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Assessment of cassava waste effluent effect on some water sources in Ilorin, Nigeria

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ABSTRACT

This paper reports effect of cassava waste effluent on surface and underground water resources in Ilorin, Nigeria. Three cassava processing sites located near streams and well at Agbo-Oba, Tanke and Oko-Erin areas within Ilorin City were studied. Effluents were collected during rainy season (August and September) and part of the dry season (January and February). Physical, chemical and bacteriological parameters of the cassava waste effluent collected were analyzed using World Health Organization (WHO) standards for drinking water as base line. From results, the average cyanide content (0.35 mg/L) for the samples was found to be higher than the level allowed (0.1 mg/L) for drinking water. Also the least value of 15.5 mg/L color of the total samples was higher than the recommended value (15.0 mg/L), while the 0.03 and 0.15 *Escherichia coli* values obtained were far above zero count/100 ml recommended by WHO as permissible for drinking water. Therefore, cassava waste effluent discharged from the processing sites monitored needs to be treated thoroughly before discharging them to adjacent water sources.

Keywords: Cassava waste effluent, pollution effect, surface water, ground water.

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INTRODUCTION

Liquid waste effluent contributes major health hazard especially in areas that were not properly managed. In most developing nations of the world, liquid waste generates through the activities of agricultural, industrial and domestic wastes discharge into water sources can take its toll on human health. This may be why generally in many developing countries, endemic and epidemic gastrointestinal (cholera, dysentery and water borne) diseases are prominent in communities (Daschner et al., 1996; WHO 2004). The World Health Organization (2015) reported that 80% of diseases afflicting man are water borne in developing countries which are directly connected with contaminated drinking water and this can cause endemic and epidemic gastrointestinal disease in the world (WHO 2004; Jones et al., 2006). It was reported that numerous epidemics of waterborne disease had caused gastrointestinal illness in Canada (Sterling et al., 2001; Jones et al., 2006).

It was reported that the majority of the wastes generated in urban market and domestic wastes in the developing nations as agricultural waste which reported as a high chemical content that is injurious to health (US-EPA, 1992). Leachates from wastes at dumpsite are potential sources of contamination of both ground and surface water (Odukoya et al., 2002). A staggering 80 to 90% of all wastewater generated in developing countries is discharged directly into surface water bodies (UN Water, 2008). Unmanaged wastewater can be a source of pollution, a hazard for the health of human populations and the environment alike. The Millennium Ecosystem Assessment (MEA, 2007) reported that 60% of global ecosystem services are being degraded, and highlighted the inextricable links between ecosystem integrity and human health and wellbeing. Ahmad and Saadieh (2007) reported that water quality is being drastically affected by untreated waste water, sewage, industrial waste dumping and agricultural run-off. This had resulted in gradual contamination of water quality in the Lebanese rivers.

Pollution of surface and ground water sources by the effluent discharged depends on the composition of the

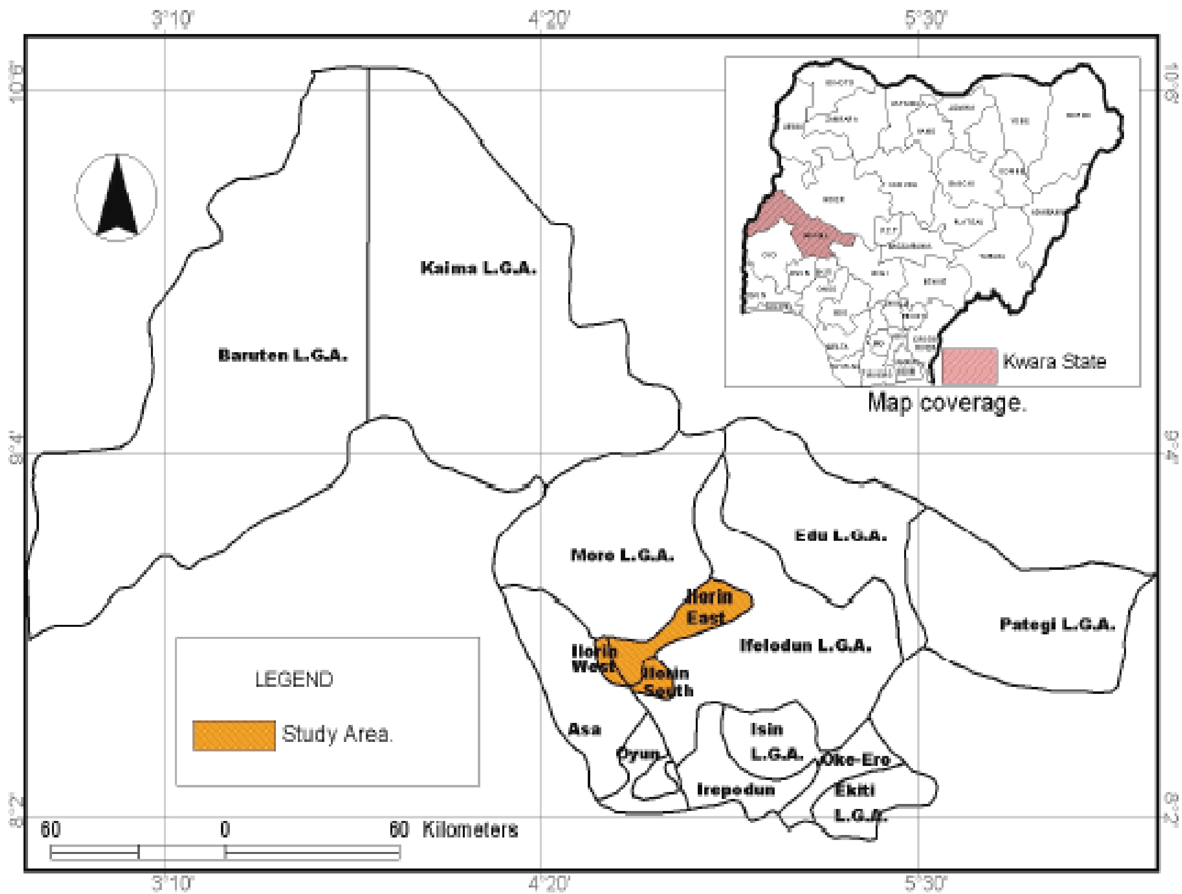

Figure 1. Map coverage of ecological zone of Ilorin (Source: CTN, 2015).

