IMPACT OF CASSAVA PROCESSING ON THE WATER QUALITY OF SELECTED TROPICAL STREAMS IN DELTA STATE SOUTHERN NIGERIA

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Accepted:05/03/2016
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Abstract
Effects of cassava processing on the water quality of selected tropical streams (Atochi, Inyite and Iyida) in Southern Nigeria have been experimentally studied. The study was carried out on a weekly basis for a period of four months within the rainy season (June-September) in the year 2013. Three sampling stations were established along the river courses (upstream, midstream and downstream of the cassava processing site). Results of physico-chemical analysis of the water samples showed that cassava processing caused a decrease in dissolved oxygen and pH and an increase in biochemical oxygen demand (BOD), chemical oxygen demand (COD), total microbial count (TMC), temperature, phosphates, sulphates and nitrates. Using a water quality index (WQI) in classifying water quality of the streams show that the values of the index are generally greater than 2 at sampling points A (downstream) and C (upstream) across the three streams indicating that the water quality at sampling points A and C in the three water bodies is acceptable. However, at sampling point B (mid stream) across the three water bodies the water quality index ranges between 0.6 and 1.06 indicating that the water quality at sampling point B across the water bodies is poor.

Keywords: Cassava, water quality index, streams, southern Nigeria.

Introduction

Cassava is the third largest source of carbohydrates for human food in the world[1]. Cassava roots are very rich in starch, and contain significant amounts of calcium (50 mg/100g),phosphorus (40 mg/100g) and vitamin C (25 mg/100g)[2].A great diversity of products is derived from cassava. The most representative are *garri* in West Africa, *chickwangue* in Central Africa, and *atap* and *ugali* in East Africa. Tapioca and *fufu* (*akpu*) are made from the starchy cassava root flour. Cassava has been used extensively as cereals in South America. It is also used in making cassava cake, a popular pastry and can also be used to make alcoholic beverages.

Cassava varieties are often categorized as either "sweet" or "bitter", signifying the absence or presence of toxic levels of cyanogenic glucosides. The so-called "sweet" (actually "not bitter") cultivars can produce as little as 20 milligrams of cyanide (CN) per kilogram of fresh roots, whereas "bitter" ones may produce more than 50 times as much (1g/kg)[3]. A dose of 40 mg of pure cassava cyanogenic glucoside is sufficient to kill a cow[4]. It can also cause severe calcific pancreatitis in humans, leading to chronic pancreatitis. However, consumption of insufficiently processed bitter cassava may cause konzo (also called mantakassa), a paralytic neurological disease. Toxicological effects of cyanide on organisms have been documented by various authors[(4, 5, 6, 7)]. There are also reports indicating that dissolved hydrocyanic acid resulting from the processing of cassava tubers may lead to death of fish and other aquatic organisms [(8, 9, 10, 11,12)].

Cassava roots and leaves should not be consumed raw because of the toxicological effects of the two cyanogenic glucosides(linamarin and lotaustralin). These are decomposed by linamarase, a naturally occurring enzyme in cassava, liberating hydrogen cyanide (HCN)[9]. Societies which traditionally eat cassava generally understand that some processing (soaking, cooking, fermentation, etc.) is necessary to avoid getting sick. A major feature of cassava processing in Africa methods requires a lot of water. For starch production, however, water is required at all stages irrespective of processing scale. For example, in Cong Hoa village, Vietnam, the total volume of water required to process 300 tonnes of roots for the area is about 2,400 m^3[(13)]. In many cassava processing areas, water is also obtained from a surface water supply, especially streams and rivers.

Cassava processing is generally regarded as a burden on natural resources and produces large amounts of effluent high in organic content. If untreated this may be displayed in the form of stagnant effluent ponds from which strong odours emanate. As a consequence of the visual display of pollution, cassava is often perceived by local populations as contributing significantly to environmental damage and water deficit. Yet, despite this notion, supported mainly by the visual display of pollution, few systematic impact studies have been conducted[9]. Most studies have tended to focus on the quantity and composition of waste produced by this industry, but do not consider the environmental impact. In the study area, cassava is mostly prepared for *fufu* or *akpu*. This is done by soaking peeled cassava roots in jute bags and left in the stream or river for a period of 7 days for the purpose of fermentation. The continuous increase in supply and demand for cassava products such as *fufu* or *akpu* in developing countries such as Nigeria and the use of rivers and streams for the processing calls for impact studies on the water quality of such water bodies. This is in addition to the fact that most of the water bodies serve the purpose for drinking and other domestic activities.

