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ECONOMIC OF CASSAVA PEEL ACTIVATED CARBON IN TREATMENT OF EFFLUENT FROM CASSAVA PROCESSING INDUSTRY

O.O. Olayiwola

Research Scholar, Development Policy Centre (DPC), Ibadan, Nigeria
Email: olubodun_2008@yahoo.com

ABSTRACT

The major aim of this study was to produce Zinc Chloride activated carbon from cassava peels which is a major solid waste from the cassava production process. The wastewater from cassava processing was treated using a peroxide oxidation process before being subjected to adsorption using Cassava Peel Activated Carbon (CPAC) at different activation levels. Results from the study shows that CPAC at activation ratio of 1:1 was the most effective as all parameters after adsorption with the exception of suspended solids fell below FEPA interim standard on discharge. The CPAC at 2:3 activation ratio also met the discharge standards but after 8 hrs of contact time. The result shows that CPAC could be adopted for treatment of cassava industry wastewater. Decontamination efficiency of the of the CPAC was 100% for Ni, Cd, Cr and CN at all activation levels while BOD_5 removal for no activation, 1:3, 2:3, 1:1 $ZnCl_2$ activation levels were 78.8, 85.9, 87.9 and 92.9% respectively. The CPAC exhibited the lowest values for Ca removal efficiency of 8.9, 8.9, 10.1 and 10.1% for no activation, 1:3, 2:3 and 1:1 activation levels respectively. Colour removal efficiency values were 33.3, 41.7, 41.7 and 50.0% respectively after 8 hours of contact time.

Keywords: Decontamination, wastewater, cassava peel carbon, chemical activation

INTRODUCTION

Cassava (Manihot esculenta Crantz) is a major staple food in many tropical countries, Nigeria inclusive. About 10 million tonnes of cassava are processed for gari annually in Nigeria alone (Okafor,1992). Obadina et al. (2006) stated that cassava peels account for up to 10 % of the wet weight of cassava tubers. This translates to about a million tonnes of cassava peels annually. This statistics is for only gari production. Other food substances are produced from cassava as well. Annual cassava production in Africa is about 84 million tons (NWRI, 2012). In cassava processing communities, huge amounts of process wastewater and solid waste are generated and may constitute an environmental menace. According to Mijinyawa and Lawal, (2008) and Ewemoje et al.(2011), there is the need for wastewater from agricultural processing activities to be treated before they are discharged into the water courses or open fields in order to reduce potential environmental hazards.

Water usage in industrial processes is an inescapable aspect since it is used for various purposes including sanitation. Industrial wastewater could be viewed as originating from the wet nature of most industries which require large quantities of water for processing and disposal of their wastes. According to Asia and Akporhonor (2003), wastewaters are unavoidable by-products of any processing activity. Whatever processing procedures are used for preparing products, there will always be an aqueous liquid as by-product. Most industries are therefore, located near water sources. The effluents from these industries are usually discharged into the nearest watercourse. At times they are indiscriminately disposed on adjacent land leading to infiltration and pollution of the underground water reservoir. It is important to note that about 60% of the Nigerian populace (both rural and some urban) still source for domestic and sometimes drinking water from ponds, streams, shallow wells and other groundwater sources. This justifies the concern for increases in the level of pollutants in surface and groundwater thus making water monitoring even more vital (Morenikeji, 2010).

The aquatic environment is one of the ultimate recipients of pollutants and aquatic organisms are through bioconcentration and biomagnification, often subjected to high levels of chemical pollutants Zorgorc-Koncan and Cotman, 1996). It has been reported that industrial effluent has a hazardous effect on water quality, habitat quality, and complex effects on flowing waters (Ethan et al. 2003). Industrial wastes and emission contain toxic and hazardous substances, most of which are detrimental to human health.

One of the byproducts of cassava processing is the effluent. Cassava processing effluent if allowed to run freely along soil surfaces contaminate surface water as it percolates into underground water and sub soil with serious adverse effect on human, fauna and flora (Ogundola and Laisu, 2007). Research has been conducted on the negative effects of cassava processing effluent on selected aquatic life (Adeyemo, 2005) as well as terrestrial plants (Olorunfemi et al. 2011).

Activated carbon (AC) is one of the most popular adsorbents used in numerous industries for the removal and recovery of organic and inorganic compounds from gaseous and liquid streams (Foo and Lee, 2010).