waste, distance apart and the medium or layer through which the discharge travels. This means the flow of wastes can be downward into the ground or outward flow into streams or other surface water (Ololade et al., 2009). The aquatic animals that reside in around surface water like lakes, ponds, streams, pools and reservoirs are also affected by the contaminants through over flow or seepage into improperly constructed surface and ground water systems due to pollutants from organic compounds and biological matter that could exhibit toxic effect on aquatic life and the public (NYWEA, 2007). Natural recovery is an attractive alternative for managing many contaminated cassava sediment sites. This process involves leaving contaminated sediments in place and allowing ongoing aquatic, sedimentary and biological processes to reduce the bio-availability of contaminants in order to protect them (NRC, 2001).

Cassava processor discharges large volumes of cassava waste water that contain large amounts of organic matter, suspended solids and various inorganic constituent. Toxic substances are perhaps the most serious problem in water; these include cyanide (Cn^-), arsenic (As), excess boron (B), excess chloride (Cl^-), excess manganese (Mn^{2+}), lead (Pb^{2+}) and hydrogen which affects human health and are detrimental to agricultural crops and industrial purposes. Also, the presence of human pathogen is an equally important criterion, since coliform bacteria are excreted in large number by man and animal, and their presence in water are potential sources of disease producing micro-organism, this has been a major non-point source (NPS) pollution problem (US-EPA, 2002; Karathanasis et al., 2006). It is important to determine the factors that are responsible for pollution, its effect on man and his activities, the biochemical quality of the water under study with regard to the World Health Organization (WHO) and Federal Environmental Protection Agency (FEPA) standards for drinking water and to suggest ways of eradicating it in our society.

Ilorin city is located in the Southern Guinea Savannah ecological zone of Nigeria, there are two seasons; wet season from March to October and dry season from November to February with heavy rainfall occurrence between June and September, although not showing on the map in Figure 1. A study was conducted by Olalekan (2002) that the water fetched from the stream near the cassava processing site at Agbo-oba was used by the people making cement blocks, for farm irrigation, crop

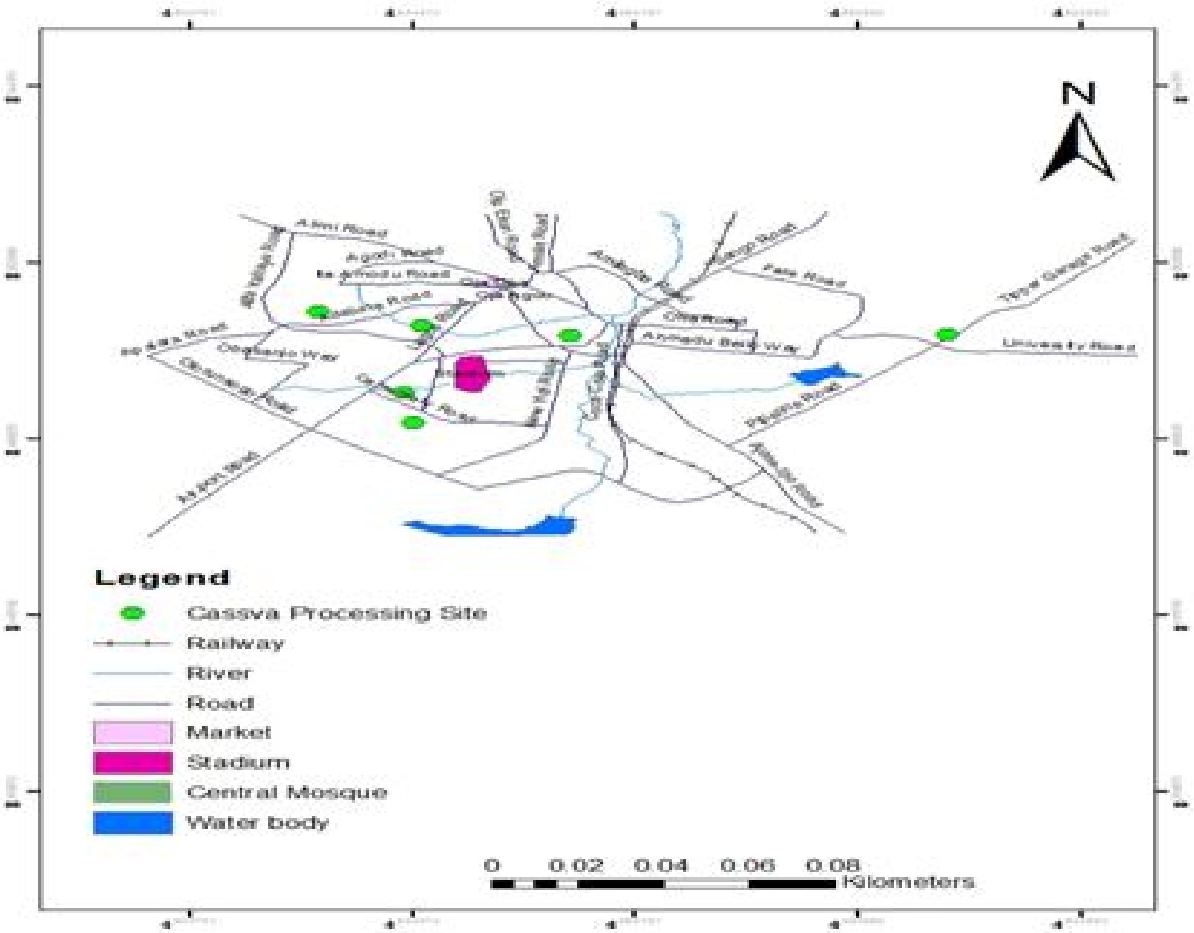

Figure 2. Map showing the study areas (Kaseem, 2015).