Materials and Methods

Description of the study area

The study area is Southern Nigeria. Specifically, the area is located in the north central area of Delta State of Southern Nigeria. The area is criss-crossed by a number of streams and rivers. The water bodies in the area are of importance; as a source of drinking water, processing of agricultural products (cassava), washing, bathing and subsistence artisan fishing. For the purpose of this study, three water bodies that serve the purpose of cassava processing were selected. The water bodies are; Atochi, Inyite and Iyida streams. The water bodies are located between latitude $5^{o}43^{1}$N and $5^{o}30^{1}$N and longitude $6^{o}20^{1}$E and $6^{o}12^{1}$E (Figure 2.) They are non-tidal freshwater ecosystem that are principally fed by ground seepage from aquifer in the thick rainforest in the area and, secondly, by precipitation and surface runoff from riparian communities. The water bodies traverse major cassava farming communities such as Isheagu, Nsukwa, Abah Unoh among others.

The area is within the humid tropical zone with defined dry (November – March) and rainy (April – October) seasons. The rainy season is brought about by the Southwest trade wind blowing across the Atlantic Ocean. The dry, dusty and often cold Northeast trade wind blowing across the Sahara desert dominates the dry season and brings a short spell of harmattan[14]. The relative humidity of the area is high with values ranging from 70% in January to 80% in July. Previous study[14] of the area reveals the average atmospheric temperature to be 25.5ºC in the rainy season and 30ºC in the dry season months (19.8 - 50.1mm).

The ecology of the area is characterized by a vast flood plain built up by accumulation of sedimentary deposits washed down into the Niger and Benue Rivers.. The vegetation of the area is characterized by sandy coasts, ridge barriers, brackish or saline mangrove forest; fresh water swamp forest, and tropical rain forest. The area is the largest wetland in West Africa and one of the largest mangrove forests in the world[15]. The geology of the Niger Delta area is such that the area comprises a lower unit (Akata formation, Eocene 600-6000m thick), a middle parallic unit (Agbada formation, Eocene 300-4500m thick) and an upper continental sequence of (Benin formation, Miocene 200-2000m thick) [(16)].

Cassava processing technique in the study area

Cassava root consists of 60 to 70% water and has a shelf life of 2 to 3 days. Once harvested, it has to be either consumed immediately or processed into more stable product forms. Processing it into dry form reduces the moisture content and converts it into a more durable and stable product with less volume, which makes it easier for transportation. Processing is also necessary to eliminate or reduce the level of hydrocyannic acid (HCN) or cyanide in the crop and to improve the palatability of the food products. Processed cassava products are also used as raw materials for a number of small- or medium-scale industries in Africa. Both the tubers and leaves of cassava contain cyanide, which can be poisonous. The poisonous levels depend on the variety of the crop. Thus, to ensure that cassava tubers and leaves are safe for human consumption, the HCN must be removed or considerably reduced. Depending on the method used to process cassava, cyanide level can be reduced by between 69.85 to 100%.

The tubers are detoxified by hydrolysis of linamarin and lotaustralin by the enzyme linamarinase located in the root peels, into HCN (hydrogen cyanide), which is volatile and evaporates rapidly at temperatures above 28 ^{0}C[7]. Some measure of detoxification can also be achieved by mechanical disintegration (pounding, grating or chipping the tubers).

Cassava processing techniques in the study area are many and varied depending mostly on the end product so desired. In this study, the most commonly consumed product of cassava was considered and in this case *akpu or fufu*.

The flow chart of producing *akpu or fufu* from fresh cassava tubers is depicted in Figure 1. The traditional process of *fufu* production involves: (i) Steeping (soaking) of peeled and washed cassava roots for 5-7 days. Steeping is usually done in jute bags in the streams. (ii) Fermentation, which takes place during the steeping stage, after which the fermented tubers are mashed and sieved with baskets or perforated aluminum basins to remove the chaff. (iii) Dewatering, boiling and pounding or kneading of resultant pulp in a mortar.

