137	0.106
6	0.00113	0.088	0.00050	0.00037	0.079	0.482	0.103

The ecological risk index of the heavy metals in the various stations is shown in Table 4. Results of the ecological risk index when juxtaposed with the Hakanson (1980) terminologies used to describe it showed that the metals did not pose ecological risk to the environment.

Table 4: Ecological Risk Index of Heavy Metals in Roadside Dust at Different Locations in Forces Avenue

Sample location	Ecological Risk Index of Heavy Metals						
	Pb	Cd	Cr	Fe	Zn	Ni	Cu
1	0.036	11.64	0.0050	-	0.326	3.590	2.645
2	0.029	15.00	0.0036	-	0.285	3.895	2.495
3	0.031	13.50	0.0048	-	0.319	3.560	2.410
4	0.033	14.25	0.0030	-	0.397	3.575	2.290
5	0.036	13.89	0.0032	-	0.306	3.425	2.645
6	0.028	13.14	0.0022	-	0.397	3.620	2.575

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IV. Conclusion

The concentrations of the heavy metals from the roadside dust in the study area were lower than the background values given by DPR for all the metals. The heavy metals most likely have originated from natural causes rather than human influence (anthropogenic factors). Despite the fact that the extent of contamination is very low (ie within the stipulated limit), yet adequate steps should be taken to keep any incidence of increase under control to avoid any consequence or implications that will arise from such occurrence.

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The Collapse of Mud Living Economies in Bessie Head's Serowe the Village of the Rain Wind

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Abstract- Bessie Head's ethnographic reportage in Serowe: The Village of the Rain Wind is an important historical document to locate the collapse of sustainable communities and reproductive generation. In this essay, I argue that Head's ethnographic reportage at this historical intersection at the cusp of neoliberalism chronicles how international, national, and regional politics in collusion with transnational pharmaceutical companies undermine women's reproductive bodies and family structures. The result is the reproductive collapse of tribal communities and the absorption of indigenous peoples into the global capitalist economy.

Keywords: bessie head; botswana; capitalism; reproductive collapse; reproductive control; reproductive justice; indigenous communities; ethnography.

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Mary Louisa Cappelli, MFA, JD, PhD

Abstract- **Bessie Head's ethnographic reportage in Serowe: The Village of the Rain Wind is an important historical document to locate the collapse of sustainable communities and reproductive generation. In this essay, I argue that Head's ethnographic reportage at this historical intersection at the cusp of neoliberalism chronicles how international, national, and regional politics in collusion with transnational pharmaceutical companies undermine women's reproductive bodies and family structures. The result is the reproductive collapse of tribal communities and the absorption of indigenous peoples into the global capitalist economy.**

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I. Introduction

South African writerBessie Head's ethnographic reportage, Serowe: The Village of the Rain Wind, is a historical non-fiction narrative in which she collects oral histories of a hundred different members of the village to explore the social reforms within a changing socio-political landscape. In this ethnographic discourse, Head excavates the liminal spaces of postcolonial Botswana to uncover the "politics of truth" from the lived experiences and memories of those individuals who witnessed a history different from the historical record of colonial trespassers. Patterned after Ronald Blythe's Akenfiled: Portrait of an English Village, Head's historical testimonies bare witness to a humble portrait of "mud living" in which in spite of Western developmental projects most women and children have few resources and suffer from food and water insecurity. Head's documentation of Serowian testimonies suggests that programs aimed at population control ignore the real economic disparities that exist within the social structures under discussion. Moreover, it testifies to the fact that patriarchal authority, political programs and the development of thanato-technologies aimed at the regulation and control of women's bodies and livelihoods are directly related to periods of socio-economic and political instability. [i]

I, therefore, scrutinize the narrative reportage and individual subjectivities to examine how colonial and post-independence capitalism altered women's reproductive systems and shattered indigenous kinship and family networks. In exhuming these voices, I bring into conversation Serowan voices to specifically interrogate the complex intersecting forces that led to the collapse of sustainable livelihoods and kinship structures. Head's ethnographic recording of oral histories share a dominant analytical stratagem—bringing awareness to the patriarchal interruption of female sovereignty and the exertion of patriarchal control over female bodies and reproduction. Her reportage suggests that multiple intersecting forces prey on women's subsistence livelihoods, most notably the invasion of capital and its polarizing effects on subsistence economies and reproduction of kinship structures. In particular, Head corroborates how maldevelopment projects and population control policies aimed at policing female reproductive systems have led to demographic collapse amongst the tribal populations.

