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Wastewater management for irrigated farming: Composition, morphology and production level variation in *amaranthus sp.* irrigated with peroxide-aeration treatment recycled cassava processing effluent

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ABSTRACT

Environmental pollution, erratic rainfall pattern and increasing population are some of the contributing factors to the currently experienced global food stress. To this end a pilot scale peroxide-oxidation treatment system was setup for recycling effluent from cassava processing industry with the aim of cultivating *Amaranthus* plants. Results revealed that the quality of derived effluent largely met NESREA standards for discharge to water bodies with parameter values such as pH (7.1), CN (0.03 mg/l) and SO_4 (5.20 mg/l) as well as irrigation water quality standard as specified by FAO with parameter values such as Sodium (34.4 mg/l), Magnesium (33.2 mg/l) and Calcium (75.2 mg/l). Comparison of plant morphological development (foliage, stem girth, plant height and average leaf area) revealed that for *Amaranthus* at treatment levels of 25, 50 and 75% were better than the control treatment. Analysis of mineral content in the vegetables revealed that *Amaranthus* bioaccumulated iron, potassium and nitrogen at all the treatment levels (25, 50, 57 and 100%) considered in comparison to the control. This study has therefore revealed that effluent from the peroxide-oxidation treatment of cassava effluent can be safely used in irrigation of *Amaranthus* at a concentration not greater than 75%.

Keywords: Effluent, Amaranthus, bioaccumulation, water reuse, peroxide

1. INTRODUCTION

The importance of water to the sustenance of life on earth cannot be underestimated, it is therefore imperative to protect its supply. Although the earth's surface is covered by 70% of water, 97.5% are from oceans and seas which are usually regarded as being too salty for consumption and agricultural purposes.

According to FAO, (2017), About 90% of the increment in global food production required by 2050 is projected to take place in developing countries, whose share of global food production is expected have risen to 74% (from 67% in 2007). According to World bank, (2020), Irrigated agriculture accounts for 20% of the total cultivated land and contributes 40% of the total food produced worldwide. *Amaranthus* originated in America and is one of the oldest food crops in the world, with evidence of its cultivation reaching back as far as 6700 BC. *Amaranthus* species are a highly popular group of vegetables that have been classified into different species (Fejér et al., 2017; Wolosik and Markowska, 2019; Park et al., 2020; Fejér et al., 2021). According to Wolosik and Markowska, (2019), the plant has ecological advantage due to its unique photosynthetic pathway which gives rise to a very efficient assimilation of CO_2 as well as more efficient water economy. These plants have been reported to consume 60% of the water needed for production of biomass compared with other C3 plants. Research conducted by Kadoshnikov et al., (2005) revealed that *Amaranth* leaves are excellent sources of protein, with its maximal accumulation in the blossoming phase (17.2–32.6% from dry weight for various samples). The seeds have also been noted to contain a significant level of nutrients which could be utilized for both human and animal food (Tang and Tsao, 2017; Biel et al., 2017; Ngugi et al., 2017; Singh and Punia, 2020; Park et al., 2020).

According to Izah et al., (2018), effluents from cassava processing activities have serious impacts on the environments with the main effect being acidification arising from hydrolysis of compounds in cassava amongst which are cyanogenic glucoside, linamarin and lotaustralin (methyllinamarin) producing hydrogen cyanide, which is also toxic to both terrestrial and aquatic organisms. The recent increment in world population has led to a corresponding increment in production and processing of cassava thereby increasing the amount of cassava effluent and solid waste materials discharged carelessly into the environment. According to Osunbitan, (2012), production scale is a key determinant when considering pollution; therefore, it will be correct to assume that large-scale processing will have the largest environmental impact if left unattended. According to Omotosho and Ewemoje, (2020), effluent from cassava production in Nigeria has been estimated to be as high as 105 billion liters per annum, this could serve as a good source of water augmentation if harnessed especially with the unreliable rainfall patterns presently being experienced as well as need to increase food production beyond the capacity of rain fed agriculture. It is therefore imperative to ensure that effluent from cassava production is adequately treated to protect the environment and, in the process, look into food production from this conservative activity. To this end the research aims to investigate the effect of treated cassava processing effluent on plant growth parameters in *Amaranthus sp.* and if the water source could be leveraged for increasing *Amaranthus* production especially with the recent erratic rainfall patterns.