Table 1. Features of the water sources.

Location	Agbo-Oba	Tanke	Oko-Erin
Water source	Stream	Well	Well
Distance from point of discharge	15.5 m	10.4 m	13 m
Covering	Open	Covered	Covered
Lining	flowing water	Lined	Unlined
Material for lining	-	Concrete	natural clay
Materials for covering	-	Plank	iron cover
Physical condition	not conducive	fairly conducive	fairly conducive
Remark	unhygienic water	fair ideal environment	Not ideal environment
Uses	block-making, irrigation, bathing	drinking, bathing, cooking, washing	drinking, bathing, cooking, washing

processing, washing and bathing. It was also observed that water sample collected from the wells near the processing sites at Tanke and Oko-Erin was used for drinking and domestic purposes like washing, flushing, bathing and cassava processing. The three cassava processing sites are shown in Figure 2. In addition, Table 1 presented the features of the water sources at the three sampling locations. It is therefore necessary to evaluate the extent of pollution of effluent discharged by cassava waste on adjacent surface and ground water systems. This study aimed at providing baseline data necessary for assessing the pollution effect of cassava waste effluent on surface and ground water sources in Ilorin city. It quantifies the pollutant loading into nearby streams and wells, paving the way for a total evaluation of water pollution emanating from cassava processing sites in Ilorin metropolis.

METHODOLOGY

Study area

The study areas are located within Ilorin city, capital of Kwara State of Nigeria with Longitude 4° 35′ E and Latitude 8° 30′ N. The capital city, Ilorin is situated 306 km inland from the coastal city of Lagos and 500 km from the Federal Capital, Abuja (CTN, 2015). This is a summer rainfall area, with an annual rainfall range of 1000 to 1500 mm. The months of December and January coincide with the cold and dry harmattan period. Average maximum temperature varies between 30 and 35°C (CTN, 2015). The study areas located within Ilorin city were the three cassava processing sites at Agbo-Oba, Oko-Erin and Tanke as shown in Figure 2.

Field data collection

The water sample collection was done in three stages; sample was collected from the point of discharge of cassava waste effluent (sample A), then 3 m away from the discharged point (sample B) and the water from stream and wells (sample C). The water samples were taken twice on monthly basis during the raining season (August and September, 2011) and dry season (January and February, 2012), generally in the middle of the month, using auto clave bottles which were washed initially with acid solution and distilled water (1:1 HCl / water). After collection, samples were kept at room temperature and analyze within 24 h.

Analysis of physical and chemical parameters

In the laboratory, the level of colour, Temperature T, turbidity (T), odour, taste, total solids (TS), dissolve solids (DS), and suspended solids (SS), Cyanide (Cn^-), Ammonia (NH_3), Carbon dioxide (CO_2), Calcium (Ca^{2+}), Copper (Cu^+), Chlorine (Cl^-), Lead Pb^{2+}, Iron (Fe^{2+}), Manganese (Mn^{2+}), Nitrate (NO_3^-), Sulphate (SO_4^{2-}), pH and total hardness (TH) were analyzed. The initial turbidity (on the raw water) and final turbidity was measured using portable turbid meter and the results were in function of with nephelometric turbidity units (NTU). The pH, TDS and salinity were measured using sension 378 Laboratory Multiparameter meter. Sulphate, Nitrate and phosphate measurements were analyzed by Hach DR/2500 laboratory spectrophotometer using standard methods (Hach, 2004; Ahmad and Saadieh, 2007).

Nitrate was analyzed using method 8039 (Powder Pillows or Accuvac Ampuls) and this could be called a cadmium reduction method (a technique-sensitive method). In this case, cadmium metal reduced nitrates in the sample to nitrites, this resulted to the reaction of Nitrite ions with sulphate acid in an acidic medium to form an intermediate diazonium salt. Then salt reacted with gentisic acid to form an amber colored solution. Test results were measured at 500 nm in function of mg/L NO_3^-.

Sulphate was carried out using method 8051 (Powder Pillows or AccuvacAmpuls). SulfaVer 4 method is based on the turbidity due to the presence of sulphate. Sulphate ions in the sample reacted with barium sulfaver 4 and form a precipitate of barium sulphate. Sulfaver 4 also contains a stabilizing agent to hold the precipitate in suspension. It was observed that the amount of turbidity formed was proportional to the sulphate concentration. Test results were measured at 450 nm and recorded in function of mg/L, SO_4^{2-}.

Phosphate was analyzed by DR/2500 using the method 8048 (Powder Pillows or Accuver Ampuls), also known as phosver 3 (ascorbic acid) method. Phosphorus active (orthophosphate) reacted with molybdate complex in an acid medium to produce a mixed phosphate/molybdate complex. After reduction of the complex, ascorbic acid gave an intense molybdenum blue color. Test results were measured at 880 nm as a function of mg/L, PO_4^{3-}.

Microbiological analysis

For bacteriological tests, *Escherichia coli (E. coli)*, biological oxygen demand (BOD) and total coliform counts were carried out immediately on the sample collected on getting to the laboratory. The *E. coli*, BOD and total coliform counts were performed with membrane filtration methods (m-ColiBlue24). In 24 h, Hach's m-coliBlue 24 broth gave result for total coliforms and *E. coli* simultaneously. *E. coli* colonies appeared in blue while the rest of the coliforms showed red. In order to make the count more feasible, dilutions were made to concentrated cassava waste effluents.