In this analysis, I examine the collision of local pro-natalist values and the international political influence of Neo-Malthusian ethics that focus on controlling women's reproductive systems in the interest of capitalism. I argue that colonial and post-independence capitalism undermined bride price and polygamous relations and replaced them with gendered production systems, monogamous relations, and Neo-Malthusian notions that disempowered women and fueled the collapse of traditional family reproductive units. It is my hope that this essay will contribute to scholarship on how Western development and empowerment rhetoric for rural and indigenous women of the Global South interrupts and displaces traditional coding systems and subsistence livelihoods in the interest of capital, pharmaceutical commercial interests, and geopolitical population control.

II. Breakdown of The Family

Influenced by a line from Telmaque's poem, "Where is the hour of the beautiful dancing birds of the

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[i] I synthesize Ewa Charkiewicz's(2009) theory of how military strategies of thanato-economics, "wages war not only on distant others, but also, as Foucalt and Brennant point out, war against its own populations" (Charkiewicz 80).

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sun-wind," Head (1981) renames "Serowe the village of the rain-wind" (p. vii). In her romantic pastoral, people live in communal harmony and "time stands still in the long silences" and birds dance through "the deep blue, Serowe sky"(p. vii). In her idyllic horizon of birds "playing and dancing" Head finds a sense of wholeness; "a feeling of how strange and beautiful people can be–just living" (p.ix) and "having babies" (p. xi). Head juxtaposes her initial romanticism of "subsistence living" with the bitter reality reported by her villagers who must endure and feed their children on the "barest of necessities" (p. ix). Amidst the playful birdsong, Head contrasts how "the breakdown of family life is one of the great debating points of the village. Of all the tribes living in Botswana, none has experienced so much change and upheaval as the Bamangwato. It was as though old securities had clung to were stripped away at one blow during Khama's rule" (p. 70). In place of traditional kinship systems, elder Serowans carry their Christian bibles and their beliefs in God, while the younger generations live amidst the collapsing family order. Head writes, "Nowhere is this more evident than in the breakdown of family life in Serowe" (p. 70). Family collapse affects old and new. Many children are birthed to unwed mothers and absent fathers, many "who will never know who their real father is" (p. 70).

In an astonishing statistic, Head writes that 97 children out of 100 are illegitimate (p. 70). Sadly, Head's statistics and oral reportage in the late 1970s provide an archeology of reproductive data testifying to the material reasons behind collapsing family structures. Family breakdown was most felt by the Bamangwato tribe in Botswana when Khama came to power to impose Christianity and "blow away" traditional customs (p. 70).[ii] According to Head, Christianity forced people to either accommodate or "abolish" indigenous beliefs, rituals, and customs, hence denying them of long-established comforts and belief systems which traditional structures offered (p. xiii). Head points out that the discipline that Christianity imposed was both "internal and private" (p. xiv). She writes: "People might not have realized this, and this might account for the almost complete breakdown of family life in Bamangwato country, which under traditional custom was essential for the survival of the tribe" (p. xiv). Yet, Head claims that not one of her interviewees were willing to go on record to hoist all the blame on Khama's reforms (p. 70).

It is questionable whether Head's reverence for Khama as a "grand" "classic" heroic figure of "great gestures" and "lofty God of Mount Olympus, the great Lincoln of Southern Africa" clouded her own reportage (Vigne, 1991, p. 177). Coreen Brown (2002) posits that because "Khama's humanity was an exception to the general savagery, abomination and 'heathendom' that otherwise flourished in his land, she must claim for all Khama's people his finer qualities" (p. 137). European Christian missionaries courted Khama's attention and were able to influence his government by implementing ideological apparatuses to supplant tribal structures (Makgala, 2002, p. 161). Under Khama's rule, traditional customs were brutally displaced by the introduction of Western capitalist economy, crushing all signs of tribal systems on its way to progress and development. Tribal peoples were dispossessed of their land, resources, and human dignity, forcing them to live in the shantytowns of the "landless proletariat" (Clayton, 1998, p. 57).

Head emphasizes how Khama's "enlightened reforms" shaped Serowe's past and present with the elimination of indigenous customs and practices that were deemed inhumane by Christian standards, "especially the bogwera or circumcision rites in which the death of one of the initiates was obligatory" (Brown, 2003, p. 137). Among Khama's many other reforms were the discouragement of polygamous structures and the elimination of bride price (Brown, 2003, p. 137).Because "single families often made a nation," in its biological reproduction of lineages, the destruction of these kinship systems had far reaching effects on tribal continuity (Head, 1981, p. 71).