2. MATERIALS AND METHODS

Peroxide oxidization treatment of wastewater

Cassava processing wastewater was collected from a local cassava processing factory at Apata community of Ibadan located in the South Western part of Nigeria. The pH of effluent collected from cassava processing wastewater was taken to a range between 10 and 11 by back titrating it with 0.5 M of NaOH (Figure 1) in an oxidation tank in order to have about 99% CN in the form of HCN content in solution as suggested by Omotosho et al., (2018). Hydrogen peroxide with a concentration of 50% was then introduced at a rate of 2.5×10^{-2} ml/l of wastewater (approximately 0.5 g H_2O_2/g of CN^-) to ensure oxidation where hydrogen cyanide (HCN) is converted to cyanate (CNO) and water molecule (H_20). In order to achieve substantial level of peroxide oxidation as well as cyanide degeneration the wastewater was allowed to a 3-hour reaction time.

The wastewater was thereafter transferred to the aeration chamber where the water was agitated by the paddle system powered by a variable speed electric motor (1.5 hp) for an hour. Effluent displacement from the aeration chamber was achieved by introducing oxidized effluent through the entry valve of the aeration compartment at a displacement rate of 2.5×10^{-1} l/min to ensure that the system does not become overloaded.

The resulting effluent was then introduced into a 1.4 m depth graded sand (0.5-2.0 mm) filtration tank at a flow rate of 1.0×10^{-2} l/s following recommendations by Environmental Protection Agency, (1995) for intermediate slow sand filter media. The pH of the effluent was corrected back to neutral range by addition of 0.1 Molar H_2SO_4 at the required dosage.