Ineffective and inefficient waste management is one of the most pressing environmental problems facing many cities in the developing world (Coker et al. 2009). Therefore, the issue of solid waste management can no longer be regarded as a simple one mainly influenced by the idea of allowing anybody that has no passion, professional training and technical knowhow to be involved in its management (Kalu, et.al, 2009). To this end the objectives of this research are:

To produce activated carbon from cassava peels through chemical activation method and test the efficacy of produced activated carbon in treatment of wastewater from cassava processing industry.

To compare the efficiency of cassava peel carbon with activated cassava peel carbon in decontamination of wastewater from cassava processing industry.

METHODOLOGY

Waste cassava (*Manihot esculenta* Crantz) peels and process wastewater used for the study was collected from a cassava processing industry in Ibadan, Nigeria. The cassava peels were then inspected, washed and sundried to a moisture content of between 8-10% wet basis. The dried cassava peels were then carbonized using a muffle furnace (Carbolite, England Model AAF 11/18) at a temperature of 420^0 C for a period of 90 mins. Then the cassava peel carbon (CPC) was allowed to cool overnight under inert conditions thereby yielding the base carbon material (plate 1) for activation.

The CPC size was reduced to 500µm. The reduced carbon was then pre-washed to remove any form of dirt that may have been attached during the size reduction process and later dried in the oven at 120^0C for 8 hrs. Three samples of the CPC were activated using $ZnCl_2$ at activation ratios of 1:3, 2:3 and 1:1 to yield the cassava peel activated carbon (CPAC) used in the treatment process.

The wastewater sample collected was taken to alkaline range by the addition of 0.5M NaOH until the pH was at 10.0. Hydrogen peroxide at 50% concentration was then added at a dose of 0.5 grams H_2O_2 per gram of CN^- oxidized. The wastewater was then left for a period of 2 hrs to ensure a reasonable level of oxidation and cyanide destruction before filtration was carried out in an intermediate sand filter column.

Plate 1. Cassava Peel Carbon (CPC)

Oxidized wastewater was released simultaneously into four adsorption columns containing the CPC (0:1) in one column and CPAC at activation levels 1:3, 2:3 & 1:1 in the other three columns at the rate of 0.378 l/hr. Water samples were strained from the adsorption columns after a period of 2, 4, 6 and 8 hours. The process flow diagram is shown in fig. 1.

The percentage decontamination of the adsorbent is a measure in percentage of the amount of adsorbate adsorbed by the adsorbent from a given solution. The percentage decontamination (D^i) of the wastewater was calculated using the equation

$$D^i = \left[\frac{(C_i - C_f)}{C_i}\right] x\ 100 \qquad (1)$$

Where C_i and C_f (mg/l) are concentrations of ions in wastewater before and after treatment respectively

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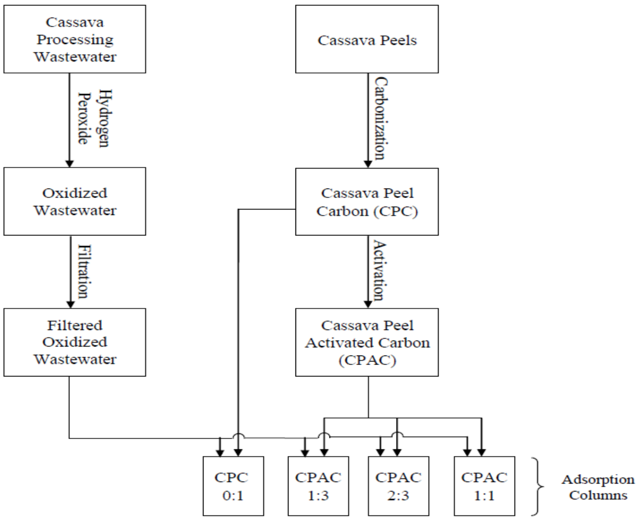

Figure 1. Process flow for adsorptive treatment

IUPAC, classifies adsorbent pores into three groups namely: micropores (diameter <2 nm), mesopores (2–50 nm) and macropores (>50 nm). Pore size is one of the factors which affect the adsorption characteristics of adsorbent materials, it is therefore important to take note of this characteristic when considering adsorbent material usage. The average pore length, pore width, pore area and surface area of the CPC and CPAC were measured from the SEM images using a Java interactive software program called Image J. The software was programmed with each of the image parameters such as magnification, unit and plot area and used to simulate a surface plot of the unit area of the carbon surface. This plot gave an idea of the pore space and surface orientation of the material.