Sampling Sites

Three surface water sampling sites were established along some portion of each of the studied water bodies (Atochi, Inyite and Iyida streams) (Figure 1). Detailed description of the sampling sites is presented in Table 1. This pattern of sampling technique was devised to give a profile of pollutants distribution from the fall out point (Point B), and upstream and downstream.

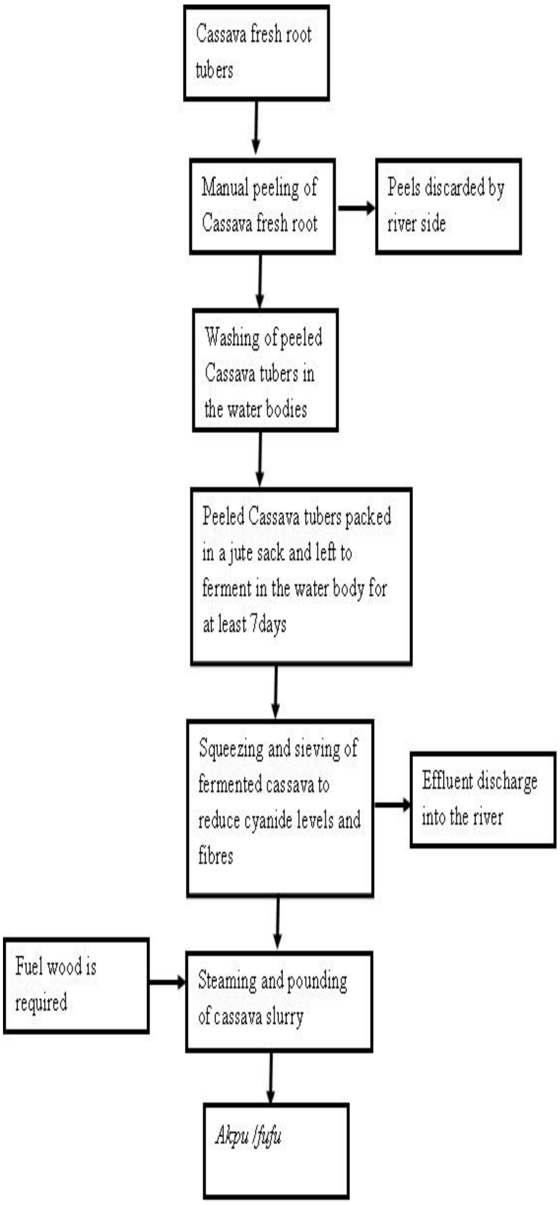

Fig. 2: Flow Process for *Akpu/fufu* production from cassava

Table 1: Description of sampling sites

Site Code	Description
A	About 1km upstream from Site B (fall out point). There are no significant human activities except for fishing activity.
B	High presence of human activities (bathing, fetching of drink water, washing of clothes, and cassava fermentation).
C	About 1km downstream from Site B (fall out point). There are no significant human activities except for fishing activity.