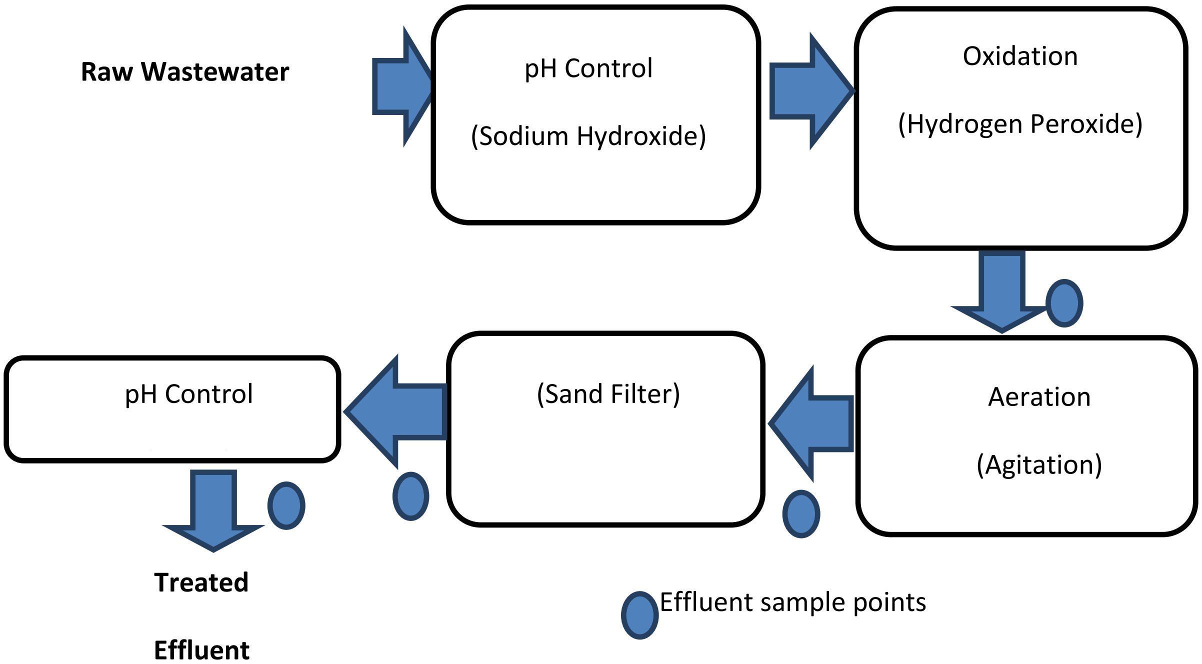

Figure 1 Flow chart of wastewater treatment procedure

Water analysis

Water samples were collected for analysis of biological parameters at the specified sample points in the treatment process line sterilized opaque coloured glass bottles. Two drops of manganous oxide was added to the samples to ensure that the BOD_5 values do not vary until they are analysed. Analysis of parameters such as colour, TSS, TDS, turbidity, odour, were done following recommendations by WHO/EC combined standards and don in accordance with methods described by Ademoroti, (2006). Light and heavy metals like Zinc (Zn), Chlorine (Cl), Iron (Fe) and Magnesium (Mg) were analysed by spectrophotometry using AAS machine with HNO_3 as the reagent. Biological parameters such as BOD_5 and DO were determined in accordance with WHO/EC combined standards, following the procedures described by Ademoroti, (2006). Analysis of cyanide concentration in the water was done using a spectrophotometer (Spectrumlab 23A) employing the alkaline picrate method.

Experimental Design for Plant growth parameter determination

Effect of the treated effluent on plant growth parameters as well as mineral composition was studied by applying effluent derived from the treatment process to potted *Amaranthus sp.* at four levels of dilution with groundwater (Figure 2). The test crops were also irrigated with raw wastewater to compare the effect of pollution levels and experimental setup established in 4 replicates thus giving a total of 24 experimental units each containing a total of 6 stands of *Amaranthus* plants. The increment in average values for each of the considered plant growth parameters were calculated with the aid of the formula given below.

$$Average\ increment\ in\ plant\ growth\ parameter = \frac{\sum_{i,j,k,l}\varphi}{\mu} - \frac{\sum_{i,j,k,l}\beta}{\omega}$$

Where i, j,k,l = plant growth parameters (leaf number, plant height, stem girth and leaf area)