RESULTS

CPC and CPAC have quite unique physical characteristics and this is partly responsible for their differential behavior in adsorption process. Table 1 shows the result of characterization studies of CPC and CPAC at various activation ratios. The result shows that the ash content is higher in CPC thus showing that activation reduces ash content of the carbon material. Bulk density on the other hand increased with activation level. Analysis of moisture contents of the different carbons show that even though the materials were stored under the same condition the carbon materials that were activated had higher moisture content which increased with activation level, this may have been due to the presence of residual hygroscopic activation salts in the activated carbon.

Table 1. Characteristics of cassava peel activated carbon at different Activation ratio

Sample	$ZnCl_2$ Activation Ratio	Ash Content (%)	Moisture Content (%)	Bulk Density (g/cm^3)
CPC	0:1	2.65	2.31	0.407
CPAC	1:3	2.38	2.38	0.410
CPAC	2:3	2.44	2.42	0.413
CPAC	1:1	2.47	2.71	0.415

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An observation of the average pore width and length showed that the CPC and CPAC had predominantly mesopores as indicated in Table 2. Thus showing that theoretically the carbon should be a good adsorbent material.

Table 2. Analysis of pore space and surface area of cassava peel carbon

Sample	Average pore length (nm)	Average pore width (nm)
CPC (0:1)	13.8	10.4
CPAC (1:3)	25.2	16.7
CPAC (2:3)	27.7	18.9
CPAC (1:1)	37.3	28.7

Results were obtained from subjecting 1.5g of CPC & CPAC to SEM

An observation of the cassava peel carbon's surface reveals that the pore space development for the pure cassava peel carbon was not very pronounced as shown in the SEM image (plate 2), the Image J surface plot also shows a relatively smooth surface configuration for the carbon (fig. 2), this surface configuration is directly related to the adsorptive surface availability since smooth surfaces offer lower adsorption surfaces in adsorbents.

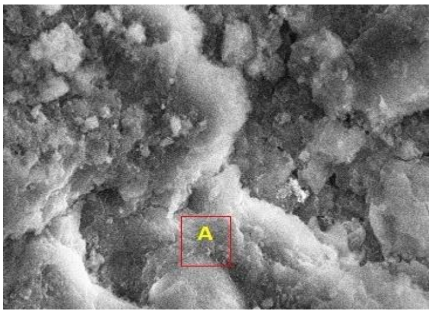

Plate 2. SEM image of CPC

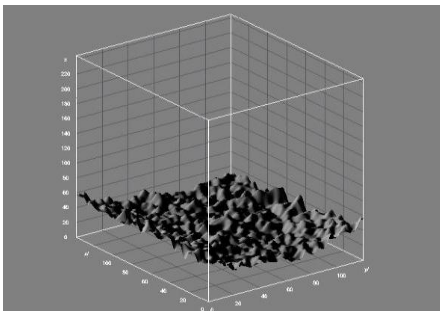

Fig. 2. 3D Surface plot of area A on CPC

Cassava peel activated carbon at 1:3 Zinc Chloride activation level showed relatively larger pore opening characteristics when compared to the pure cassava peel carbon as shown in the spectrometry image (plate 3). The surface plot also shows a more pronounced increment in surface area (fig. 3), thus it can be predicted that the adsorbent would be more effective than pure cassava peel carbon in adsorbing materials.