Arguably, one of the advantages of polygamy was to create cohesive patrilocal and patrilineal kinship systems that fostered relationships of power and reciprocity through nation-building. In addition, it secured "every woman in the society of a husband, and that she was performing her reproductive functions under fairly secure circumstances" (Head, 1981, p. 71). In traditional Botswana kinship systems, links of power and authority flow and interconnect through networks of patrilineal ancestries. While male members benefit from patrilineal privilege, the system also functions to provide assistance and welfare for women. Elder mothers of sons particularly benefit from the privileges inherent in this system. In comparing indigenous structures in India and Africa, Stanley J. Tambiah (1989) observes that African women enjoy some degree of personal self-sufficiency. Synthesizing Kathleen E. Gough's work on kinship systems in a Tamil village, Tambiah maintains:

The focus of interest of most African patrilineal systems is the reproductive capacity of woman and the maximum number of children she will bear; that African polygyny and matrifiliation are part of a special kind of patrilineal configuration; and that's because a married women's sexuality itself is not curbed and because her children's kinship is never in doubt. (p. 415)

The argument that women have been passive objects in a male dominated kinship system precludes discussions of women's productive and reproductive contributions to the maintenance of indigenous livelihoods. Female productive and reproductive capacities are the most vital forms of agency and

[ii] Seretse Goitsebeng Maphiri Khama was the first President of Botswana and in office from 1966 to 1980.

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resistance—a fact that many feminists from both the Global North and South are afraid to acknowledge because of fears of bringing into play maligned theoretical notions of "biological essentialism."

While many African Marxist Feminists argue that polygamous structures locate women in passive positions of gendered subordination, it is also true that women enjoy a certain degree of inherent value as producers of children whose reproduction is imperative for the safeguarding of pastoral kinship systems. Children contribute to the functioning of the kinship system through maintaining and in some cases extending the cohesive social unit. Their labor in cattle production and agricultural output are vital to the economy of traditional subsistence livelihoods (Tambiah 1989, p.415). In The Pastoral Continuum: The Marginalization of Tradition in East Africa, Paul Spencer (1998) observes that the articulation of polygamous structures provides a "meaning life style to which pastoralists remain committed. The evidence from successful pastoralist cultures in particular suggests an institutionalized complex that adjusted to change" (p. 2). Polygamous kinship structures are strategic interdependent arrangements aimed at maintaining indigenous knowledge needed for survival and adaptation amidst changing and often vulnerable social and ecological conditions. Head reports some extended families had close to six hundred members and the introduction of monogamy has had a devastating effect (71). Akin to large family run enterprises with vast geographical networks of exchange, loan, and gift circuits, these alliances are crucial in times of severe drought conditions. Although in a different geographic and tribal location, evidence from my own research with the Barabaig pastoralists in Eastern Tanzania corroborates Spencer's observations that polygamous relationships were (are) necessary in order for indigenous pastoral economies to grow and survive. [iii]

The patrilocal kinship system was able to sustain itself through an adult royal lineage led kgosi who joined in an assembly (Kgotla), which acted as a juridical body to hear cases and provide resolution for village conflicts. The kgotla's administrative decrees were distributed and reinforced by male head's of their particular family units, the Kogtla overseeing community cohesion. Although land itself was held in common and was distributed by the Kgosi through patrilineal structures, women maintained customary land privileges as wives and members of their individual family units. [iv]

According to a Setswana saying "*Kgosi ke Kgosi ka batho,* –The *kgosi* is *kgosi* by the grace of the people.[v] Designated with its privileged position by the people themselves, they can remove the *kgosi* for abuses of power not in the interest of the community. Head (1995) narrates the checks and balances within the kgosi in which corrupt dikgosis like Matenge are confronted by the local villagers in her novel, When Rain Clouds Gather. She further observes the "treasured" meeting places of women who took over the kgotla to discuss issues of their own concern.

Head (1981) observes that after the end of Bamangwato leadership "a gaping hole" swelled in "the fabric of society. Its main victims are women who now rear large families of children on their own outside the security of marriage" (p. 71). In particular she witnesses the impact of Christian institutions on existing kinship structures:

Marriage in church certainly struck the final deathblow to polygamy but the immense amount of change and strain people have endured seems unfortunately to have struck a deathblow to the male. He ceased to be the head of the family, and his place has been taken by a gay, dizzy character on a permanent round of drink and women, full of shoddy values and without any sense of responsibility for the children he so haphazardly procreates. (p. 72)

Many villagers still recall royal ancestry of tribal chiefs and headmen, their family line extending back in history to embrace the vitality of its deep historical roots. Like the "Testament" and "just as sacred," traditional polygamous structures as well as marriage itself disintegrated with Khama's reforms (Head, 1981, p. 71). Head (1981) observes that: "All Seowans live with the tail end of the polygamy story" (p. 71).

Head's oral history taken from 34 year-old weaving instructor Ndoro Sekwati reports on the impact of marriage dissolution. As stated by Sekwati, "Women are no longer certain of marriage but they still have children and have to support them" (Head 199). Sekwati describes how in the past the only aspiration girls had was marriage; the only knowledge they possessed was that of plowing the fields. "There was no other life for women, outside of that" (Head 198). Instead of money, the women received food, which she says is "the history of our women fright from the olden days; they have no other history. Many women still live like this, but the one big change that has taken place is that marriage has now become a thing of the past" (Head199). Yes, women still bear children, but outside the protective kinship network of food security.

