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SUITABILITY OF RUNOFF WATER QUALITY FOR IRRIGATION FROM A PLOT TREATED WITH CASSAVA EFFLUENTS

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The quality of runoff from a plot treated with cassava waste was examined in the laboratory to evaluate the runoff water quality for irrigation purposes. To study the runoff quality, rectangular soil plots with 840 mm x 302 mm text area were used. The experiment had a 3 x 5 factorial design with two independent variables. The independent variables were cassava effluent resident time (12 h, 24 h and 36 h) and cassava effluent addition rate (0, 10, 20, 30 and 40 m3/ha). At the end of each experimental run, runoff was collected, and soil loss and runoff quality were determined. On the average, the soil loss from the plot increased from 10.05 kg/ha/mm when no effluent was added to 76.46 kg/ha/mm of simulated rainfall when 40 m3/ha of effluent was added. Soil loss from the plot also increased from 15.19 kg/ha/mm to 50.10 kg/ha/mm as the resident time increased from 12 h to 36 h. The EC of all the runoff samples from the plots are within the "good" class criterion for irrigation water. The highest EC value of 0.335 dS/m was observed when 40 m3/ha of cassava effluent was on the soil for 12 h. The result of the qualitative analysis also revealed that all the runoff water obtained from the different combinations of the two factors met the EPA total solid standard of not more than 500 mg/l. SAR values of all the runoff water collected from the plots are also within the low sodium hazard classification. With the addition of amendments to slightly increase the pH, the runoff water is suitable for irrigation purposes.

INTRODUCTION

Cassava *(Manihot esculenta)*, an important root crop in sub – Saharan African is a carbohydrate staple food that provides energy for about 500 million people in the world. It is also the third most important food source in the tropics after rice and maize (Cock, 1985). Cassava is one of over 2,000 plant species known to be cyanogenic (Conn, 1980). Cassava roots are very starchy and the young leaves are a good source of protein (Bradbury and Holloway, 1988). Cassava roots are the most perishable of the major root crops and deteriorate in air at ambient temperature in 3 – 4 days. In subsistence agriculture, the plants are left in the ground until needed for food or for processing to overcome the problem of storage (Ingram and Humphries, 1972; Rickard and Coursey, 1981). The roots can be left in the ground for several months after reaching maturity but a disadvantage of this system is that large areas of land are occupied by a crop which is already mature and is thus unavailable for further use.

Cassava produces two cyanogenic glucocides; linamarin and a small amount of lotaustralin. These cyanogens, which can be converted to toxic hydrogen cyanide (Rosling, 1988) are distributed widely throughout the plant with large amounts in the leaves and root cortex. An endogenous glucocide found in cassava can hydrolyze linamarin and lotaustralin to cyanohydrin which in turn can break down to hydrogen cyanide. Cyanogenic glucocides, cyanohydrins and hydrogen cyanide can thus be found simultaneously in cassava products. The twin problems of perishability and the poisonous nature of the cyanide present in cassava roots have been partly overcome by the development of a large number of traditional forms of processing in different parts of the world. In West Africa, a roasted product called ”gari” is produced most commonly from cassava roots.

In the production of “gari”, cassava roots after peeling are bruised by grating. Under normal physiological conditions, the tissues of cassava do not contain free cyanide but this is liberated after grating indicating that the enzyme and substrate are located in different compartments within the intact plant. Since cyanogenic glucocides are soluble, the physical removal of water from the grated cassava mash results in elimination of these glucocides. The water is then squeezed out in a press and this process takes 2 – 5 days, the damp product is dried and hydrogen cyanide removed by roasting in a metal dish over a wood fire. This reduces the retention of cyanide in “gari” to only 1.8 – 2.4 % (Oke, 1994; Dufour, 1994; Cardoso et al., 2005). This traditional method of cyanogen removal from cassava is very efficient, because it is possible to obtain a cyanogen – free product, irrespective of the variety of cassava used (Oke, 1994).

Waste from the pressed cassava mash is a liquid residue which shows high biochemical oxygen demand (BOD), cyanide and mineral contents. From the analysis of cassava effluents sampled from three towns in southwestern Nigeria, Abiona et al. (2005) reported that the waste among other constituents consists of heavy metals such as Cu, Mn, Fe and Pb. However, Pb is detected in the effluents from only one out of the three towns considered. In addition to the heavy metals, other ions present in the cassava waste liquid residue include Na, Ca, Mg and HCO_3. When the effluent is pressed out of grated cassava mash, no or little effort is made to channel and collect the waste for proper disposal. Part of this effluent infiltrates into the soil while the remaining part that is left on the soil surface is easily washed away by runoff water to nearby streams during and after rainfall. The impact of the dissolved effluents in the runoff water on the receiving stream has yet to be quantified.