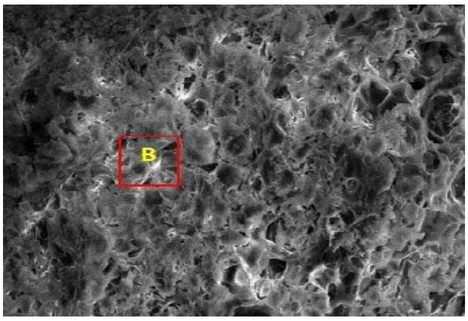

Plate 3. SEM image of CPAC at 1:3 activation ratio

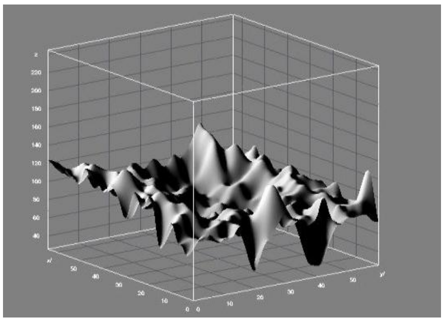

Fig.3. 3D surface plot of area B on CPAC at 1:3 activation ratio

Image from the ratio 2:3 Zinc Chloride activation of cassava peel carbon shows that the material exhibited a hexagonal honeycomb structure (plate 4) while the surface plot showed a rough surface with an increased area this also theoretically indicates good adsorptive surface characteristics. The material exhibited a very obvious effect of chemical activation on the carbon material.

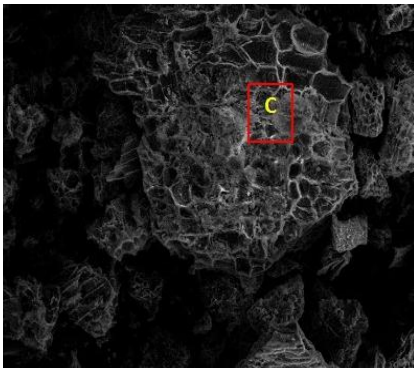

Plate 4: SEM image of CPAC at 2:3 activation ratio

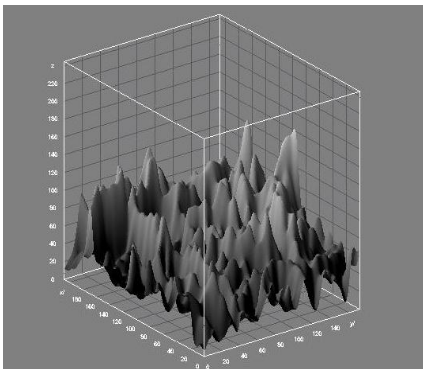

Fig. 4. 3D Surface plot of area C on CPAC at 2:3

Cassava peel activated carbon at 1:1 Zinc Chloride activation level was observed to have a spongy structure (plate 5), indicating that the activation process had created pores on the surface of the carbon material. This structure also shows that the material will be a very good adsorbent theoretically. The surface plot also shows a rough configuration (fig. 5) thereby creating more surface for adsorption process.

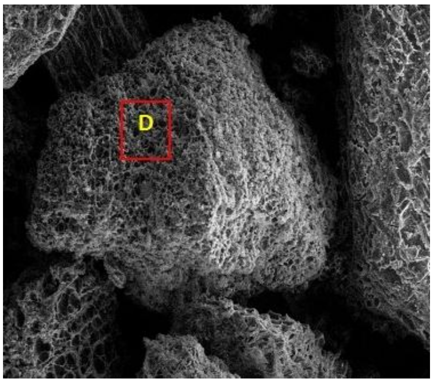

Plate 5: SEM image of CPAC at 1:1 activation ratio

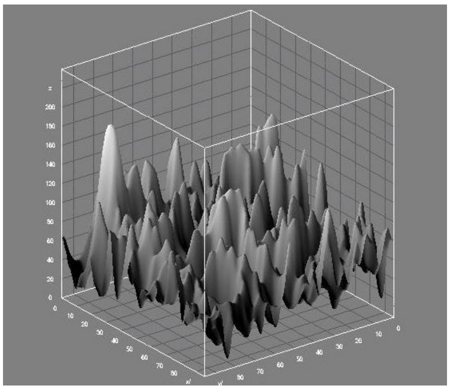

Fig. 5. 3D Surface plot of area C on CPAC at 1:1 activation ratio

The removal efficiency of the CPAC adsorption (fig. 6) showed that it was able to effect 100% removal for Cd, Ni, Cr and CN. The BOD_5 removal efficiencies were 78.8, 85.9, 87.8 and 92.9% for 0:1, 1:3, 2:3 and 1:1 $ZnCl_2$ activation levels respectively. The maximum colour removal efficiency was 50% at 1:1 activation level. The result shows that activation of cassava peel carbon had no effect on the adsorption of Fe, Ni, Cr, Cd and CN. However, Ca, Mg, Zn, PO_4, SO_4, NO_3, Cl and colour showed progressive increase in decontamination levels with Ca having the least value. Mn showed a reduction in decontamination with increase in activation level thus indicating that activation to some level has some negative effect on Mn adsorption in CPAC.