[iii] Leveled on top of polygamous structures is another hierarchical stratification based on gerontocracy in which young men and women are dominated by senior elders.

[iv] See Van Allen, Judith Imel. "Free Women: Kinship, Capitalism, Gender and the State in Botswana." Diss. University of California, Berkeley, 2002. Print.

[v] See Ørnulf Gulbrandsen *The State And The Social: State Formation in Botswana and its Precolonial and Colonial Genealogies,* 2013.

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One of the many factors leading to the breakdown of the family is the elimination of the tradition of bogadi, bride price—"the offering of a gift of cattle by a man to his wife's family at the time of marriage" (Head, 1981, p. 72). Bogadi was essential to the foundation of family life by creating a network of bonds and circulating resources over an expansive geographical area. Head (1981) writes:

It (Bogadi) was a marriage contract and without it there was no marriage.

All children born of the house of bogadi were recognized as legitimate.

But its ramifications went deep and stretched out to all the children a woman might bear in her lifetime, irrespective of whether another man other than her husband might have fathered her children. It also had undertones of a sale bargain, as if women were merely a marketable commodity. Of the five principal tribes in the country only the Bamangwato and Batawana have abandoned the bogadi tradition, and there seems to be nothing to bridge the ill-defined gap between one way of life and another. No one seems to know what the right sort of relationship between men and women should be, that would be sacred and of mutual benefit. (p. 72)

Varying opinions exist on the significance of bride price: According to Radcliffe-Brown's juridical thesis, bride price is a sort of "indemnity" and remuneration to a family that loses one of its members (qtd. in Tambiah, 1989, p. 414). Driberg argues, on the other handthat "women were not bartered away in Africa in communal transactions" (Tambiah, 1989, p. 414). The transactional nature of bride price suggests a "marriage settlement" that created a sense of equilibrium between the bride and groom's families (Tambiah, p. 414). Labels such as "'inequality,' 'domination,' 'prejudice,' and male chauvinism,'" were designated to describe it (Tambiah, p. 414). African aphorisms such as "Cattle beget children," and "We are bought like cattle" fueled theoretical designations as a form of commercial purchase for marriage (Tambiah, p. 415). Polygamy and bride price go hand in hand with securing economic stability amongst kinship relations. As socio-economic and political transactions, they are interconnected to the reproduction and reproduction of their traditional communities over time.

In Dismantling Black Manhood: An Historical and Literary Analysis of the Legacy, Daniel P. Black (1997) reports bride price also served as a "form of insurance for the good treatment of the daughter" (p. 29). The "material presentation" acted as a binding agreement tendered for the daughter's future physical security. If a husband mistreated a daughter, she had recourse, as her male family members would intervene by beating and punishing him "(experientially) the injustice he inflicted upon his spouse" (Black, p. 31). In addition, married women seldom went hungry, as husbands who left their wives and children vulnerable to food insecurity were treated with village disdain. Husbands were expected to provide for their family and if they didn't they incurred the scorn and social ostracism from other village members. "So important was it to provide for one family adequately that, on occasions, a husband would help his wife with female-centered activities, which yielded an economic contribution to the family" (Black, p. 31).

According to the historical observations of Head's Keitese Lefhoko, "Men used to love their wives in the old days and women were tough to get. Their parents made tough bargains too. I really don't know what has caused the breakdown of family life because there are so many factors to consider, but I do know that women no longer regard themselves as a prize that has to be won" (Head, 1981, p. 75). In another one of Head's oral histories, Balebe Olegeng reports, "I don't know for sure when married life broke down, but by the time I started to notice the world, I could see there was no more marriage here in Serowe. My grandmother had been married and so had my mother but in my time, marriage suddenly went out of fashion" (pgs. 75-76). Balebe Olegeng claims that most villagers "grew up" without polygamy and bodagdi. In the past, the dominant question asked was: "Who was your father?" (Head, 1981, p.77). "If you had no proper father you were nothing in the society" (Head, p.77). Similar inquiries persist today, and some women are humiliated by conceiving children "outside marriage" and so have equipped their children with a prepared response: "My father was killed by a train" (Head, p.77). Balebe Olegeng insists that she has told her children the honest reality of her situation. "When they asked me who their father was I said: 'You have none'" (Head, p. 77). She asks: "What can we do? You can't force a man to be a father" (Head, p. 77). Both metaphorical and very real, this patriarchal capitalist train has left a mass grave of broken relationships and vulnerable indigenous communities on its path to "progress" and "development."