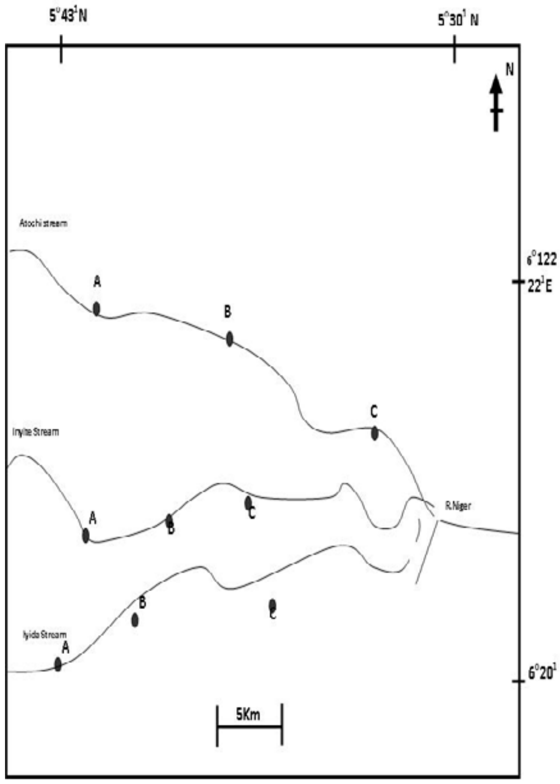

Fig. 1: Map of the water bodies showing sampling points

Sampling procedures

Water samples from the streams were collected in plastic containers pre-treated by washing them with 0.1M dilute hydrochloric acid and sun-dried. At each of the sampling site, the plastic containers were first of all rinsed with the water to be collected. One container at a time, with its lid closed was then dipped into the water body to a depth of about 30cm from the surface where the lid was removed to fill the container with water. The lid was replaced immediately, and the container with the water sample taken out of the water body. (Replacing the lid of the container at the sampled depth excludes air and prevents contamination of the water sample with microorganisms from the environment). Samples for microbial analysis were collected in sterilized McCartney glass bottles and stored in an ice-chest. All water samples were transported immediately to the Federal University of Petroleum Resources, Department of Environmental Science Effurun,Delta State laboratory for analysis.

Water samples for the study were collected on a weekly basis for a period of four months within the rainy season (June-September) for the year 2013.

Measured parameters and methodology

Parameters analysed for in all samples collected were: pH, electrical conductivity, turbidity, temperature, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), dissolved oxygen (DO), total dissolved solids (TDS), phosphate, sulphate, nitrate, hydrocyanic acid (HCN), and total microbial count (TMC). The flow velocity, depth and width of each of the studied water bodies were also determined. These parameters are good environmental impact indicators for monitoring drinking water quality [17,18].

The pH, turbidity, electrical conductivity, dissolved oxygen (DO), total dissolved solids (TDS) were measured *in-situ* using a multi-parameter water quality meter (model 600 UPG). The multi-parameter water quality monitor was properly checked and calibrated before and after use. Biochemical oxygen demand (BOD) of the water samples was determined using the Winkler Titration Method [17]. Total suspended solids (TSS) in the water samples were determined using the weight loss method[18]. Hydrocyanic acid (HCN) concentration in the water samples was determined using the gravimetric method [19]. Nitrate concentration of the water samples was determined using the ultraviolet spectrophotometric screening technique. (Unicam uv/visible spectrophotometer-MS/27). The method involves reading of the absorbance of the sample solution in the spectrophotometer at 410nm. Values are used to plot calibration graph and the concentration of nitrate in the sample was read from the calibration curve using the regression equation[17]. Concentrations of sulphate and phosphate were read directly from the spectrophotometer at a wavelength of 420 nm. The method involves preparation of standard and sample solutions and absorbance read at 420nm. Calibration curves are plotted from which sample concentrations are obtained[17].Total microbial count of samples was determined using the rapid agar dipstick method. The choice of the rapid agar dipstick method is based on it's ease of application and reliability; it can be used on site and is widely reported in literature [20, 21, 22, 23, 24].An agar nutrient dipstick was dipped into the sample for 20 minutes. The stick was then removed and incubated in a warm oven for 24 hours. The population of microorganisms was determined by comparing it with a calibrated chart provided by the manufacturers (Boots Micro – Check Company, Nottingham, UK).

Water flow velocity was measured three times by timing a float (average of three trials) as it moved over a distance of 10 m in the middle of the channel [25]. Depth and width were measured in the sample area using a calibrated stick.

The water quality at each of the sampling points in the studied water bodies (streams) was assessed using the Water Quality Index (WQI) as reported [26]. Equation 1 gives the water quality index.

$$\text{WQI} = \text{Log}\frac{DO^{1.5}}{3.8^{TP}\,Turb^{0.15}15^{TMC/10000} + 0.14EC^{0.5}} \quad 1$$

Where, DO is the dissolved oxygen (% oxygen saturation); Turb is the Turbidity (nephelometric turbidity units (NTU); TP is the total phosphates (mg/L); TMC is the total microbial count (cfu /100 mL) and EC is the electrical conductivity in (µS/cm at 25°C).