In Nigeria, readily available information on cassava is on the different processing techniques to remove or reduce the cyanogen content of the end product. Little attention has been given to the impact of the cassava waste constituents on the soil and water environments. This study is aimed at examining the quality of runoff from an experimental plot treated with cassava waste with the view of evaluating the runoff water quality for irrigation purposes, and possible hazards to farm crops.

MATERIALS AND METHODS

Samples and Cassava Effluent

The soil used in this study is classified at a series level as Iwo series (Ojanuga, 1975) and as Ferric Luvisol by the USDA system (Soil survey Staff, 1992). It was derived from granite and gneiss parent material. The texture of the plough layer (0-15cm) is sandy loam having 72% sand (>20 mm), 11% silt (2 – 20 mm) and 17% clay (< 2 mm) with organic matter content of 2.15 %. The soil sample was collected from the top 150 mm of an uncultivated soil profile at the Teaching and Research Farm of the Obafemi Awolowo University, Ile – Ife, Nigeria. The soil sample was air dried to moisture content of 8 % and pulverized to reduce clods to smaller fractions to pass through a No. 10 sieve, with an apparent opening size of 2 mm. The cassava effluents used in this study was collected from a “gari” processing centre on Road 8 of Obafemi Awolowo University, Ile – Ife. Some of the properties of the effluent are shown in Table 1.

Rainfall Simulation

The experimental apparatus consists of a nozzle type rainfall simulator, with conical spray formation and an area of coverage of 0.6 m^2. The nozzle was placed at a height of 3 m and the average drop size was about 2.1 mm with a terminal velocity of 9 m/s, while operating at pressure of 40 kN/m^2. At this pressure, the impact energy of simulated rain was about 275 kJ/ha/mm. The rainfall simulation was used to create rainfall intensity of 100 mm/h (which is the average rainfall intensity experienced during the peak rainfall period in the study area) for 30 minutes. The soil box is rectangular in shape with 840 mm x 320 mm text area and with a slope of 1%. It was elevated above the ground surface to eliminate the splash effect of soil on the ground into the soil box. The soil in the soil box was compacted to bulk density of 1.50 g/cm^3 before the commencement of the experiment to simulate the field average soil bulk density in the area. Figure 1 shows the rainfall simulator used in this experiment.

Table 1. Quantity and composition of the Cassava effluent.

Composition	COD (mgO_2/l)	BOD (mgO_2/l)	pH	Cl^- ppm)	NO_3^- (ppm)	K^+ (ppm)	Na^+ (ppm)	Mg^{2+} (ppm)	Ca^{2+} (ppm)
Quantity	8,800	3,608.0	4.3	2013.5	57.7	11,250.0	21.0	1149.3	52.0

Experimental Design and Analysis

The experiment was a 3 x 5 factorial design with two independent variables (one of three levels and the other of five levels). The independent variables were: cassava effluent resident time period before the experiment (12 h, 24 h and 36 h) and cassava effluent addition rate (0 m^3/ha (control), 10 m^3/ha, 20 m^3/ha, 30 m^3/ha and 40 m^3/ha). This gave 15 experimental runs and there were three replicates of each run. The dependent variables were soil loss and the quality of the runoff water (irrigation water quality parameters). Soil loss data were subjected to analysis of variance (SAS, 2000) to determine the effect of the treatment.