Head quotes C.G. Mararike's short story Why Marry? which narrates the escapades of a D.D.'s single beer drinking son B.B., a graduate of the London School of Economics, who "could have married if he wanted to but saw no point 'in buying a cow if he could get its milk free'" (p. 73). [vi] Mararike's narrative suggests that among other things, that implicit in sexual relations is a quid pro quo of future obligation if the terms of consideration are negotiated for the whole instead of the parts. He further implies that the failure to live up to these terms is a result of women who willingly breach the terms of their own sexual arrangements by delivering "the milk" without any consideration of future obligations as a the result of the sexual transaction. The

[vi] Printed in the Botswana magazine, *Kutlwano*.

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consequence is that the system of incentives for men and protections for women entering into sexual relations have evaporated, and relationships that once were "sacred" and of "mutual benefit" has also vanished (Head, p. 72).

Some of Head's testimonies present a nostalgic reminiscence for the "old days" when men and women maintained kinship obligations. Although Head's seventy year-old Mpatelang Kgosi does not blame Khama for family collapse, he does correlate how the replacement of bride price with monogamous marriage impacted men's decision on when and whom to marry. Age and timing of marriage are now factors of consideration as "men often preferred to marry very young women. Since men had only a choice of one wife, he would wait until the age of thirty, without any contact with women until his wife was fully grown" (Head, p. 74). His chastisement of restless women who "chase money" from partner to partner never to find peace and men who chase women for sex, suggest a liberated sexual freedom unencumbered by the consequences of child birth and its traditional responsibilities. As stated by Kgosi "…no longer do men care about the position of being a father" (Head, p. 74). In Head's country of "fatherless children," Kgosi claims that under this new socio-economic arrangement of non-binding sexual relations, children are "encourage[d] to do the same" (Head, p. 74). In his most revealing opinion of the social changes, Kgosi reports:

It looks as though many new evils have come with the laws of independence. In 1967, the government introduced a new marriage law, whereby once children reach the age of twenty-one they may marry without their parent's consent. The result of this is that we now have a large number of divorces. The new style here is to be married for about two years and then divorce. On top of this, family planning was introduced. We can just give it its proper name, which is birth control. At first I did not mind all the adultery and many bad things that were going on because it was producing children. Now the women have seen that they need not bear children. One day there will be no people at all in this country because women are reluctant to bear children. (Head, p. 74)

For those women who do bear children outside the protections of marriage it is an understatement to say that life is difficult. Eighteen year-old Lebang Moremi claims she was influenced by her peers to have sex and began doing so without any information about contraception. She was sixteen when she conceived her first child and discovered "what happens to girls who become pregnant—there is no help for them, not even from the law" (Head, p. 78). Although the father denied his paternity, the District Commissioner did provide her with some economic recourse of R10 a month for child support, although most women receive little to no child support (Head, p. 78). Lebang Moremi blames a patriarchal judicial system for women's lack of protection: She observes that neither the legal discourse at the kgotla or the police camp, protects a woman" (Head, p. 78). According to Moremi, patriarchal collusion between both old and new systems have doubly marginalized women leading to the feminization of survival:

In the case of kgotla, from Chief Tshekedi's time, a ruling was made whereby a woman could claim damages in the form of cattle for the first child. There is no pressure for damages for the second, third, and so on. So a man knows that if he makes a baby with a women who already has a child, the kgotla won't trouble him to pay damages and from then onwards we women get taken advantage of. We have a second appeal for help –to the District Commissioner's office. This involves money for maintenance, not cattle. There was a new maintenance law passed two years ago whereby the men are required to pay R5 a week maintenance now. This frightens the men a little. (Head, p. 78)

Yet even with these laws, most fathers have escape[d] financial social and financial responsibility for their offspring born outside of marriage. For Marembe as well as other mothers raising children on her own, life "it is not a good life" for mother or child (Headp. 79). Children observe the behavior of their mothers, "lose respect all respect for her" and commence to follow in her pattern in a Botswana where now both mothers and daughters have internalized a socially prescribed culpability for the breakdown of family relations (Head, p. 79). In Marembe's world of patriarchal abandonment, children "run wild," daughters pattern their sexuality after their mother with "one man after another," and sons "become thieves," raiding villages for bare necessities (Head, p.79). Women bear the burden of not only providing physical and emotional security in a world of diminishing resources, but also the psychological toil of children's behavior.