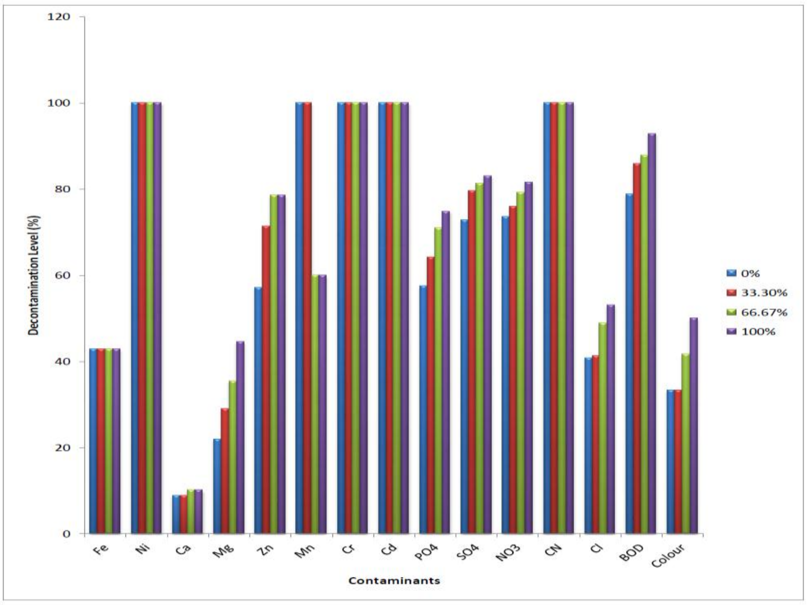

Figure 6. Graph of decontamination level at the different activation/impregnation ratios

A comparison of the characteristics of effluent from the treatment process with FEPA interim standard on discharge (Table 2) for all classes of industry and also standards for irrigation water showed that the effluent did not meet the requirement for discharge. This is due to its inability to reduce the suspended solids content of the water. A good removal of suspended solids could be achieved by increasing the particle size of the CPAC and incorporation of a sedimentation facility at the end of the treatment process. The effluent however met the standard for use as irrigation water for agricultural purposes.

RESEARCH FINDINGS

This study has attempted to solve the problem of both solid and wastewater disposal in the cassava processing industry by using solid waste (peels) as a precursor for production of activated carbon. This was then used in the adsorptive and filtrative treatment of the wastewater from the same industry. The study revealed that wastewater from cassava processing industries could be effectively treated using a combination of hydrogen peroxide oxidation and sorption with $ZnCl_2$ at activation levels of 2:3 and 1:1 and with 8 and 6 hrs contact time respectively. The study also revealed that the effluent from the treatment process is suitable for irrigation. This could prove to be very useful especially in regions where there is need for reuse of water for dry season farming as cassava processing is usually done all year round. The treated water could be discharged into nearest water course during the wet season and diverted for irrigation purposes during the dry season. The method of solid waste treatment also has the advantage of reducing space occupied by the solid waste material as the weight of the cassava peels reduces by about 61% while the volume reduction could be as high as 80% thereby leading to a more efficient utilization of space. Based on the results obtained from the study the following recommendations are being put forward:

1. The effluent from the adsorption process at 2:3 and 1:1 Zinc Chloride activation levels could be used for irrigation purposes after contact time of 8 and 6 hrs respectively.

2. The CPAC at either 1:1 or 2:3 activation ratio could be used for treatment of wastewater from cassava processing industries. However, provision should be made for a sedimentation / clarification tank to cater for the removal of suspended solids present in the final effluent if it is to be discharged into the nearest water course safely.
3. Onsite treatment plants could be incorporated into the design of cassava processing factories in order to reduce the overall environmental pollution effects of the industry.

Table 2: Summary of Comparison of Results From Treatment Process after 8 Hours Contact Time with FEPA Interim Discharge Standards for all classes of Industries.

