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Agricultural Valorization of Wastewater in Dschang, West - Cameroon: An Alternative to the Fertilizer Problem and to Good Environmental Management in Urban Areas

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Authors' contributions:

This work was carried out in collaboration among all authors. Author HNT designed the study, wrote the protocol and wrote the first draft of the manuscript. All authors HNT, ET, SK, PAT and TN performed the statistical analysis, managed the analyses of the study, the literature searches, read and approved the final manuscript.

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ABSTRACT

The agricultural valorization of wastewater has not been part of water resource management and poverty alleviation policies in Cameroon due to insufficient knowledge on its virtues. The aim of this

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work was to promote sanitation by using wastewater in agriculture in Dschang Municipality, through evaluation of its fertilizing power. The study focused on three selected crops including lettuce (leaf vegetable), eggplant (fruit vegetable) and carrot (root vegetable). The experimental design was a split-plot and composed of nine (09) randomized blocks. The work was done both in the rainy season and in the dry season. Raw wastewater (E1) and urban surface water (E2) were used, while drinking water (E3) aided as control. The plots that received raw wastewater showed the best yields followed by the plots that received urban surface water. Up to 13 tons of lettuce per hectare, 19 tons of carrots per hectare and 61 tons of eggplants per hectare were obtained on the E1 plots. The yields of E1 were 1.5 to 7.4 times higher than those of E3 plots in the rainy season, and 3 to 4.4 times higher in the dry season. The yields of E2 plots were 1.1 to 2.2 times higher than those of E3 in the rainy season and 1.7 to 4.4 times higher in the dry season. These results show the fertilizing power of raw or diluted wastewater. In their poverty alleviation policy, the public authorities of the Dschang Municipality should promote the use of wastewater as fertilizers for crops not consumed raw, as alternative solution to wastewater management in this city.

Keywords: Wastewater; valorization; fertilizing power; environmental management; Dschang; West-Cameroon.

1. INTRODUCTION

The use of wastewater in urban agriculture is a long-standing and widespread practice in both developed and developing countries [1,2,3]. It is estimated that more than 20 million hectares of agricultural land worldwide receive wastewater [2,3,4,5], an area equivalent to almost 7% of the total agricultural land receiving wastewater worldwide. In Africa, many countries are yet to integrate wastewater use in agriculture during water resources planning, while some countries no longer consider wastewater as waste to be disposed of but as an integral part of potential water resources. However, Africa is going through a historical period of demographic explosion, with a population expected to double by 2030 compared to 2010 [6,7]. This very high population increase in African cities is at the root cause of many problems such as unemployment, water resource management, and waste and sanitation problems. In this context, urban agriculture appears as an alternative to solve these problems. Market gardening in marshy lowlands appears as the main activity of urban agriculture. These shallow areas, being waterable and irrigable, allow off-season production, especially of vegetables.

In Cameroon, the use of wastewater in agriculture is done unconsciously; wastewater and other wastes produced in cities are generally mixed with water from rivers used for irrigation [8]. The use of wastewater in agriculture can contribute not only to sanitation, but also can partly solve the problem of fertilizers whose exorbitant prices are no longer affordable by a majority of market gardeners, with generally low-income. Indeed, even when treated, wastewater recycles organic matter and offers a greater diversity of nutrients than any commercial fertilizer can provide. It provides many trace elements such as cobalt, copper, iron, manganese, molybdenum and zinc, which are essential for optimal plant growth [3,7,9,10]. Hence the need to focus on the fertilizing power of water used to irrigate crops in Cameroon, in order to promote this practice in that country. The aim of this work was to promote sanitation, by using wastewater in agriculture in Dschang Municipality, through evaluation of its fertilizing power. The results obtained will serve as baseline data for wastewater management for agricultural use in this locality.

2. MATERIALS AND METHODS

2.1 Study Area

Located in the West Region of Cameroon, Dschang Subdivision is the head quarter of the Menoua Division. The town extends over part of the villages of Foto and Foréké-Dschang between latitudes 5°10' and 5°38' North and between longitudes 9°50' and 10°20' East. It has an average altitude of 1400 m. This area is located in the South - West slope of the Bamoutos Mountains, and is dominated by low plateaus strongly dissected by small valleys sometimes swampy. The climate is characterized by a dry season from mid-November to mid-March and a rainy season from mid-March to mid-November (Fig. 1).