III. Planned Parenthood

Head's reportage of 34 year-old Marit Kromberg, a maternal, child health services and family planning administrator, reveals the helplessness of mothers who frequently experienced the death of their babies from diarrhea. "We were trapped in a vicious cycle from which there was no release" (Head, p. 38). Health assistance aimed at prenatal, postnatal and infant care appears to have been disregarded in favor of family planning policies. Kromberg affirms this proposition as she states, "What Iwanted to do was get in on some health planning from the District council and the central government" (Head p. 138). Nowhere does she mention she wished to develop solutions to infant death and early childhood death due to diarrheal disease, malnourishment, pneumonia, and tuberculosis. Given this scenario, Botswana was ripe for Second Wave Western Feminist rhetoric of birth control and the 1968 arrival of a delegation from International Planned

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Parenthood Federation on family planning to alleviate the cause of infant death—birth.

As stated by Marit Kromberg: "We were able to show them that some of the women wanted it and also to demonstrate that some women feared to plan, due to the high death rate among babies—perhaps a third of any woman's babies at that time, did not live to the age of five and this made it very difficult for a mother to plan" (Head, p.139). The vacuum of human capital development created a desperate need, which Western NGOs attempted to fill with their enlightened notions of western feminist liberatory politics. Rather than understanding the traditional cultural reasons for multiple births to ensure the economic productivity and security of the family unit and establishing policies that addressed the ongoing stability of family production units, the eugenics policy proposes that Botswana women would be better off with birth control developed by transnational pharmaceutical conglomerates rather than suffering the harsh reality of infant mortality. In order for countries like Botswana to get assistance with their tribal populations who lack access to basic human resources like food and health care, they have had little choice but to enter into unbalanced Neo-Malthusian population control agreements. The government, unable to provide their own social tourniquet to control infant mortality rates, entered into a contract with IPPF to "introduce family planning" in exchange for "maternal health care and child health" (Head, p.139). Head's reportage at this historical intersection chronicles how international, national, and regional politics shape women's reproductive experiences and family structures (Mullings, 1995, p. 123). While I do not deny that the freedom to engage in sexual activity without the worries of pregnancy has emancipatory effects for women in terms of granting them behavioral "choices," it is also true that IPPF has created pockets of "stratified reproduction" in which motherhood is discouraged and sexuality encouraged amongst black and brown indigenous populations (Mullings, p. 129). [vii] In this population control ideology, African communities are ripe for contraception and population control. Yet, reproductive justice activists have argued summarily that disrupting traditional birthing codes and systems also disrupts cultural integrity and is a form of black genocide (Roberts, 1997, Ross & Solinger, 2017). The regulation, surveillance, and control of women's reproductive systems appear to be the first step in regulating, surveilling, and controlling tribal demographics. This focus on population control masks the more complicated discussions of infant mortality, poverty, and socio-economic and political inequality. In this privileged binary, USAID, transnational pharmaceutical companies and corrupt governments target tribal communities with the least amount of resources for the overconsumption of the Global North.

Although not in Botswana, Esther Wangari (2002) problematizes IPPF's planning policies of impoverished women in Kenya to interrogate the rhetoric of empowerment of reproductive technologies aimed at policing women's bodies to satisfy the overconsumption of resources by the Global North. According to Wangari, "High fertility rates in the Third World are blamed for lack of economic growth, environmental degradation, and the low status of women, among other ascribed effects" (2002, p. 298). Notions of "choice" and "free will" for women in Botswana appear to be ineludibly restricted and constrained by a similar complicated web of power relations in which the right to choose often excludes "information about possible side-effects and health care delivery," which she considers to be "blunt racism against the people of colour" (Wangari, 2002, p. 307). Their "bodies and families" become "dumping grounds" and repositories for "new and banned reproductive technologies of the West" (Wangari, 2002, p. 308).In this socio-political economic arrangement, pharmaceutical companies and the governmental elite collaborate to maintain the marginalization of unwanted peoples in a system where the elite maintain their political power by reducing peripheral factions and pharmaceutical companies economically benefit from the demand of their new contraceptive technologies.

In this case it appears that Gayatri Chakravorty Spivak (2013) is correct when she states: "All initiatives of population control or genetic engineering are cruelly unmindful of the dignity of reproductive responsibility" (p.190). Spivak joined in a movement against Ciba-Geigy, which is now Novaris to show that these companies dump pharmaceuticals on women of the Global South, which harmfully affects their personal, cultural, and economic well-being (p.190). Spivak (1999) argues that "The blame for the exhaustion of the world's resources is placed on Southern population explosion. And hence, upon the poorest women of the Global South" (p. 385). She further notes how placing attention on the subaltern reproductive systems diverts attention to "Northern over-consumption: the two faces of globalization" (1999, p. 385). Farida Akhter takes this idea further and condemns "the individual right of woman over her own body as an unconscious mirroring of patriarchal ideology" (qtd. in Spivak, 1999, p.386). Akhter establishes how the United States established reproductive control policies in conjunction with "International Planned Parenthood Federation and the Population Council, which was funded by the Rockefeller Foundation and United States National Academy of Sciences" whose job it was to lay a political foundation connecting "the political elites in the Global South in order to prepare the ground for US-sponsored

[vii] I feel it is important to clarify that I am a supporter of Planned Parenthood. I am not in support of selective planned parenthood to reduce brown and black populations.