φ = Value of plant growth parameter at the end of experiment

ω = Total number of plants stands at the start of the experiment

β = Value of plant growth parameter at the beginning of the treatment

μ = Total number of plants stands at the end of the experiment

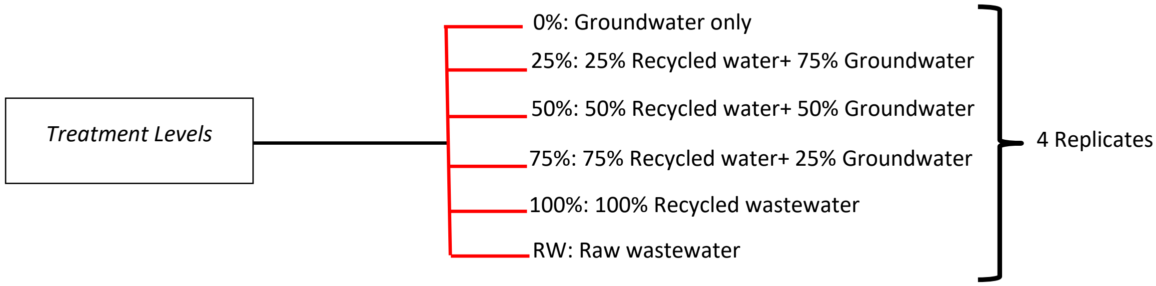

Figure 2 Schematic for treatment water application

Collection and treatment of soil samples

Soil samples (sandy loam soil) were collected from the Southern farm of the Institute of Agricultural Research and Training, Moor Plantation, Ibadan. The soil sample were collected from the top 12 cm layer, sieved then packed in sacks and transferred to the Institute's Soil Laboratory for the determination of its physical and chemical compositions as well as its characteristics. Plant residues and gravels in the soil samples were removed by passing the soil through a 5 mm sieve so as to obtain a relatively homogeneous soil sample. The soil was then packed into the buckets and compacted to the bulk density of the soil (1.39 g/cm^3) as determined during the initial soil analysis to simulate the bulk density of the soil at the place of soil collection.

Irrigation interval and depth

The irrigation depth and interval that was used for planting the *Amaranthus sp.* were 6 mm at 3-day interval as recommended by Osunbitan et al., (2012).

Determination of Water use Efficiency

At maturity, four randomly selected plant stands were removed and carefully washed to eliminate soil matter from the roots. The individual weights of the roots and leaves were obtained by removing them from the stem and weighing them on a sensitive scale. Field water use efficiency (kg/m^2) was determined on harvest weight basis from the relationship below:

$$WUE = \frac{M_b}{C_w}$$

where:

WUE = water use efficiency in kg/m^3,

M_b = sum of fresh weight of leaves, stems and roots in kg,

C_w = cumulative amount of water used (m^3)

Determination of Plant Growth Characteristics

The procedures used in determination of the selected plant growth characteristics are discussed below;

Plant height: The height of the shoot zone of the test plants were taken with the aid of a transparent ruler. The measurements were taken weekly throughout the period of experiment.

Plant girth: This is the thickness/diameter of the plants. Measurements were taken using a sensitive digital veneer calliper on a weekly basis at a predetermined height above the soil.

Number of leaves: This measures the intensity of foliage productivity of the plant. Data was taken on the number of leaves on each of the stands of the test plants.

Leaf area: This measures the area of the foliage of the plants. Measurement was taken for representative stands of each experimental line and recorded on a weekly basis. Leaf area estimate (LAE) was estimated using the formula below as recommended by Schrader et al., (2021).

$$LAE = leaf\ length\ (cm)\ x\ width\ (cm) x\ Corection\ factor\ (0.65)$$

Statistical analysis

The data obtained was subjected to Two-way ANOVA using the GLM procedure of the of the 23. SAS Institute Inc., (2004) to determine the effect of treatment on measured parameters in the plants. Means were separated using DMRT. The analysis was performed at 5% significance level.

3. RESULTS AND DISCUSSION

Odour level stability of treated effluent

A comparison of the dissolved oxygen (DO) content of the wastewater and the treated effluent revealed that the cassava processing wastewater at the start of the comparison had an average value of about 1.5 mg/l which was below hypoxia boundary (2 mg/l) for water as shown in Figure 3, the treated effluent was however observed to have an average value of 4.5 mg/l which was above the hypoxia boundary. The DO was however observed to have been reducing rapidly within the first three days after treatment while the rate of reduction was less rapid during the following four days with which the parameter dropped below the hypoxia boundary for water. The observed trend in DO was had direct proportionality to observed odour levels in the effluent while in storage as it was also observed to have increased with time. The rapid reduction in DO within the first three days may have been due to the combination of relatively high DO, nutrient matter and aerobic microorganisms in the treated effluent. This rapid reduction in the DO may have contributed to an increase in the odour level of the treated water with time during storage. This implies that if the treated effluent is to be stored for a longer period of time there is the need for the inclusion of a periodic aeration system in the storage facility.