Results and Discussion

Results indicating the physico-chemical characteristics of the surface water bodies (streams) collected at the different sampling points along some portion of the streams are presented in Table 2. Results indicates that, the surface waters are slightly acidic with pH ranging between 5.70 and 5.90 especially at point A and at sampling point C between 5.90 and 6.10. The acidic pH at these points (A and C) may have resulted from humic acid (HA) formed from decaying organic matter (leaves) which is consistent with the report of the Niger Delta swamp environment [27,28]. However at point B the pH values range between 3.5 and 4.1 indicating an acidic environment. This may have resulted from substances such as hydrocyanic acid that may have entered the water during the fermentation and washing of cassava. Water bodies receiving untreated cassava water have been reported to be highly acidic, sometimes with pH as low as 2.6 [29]. This acidity is unsuitable for the survival of freshwater fish and bottom dwelling invertebrates [12] and also below values recommended for good quality water [30].

Temperature of surface water bodies varied between 27.00 and 27.30°C and between 27.0 and 27.5 ^{0}C for sampling points A and C respectively. Temperature values recorded in sampling point B ranged between 28.5^{O}C and 29.0^{O}C, indicating a generally warmer condition which may be attributed to the activities (bathing, fetching of drink water, washing of clothes, and cassava fermentation) taking place in that sampling point. However, temperatures recorded in surface water bodies at the sampling points A, B and C are consistent with temperatures recorded in surface water bodies in the tropics [27].

The turbidity of the water bodies at sampling points A and C ranged between 2.3 and 2.9 nephelometric turbidity units (NTU) and between 3.1 and 3.6 NTU respectively. The low levels of turbidity values accounts for the visible observation of the river/stream beds from the surface level. However, at point B turbidity values ranging from 7.5 to 8.0NTU were recorded within the area. The higher turbidity values may not be attributed to effect of cassava prosessing but presence of human activities such as washing of clothes which is a common occurrence at sampling B.

The electrical conductivity of the water bodies at sampling points A and C ranged between 14.3 and 19.5 µS/cm and between 15.6 and 17.0µS/cm respectively. At sampling point B electrical conductive values ranged from 22.5 and 28.7 µS/cm. The levels of electrical conductivity may be attributed to the presence of rocky materials prevalent in the area as have been similarly observed [31]. In addition the ionisation of HCN into its polar units may have contributed to higher conductivity. Similar electrical conductivity variation along the length of Orogodo River has been reported[32].

The observed DO levels at sampling point A (5.40 – 7.40 mg/l) and at sampling point C (6.1 -6.8 mg/l) are adequate for marine life survival. DO level maintained above 5 mg/l is required for the survival of fish and other aquatic life [33]. At sampling point B, DO levels (3.9 - 4.4 mg/l) were generally below that that can maintain aquatic life [33]. DO in water is usually depleted, if organic matter undergoing biological degradation is present such as has been observed at point B.

The observed COD and BOD levels at sampling points A (270 - 330 and 130 - 290 mg/l respectively) and at sampling point C (290 – 340 and 110 – 210 mg/l respectively). At sampling B COD and BOD values are (4000 – 4300 mg/l and 1250 and 1970 mg/l respectively). The COD levels in the water bodies especially at point B is low compared with 30,000 mg/l that is reported for starch processing companies[3]. The relatively high levels of BOD can be attributed to the presence of decaying organic matter especially at sampling point B. The obtained BOD levels at sampling B is consistent with cassava wastewater released by medium-scale processors in India [34]. These values (at sampling points A and C compare well with those reported for other water bodies in the Niger Delta [27]. Using the BOD values as standard for evaluation the water bodies in the area may be classified as moderately polluted at point A and C and heavily polluted at point B [17].

The observed TDS and TSS levels at sampling points A (380 - 430 and 280 – 510 mg/l respectively) and at sampling point C (376 - 450 and 330 – 590 mg/l respectively). At sampling B TDS and TSS values are (11,300 – 12,340 mg/l and 2960 – 7350 mg/l respectively).