	Activation Ratio			
Parameters	**0:1**	**1:3**	**2:3**	**1:1**
Temperature	√	√	√	√
Colour (Lovibond Units)	×	×	√	√
Total Dissolved Solids (TDS)	√	√	√	√
Total Suspended Solids (TSS)	×	×	×	×
pH	√	√	√	√
BOD_5	×	×	√	√
S^{2-}	√	√	√	√
CN^-	√	√	√	√
SO_4^{2-}	√	√	√	√
NO_3^-	√	√	√	√
Fe^{3+}	√	√	√	√
PO_4^{3-}	×	×	√	√
Mn^{2+}	√	√	√	√
Phenol	-	-	-	-
Cl^-	√	√	√	√
Cd^{2+}	√	√	√	√
Hg	-	-	-	-
Ni^{2+}	√	√	√	√
Mg^{2+}	√	√	√	√
Ca^+	√	√	√	√
Zn^{2+}	√	√	√	√

√ : Meets FEPA Discharge Standard
× : Does not Meet FEPA Discharge Standard
- : Not Detected in Wastewater Sample

REFERENCES

1. Asia, I. O. and Akporhonor, E. E. (2007) Characteristics and Physciochemical Treatment of wastewater from Robber Processing Factory, *International Journal of Applied Science Research*, vol. 4(4): 397-402.

2. Coker, A., Sangodoyin, A. Y., Sridhar, M., Booth, C. Olomolaiye, P. and Hammond, F. (2009) Medical Waste Management in Ibadan, Nigeria: Obstacles and Prospects, Waste Management vol. 29 : 804-811.
3. Ethan, J. N., Richard, W. M. and Michael, G. K. (2003) The effect of an industrial effluent on an urban stream benthic community: water quality vs. habitat quality, *Environmental Pollution* vol. 123(1):1-13.
4. Ewemoje, T. A., Omotosho, O. A. and Abimbola, O. P. (2011). Life Cycle Assessment of hatchery production process to point-of-lay of a poultry system in a developing country, Proc. Nigeria Institution of Agricultural Engineers conference (Ilorin 2010), Oct. 2010, pp. 122-125.
5. Foo, P. L. Y. and Lee, L. Y. (2010) Preparation of Activated Carbon from *Parkia Speciosa* pod by Chemical Activation, Proc. World Congress on Engineering and Computer Science (WCEC 2010), pp. 98-104.
6. Kalu, C., Modugu, C. C. and Ubochi, I. (2009) Evaluation of solid waste management policy in Benin metropolis, Edo State, Nigeria, *African Scientist* vol. 10(1): 68-72.
7. Mijinyawa, Y and Lawal, N. S. (2008) Treatment Efficiency and Economic Benefit of Zartech Poultry Slaughter House Wastewater Treatment Plant, Ibadan, Nigeria, *Scientific Research and Essay* vol. 3(6): 219-223.
8. Morenikeji, O. A. (2010) The final hurdle to be crossed in the eradication of *dracunculiasis* in Nigeria, *American Science*, vol. 6(2):76-81.
9. Nwaogwu, L. A., Agha, N. C., Alisi, C. S. and Ihejirika, C. E. (2011) Investigation on the effect of cassava effluent-polluted soil on germination, emergence and oxidative stress parameters of *Telferia occidentalis*, *Journal of Biodiversity and Environmental Sciences (JBES)* vol. 1(6): 104-111.
10. Obadina, A. O., Oyewole, O. B., Sanni, L. O. and Abiola, S. S. (2006) Fungal enrichment of cassava peels proteins, *African Journal of Biotechnology*, vol. 5(3):302-304.
11. Ogundola, A. F. and Laiasu, M. O. (2007) Herbicidal effects of effluent from processed cassava on growth performances of *chromolana odorata* weeds population, *Afri. J. Biotech,* vol. 6: 685-690.
12. Okafor, N.(1992) Commercialization of fermented foods in Sub-Saharan Africa, In Application of Biotechnology to traditional fermented foods. pp. 165-169. National Academy press, USA, 1992.
13. Olorunfemi, D. I., Okoloko, G. E., Bakare, A. A. and Akinboro, A. (2011) Cytotoxic and Genotoxic Effects of Cassava Effluents Using *Allium cepa* Assay, *Research Journal of Mutagenisis*, vol. 1(1):1-9.
14. Zagorc-Koncan, J.and Cotman, M. (1996) Impact assessment of industrial and municipal effluents on surface water - A case study, *Water Sci. Technol*., vol. 34(8):141-145.