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Effect of cassava effluents on domestic consumption of 'shallow well' water in Owo Local Government Area, Ondo State, Nigeria

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ABSTRACT

Cassava (*Manihot esculenta* Crantz) is a very important staple food in most developing countries. During its processing into cassava starch or 'gari', wastewaters effluent are generated and are indiscriminately discharged into the environment or public sewers thereby polluting the soil and invariably discharge into nearby shallow 'wells' representing a risk for the environment because of its cyanogen's content, and the reduced quality of the shallow 'well water' made it less suitable for human consumption. The objective of this study is to analyze the contaminated water resources in five selected cassava processing factories for various physical, chemical, and biology parameters. The parameters determined were colour, odour, turbidity, PH, Cl, Ca, NO_3^-, Na, Mg, TDS, K, Cu, Zn, Mn, Fe, etc. The five centers were all predominantly processing cassava into gari with high volume of wastewater and solid wastes being discharge into the environment. Results showed that cassava waste water led to increase in iron, sulphate, potassium, sodium, chromium, cadmium, etc. of the receiving 'shallow well' water.

Keywords: Cassava, gari, wastewater, shallow well.

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INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a very important staple food in most developing countries. It has its origin in South America and is extensively cultivated as an annual crop in tropical and subtropical regions of the world for its edible starchy, tuberous root. It is known to be a major source of carbohydrate with Africa being the largest centre of production (Claude and Denis, 1990; Ehiagbonare et al., 2009). It is a major staple food in Nigeria and therefore produces large volumes of waste that create environmental nuisance in the region (Mbongo and Antai, 1994; Horsfall et al., 2003; Oboh, 2006). These wastes would even be more problematic in future with increased industrial production of cassava products such as starch and cassava flour. Figure 1 shows the process flow chart for cassava waste water.

As shown in Figure 1, the wastewater extract results from the process of peeling, washing, grinding, and dewatering of cassava tubers. The cassava tubers are peeled, and the discarded peel forms the first stage of the solid waste. Subsequently, when the flesh of the cassava tubers are grated and dewatered, wastewater is obtained. Furthermore, after dewatering, the resulting cassava semi-solid mass is then sieved and the ungrated fibres are then discarded as the final solid waste.

Cassava processing into food, starch and gari generates two liquid residues. The first results from the washing and peeling of cassava roots, and generally contains a large amount of inert materials with low chemical oxygen demand (COD); the second results from draining the starch sedimentation tank, and have a high contaminating load of COD and BOD. In view of the high BOD, COD and cyanide concentration, the effluent poses a serious threat to the environment and quality of life in the rural areas where the processing units are mainly located. Starch and 'gari' production usually involves simple technology, consuming an average of 23 m^3 of water per tonne of cassava. This also generates a contaminating load of about 180 kg of COD per tonne of