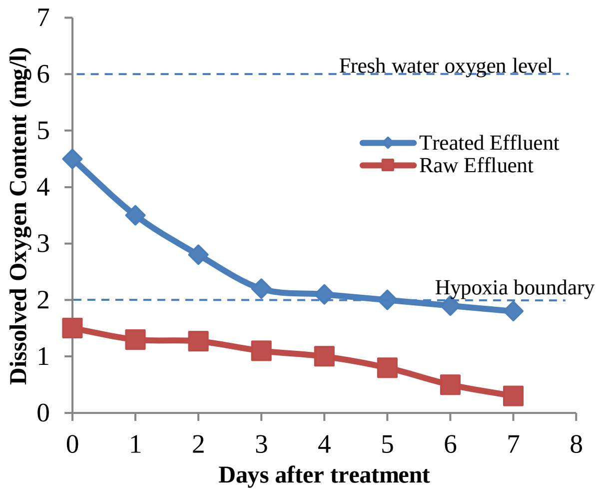

Figure 3 Comparison of dissolved oxygen content in treated and raw effluent against time

Treated effluent quality

Table 1 shows the values of parameters in raw wastewater as well as treated effluent in comparison to FAO irrigation water quality standards. The pH, Ca and Mg values obtained for the raw wastewater was observed to be outside the specified effluent quality range, however after treatment the collected effluent quality were observed to all have been within specified range. A comparison of the raw wastewater and treated effluent with water FAO quality standards revealed that he pH, Ca and Mg values obtained for the raw wastewater was observed to be outside the specified effluent quality range, however after treatment the collected effluent quality were observed to all have been within specified range. This implies that the effluent can easily be utilized for irrigation without the fear of damage to soil structure and erosion development arising from acidity as observed by Matsumoto et al., (2018). The treatment also reduces the likelihood of calcium and magnesium accumulation in soil which could lead to a disruption of Ca/Mg ratio in the soil thereby affecting plant yield as observed by Yan and Hou, (2018).

Table 1 Comparison of Raw wastewater and effluent quality with Irrigation water quality standards

Parameter*	FAO Standard**	Raw Wastewater	Treated Effluent
pH	6.5-8.4	4.5	7.1
Electrical Conductivity^{m}	<1.5	0.7	0.9
Sodium Absorption Ratio	<6.0	3.9	4.9
Calcium	40-120	125	75.2
Magnesium	6-24	50	33.2
Potassium	5-10	7.5	7.4

Sodium	0-50	30.1	34.3
Iron	2-5	0.9	0.7
Alkalinity	1-100	53.1	73
Bicarbonate	<120	54.2	76
Chloride	<140	36.6	22.3
Sulphate	<400	15.2	5.2
Salt Concentration	<960	545	567
Boron	2-8	6.4	6.6

* All units mg/l unless otherwise stated *m* 1EC unit = (TDS x 640) mg/L

** FAO Standard for irrigation water quality adapted from Ayers and Westcot (1985)

Foliage development

A comparison of the average increment in number of leaves over the treatment period at different treatments as shown in Table 2 revealed that the plants under dilution treatments (25, 50, 75 and 100%) exhibited higher average leaf development than the control (0%) treatments with 75% treatment yielding the highest level of development. The table also showed that the plants under the raw wastewater treatment had a relatively retarded growth when compared to other treatments and control. The observed boost in leaf production level in the different dilution levels (25, 50, 75 and 100%) as compared to the control (0%) may have been due to the presence of some form of assessable nitrogenous compounds in the treatment effluent leading to a possible boom in nutrient level as observed by Ashrafi et al., (2020). The results also revealed that the plants under the raw wastewater treatment had a relatively retarded growth which may have been due to inhibitory effect of the raw wastewater on the plants as suggested by Izah et al., (2018).