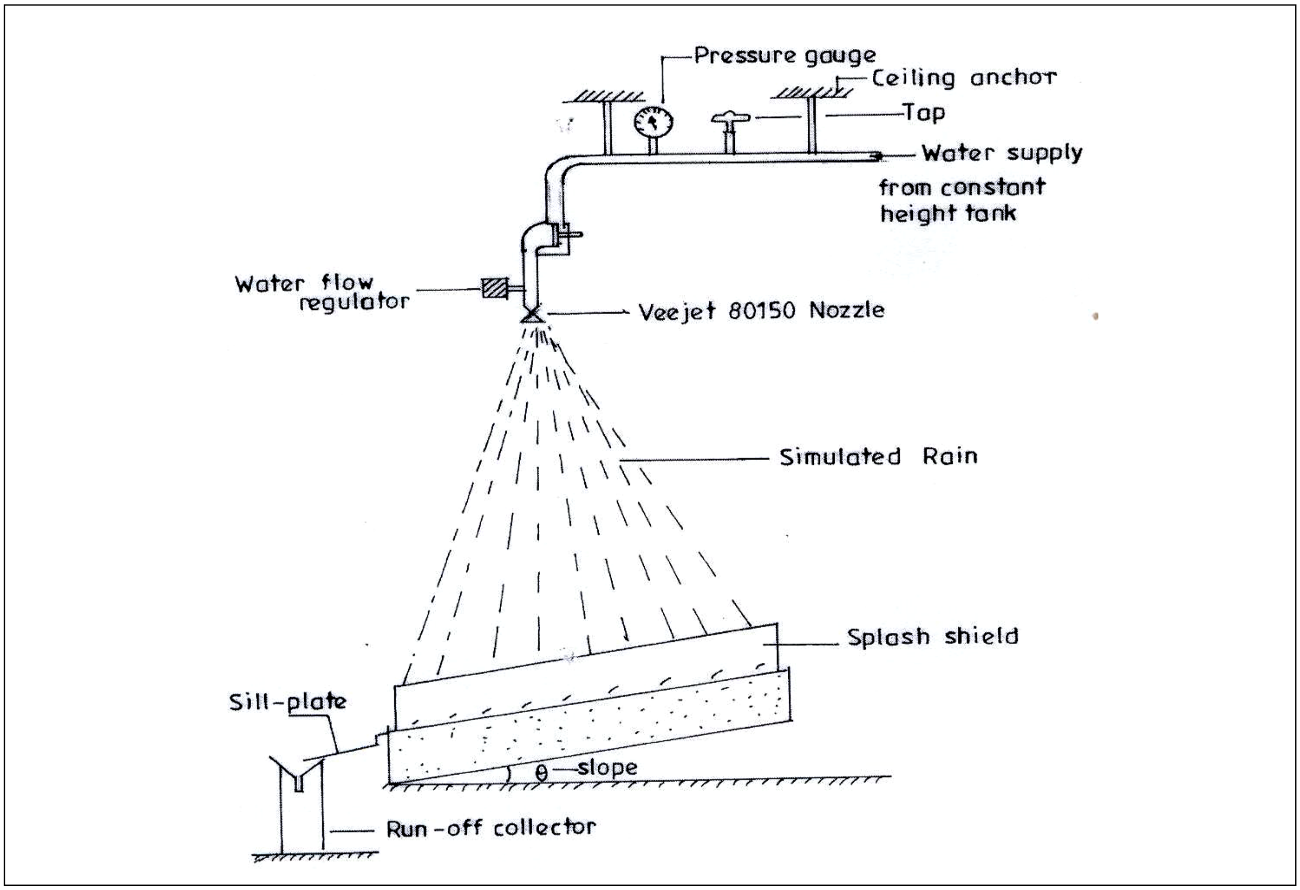

Figure 1. The rainfall simulator.

Soil Loss Measurement and Runoff Quality Determination

The runoff was collected in a 50 l bucket. After each experimental run, the sediment was separated from the runoff water using a No. 22 sieve, with an apparent opening size of 0.2 mm followed by sedimentation-decantation of the sample of the filtrate after it had been thoroughly mixed. The soil loss from the plot after its separation from the runoff was dried in the oven at a temperature of 105^{o}C for 24 hours and its weight determined.

The runoff water collected was stored in a rubber container prior to testing to prevent contamination as usually is the case with metallic containers. The pH of the runoff sample was determined using a pH meter after the standardization of the meter with buffer pH of 4, 7 and 9. Sodium (Na) ion was tested using flame photometer while magnesium (Mg) and calcium (Ca) ions were tested using atomic absorption spectrophotometer. Irrigation water rich in bicarbonate content tends to precipitate insoluble calcium and magnesium in the soil as their carbonate. The bicarbonates of the runoff water were determined by laboratory tests of precipitation of soluble calcium and magnesium from the runoff water samples to obtain carbonate using Equation 1 (Michael, 1999):

$$2HCO_3 + Ca = CaCO_3 + H_2O + CO_2 \quad (1)$$

Irrigation Water Quality Parameters Determination

The salinity of the runoff water which is the total sum of all the ionized dissolved salts in the water without reference to the specific ions present was characterized using the electrical conductivity (EC) of the runoff water from the plot treated with cassava waste (James, 1993). The effect of salinity is to restrict the availability of soil water to the plant. The presence of salt in soil water increases the energy needed to remove water from the soil. The sodium hazard of the runoff water was measured using the sodium adsorption ratio (SAR) which is one of the most reliable indices used in expressing or determining the exchangeable sodium in the soil. The sodium adsorption ratio (SAR) was determined using Equation 2 (Michael, 1999):

$$SAR = \frac{Na^{+}}{\sqrt{\left(Ca^{+} + Mg^{2+}\right)/2}} \quad (2)$$

RESULTS AND DISCUSSION

Soil loss

Table 2 gives the mean soil loss for the five levels of cassava effluent application and the three levels of the effluent resident time within the soil. From the table, as the rate of cassava effluent incorporation increased, soil loss also increased for the three resident times. Table 3 shows the mean effects of the two considered treatments on the soil loss from the plot.