2.2 Origin and Characteristics of the Water used for the Field Experiment

Three types of wastewater were used in this study, namely raw wastewater (E1) from the

University of Dschang's wastewater treatment plant, and urban surface water (mixed wastewater) which receives all the wastewater from the University of Dschang's application and research farm (E2). Drinking water (E3) was used as control. These waters were collected and analysed once a week for one month during the dry and rainy seasons. The pH and electric conductivity of the water was measured with handhold Cyberscam PD 300 of WTW. Five days biochemical oxygen demand (BOD_5) was measured using the BOD TrackTM of Hach Company. Chemical oxygen demand (COD) was read using the DR2500 spectrophotometer after the dichromate digestion of the samples on the Hach DRB200™ reactor. $PO4^{2-}$, $NO3^{+}$ and K^{+} were measured using RQflex plus 10 Reflectometer of Merck.

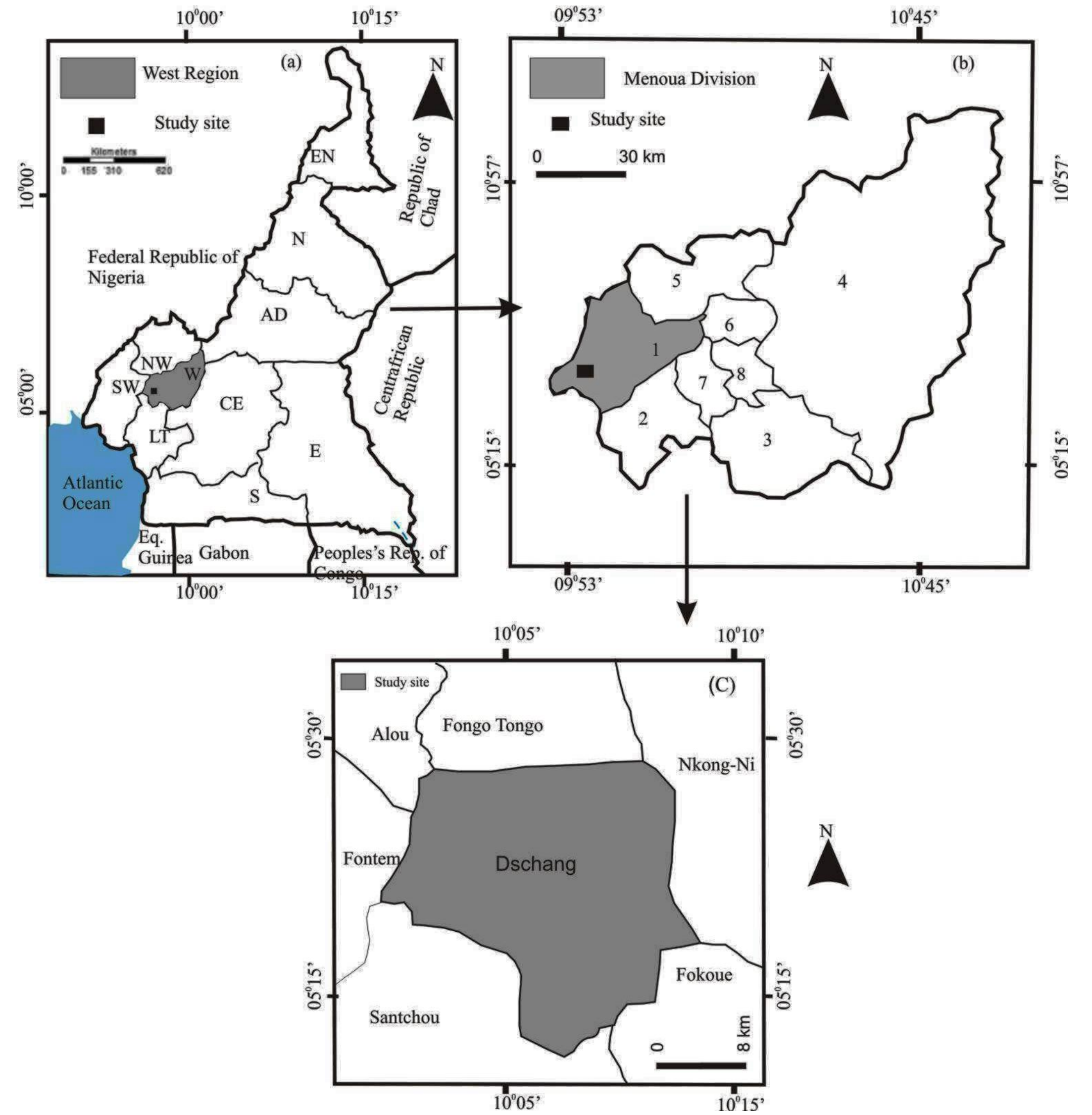

Fig. 1. Location of the study site in Cameroon (a), in the West Region (b) and in the Menoua Division (c). EN–Exreme North Region; NW–North West Region; N–North Region; AD–Adamawa Region; CE-Centre Region; E–East Region; LT–Littoral Region; S–South Region; SW–South West Region; W–West Region. 1-Menoua Division; 2-Upper-Nkam Division; 3-Nde Division; 4-Noun Division; 5- Bamboutos Division; 6-Mifi ; 7-Upper-Plateau Division; 8-Koung-Ki Division

2.3 Soil Characterisation of the Experimental Site

For the physicochemical characterisation of the soil at the experimental site, one composite soil sample was collected per depth (0-10 cm). The soil sample was air-dried in the shade, crushed and passed through a 2 mm sieve. The following analyses were carried out: particle size distribution analysis (texture) according to Gwet and Bauder method [11] based on stock's law; pH and electrical conductivity in the ratios of 1 : 2.5 soil-to-water ratio; organic carbon according to Walkey and Black method [12]; total nitrogen according to the Kjeldhal method [13]; available phosphorus according to Bray 2 method [14]; cation exchange capacity (CEC) according to the Metson method; Na and K were determined by flame spectrophotometry.

2.4 Experimental Plot Layout