The hydrocyanic acid levels of the water bodies at sampling points A and C ranged between 0.7 and 1.4 mg/l and between 1.5 and 2.1 mg/l respectively. The low levels of hydrocyanic acid may be due to unidentified sources of cyanide. However, at point B cyanide values ranging from 22.0 to 27.1 mg/l were recorded within the area. The higher hydrocyanic acid is directly related to the processing of cassava which is a common occurrence at sampling B. As cyanogenics glucosides, linamarin and luatostralinare synthesised in tissues of cassava plant, in the course of cassava processing cyanide is released into the environment in the form of hydrocyanic acid [7]. Cyanide content in by-products and wastes also depends on the cassava variety. The high yield varieties used throughout the study area generally contain high amounts of HCN. For example, an equivalent of 13mg HCN per liter of water has been reported [9].

The nutrient content of water is an indication of the degree of sustainability of the system of primary production. At very high concentration of nutrients, eutrophication in river bodies may be possible. The ranges of phosphate, sulphate and nitrate in the study river bodies at sampling points A and C were (0.30 – 0.92 and 0.20 – 0.60), (3.6 – 5.8 and 5.2 – 6.7) and (1.76 – 1.80 and 1.03 – 1.20) mg/l respectively. However, at point B phosphate, sulphate and nitrate values ranging from (1.95 – 2.80 mg/l), (14.5 and 16.6 mg/l) and (3.30 – 3.70mg/l) respectively were recorded within the area. The high level of sulphate especially at point B can be attributed to the human activities such as washing of clothes with the use of detergents whose main component is sulphate and may not be related to the activity of cassava processing[35]. The level of nitrate across the sampling points in the water bodies may be due to the natural process of photochemical oxidation of nitrogen to give oxides of nitrogen during lightning and thunderstorms, which becomes soluble during rainfall. Similar observations have been made for the concentration of nitrate in harvested rainwater [26, 36, 37].

$$N_2 + O_2 \longrightarrow NO_2 + H_2O \longrightarrow HNO_3 + HNO_2$$

Total microbial count (TMC) in the water bodies at sampling points A and C ranged between 180 and 195 (colony forming unit) cfu/ml and between 170 and 210 cfu/ml respectively. However, at point B TMC values ranging from 370 to 410 mg/l were recorded within the area. The higher levels of TMC at sampling point B may result from the discharge of cassava processed water into the streams at that point. When this water is released directly into streams and rivers, residual starch can cause rapid growth of bacteria, resulting in oxygen depletion and detrimental effects on aquatic life [38].

Results of the assessment of the water quality of the streams at the sampling points using the water quality index as reported [38]are presented in Table 3 and illustrated graphically in Figure 3.

The water quality index (see Table 3.0) show that the values of the index are generally greater than 2 at sampling points A and C across the three water bodies. This means that the water quality at sampling points A and C in the three water bodies is acceptable. However, at sampling point B across the three water bodies the water quality index ranges between 0.6 and 1.06. This means that the water quality at sampling point B across the water bodies is poor indicating that most parameters have deteriorated.