Table 2 Increment in average values of plant growth parameters during the period of treatment

Treatment Level (%)	Average No. of Leaves	Plant Height (cm)	Stem Girth (mm)	Leaf Area (cm^2)
0	25.17 ± 0.12	19.96 ± 0.11	4.45 ± 0.21	34.72 ± 0.13
25	25.64 ± 0.21	22.29 ± 0.22	4.55 ± 0.23	35.45 ± 0.12
50	27.20 ± 0.22	20.64 ± 0.11	4.68 ± 0.2	35.46 ± 0.2
75	27.92 ± 0.23	20.72 ± 0.24	4.67 ± 0.1	34.77 ± 0.11
100	27.90 ± 0.14	19.98 ± 0.23	4.47 ± 0.2	31.31 ± 0.22
Raw	21.25 ± 0.12	13.96 ± 0.11	2.22 ± 0.21	11.68 ± 0.22

Plant height

Results on Table 2 showed that the average plant height increment for the treatments at 25, 50, 75 and 100% dilution levels were observed to have been higher than the control treatment (0%). The raw wastewater treatments were however observed to have yielded plants with heights lower than the control treatment. The observed trend may also have been due to increment in available nutrients in the soil as a result of augmentation from the applied irrigation water as observed by Ashrafi et al., (2020). This augmentation in available nutrient may have also lead to improvement in the development level of plant vascular bundles as observed by Hajihashemi et al., (2020). The result also confirms the inhibitory nature of cassava processing effluent on plant growth and vascular development as observed by Ogunyemi et al., (2017).

Stem girth

Result obtained from comparison of the average increment in plant stem girth during the treatment period as shown in Table 2 revealed that the plants under dilution treatments levels 25, 50 and 75% exhibited higher stem girth development than the control (0%) which was 4.45 mm. Measurements taken from plant samples under the raw wastewater treatment were observed to have the lowest value (22.22 mm) for stem girth development. The observed trend in stem girth development may have been due to assimilation of increased levels of nutrients in the soil as a result of augmentation from the applied irrigation water this was in tandem with observations made by Ashrafi, et al., (2020). The increment in available nutrient may have also led to improvement nutrient translocation as a result of better development level in plant vascular bundles as observed by Hajihashemi et al., (2020). The result also showed that there was a reduction in stem girth for plants cultivated with the raw wastewater which confirms claims made by Osim, (2021) that plant growth and yield levels are hindered by enzymatic activity reduction, interference in physiological processes, damages to cell membranes and limitation of biosynthesis of metabolites resulting from presence of wastewaters.

Leaf area

The results obtained from measurement of leaf area of the plants (Table 2) revealed that the *Amaranthus* plants under the dilution treatments 25, 50 and 75% had values of 35.45, 35.46 and 34.77 cm^2 which were larger than the value obtained for control (34.73 cm^2). The leaf area value obtained for plants harvested under raw wastewater irrigation was also observed to have been 11.68 cm^2 which was the lowest. Results showed that in diluted form, treated effluent improved the foliar development of the plant which may have been an effect of some form of available nitrogenous compounds in the water. However, at 100% treatment level there must have been some level of toxicity resulting from excessive nutrient levels thereby causing a reduction in photosynthetic levels and biomass formation as well as leading to abnormal anatomical changes as observed by Hajihashemi et al., (2020). The toxic nature of raw waste water on plant growth was also noticed in folia development in plants cultivated with raw cassava processing effluent; this was also observed in studies carried out by Osim, (2021).

Crop water use efficiency

A comparison of calculated water use efficiencies at the different treatments (Table 3) revealed that for *Amaranthus* WUE at the various levels of treated effluent dilutions (25, 50 & 75%) were slightly higher than what was obtainable for the control (1.40 Kg/m^3). The WUE for *Amaranthus* at 100% treated effluent was however observed to have given a lower value than the control and other dilution treatments. *Amaranthus* plants supplied with raw cassava processing effluent was however observed to have given the lowest value of WUE of 0.31 Kg/m^3. The range of values obtained for the control, dilution treatments as well as the treated effluent were all observed to have been within the range of values (1.39 - 2.43) obtained by Ogunlela et al., (2017) while the WUE value for the raw wastewater was below range this may be due to inhibitory tendencies of cassava processing effluent as reported by Izah et al., 2018.