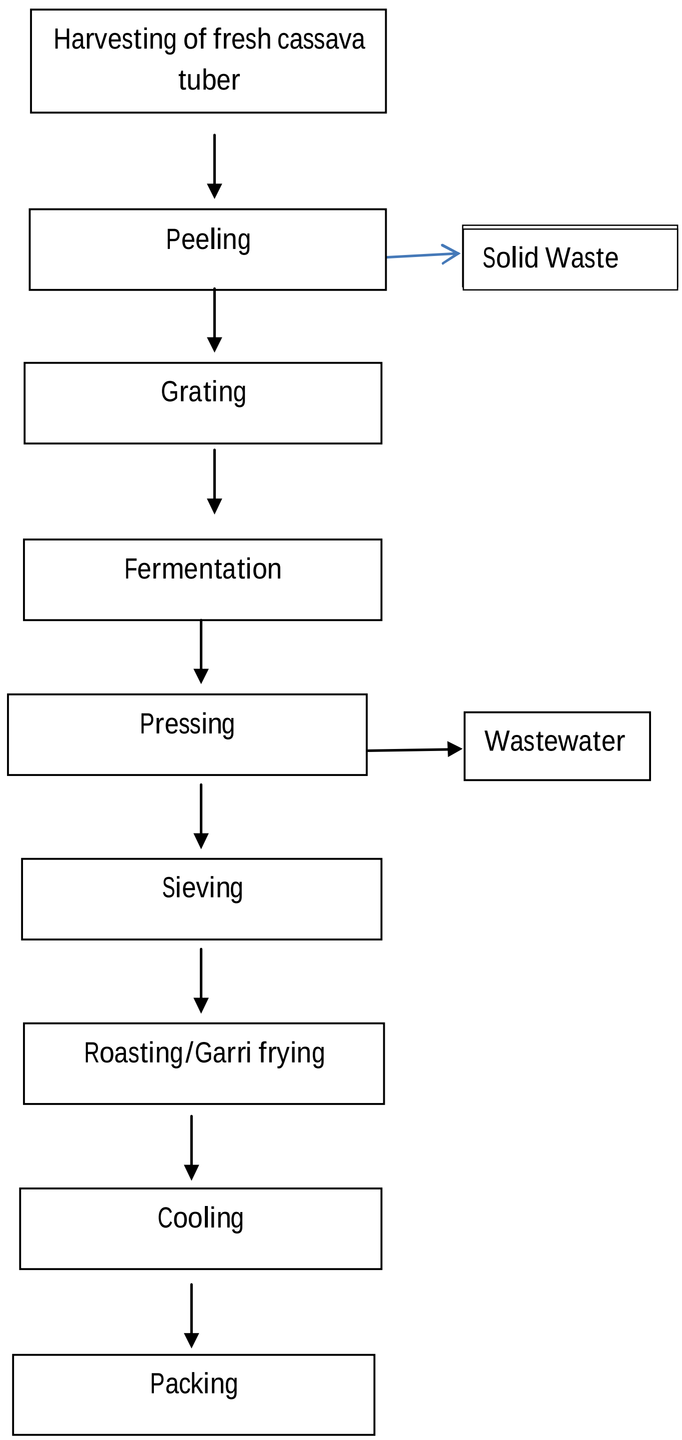

Figure 1. Gari processing flow chart.

roots (Raddatz, 1986). Wastewater from cassava processing is subject to relatively rapid breakdown, it is odorous and its microbial content is often high. There is the additional problem of the presence of simple and complex cyanide with different degrees of solubility, toxicity and stability (Ekpechi, 1994). The presence of varying amounts of *cyanogenic glucoside* and their breakdown products – *cyanohydrin and hydrogen* cyanide in cassava and cassava-food products has been a cause of concern because of their possible effects on health and on the environment.

One of the major threats to the environment by 'gari' and starch processing industry is the *hydrocyanic acid* and the unbroken down *cyanogenic glycoside – linamarin* and *lotaustralin* which produces toxic and acidic effect. If these products are not properly treated, they constitute potent toxicant to the soil, soil organism, water and plants. Other by-products such as unrecoverable starch, the peel and wastewater could result in the generation of objectionable odour and constitute breeding grounds for flies and insects, which are carriers of diseases. The peel not only contains *cyanogenic glycosides* and free cyanide which can be degraded and leached into the soil, the wastewater could also change some other soil properties because of its total solid, total organic carbon, nitrogen and phosphorus. With the increasing popularity of new appropriate technologies for 'gari' and cassava processing in general, which can also be applied on a large scale, the future will see larger cassava processing plants and waste handling may become a major problem (Osunbitan et al., 2000). Disposal of effluents from cassava processing is becoming an increasing problem and more problems may also arise due to high solid content in the effluents rather than from the *cyanogens.* With these major threats to the environment by the 'gari' processing industry and the increasing future demand for the commodity especially in Nigeria, there is need for evaluating the impacts of these wastes on the water quality within the processing locations.

Study area

The study area was Owo, the headquarters of Owo Local Government Area, Ondo State, Nigeria. It is located about 45 km east of Akure, the Ondo State capital. It is situated at 7.2° North latitude, 5.59° East longitude and 305 m elevation above the sea level as shown in the Figure 2.

The town falls within the sub-equatorial region characterized by a tropical climate, the temperature is relatively high throughout the year with an average daily temperature of about 27°C with marked seasonal changes in rainfall and relative humidity. Owo, like other tropical area of Nigeria enjoys abundant rainfall of over 1,500 mm yearly.

MATERIALS AND METHODS

An investigation on various cassava processing locations in Owo local government was carried out. After which five major locations were chosen because of the high

Figure 2. Map of Ondo State showing local government areas.

population density of the areas. Water samples, at least five, from each location was collected from wells water that are close or near to the gari processing industry by using water specimen bottles. Immediately each bottle was filled, it was labeled and the sample was taken to the laboratory within an hour so as to maintain the condition of the sample (Ondo State water co-operation, Alagbaka, Akure for analysis) using standard laboratory methods and procedures. The result was compared with the World Health Organization (WHO) standard and was analyzed and generally discussed in line with the standard limit.