Table 2.0: Mean Values of Measured Parameters in Streams

	Atochi Stream			Inyida Stream			Inyite Stream		
	A	B	C	A	B	C	A	B	C
pH	5.8± 0.04	3.7± 0.03	5.9± 0.04	5.9± 0.03	4.1± 0.04	6.0± 0.04	5.2± 0.04	3.5± 0.04	6.1± 0.04
Temperature(ºC)	27.0± 0.06	29.0± 0.06	27.2± 0.05	27.1± 0.06	28.5± 0.05	27.5± 0.06	27.3± 0.05	28.7± 0.06	27.0± 0.05
Turbidity(NTU)	2.9± 0.01	8.0± 0.01	3.6± 0.01	2.3± 0.01	7.5± 0.01	3.1± 0.01	2.9± 0.01	7.9± 0.01	3.5± 0.04
Electrical Conductivity (µS/cm)	19.5± 0.2	26.0± 0.4	17.0± 0.5	14.3± 0.2	28.7± 0.5	15.6± 0.4	18.9± 0.2	22.5± 0.4	16.5± 0.3
DO (mg/l)	6.30± 0.01	4.10± 0.01	6.60± 0.01	6.40± 0.01	3.90± 0.01	6.10± 0.01	6.80± 0.01	4.40± 0.01	6.20± 0.01
COD (mg/l)	270± 0.4	4000± 0.5	290± 0.4	330± 0.6	4300± 0.5	310± 0.4	280± 0.6	4210± 0.5	340± 0.4
BOD (mg/l)	130± 0.2	1400± 0.3	110± 0.2	290± 0.2	1250± 0.2	204± 0.4	190± 0.4	1970± 0.2	210± 0.4
TDS (mg/l)	430± 0.01	11,300 ±0.01	450± 0.01	410± 0.01	11, 970 ±0.01	376± 0.01	380± 0.01	12,340 ±0.01	450± 0.01
TSS (mg/l)	307	2,960	330	280	7350	590	510	5,660	475
Hydroxyl anicacid (mg/l)	1.4± 0.01	22± 0.01	2.1± 0.01	0.9± 0.01	27.1± 0.01	1.7± 0.01	0.7± 0.01	26.5± 0.01	1.5± 0.01
Sulphate (mg/l)	4.8± 0.02	14.5± 0.02	5.2± 0.02	3.6± 0.02	16.6± 0.02	6.3± 0.02	5.8± 0.02	15.7± 0.02	6.7± 0.02
Phosphate (mg/l)	0.30± 0.01	2.80± 0.04	0.20± 0.02	0.80± 0.01	1.95± 0.02±	0.20± 0.01	0.92± 0.02	2.45± 0.02	0.60± 0.02
Nitrate (mg/l)	1.76 ± 0.02	3.30± 0.02	1.20± 0.04	1.10± 0.03	3.40± 0.6	1.03± 0.02	1.80± 0.02	3.70± 0.5	1.10± 0.02
TMC (cfu/ml)	190± 0.4	370± 0.02	201± 0.6	195± 0.02	410± 0.02	170 ± 0.02	180± 0.02	390± 0.02	210± 0.02
Water flow velocity (m/s)	0.6- 1.2 m/s								
Depth of water bodies (m)	1.2-2.9m								
Width of water bodies (m)	27 -43m								

Table 3: Water Quality Index WQI) of the Streams

Streams	Water Quality Index		
	Sampling Points		
	A	B	C
Atochi	2.31	0.60	2.38
Inyite	2.07	0.86	2.69
Inyida	2.11	1.06	2.35

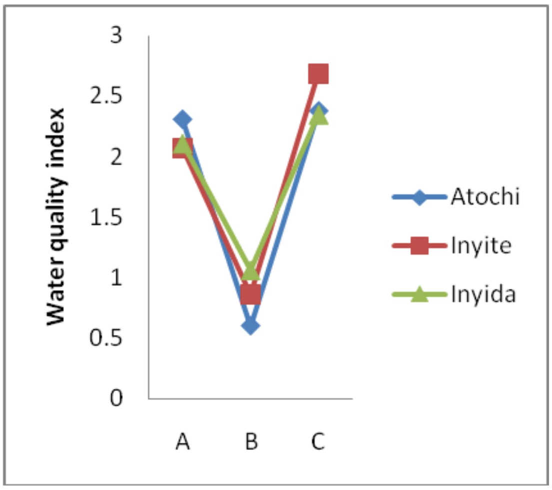

Fig. 3: Water quality index at the sampling points of the studied streams

Conclusion

The environmental impact of cassava processing in some tropical streams in Delta State southern Nigeria has been studied. The continuous increase in supply and demand for cassava products such as *fufu* or *akpu* in developing countries such as Nigeria and the use of rivers and streams for the processing have necessitated the study. This is in addition to the fact that most of the water bodies serve the purpose for drinking and other domestic activities.

Results of the assessment of the water quality of the streams at the sampling points indicate that the water quality at sampling point B is poor. Cassava processing related water pollution problems has been observed. The water used in aqueous extraction methods helped to release hydrocyanic acid into the water bodies. From the study, there is little risk of water contamination from cyanide on a broad scale. However, site-specific effects can be significant especially at point B.

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