Table 3 Water use efficiency at different treatment levels

Treatment Level (%)	0	25	50	75	100	Raw Wastewater
Water use efficiency (Kg/m^3)	1.40	1.41	1.43	1.42	1.35	0.31

Nutrient bioaccumulation

Mean values for nutrient bioaccumulation as shown in Table 4 revealed that means of treatments were observed to have been statistically the same (p>0.05) when compared to the control for Mg, Na, Mn and Cu. Result of mineral nutrient bioaccumulation with respect to control as shown in Table 5 also revealed that there was selective bioaccumulation of Mg at 25%, Na at 75 and 100% K at 50% and Mn at 25, 75 and 100% treatment levels. There was an observed reduction in mineral nutrients for Zn, Pb, Ca and Cu. Nutrient bioaccumulation was however observed to have occurred for Fe, P and N at all dilution treatments (25, 50, 75 and 100%) when compared to control (0%).

Comparison of result of mineral nutrient bioaccumulation with respect to control revealed that there was selective bioaccumulation of Mg at 25%, Na at 75 and 100% K at 50% and Mn at 25, 75 and 100% treatment levels. Nutrient bioaccumulation was however observed to have occurred for Fe, P and N at all dilution treatments (25, 50, 75 and 100%) when compared to control (0%), this bioaccumulation may have been due to plants ability to assimilate these elements under the prevailing conditions. There was also an observed reduction in mineral nutrients for Zn, Pb, Ca and Cu which may have been due to the plants inability to retain these nutrients when irrigated with the treated effluent. Statistical analysis of mean values for nutrient bioaccumulation as showed that means of treatments were observed to have been statistically the same (p>0.05) when compared to the control for Mg, Na, Mn and Cu.

Table 4 Mineral composition of *Amaranthus* under different treatments

Treatment Level	Mineral Content♦ (%)										
	Mg	Zn	Pb	Ca	Cu	Fe	Na	K	P	Mn	N
0%	1.50^{a}	0.70^{a}	0.09^{a}	1.21^{a}	0.06^{a}	0.09^{a}	12.40^{a}	8.50^{a}	0.57^{b}	0.0020^{a}	0.23^{b}
25%	1.51^{a}	0.55^{b}	0.0020^{ab}	0.97^{c}	0.05^{a}	0.11^{a}	12.39^{a}	4.88^{ab}	0.93^{a}	0.0021^{a}	0.26^{b}
50%	1.48^{a}	0.52^{b}	0.0026^{b}	0.84^{c}	0.06^{a}	0.15^{b}	13.13^{a}	9.14^{a}	0.91^{a}	0.0015^{a}	0.25^{b}
75%	1.49^{a}	0.46^{c}	0.0027^{b}	0.72^{bc}	0.05^{a}	0.13^{b}	13.36^{b}	6.17^{b}	0.54^{b}	0.0021^{a}	0.29^{a}
100%	1.43^{a}	0.49^{b}	0.0031^{c}	0.35^{c}	0.05^{a}	0.12^{b}	13.56^{b}	6.38^{b}	0.63^{ab}	0.0024^{a}	0.31^{a}
Raw Wastewater	1.49^{a}	0.45^{c}	0.09^{a}	1.06^{b}	0.05^{a}	0.10^{a}	12.67^{a}	7.65^{a}	0.69^{ab}	0.0009^{ab}	0.29^{a}

♦Superscripts with the same letters along the column are not significantly different at p ◎ 0.05.