RESULTS AND DISCUSSION

This work assessed the pollution of effect of cassava waste effluent discharged on surface and ground water in three locations of Ilorin city during the rainy and dry seasons. The results of the physical, chemical and bacteriological analyses carried out on water samples were presented and compared with World Health Organization (WHO) limits for drinking water. Tables 2 and 3 presented the analysis of water samples collected from Agbo-Oba processing site in the rainy and dry season. The respective values of turbidity, 5.55 and 7.75

Table 2. Analysis of water samples at Agbo-Oba during rainy season.

Tests	Sample A	Sample B	Sample C
Cn^- (mg/L)	0.25[a]	2.81[a]	1.50[b]
TH(mg/L)	10.30[a]	25.85[b]	50.90[c]
Ca^{2+} (mg/L)	7.80[a]	19.55[b]	39.00 [c]
Mg^{2+} (mg/L)	2.50[a]	6.20 [b]	11.95[c]
Cl^- (mg/L)	8.95[a]	10.00[b]	12.50[c]
Mn^{2+} (mg/L)	0.90[a]	0.45[b]	2.10[c]
SO_4^{2-} (mg/L)	19.50[a]	11.40[a]	22.00[a]
pH	6.40[a]	4.26[b]	4.39[b]
Color	15.10[a]	17.20[b]	18.00[c]
BOD (mg/L)	5.00[a]	5.20[a]	5.25[a]
E. coli	0.10[a]	0.04[b]	0.05[b]
T	5.55[a]	5.70[a]	6.15[b]
DS (mg/L)	400[a]	560.50[b]	721.00[c]
SS (mg/L)	850[a]	880.50[a]	951.50[b]
TS (mg/L)	1200[a]	1440[c]	1674[c]

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at p< 0.05 in the two-sided test of equality for column means.

Table 3. Analysis of water samples at Agbo-Oba during the dry season.

Tests	Sample A	Sample B	Sample C
Cn^- (mg/L)	0.35[a]	2.80[b]	1.40[c]
TH (mg/L)	10.70[a]	25.70[b]	51.50[c]
Ca^{2+} (mg/L)	8.00[a]	19.80[b]	39.00[c]
Mg^{2+} (mg/L)	2.70[a]	6.28[b]	12.50[c]
Cl^- (mg/L)	9.20[a]	10.15[b]	13.20[c]
Mn^{2+} (mg/L)	1.10[a]	0.60[b]	2.30[c]
SO_4^{2-} (mg/L)	17.75[a]	20.50[b]	21.40[c]
pH	5.37[a]	4.25[b]	4.36[c]
Color	16.00[a]	17.20[b]	18.00[c]
BOD (mg/L)	5.00[a]	5.10[a]	15.00[a]
E. coli	0.15[a]	0.03[b]	0.05[b]
T	7.75[a]	5.60[b]	6.25[c]
DS (mg/L)	430.00[a]	480.00[b]	580.00[c]
SS (mg/L)	690.00[a]	790.00[b]	880.00[c]
TS (mg/L)	1190.00[a]	1270.00[a]	1360.00[b]

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at p< 0.05 in the two-sided test of equality for column means.

mg/L were recorded for the water samples collected from a nearby stream in the rainy and dry season. This may be attributed to the higher production of effluent and hence, their direct discharge into the stream. This indicated that high concentrated samples were obtained in January and February, 2012 while rain had diluted the samples collected in August and September, 2011. The values of the colour recorded for stream water in rainy and dry season were 15.10 and 16.0 mg/L, respectively. The colour of water samples was not attractive, the sample that was taken from the point of discharge was white, this indicated high concentration of the effluent while the sample collected at 3 m distance from the discharge point was brown, this showed that the sample had partially fermented and probably reacted with soil particles.

From Tables 2 and 3, it was observed that these constituents; Ca^{2+}, Mg^{2+}, Cl^-, Mn^{2+}, DS, TS and Turbidity were significantly different at $P < 0.05$ across the three sampling points. Similar trend was also observed for TH and color across the sampling points. This could be

Table 4. Correlation analysis of water samples at Agbo-Oba during rainy season.

	Cn^{-1}	TH	Ca^{2+}	Mg^{2+}	Cl^{-}	Mn^{2+}	SO_4^{2-}	Ph	Color	BOD	*E. coli*	T	DS	SS	TS
Cn^{-}	1														
TH	-.953**	1													
Ca^{2+}	-.957**	1.000**	1												
Mg^{2+}	-.948**	1.000**	.999**	1											
Cl^{-}	-.963**	.974**	.977**	.969**	1										
Mn^{2+}	-.928**	.786**	.792**	.779**	.833**	1									
SO_4^{2-}	-0.324	0.23	0.23	0.236	0.31	0.52	1								
pH	0.538	-.754**	-.749**	-.760**	-.676*	-0.191	0.214	1							
Color	-.857**	.956**	.954**	.959**	.884**	.612*	0.022	-.871**	1						
BOD	-0.509	0.486	0.495	0.473	0.562	0.33	-0.262	-0.503	0.535	1					
E. coli	0.417	-.664*	-.655*	-.677*	-0.53	-0.079	0.189	.950**	-.813**	-0.253	1				
T	-.854**	.810**	.816**	.806**	.881**	.764**	0.4	-0.517	.739**	.731**	-0.34	1			
DS	-.909**	.991**	.990**	.991**	.956**	.698*	0.139	-.836**	.976**	0.523	-.743**	.787**	1		
SS	-.867**	.835**	.836**	.838**	.797**	.752**	0.222	-0.545	.851**	.591*	-0.482	.855**	.806**	1	
TS	-.901**	.988**	.987**	.988**	.956**	.688*	0.137	-.841**	.969**	0.513	-.746**	.775**	.999**	.781**	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

attributed to the variation in the concentrations of the constituents stated above chiefly Mg^{2+} and Ca^{2+}. The Cn^{-} and SS were found to be significantly different for Sample A but not significantly different from the sampling point, Sample B and C. The *E. coli* count and pH were not found to be significantly different for Samples B and C but significantly different from the sampling point within the stream. In addition, there was no significant difference between the SO_4^{-2} and biological oxygen demand (BOD) across the three sampling points.