On average, the soil loss from the soil bed increased from 10.05 kg/ha/mm when no cassava effluent was added to 76.46 kg/ha/mm of simulated rainfall when 40 kg/ha of cassava effluent was applied to the soil bed. However, the soil loss first decreased from 10.05 kg/ha/mm to 9.81 kg/ha/mm when 10 kg/ha cassava effluent was added to the soil plot before increasing with a further increase in the rate of cassava effluent addition. With the exception of the highest level of cassava rate considered, all the other levels of cassava effluent addition used in this study were not significantly different in their effect on the soil loss from the plot ($P < 0.05$). The higher the rate of cassava effluent addition into the soil plot the higher the soil loss. Mean soil losses were 9.81, 24.27, 25.49, and 76.46 kg/ha/mm for the four cassava effluent rates respectively. Cassava effluent rate of addition to the soil plots produced a significant effect on the soil loss ($P<0.1$). The first decrease in soil loss observed when the first level of cassava effluent was added to the soil

Table 2. Soil loss as a function of effluent rates and resident time.

Resident Time (h)	Soil loss from soil bed (Kg/ha/mm)				
	Effluent Rates (Kg / ha)				
	0	10	20	30	40
12	10.22	4.70	14.69	16.60	29.76
24	9.56	4.74	24.35	24.63	48.46
36	10.37	19.98	33.76	35.23	151.17

Table 3. Mean soil loss values (kg/ha/mm).

Treatment		Mean Value*
Cassava Effluent Rate (kg/ha)	0	10.05^{a}
	10	9.81^{a}
	20	24.27^{a}
	30	25.49^{a}
	40	76.46^{b}
Resident Time (hr)	12	15.19^{a}
	24	22.35^{a}
	36	50.10^{b}

box may be as a result of the starch content of the effluent, which will tend to bind the soil particles together thereby reducing soil loss from the text plot. However, increasing the application rate of the effluent is likely to disperse the soil particles, especially with increase in the resident time in the soil thereby exposing the particles to erosion.

It can also be seen from the table that as the resident time increases, soil loss also increases. The soil loss from the bed increased on the average from 15.19 kg/ha/mm of simulated water when the effluent was 12 h in contact with the soil to 50.10 kg/ha/mm when it was 36 h in contact with the soil. All the three resident times of the effluent with the soil before the start of the experiment were not significantly different in their effect on the soil loss ($P<0.05$). Mean soil losses as functions of the resident times of 12, 24 and 36 hours were 15.19, 22.35, and 50.10 kg/ha/mm respectively. However, resident times of 12 and 24 hours were not significantly different in their effects on the soil loss.

Runoff Water Quality Analysis

The results of the runoff water sample analysis from the soil bed treated with cassava effluent are shown in Table 4. The quality of the runoff water samples from the plot treated with cassava effluents viz–a–viz irrigation may be considered in terms of pH, alkalinity, salinity and sodium hazards. The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (EC). Table 5 gives some permissible limits of electrical conductivities for classes of irrigation water. The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water is available to plants, even though the soil may appear wet. Because plants can only transpire “pure” water, usable plant water in the soil solution decreases dramatically as EC increases (Bauder et al., 2007).

From Tables 4 and 5, the electrical conductivities (EC) of all the runoff samples from the plots for all the four levels of cassava effluent application rates and the three levels of resident time considered in this work are within class 2 (good water criterion) of irrigation water. The highest EC value of 0.335 dS/m was observed when 40 kg/ha of cassava effluent was on the soil plot for 12 hours before commencing the runoff experiment while the lowest EC value of 0.265 dS/m was observed when 10 kg/ha of cassava waste effluent was on the soil surface for 12 hours.

The acidity or alkalinity of irrigation water is expressed as pH (< 7.0 acidic; > 7.0 basic). The

Table 4. Quality measures of the runoff water samples.