There are two main peak cassava processing seasons in a year, which commences in April and last till June and the other peak, starting from August till November before the dry season of the year begins. It was ensured that samples were taken from each 'well' water at both the peak period of cassava processing and also at periods when waste discharge are minimal. Water samples were collected every week for both the peak and minimal discharge periods from the five locations and these were analyzed for both various physical, chemical, and biological parameters.

Since the main objective of the study is to examine the effect of cassava-processing waste on water quality therefore, a total of 19 physico-chemical parameters were determined namely: pH, electrical conductivity (EC), dissolved oxygen (O_2), turbidity (by nephelometric method), dry residue (DR), suspended solids (SS), oxidability (organic matter, OM), chemical oxygen demand (COD), color, Cl^-, Na^+, PO_4^{3-} , NO_2. NO_3, NH_4^+, Fe, Mn, Cu and Zn. Dissolved oxygen, pH and turbidity (given in nephelometric units) were determined on site while all other parameters were analyzed in the laboratory. Sample were collected in *lamotte* bottles and transferred to three different types of containers, namely: (a) 1-1 polyethylene bottles most of which used for analysis; (b) 100 ml polyethylene bottles containing 0.20 ml of ultrapure nitric acid – intended to reduce the absorption of element on the container walls – which were used to determine heavy element; and (c) the containers used in the site determinations. As a rule, samples were stored in a refrigerator at 3°C prior to analysis. Nitrate and nitrite were determined by UV absorption spectrophotometry at 200 and 425 nm, respectively. Ammonium was determined by using a selective electrode. Chlorine was quantified potentiometrically and phosphate by molecular spectroscopy (using ammonium molybdate after digestion in hot nitric acid). Iron, manganese, copper, and zinc were measured by atomic absorption spectrometry. Organic matter was determined titrimetrically following oxidation with potassium permanganate.

RESULTS AND DISCUSSION

Quality standard in drinking water

The result of water quality analysis in relation to drinking and other domestic purposes are as presented in Table 1. This showed that all the five locations have their resulting waste disposed into nearby 'Wells'; which create severe environmental problems like murky colour of the Well water, foul odour, mosquito nuisance and the risk of epidemics. The aesthetic and beauty of the environment is also a substantially affected. Rating water quality according to the maximum and highest desirable value of water quality parameters (Table 2) or whether they constitute a threat to human health particularly when they occur in levels above the minimum allowable threshold in water intended for human consumption showed that only Location II with TDS of 269 mg/L is safe for drinking in terms of TDS (Table 3).

Hardness ranges between 166 and 362 mg/L, which fell within the permissible level of drinking water standards. High level of hardness is always responsible for excessive scale formation (WHO, 1971). The BOD ranged from 70 to 290 mg/L. These values were significantly higher than those recommended by the ASCE standard which gave a source with BOD > 4 mg/L as a threat to human health. The value shows that in all locations where cassava wastes are directly discharged to 'Well' there is serious pollution. Nitrate concentration ranged from 3.3 to 83.7mg/L, while the maximum permissible level of 45 mg/L was recommended.

Table 1. Physico-chemical parameters of water samples from processing locations.

Parameter[a]	Iyere (I)	Ijebu (II)	Ehinogbe (III)	Emure-Ile (IV)	Ilale (V)
pH	7.65	7.85	8.00	7.70	7.50
Salinity (ppt)	0.5	0	<1	<1	0
Conductivity (hmhos/cm)	1170	400	750	800	450
Total phosphorus(mg/L)	4.0	1.5	3.0	2.0	1.0
Total nitrogen (mg/L)	<1	1.1	<1	0	0
Nitrate-N (mg/L)	16.4	3.3	5.2	83.7	12.5
Alkalinity as $CaCO_3$ (mg/L)	265	195	376	285	220
Hardness as $CaCO_3$ (mg/L)	240	166	362	330	172
Total dissolved solids (mg/L)	735	269	556	565	727
Direction and distance from source	5 E	24 NW	6 W	8 W	4 E

[a] average of 3 replications.

Table 2. Maximum and highest desirable values of water quality parameters.