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control of population growth by Third World Countries" (Morton, 2007, p. 138).

The Family Planning Board trained and supervised "female family planning workers" sending them into rural communities to educate women about birth control technology, specifically intra-uterine devices. Deemed unsuccessful at limiting birth rates, the Board coerced rural women "into accepting contraceptives" by offering financial inducements (Morton, 2007, p. 136).

In 1971, Akhter observed the collusion of USAID and pharmaceutical companies alleging that USAID noticeably augmented its financing of population control programs and identifies two motives for the increased funding:

One was the US wanted to control nationalist movements, and Third World opposition to the foreign control of resources in general, and it saw an opportunity to do so by funding population control activities; the other was that the US government wanted to help pharmaceutical manufacturers to find new markets for birth control pills. (Morton, 2007, p. 136)

Through her involvement in FINNRAGE and UBINIG, Akhter attacks government and transnational business and NGO development rhetoric aimed at women's reproductive systems instead of support and funding directed towards female wellbeing, sustainable livelihoods and family planning that includes right to have or not have children. In EcoFeminism, Maria Mies and Vandana Shiva (1993) posits thatthe discussion of reproductive rhetoric is based on Western concepts of individualism and bourgeois values. Mies and Shiva asserts that "reproductive rights' for women, propagated by feminist groups in the West, have no meaning for the majority of women" of the Global South," who are covered by population control measures," political sentiment similarly repeated in Serowe (p. 190).

Certainly, all women should have the choice to give or not give birth, to choose how many children to have or not to have; however, Head's ethnographic reportage evidences something otherwise. Population control programs in Serowe have cared more about reducing birth rates than about infant mortality rates and empowering women to make informed choices over their reproductive and sexual bodies. [viii] Spivak (2013) is correct in her observation that, "all initiatives of population control and genetic engineering are cruelly unmindful of the dignity of reproductive responsibility" (p. 190). [ix]

Spivak's "movement against reproductive and genetic engineering confronts the multinational pharmaceuticals and their conglomerate associates" (2013. p. 190). In "Claiming Transformation," Spivak contends that "women are the target of contemporary international civil society, by which she means the 'United Nations and the powerfully collaborative Non-Governmental Organizations (NGOs)'" (qtd. in Morton, 2007, p. 134). International development projects in the form of the World Bank and the International Money Fund are designed to create politico-economic dependencies wherein the countries of the Global South become financially indebted to the Global North and led into believing that reproductive technologies are a common good (Morton 135).In a socio-political structure that seems intent on curtailing tribal existence, cultural survival questions plague Head's reportage.

According to Tola Olu Pearce (1995), interest in population control policies in the Global South is an ongoing concern recently resuscitated with today's environmental crisis and booming pharmaceutical industry (p. 200). Pierce identifies that "little attention is paid to the disproportionate amount of resources consumed by the developed world" (p. 200). Neo-Malthusian rhetoric proposes birth control as a regulatory measure to restrain unchecked population growth, which exacerbates the ecological carrying capacity of the region and poses a threat to "world ecological stability" (Pierce, p. 200). Pearce further observes that "With the growing poverty and disease in Africa, aggravated by SAPs, the fear of population invasion and resource consumption by the poor nations may escalate into fears of the health problems spread by poverty stricken nations" (p. 200). Today, Botswana

[viii] Note the 2010 Procurement Planning and Monitoring Report, USAID, a major donor to International Federal of Planned Parenthood has worked diligently to reduce stock-outs in Bangladesh, Dominican Republic, El Salvador, Ethiopia, Ghana, Kenya, Liberia, Malawi, Mozambique, Nicaragua, Nigeria, Paraguay, Rwanda, Sierra Leone, Tanzania, and Zambia. Also of note are the shipments of intra-uterine devices (IUDs) to Uganda, implants to Rwanda, and combined oral contraceptives to El Salvador. While I am a strong advocate of "choice," I am nonetheless wary of the hegemonic exportation of Western perceptions of reproductive rights and its inadvertent (or planned?) side effects, which coerce reproductive limitations on subaltern women and their traditional cultures, traditions, and family structures.