Effluent Rate (kg/ha)	Resident Time (h)	pH	Na^+ ppm	Ca^{2+} ppm	Mg^{2+} ppm	HCO_3^- ppm	Total Dissolved Solid ppm	EC m mhos/cm at 25^OC	SAR
10	12	7.01	6.00	80	5.31	14	170	265	0.175
	24	6.44	4.85	20	5.46	7	198	310	0.247
	36	7.06	4.60	24	4.86	6	173	270	0.224
20	12	6.94	11.50	60	6.08	12	205	320	0.378
	24	6.42	3.75	42	5.01	9	211	330	0.145
	36	7.17	4.65	56	4.78	5	198	310	0.160
30	12	6.85	4.65	70	5.67	4	195	305	0.144
	24	6.37	10.50	60	4.92	9	192	300	0.350
	36	7.20	4.00	40	4.30	9	174	272	0.160
40	12	6.87	2.50	56	5.23	8	214	335	0.086
	24	6.70	4.50	58	5.04	9	189	295	0.152
	36	7.06	3.60	20	4.95	7	198	310	0.187

Table 5. Suggested criteria for irrigation water use based upon conductivity.

Classes of water	Electrical Conductivity (dS/m)*
Class 1, Excellent	?0.25
Class 2, Good	0.25 - 0.75
Class 3, Permissible[1]	0.76 - 2.00
Class 4, Doubtful[2]	2.01 - 3.00
Class 5, Unsuitable[2]	?3.00

*dS/m at 25ºC = mmhos/cm
[1]Leaching needed if used.
[2]Good drainage needed and sensitive plants will have difficulty obtaining stands.

Source: Bauder et al., (2007)

normal pH range for irrigation water is from 6.5 to 8.4. The results of the analysis of the runoff water from the plot revealed that the pH ranged from 6.37 to 7.20. From Table 4, there is no combination of the two factors considered (effluent rate and resident time) that resulted in the pH of the runoff that is above the maximum pH of 8.4 for irrigation water. However, when the first three levels (10, 20, and 30 kg/ha) of the cassava effluent were allowed to be on the soil plot for 24 hours before commencing the runoff experiment, the pH of the runoff water collected was less than the minimum recommended pH of 6.5 for irrigation water. Hence, the runoff water from these plots is not suitable for irrigation purposes in terms of pH.

The values obtained for the total dissolved solids of the runoff water from all the treatment combinations varied from 170mg/l to 214mg/l. This is one of the parameters used to measure the salinity of water, sometimes referred to as the total salinity. Total dissolved solids in water according to the EPA (1990) should not be more than 500 mg/l. From the results of the analysis, all the runoff water obtained from different combinations of effluent rate application and resident times met this standard. The sodium adsorption ratio (SAR) is used to express the sodium hazard of the runoff water. This index quantifies the proportion of sodium (Na) to calcium (Ca) and magnesium (Mg) ions in the runoff water. Calcium holds together, while sodium pushes soil particles apart. This dispersed soil will readily crust and have water infiltration and permeability problems. From the classifications of irrigation water based upon SAR values, SAR values between 0.1 and 9 are generally classified as low sodium hazard. From the results, all the runoff waters collected from the plots are within the low sodium hazard classification and therefore could be used to irrigate any crops except sodium sensitive crops. However, many factors, including soil texture, organic matter, crop type, climate, irrigation system and management impact, determine how sodium in irrigation water affects soils. Additionally, at the same SAR, water with low EC (salinity) has a greater dispersion potential than water with high EC (Bauder et al., 2007).

CONCLUSION

Soil loss and runoff water quality from a plot treated with cassava waste effluents at different application rates and resident times in soil were investigated. The following conclusions can be drawn from the experiments:

- The higher the rate of cassava effluent addition, the higher the soil loss. Cassava effluent rate of addition to the soil plots produced a significant effect on the soil loss ($P < 0.10$)

- The soil loss from the plot also increased with increase in the resident (contact) time of effluent with soil. However, all three levels of resident time of the effluent with the soil were not significantly different in their effect on soil loss. Moreover, resident time as a factor did not significantly affect the soil loss from the plots.

· The electrical conductivities (EC) of all the runoff samples for all the four levels of cassava effluents application rates and the three levels of resident time are within class 2 (good water criterion) of irrigation water.

· The pH of the plots treated with 10, 20, and 30 kg/ha cassava effluents for 24 hours were less than the minimum recommended pH. Hence the runoff water from these plots is not suitable for irrigation purposes in terms of pH. However, all the runoff water collected is within the low sodium hazard classification.

· With the addition of amendments such as lime to slightly increase the pH, the runoff water will be suitable for irrigation purposes

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