Table 4 and 5 shows the correlation of chemical properties of the water samples gotten across three sampling points. The TH, Ca^{2+}, Mg^{2+}, Cl^{-}, Mn^{2+}, color, T, DS, SS, and TS were found to be negatively correlated with the Cn concentration. The Cl^{-1} had the most significant correlation (r = -0.963) with the Cn. The Ca^{2+} and Mg^{2+} had a perfect correlation ($p < 0.01$) with the TH, DS, TS, Cl^{-}, color, SS, T and Mn^{2+} following closely in that order. The pH and *E. coli* were negatively correlated ($p < 0.01$) with the total hardness, TH. It was observed that these parameters increased towards the stream exit. The Cl^{-1} was directly correlated ($p < 0.01$) with the Mn^{2+}, the color, the DS, the SS, the TS, and partially correlated with the pH and the Cn^{-}. No correlation was observed between the SO_4^{2-} and BOD and any of the parameters. The pH was negatively correlated with the most of the parameters apart from *E. coli* (r = 095) which was the most significant. Color was negatively correlated with the Cn and positively correlated with the other parameters apart from SO_4^{2-} and BOD. Comparing the rainy and dry seasons, most of the parameters were significantly different ($p < 0.05$) across the sampling points. The SO_4^{2-} correlated with most of the parameters. The most significant positive correlation (r = 0.95) was with color while the most significant negative correlation (r = -0.95) was with the pH.

Tables 6 and 7 presented the analysis of water samples collected from Tanke processing site in the rainy and dry season. The respective values of turbidity, 5.20 and 5.40 mg/L were recorded for the water samples collected from a partially lined well in the rainy and dry season. This indicated that less concentrated samples were obtained in August and September, 2011 (possibly diluted by rain) than samples collected in January and February, 2012. The values of the colour recorded for well water in rainy and dry season were 15.50 and 15.80 mg/L, respectively. The colour of well

Table 5. Correlation analysis of water samples at Agbo-Oba during the dry season.

	Cn^-	TH	Ca^{2+}	Mg^{2+}	Cl^-	Mn^{2+}	SO_4^{2-}	pH	Color	BOD	*E. coli*	T	DS	SS	TS
Cn^-	1														
TH	0.285	1													
Ca^{2+}	0.299	.999**	1												
Mg^{2+}	0.281	1.000**	.998**	1											
Cl^-	0.147	.987**	.986**	.988**	1										
Mn^{2+}	-0.347	.759**	.762**	.761**	.852**	1									
SO_4^{2-}	.653*	.901**	.905**	.902**	.832**	0.439	1								
pH	-.845**	-.751**	-.758**	-.748**	-.645*	-0.17	-.953**	1							
Colour	.644*	.892**	.904**	.887**	.833**	0.479	.953**	-.925**	1						
BOD	-0.002	.591*	.617*	0.575	.637*	.701*	0.378	-0.283	.607*	1					
E. coli	-.847**	-.631*	-.636*	-.637*	-0.542	-0.086	-.884**	.932**	-.831**	-0.137	1				
T	-.937**	-0.552	-0.558	-0.545	-0.416	0.101	-.821**	.953**	-.813**	-0.164	.871**	1			
DS	0.248	.979**	.987**	.976**	.980**	.810**	.857**	-.704*	.894**	.724**	-0.571	-0.499	1		
SS	0.442	.976**	.977**	.979**	.940**	.641*	.967**	-.850**	.923**	0.476	-.755**	-.666*	.943**	1	
TS	0.356	.880**	.881**	.890**	.884**	.655*	.868**	-.727**	.835**	0.44	-.785**	-0.508	.849**	.899**	1

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

water samples was fairly attractive, the sample that was taken from the point of discharge was white, and this indicated high concentration of the effluent while the sample collected at 3 m distance from the discharge point was brown, and this indicated that fermentation of the sample and reaction with soil particles occurred.

Table 8 presented correlation analysis of water samples collected in partially lined well near Tanke cassava processing site. Other parameters apart from BOD and *E. coli* showed significant difference ($p < 0.05$) across the sampling points. The pH was negatively correlated ($p < 0.01$) with most of the parameters, most especially colour ($r = 0.96$). The BOD also showed negative correlation ($p < 0.05$) with TH, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2}, colour, dissolved (DS), suspended (SS), and total (TS) solids. Table 9 showed correlation analysis of water samples collected from the well near Tanke cassava processing site. Most of the parameters across the sampling points were significantly different ($p < 0.05$). The pH and BOD from the sampling point were found to be significantly different ($p < 0.05$) from the sampling points in the exit area (sample B and C). This could be attributed to the significant correlation ($r = 0.873$) between them. Similarly trend was observed for the SS which also correlated with pH and BOD. Conversely, in terms of the dissolved solid (DS), value obtained from the sampling point (well) was significantly different ($p < 0.05$) from that of the exit. This could be attributed to its negative correlation with BOD and pH. There was no significant difference ($p < 0.05$) in T across the sampling points.

The correlation analysis of water samples constituents collected from Oko-Erin processing site in the rainy and dry season are presented in Tables 10 and 11. The respective values of turbidity, 5.40 and 5.70 mg/L were recorded for the water samples collected from an unlined well in the rainy and dry season. This resulted that less concentrated samples were obtained in August and September, 2011 (possibly diluted by rain) than samples collected in January and February, 2012. The values of the colour recorded for well water samples in rainy and dry season were 15.50 and 15.80 mg/L, respectively. The colour of water samples that was taken from the point of discharge was white, this indicated high concentration of the effluent while the sample collected at 3 m distance from the discharge point was brown, and this indicated the level of fermentation of the sample and reaction with soil particles.

The correlation analysis of the water samples constituents collected from an unlined well near

Table 6. Analysis of water samples at Tanke during rainy season.