Water quality parameter	Measured	Highest desirable level	Maximum permissible
Total dissolved solids	mg/L	500	2000
Turbidity	FTU	5	25
Colour	mg Pt/L	5	50
Iron	mg Fe^{+}/L	0.1	1.0
Manganese	mg Mn^{++}/L	0.05	0.5
Nitrate	Mg NO_3^-/L	50	100
Nitrite	Mg N/L	1	2
Sulphate	Mg SO_4/L	200	400
Fluoride	Mg F/L	1.0	2.0
Sodium	Mg Na^{+}/L	120	400
Arsenic	Mg As^{+}/L	0.05	0.1
Chromium (hexavalent)	Mg Cr^{6+}/L	0.05	0.1
Cyanide (free)	Mg CN^-/L	0.1	0.2
Lead	Mg Pb/L	0.05	0.10
Mercury	Mg Hg/L	0.001	0.005
Cadmium	Mg Cd/L	0.005	0.010

Adapted from Morgan (1989).

Table 3. Solids and BOD.

Location	TSS	TDS	TS	Total BOD
Iyere (I)	110	735	845	130
Ijebu (II)	40	269	309	90
Ehinogbe (III)	132	556	688	220
Emure-Ile (IV)	181	565	746	290
Ilale (V)	80	727	807	70

All parameters are in mg/L. TSS – Total Suspended Solids, TDS – Total Dissolved Solids, TS – Total Solids, *BOD – Biochemical Oxygen Demand.

Total solids varied from 309 to 845 mg/L while iron concentration ranged between 0.34 and 1.92 mg/L. These values are more than the maximum permissible limits for drinking water and could result in gastro

Table 4. Other physico-chemical properties from the analysis.

Parameter	Iyere (I)	Ijebu (II)	Ehinogbe (III)	Emure-Ile (IV)	Ilale (V)
Potassium (mg/L)	15	18	53	59	21
Sodium (mg/L)	21.0	22.5	85	91	26.5
Magnesium (mg/L)	8.6	12.0	21.4	19.0	11.0
Calcium (mg/L)	14.0	13.6	48.0	52.0	22.0
SAR (mg/L)	6.25	6.29	14.43	15.27	6.52
Lead (mg/L)*	Nd	Nd	Nd	Nd	Nd
Zinc (mg/L)	0.18	0.21	0.26	0.80	0.16
Boron (mg/L)	0.02	0.04	0.19	0.18	0.03
Iron (mg/L)	0.34	0.27	1.85	1.92	0.52
Chloride (mg/L)	31.4	37.4	162.0	134.0	48.7

*Nd - not determined.

intestinal irritation, tastes, discoloration and deposits (FEPA, 1991). From Table 4, the concentration of sodium, calcium and zinc fell within the WHO and EEC standards for drinking water (WHO, 1971; ASTM, 1997). Water resource unto which cassava wastes are discharged directly was investigated for suspended solids and fecal bacteria. Safe drinking water should not contain more than four fecal coliforms per 100 ml (Tchobanoglous and Eddy, 1991).

Quality standards irrigation water

The indicator of salinity, EC, varied from 400 to 1170 hmos/cm water within the high salinity water range (750<EC<2250) cannot be used on soil with restricted drainage. Even with adequate drainage, special management for salinity control may be required and salt tolerant plants should be selected. Medium – salinity water (250<EC<750) can be used for irrigation if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most instances without special salinity control measures (Ogedengbe et al., 1984). The basic effects of SAR are on infiltration rates and permeability and these falls between values acceptable for irrigation purposes. Excessive leaf absorption and crop failure occurs especially with the sprinkler irrigation on sensitive crops with sodium or chloride in excess of 3 mg/L.

The recommended limits of magnesium (50 mg/L) in irrigation water were exceeded, this will create an unfavourable soil condition as a result of high magnesium absorption. Both surface and sprinkler irrigation methods can be used with the water source. Total suspended solids and total solids values showed fairly high turbid water. Low sodium water (0<SAR≤10 mg/L) is usable on almost all soils without any sodium hazard as found in locations I, II and V, but sodium sensitive crops must be cautioned on these locations. Locations III and IV from this study have SAR of 14.43 and 15.27 mg/L respectively, in the medium sodium water category (10<SAR≤18 mg/L), which can be used without any problem in coarse textured soils or organic soils but only usable in the presence of gypsum in fine textured soils such as clay and leaching may also require. Cassava wastes discharged directly into these environments may be one of the factors responsible for the salt concentration.