Table 5 Summary of Mineral Bioaccumulation Status of *Amaranthus* under Various Dilution Treatment Levels

Plant Type	Treatment Level	Mineral Element										
		Mg	Zn	Pb	Ca	Cu	Fe	Na	K	P	Mn	N
Amaranathus	25%	+	-	-	-	-	+	-	-	+	+	+
	50%	-	-	-	-	0	+	0	+	+	-	+
	75%	-	-	-	-	-	+	+	-	+	+	+
	100%	-	-	-	-	-	+	+	-	+	+	+

+: Mineral element bioaccumulated in comparison to control

-: Mineral element reduced in comparison to control

0: No change in mineral status in comparison to control

Statistical analysis

Results of the ANOVA as presented in Table 6 showed that the duration of treatment (Days) and effluent dilution levels (Treatment) had significant ($p \leq 0.05$) effect on all the plant growth parameters (Plant height, leaf area, stem girth and number of leaves) investigated. The interaction effects were however found to have been significant for leaf area and stem girth development. Separation of means carried out by DMRT (Table 7) for number of leaves showed that the control an 25% treatment were not significantly ($p > 0.05$) different while the 50, 75 and 100% treatments were not also significantly ($p > 0.05$) different. Separation of means for stem girth revealed that values for the control and 75% treatments were not also significantly ($p > 0.05$) different so also were the values obtained at 25 and 100%. For plant height the separation of mean values revealed that the control and 75% treatment were not significantly ($p > 0.05$) different. The leaf area values mean separation showed that values for the control, 25, 50 and 75% treatment levels were the same ($p > 0.05$).

Table 6 Combined ANOVA table for plant growth parameters

Parameter	Source	DF	Sum of Squares	Mean of Square	F-Value	Pr > F
Plant Height	Days	15	34828.2	2321.88	75.15	<.0001
	Treatment	5	2890.49	578.098	18.71	<.0001
	Days*Treatment	75	1721.1	22.948	0.74	0.9482
Stem Girth	Days	15	1191.25	79.42	98.99	<.0001
	Treatment	5	221.75	44.35	55.28	<.0001
	Days*Treatment	75	49.46	0.66	0.82	0.458
Number of Leaves	Days	15	71741.3	4782.75	171.15	<.0001
	Treatment	5	1997.42	399.48	14.3	<.0001
	Days*Treatment	75	856.38	11.42	0.41	1
Leaf Area	Days	15	32245.9	2149.73	68.04	<.0001
	Treatment	5	16543.1	3308.62	104.72	<.0001
	Days*Treatment	75	3204.15	42.72	1.35	0.0431

Table 7 Separation of means for Plant growth parameters

Treatment♦	*Number of leaves*	*Stem Girth*	*Plant Height*	*Leaf Area*
0%	17.90[a]	4.11[a]	18.78[ab]	30.67[a]
25%	18.23[a]	3.75[c]	19.29[a]	29.96[a]
50%	15.48[b]	3.81[b]	17.81[b]	28.97[a]
75%	16.22[b]	4.16[a]	18.02[ab]	29.96[a]
100%	15.08[b]	3.20[c]	15.37[c]	22.16[b]
Raw Wastewater	11.29[c]	2.36[d]	12.09[d]	10.41[c]

♦Superscripts with the same letters along the column are not significantly different at *p* ≤ 0.05.

4. CONCLUSION

Results from the study revealed that the quality of effluent from the established cassava processing plant largely met FAO standards for irrigation water quality. Comparison of plant morphological development (foliage, stem girth, plant height and average leaf area) revealed that for *Amaranthus* at treatment levels of 25, 50 and 75% were better than the control treatment. Analysis of mineral content in the vegetables revealed that *Amaranthus* bioaccumulated iron, potassium and nitrogen; at all the treatment levels (25, 50, 57 and 100%) considered. This study has therefore revealed that effluent from the peroxide-oxidation treatment of cassava effluent can be safely used in irrigation of *Amaranthus* at a concentration not greater than 75%. This will be especially valuable in areas where there is a need for water reuse during the dry season as well as augmentation of water supplies for agricultural cultivation; given the current trend of irregular rainfall.

Ethical issues

Not applicable.

Informed consent

Not applicable.

Funding

This study has not received any external funding.

Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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