[ix] From my research, it appears that IPPF seems to be in a deep global web of commodity exchange with USAID being one of its major supporters. In a recent job posting, IPPF actively seeks a USAID Project Director – Family Planning and Sustainable Networks (fixed term to end 2018 and subject to successful award) to "ensure USAID Mission buy-in at country level." IPPF is actively involved in reproductive commodities exchange, global procurement and supply chain commodities management in partnership with key donors, suppliers and others, e.g. the Reproductive Health Supplies Coalition, to support its mission. The donations are coming in from the Global North. Between July 2007 and December 2009, 15 European countries committed an additional €400 million to reproductive health, with a portion of this going toward supplies. It appears that IPPF not only deals in the flow of commodities, but Western ideologies of population control of subaltern peoples and further acts as an hegemonic apparatus of USAID to ensure "USAID Mission buy-in at country level." Such preliminary investigation substantiates Spivak's assertions that the World Bank, International Money Fund, USAID and other NGOS aid and abet economic and political dependency of the Global South by concentrating on women's reproductive wombs as a cause of poverty.

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is geared to receive support from USAID, and the (UK) Government under the regional programme on Preventing Maternal Deaths in East and Southern Africa(PreMDESA) to expand contraceptive methods to include the controversial Jadelle implant a five-year contraceptive, which is NOT for sale in the US because of its deleterious side effects. [x] This is another example where US commercial market interests take precedence over human health in which products deemed unsafe for domestic are sold to disposable populations of the Global South. Reportage of this collusion was noted by Mark Dowie, Barbara Ehrenreich and Stephen Minkin (1979) in "The Charge: Gyocide: The Accused The US Government," in which they argued that US transnational drug companies systematically and intentionally engage in dumping "unsafe" and "dangerous high-estrogen birth control pills" that are "not approved for American use" in Third World countries. They further contend that contraceptive dumping is motivated by a double standard based solely on corporate profit without any consideration of existing cultural practices.

Marit Kromberg reports that the Serowans employed their own traditional custom of family planning and "child-spacing" prior to the arrival of IPPF. They believed that Serathane "a condition of bewitchment, will afflict the child if the parents do not observe the customs which cause child spacing; either by physical separation or abstinence" (Head, 1981, pgs. 139-40). Families were aware of the biological necessity of child spacing for the reproductive health of mother and child. Kromberg recounts how she used the belief in serathane as a bridge to "build on" to introduce, motivate, and "now provide mothers with modern methods of family spacing" (Head, p.140). What Kromberg did not seem to recognize was that these culturally prescribed indigenous codes of birth spacing, while certainly a method of family planning, is in direct opposition to Neo-Malthusian interest in limiting family size (Pearce, 1995, p. 203).

Kromberg also confirms how "In the old days, polygamy also helped family planning because then a husband had an alternative wife" and elder women were given a respite from on-going sexual activity (Head, 1981, p.140). Pearce observes amongst Africa's Yoruba population that "women did not always see continued sexual availability to men as a positive development" and considered "culturally imposed terminal abstinence as necessary for a well-earned rest in middle-age" (1995, p. 204). She posits the extension of women's reproductive activity through the "use of technical solutions" may actually "not always be welcomed" (Pierce, 1995, p. 205). In Head's politics of truth, this might be equally true amongst Botswana's indigenous populations with its emphasis on polygamy, bogadi, and extended kinship lineages.

The rejection by many Botswana tribals to adapt to Khama's reforms, especially polygamy, has added to the complexity of social relations. While colonialism contributed to the collapse of the family, Huma Ibrahim (1996) observes that traditional kinship polygamous relations "thrown into the modern context devastated family structure" (p. 225). Head does not shy away from the collusion of both "traditional tribal" and "Western" patriarchy in constriction of "choices" and the ongoing subordination of women. Her interviews and reportage construct a socio-sexual historiography of the myriad impositions on women's reproductive systems.

IV. Conclusion

In this essay, I have applied an interdisciplinary approach to explore the reproductive experiences, memories, and stories of women's lived and imagined realities in Bessie Head's Serowe: Village of the Rain Wind. In so doing, I have problematized how reproduction is shaped across socio-cultural geopolitical-boundaries, specifically at local/global historical junctures. Based on the often times complex and conflicting exchanges of people in real places, Head's discourses provide a materialist feminist space for understanding the socio-political ramifications of the displacement of polygamous structures, the introduction of western concepts of planned parenting and its devastating impact on tribal reproductive sustainability. Head's reportage provides a vital entry point to interrogate the complex imposition of traditional and capitalist patriarchal forces on reproductive systems and the inequitable materialist conditions that entangle women and their children in the throes of struggle and survival. More importantly, her ethnography opens another space for necessary discussions of reproductive choice, reproductive dignity, and reproductive justice-discussions, which must always include informed decisions in choosing to have or not to have children.

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[x] Jadelle is owned by Wyeth, the same company that marketed the controversial Norplant, which was taken off the US market in 2002.

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Techniques for writing a good quality Science Frontier Research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of science frontier then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

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6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

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Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

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Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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