Tests	Sample A	Sample B	Sample C
Cn^- (mg/L)	3.15^a	2.60^b	1.40^c
TH (mg/L)	9.05^a	25.00^b	50.50^c
Ca^{2+} (mg/L)	7.20^a	18.80^b	38.80^c
Mg^{2+} (mg/L)	1.80^a	6.20^b	12.20^c
Cl^- (mg/L)	8.60^a	10.40^b	12.70^c
Mn^{+2} (mg/L)	0.80^a	0.50^b	1.90^c
SO_4^{2-} (mg/L)	16.45^a	18.60^b	21.30^c
pH	6.70^a	4.22^b	4.40^c
Color	15.50^a	17.50^b	18.00^c
BOD (mg/L)	5.50^a	5.40^a	5.20^a
E. coli	0.08^a	0.03^b	0.06^a
T	5.20^a	$5.50^{a,b}$	5.80^b
DS (mg/L)	350^a	480.50^b	540^c
SS (mg/L)	690^a	700.50^b	860^c
TS (mg/L)	1041.5^a	1179^b	1400^c

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at p< 0.05 in the two-sided test of equality for column means.

Table 7. Analysis of water samples at Tanke during the dry season.

Tests	Sample A	Sample B	Sample C
Cn^- (mg/L)	3.25^a	2.70^b	1.40^c
TH (mg/L)	9.50^a	25.20^b	51.20^c
Ca^{2+} (mg/L)	7.50^a	19.20^b	39.00^c
Mg^{2+} (mg/L)	2.00^a	6.10^b	12.20^c
Cl^- (mg/L)	9.05^a	10.00^b	13.00^c
Mn^{2+} (mg/L)	1.00^a	0.60^b	2.20^c
SO_4^{2-} (mg/L)	19.35^a	21.00^b	23.45^c
pH	6.50^a	4.20^b	4.33^b
Color	15.80^a	18.00^b	20.00^b
BOD	5.80^a	5.00^b	5.10^b
E. coli	0.19^a	0.80^b	0.80^b
T	5.40^a	5.80^a	6.00^a
DS (mg/L)	470.0^a	500.0^a	630.00^b
SS (mg/L)	675.00^a	780.00^b	790.00^b
TS (mg/L)	1141.50^a	1280.00^b	1420.00^c

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at p < 0.05 in the two-sided test of equality for column means.

near Oko-Erin cassava processing site were presented in Table 12 and 13; the constituents Cn^-, TH, Ca^{2+}, Cl^-, SO_4^{2-} and pH were significantly different ($P < 0.05$) across the three sampling points. Similar trend was observed for the color, T, as well as DS, SS, and TS as a result of the significant correlation ($P < 0.05$) among them. The Mn^{2+} was found not to be significantly different in the sampling points (Sample A and B) but significantly different from the sampling point, C while *E. coli,* Mg^{2+} and BOD showed no significant difference across the sampling points (A, B and C). A perfect correlation was observed between TH and Ca^{2+}. The variation in color across the sampling points could be attributed to the variation in Ca^{2+} concentration and its significant correlation ($r = 0.92$) with color. The pH was negatively correlated ($p < 0.05$) with the most of the parameters apart from *E. coli*. It was observed that most of the parameters across the three sampling points were

Table 8. Correlation analysis of water samples at Tanke during rainy season.

	Cn^-	TH	Ca^{2+}	Mg^{2+}	Cl^-	Mn^{2+}	SO_4^{2-}	pH	Color	BOD	*E. coli*	T	DS	SS	TS
Cn^-	1														
TH	0.389	1													
Ca^{2+}	0.373	.999**	1												
Mg^{2+}	0.433	.998**	.998**	1											
Cl^{-1}	0.445	.993**	.993**	.995**	1										
Mn^{2+}	-0.184	.818**	.830**	.795**	.785**	1									
SO_4^{2-}	0.445	.995**	.993**	.994**	.997**	.777**	1								
pH	-.898**	-.746**	-.731**	-.771**	-.778**	-0.24	-.785**	1							
Colour	.745**	.888**	.876**	.900**	.910**	0.478	.919**	-.960**	1						
BOD	-0.169	-.675*	-.657*	-.633*	-.665*	-0.557	-.703*	0.494	-.665*	1					
E. coli	-.858**	-0.252	-0.227	-0.269	-0.315	0.283	-0.335	.766**	-.656*	0.438	1				
T	0.477	.848**	.859**	.879**	.854**	.644*	.829**	-.697*	.746**	-0.187	-0.103	1			
DS	.677*	.940**	.934**	.954**	.959**	.583*	.960**	-.924**	.984**	-.609*	-0.528	.845**	1		
SS	0.068	.942**	.950**	.928**	.918**	.954**	.915**	-0.482	.685*	-.614*	0.064	.787**	.776**	1	
TS	0.383	.998**	.996**	.992**	.991**	.818**	.995**	-.745**	.893**	-.718**	-0.273	.815**	.937**	.938**	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 9. Correlation analysis of water samples at Tanke during the dry season.

	Cn^-	TH	Ca^{2+}	Mg^{2+}	Cl^-	Mn^{2+}	SO_4^{2-}	pH	Color	BOD	*E. coli*	T	DS	SS	TS
Cn^-	1														
TH	-.968**	1													
Ca^{2+}	-.970**	.999**	1												
Mg^{2+}	-.970**	.999**	.999**	1											
Cl^-	-.958**	.983**	.987**	.978**	1										
Mn^{2+}	-.850**	.796**	.804**	.781**	.878**	1									
SO_4^{2-}	-.900**	.945**	.947**	.940**	.949**	.774**	1								
pH	.640*	-.741**	-.735**	-.759**	-.628*	-0.19	-.674*	1							
Color	-.837**	.924**	.910**	.919**	.870**	.607*	.892**	-.790**	1						
BOD	0.511	-.640*	-.646*	-.653*	-.579*	-0.17	-.721**	.873**	-.663*	1					
E. coli	-.642*	.721**	.725**	.733**	.660*	0.307	.825**	-.845**	.740**	-.954**	1				
T	-0.413	0.334	0.361	0.345	0.381	0.378	0.529	-0.186	0.137	-0.486	.613*	1			
DS	-.923**	.928**	.928**	.916**	.965**	.942**	.862**	-0.455	.815**	-0.355	0.452	0.228	1		
SS	-.785**	.821**	.817**	.839**	.719**	0.36	.788**	-.942**	.835**	-.823**	.894**	0.386	0.559	1	
TS	-.935**	.985**	.982**	.986**	.951**	.710**	.963**	-.807**	.955**	-.732**	.816**	0.368	.865**	.884**	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 10. Analysis of water samples in Oko-Erin during rainy season.