Human health considerations

The pH values fell within the prescribed range of 6.5 to 8.5 and aquatic living were not noticed in these water locations. Majority of communicable diseases prevailing in Nigeria are related one way or the other to water (Morgan, 1989). High pollution level of the water resource in cassava processing areas cells for an urgent mitigation action plan because they may become vehicles for pathogenic bacteria transport. The nitrate values were below the limit of 45 mg/L in all locations except one, there could be the possibility of haemoglobinemia disease among the young or babies that ingest the water over a period from this location. Turbid waters contain particles that can shield embedded bacteria from the effect of chlorination (Nwachukwu et al., 1991) thus cost of water treatment in all the locations may be higher. Polluted water can cause offensive odours and flies infested environment and eventually affect the health of the inhabitants adversely.

Water resource pollution

Concentration of cyanogens present in the water sources in or near the five cassava starch/'gari' processing centres given in Table 5 showed that the water contained considerably more than the acceptable level of cyanide. The US health services cities 0.01 ppm CN as a guideline and 0.2 ppm CN. The guidelines for Canadian drinking

Table 5. Concentration of cyanogens in the water sources near starch/'gari' processing centres.

Locations	Cyanide (mg/L)[b]		
	Total	ACH	Free
Iyere (I)	1.4	0.7	0.6
Ijebu (II)	1.6	0.6	0.9
Ehinogbe (III)	10.4	2.4	3.0
Emure-Ile (IV)	12.9	4.2	10.4
Ilale (V)	1.3	0.2	0.8

[b] Average of 3 replications.

water quality list a maximum acceptable concentration for cyanide as 0.2 mg/L. In the environment protection act of India, the tolerable limit of cyanide in drinking water is 0.05 mg/l and in the effluent 0.2 mg/L.

The level of total cyanide in the water ranged between 1.3 and 12.9 mg/L. It can be seen that majority of the cyanogen content was in form of ACH and FC. The presence of high levels of cyanide near the cassava starch/'gari' processing centres could be as a result of percolation of residual cyanide present in the wastewater discharged over time. The cyanide levels in the water sources are much higher than these permissible limits as per US, Canadian, Swiss and German regulations (Balagopalan and Rajalakshmy, 1998). These findings call for adequate treatment system for wastewater effluent of starch/'gari' processing industries before it should be discharge to the environment.

CONCLUSIONS

The study showed that apart from the high cyanide content of the wastewater, the cassava wastewater led to increase in nitrate, total dissolved solids, and BOD of the water resource near the sites. The cassava starch/gari processing centres are generating huge quantities of wastewater to the extent of an average value of about 4,000 to 6,000 L per tonne of starch/'gari' produced from the study areas under investigation. This wastewater contains very high concentration of cyanide; this will ultimately affect the quality of life where the processing centres are mostly located. Since majority of cassava-based starch/'gari' processing centres are small-scale or small clusters in nature, a simple and cost effective treatment system is essential to be developed.

The environment impact of these processing centres are more pronounced especially where cassava processors organized themselves into groups or clusters in form of co-operative societies either to secure bank loans or in the various community - 'gari' processing centres under the federal Government Community Developed and Millennium Development Goals (MDG) projects. So far, these processing industries have not made any attempt to take care of the cyanide-wastewater-effluent problems resulting from cassava for starch and 'gari' and these water sources may become vehicles for pathogenic bacteria transport.

Apart from high cyanide content, the discharge of effluent directly into 'Well' and/or spreading on land leads to higher nitrate, biochemical oxygen demand, total dissolved solids on the streams as well as a highly offensive odour in the environment.

A potential use of the effluent from the oxidation pond may be for irrigation of crops, once the effluent is degraded and the turbidity, which led to lower infiltration, has been reduced. The wastewater is rich in nitrate and it will also assists in controlling erosion especially on sandy soils because it may increase the stability of the soils.

The practice of flooding the adjacent area with the wastewater effluent should be discharged as this study has shown act may lead to the pollution of the water resource in such areas.

RECOMMENDATION

In the course of this research, it has been found that nearness of cassava processing factories had resulted in higher concentration of sulphate, potassium, nitrate, sodium, cadmium, etc. It is hereby recommended that such factories should not be sited close to wells, stream/ rivers meant for human consumption. If it is to be sited close to such places, concrete slabs should be provided where the cassava is to be pealed and washed. Furthermore, the effluent from the pressed grated cassava should be channeled to a septic tank where:

1. Such toxic materials could be destroying biologically with bacteria or microbes.
2. Water tankers could be used to convey the effluent to industry where high voltage electricity is passed into it for its decomposition.

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