Tests	Sample A	Sample B	Sample C
Cn^- (mg/L)	0.25^a	2.60^b	1.30^c
TH (mg/L)	9.30^a	25.30^b	50.70^c
Ca^{2+} (mg/L)	7.30^a	18.85^b	38.50^c
Mg^{2+} (mg/L)	6.90^a	5.80^a	11.90^a
Cl^- (mg/L)	8.60^a	10.45^b	12.80^c
Mn^{2+} (mg/L)	0.90^a	0.60^a	2.00^b
SO_4^{2-} (mg/L)	17.50^a	19.50^b	22.40^c
pH	6.40^a	4.23^b	4.44^c
Color	16.00^a	18.00^b	18.9^c
BOD (mg/L)	5.50^a	5.30^a	5.05^a
E. coli	0.08^a	0.06^b	0.05^b
T	5.40^a	$5.70^{a,\,b}$	6.00^b
DS (mg/L)	530^a	580^b	670^c
SS (mg/L)	555^a	630^b	710^c
TS (mg/L)	1080^a	1210^b	1380^c

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at $p< 0.05$ in the two-sided test of equality for column means.

Table 11. Analysis of water samples at Oko-Erin during the dry season.

Tests	Sample A	Sample B	Sample C
Cn^- (mg/L)	0.24^a	2.80^b	1.30^c
TH	9.80^a	25.0^b	51.50^c
Ca^{2+} (mg/L)	7.55^a	19.0^b	40.0^c
Mg^{2+} (mg/L)	2.30^a	6.05^b	12.95^c
Cl^-(mg/L)	9.00^a	11.15^b	14.20^c
Mn^{+2} (mg/L)	1.20^a	$0.\ 57^b$	2.20^c
SO_4^{2-} (mg/L)	13.35^a	17.25^b	19.60^c
pH	6.10^a	4.22^b	4.40^b
Color	17.50^a	19.00^a	21.0^b
BOD (mg/L)	5.70^a	5.40^a	5.20^a
E. coli	0.09^a	0.04^b	$0.06^{a,b}$
T	5.70^a	6.35^b	7.0^c
DS (mg/L)	450.0^a	530.50^b	635.0^c
SS (mg/L)	650.0^a	710.0^b	730.0^b
TS (mg/L)	1050.0^a	1240.0^b	1360.0^c

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at $p < 0.05$ in the two-sided test of equality for column means.

significantly different ($p < 0.05$). Also, the BOD showed no significant difference across the sampling points. Similar trend was observed for the pH of water samples A which was significantly different from that of samples B and C.

The results of the physical, chemical and bacteriological analyses carried out on water samples at the three processing sites were shown in Tables 2, 3, 6, 7, 10 and 11 and the results of the analyses were compared with World Health Organization (WHO) 2010 standard. This was done to show the level of pollution and contamination of cassava waste effluent on surface and ground water sources located near them. The physical properties considered were turbidity and colour. The average values of turbidity recorded for the water samples collected in the rainy and dry seasons were 5.55

Table 12. Correlation analysis of water samples at Oko-Erin during rainy season.

	Cn^-	TH	Ca^{2+}	Mg^{2+}	Cl^-	Mn^{2+}	SO_4^{2-}	pH	Color	BOD	*E. coli*	T	DS	SS	TS
Cn^-	1														
TH	0.324	1													
Ca^{2+}	0.305	1.000**	1												
Mg^{2+}	-0.159	0.561	0.569	1											
Cl^-	0.376	.992**	.991**	.592*	1										
Mn^{2+}	-0.233	.809**	.816**	.661*	.776**	1									
SO_4^{2-}	0.338	.997**	.997**	.577*	.991**	.779**	1								
pH	-.876**	-.734**	-.721**	-0.217	-.773**	-0.233	-.748**	1							
Colour	.608*	.924**	.917**	0.339	.944**	.579*	.921**	-.894**	1						
BOD	-0.261	-.689*	-.689*	-0.038	-.609*	-0.445	-.699*	0.51	-.594*	1					
E. coli	-0.569	-.734**	-.730**	0	-.712**	-0.284	-.757**	.766**	-.810**	.840**	1				
T	0.382	.858**	.855**	.609*	.910**	.691*	.847**	-.716**	.887**	-0.243	-0.487	1			
DS	0.294	.994**	.994**	.591*	.993**	.838**	.986**	-.710**	.921**	-.616*	-.676*	.898**	1		
SS	0.43	.990**	.987**	0.528	.995**	.756**	.984**	-.805**	.961**	-.634*	-.732**	.899**	.989**	1	
TS	0.37	.992**	.991**	.580*	.999**	.786**	.988**	-.767**	.947**	-.604*	-.706*	.915**	.996**	.996**	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 13. Correlation analysis of water samples at Oko-Erin during the dry season.

	Cn^-	TH	Ca^{2+}	Mg^{2+}	Cl^-	Mn^{2+}	SO_4^{2-}	pH	Color	BOD	*E. coli*	T	DS	SS	TS
Cn^-	1														
TH	0.263	1													
Ca^{2+}	0.251	1.000**	1												
Mg^{2+}	0.253	.999**	1.000**	1											
Cl^-	0.314	.995**	.995**	.995**	1										
Mn^{2+}	-0.334	.794**	.801**	.802**	.764**	1									
SO_4^{2-}	0.534	.952**	.948**	.948**	.959**	0.573	1								
pH	-.848**	-.718**	-.710**	-.712**	-.760**	-0.205	-.873**	1							
Colour	0.322	.904**	.908**	.918**	.932**	.684*	.880**	-.733**	1						
BOD	-0.304	-0.453	-0.446	-0.446	-0.403	-0.342	-0.482	0.412	-0.221	1					
E. coli	-.756**	-0.388	-0.372	-0.356	-0.4	0.098	-0.566	.733**	-0.176	0.417	1				
T	0.498	.911**	.911**	.919**	.936**	0.572	.948**	-.844**	.973**	-0.334	-0.346	1			
DS	0.339	.986**	.986**	.988**	.997**	.739**	.960**	-.775**	.957**	-0.366	-0.371	.960**	1		
SS	.596*	.870**	.862**	.855**	.882**	0.484	.930**	-.894**	.721**	-0.508	-.779**	.806**	.863**	1	
TS	0.508	.935**	.933**	.935**	.952**	0.552	.982**	-.850**	.925**	-0.323	-0.476	.974**	.965**	.873**	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

and 7.75 mg/L at Agbo-Oba, 5.20 and 5.40 mg/L at Tanke and 5.40 and 5.70 mg/L at Oko-Erin, respectively. These values were above WHO permissible level (5 mg/L). This may be attributed to the higher production of effluent and hence, their direct discharge into the stream. Also, it may be due to gradual penetration of the waste effluent into the soil and accumulated into the wells. The turbid nature allows microbial contamination of water which may be detrimental for human and animal health (Ololade et al., 2009).

The respective values of the colour recorded for water sources in the rainy and dry seasons were 15.10 and 16.00 mg/L (Agbo-Oba), 15.50 and 15.80 mg/L (Tanke) and 16.01 and 17.50 mg/L (Oko-Erin). These values were higher compared to the WHO standard. The values of water samples obtained at Oko-Erin were greater than that of Agbo-Oba while the samples of Tanke were the least. This may be attributed to the moving water of the stream and the methods of lining the wells. The colour of water samples was not attractive; the difference in the colour was due to the distance of the water sources from the point of discharge. The higher values were obtained in dry season; this resulted to higher concentration of the water samples than the rainy season. The values of turbidity and colour of water sample obtained at the three processing sites are greater than Nigeria standard for drinking water, 5 NTU and 15 TCU respectively, (NSDW, 2007). This implies that the water is not potable and may require treatment processes like screening, filtration and sedimentation. From Tables 2, 3, 6, 7, 10 and 11, the pH values of water samples for Agbo-Oba (6.40, 5.37), Tanke (6.70, 6.50) and Oko-Erin (6.40, 6.10) during the rainy and dry seasons respectively. The pH values obtained for Tanke lie within WHO (2015) and NSDW (2007) limit for drinking water (6.5 to 8.5). This may be due to lining of the well. The pH values obtained for Agbo-Oba and Oko-Erin were not compared well with the results reported by Massoud et al. (2004) and Ahmad and Saadieh (2007). This indicated that these samples were slightly acidic and needed to be treated. The lowest average DS value was obtained for Tanke (350 mg/l) while the highest was for Oko-Erin (530 mg/L). All these levels are within WHO acceptable limits for drinking water (< 600 mg/L). The values of TS of 1200, 1080 and 1040 mg/L were recorded for water samples collected from the three cassava processing sites, which were above the WHO recommendation of 1000 mg/L. The magnesium, calcium, manganese, sulphate and cyanide levels were quantified as shown in Tables 2, 3, 6, 7, 10 and 11. Magnesium level was highest for water sample in Oko-Erin and lowest for Tanke. Also manganese levels were high for all the samples but the results were not in line with consumer acceptability, 0.2 mg/L and this may cause neurological disorder in human (NSDW, 2007). Sulphate and calcium analysis shows that the water samples have low level, although sulphate level above 250 mg/L may alter the taste of water, no limiting guideline has been set by WHO reported by Ahmad and Saadieh (2007). But the maximum permitted level for Sulphate (100 mg/L) and calcium (150 mg/L) is given by NSDW (2007). Nevertheless, none of the analyzed water samples exceeded the 20 mg/L sulphate or calcium levels; and minimal variations are observed. The treatment processes such as aeration can remove the ions while coagulation process can be used to reduce the hardness. All the water samples had high Cn^{-1} values which ranged from 0.15 to 2.8 mg/L and were not in conformity with WHO standard of 0.01 mg/L. This is an indication that cassava processed in the study areas contains high cyanide content and may be toxic to thyroid and nervous system in human and poor for irrigation purpose (NSDW, 2007; Olalekan, 2002).

The bacteriological test shows the significant levels of total coliform and *E. coli* found in all water samples, but the highest levels are obtained in Agbo-Oba (both rainy and dry seasons). The values of coliform count for the samples were above zero count/100 ml WHO recommended level for drinking water. This may be attributed to higher population concentrations in that community and human wastes are being discharged into the water source upstream. Also, the wells are not properly lined as obvious from the visual observation and bacteria pollution may occur from sewage disposal from latrines and soak away found around the sites. The overall presence of *E. coli* indicates direct results of the fact that, waste effluent is still flowing untreated into the surface and ground water sources.

CONCLUSION

The pollution potential of the cassava processing sites located within city was observed to be high with fecal coliform indicating significant raw waste water input. Calcium and sulphate levels are generally within acceptable WHO limits. A baseline of data has been presented to enable assessment of future improvements made by waste water treatment plants. There is need for general treatments of the effluent discharged in these locations since people consume water from these sources for drinking and other domestic purposes. In addition, a program of monitoring water quality must be re-emphasized.

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