A plot of 400 m^2, a five years fallow, was selected in a marshy valley bottom in Campus of the University of Dschang. The study focused on three crops including lettuce (leaf vegetable), eggplant (fruit vegetable) and carrot (root vegetable). The plots were arranged in a split-plot design (Fig. 2). This layout was composed of nine (09) completely randomized blocks representing the three main treatments (raw wastewater, urban surface water, drinking water) in three replicates for each treatment. Within each block, there was a random arrangement of four plots representing the four secondary treatments which are the three types of crops used and one plot without crops to serve as control. The blocks were separated from each other by a two-metre space. The plots of the same block were separated from each other by a space of one meter. Each plot had a surface area of 4 m^2.

2.5 Cultivation and Maintenance of the Plots

After three to four weeks at the nursery, five to six lettuce plants were transplanted with a 30 cm spacing between plants. Eggplants of 4 to 5 leaves , after 4 to 5 weeks in the nursery, were transplanted with a spacing of 50 cm between plants. The sowing of the carrots was done on lines separated by a spacing of 25 cm. Approximately 0.2 g of seeds per line.

No fertilizers or pesticides were used for plot maintenance. Weeding was done manually and in a very careful manner to avoid the uprooting of the young plants. Wastewater (40 litres per 4 m^2 plot) from the Dschang University's wastewater treatment plant was applied to the beds of the blocks named "E1", just before sowing. The ridges of these blocks received only drinking water afterwards (rainwater and borehole water). The ridges of the three blocks named "E2" received stream water (40 litres per 4 m^2 plot) used by the market gardeners every two weeks in the rainy season (flood simulation), and twice a week in the dry season (market gardeners' practice) throughout the crop cycle. The surfaces of the "E3" blocks received potable water (only rainwater and water from the borehole). At crop maturity, lettuce roots were separated from the leaves and stems, carrot roots from the leaves, and eggplant roots and stems from the fruit after a two-week harvest. Lettuce leaves and stems, carrot roots and eggplant fruit were weighed and then recorded in tons per hectare.

2.6 Data Analysis

The data were subjected to simple descriptive statistical analysis and analysis of variance (ANOVA), at the 0.05 probability level, using SPSS software version 12.0 for Windows.

3. RESULTS

3.1 Characteristics of Soil and the Water used for the Experiments

The characteristics of the raw wastewater show an alkaline pH which is slightly higher in the rainy season compared to the dry season (Table 1). The NO_3^-, SO_4^{2-}, and COD are higher in the dry season, while PO_4^{2-} and BOD_5 are higher in the rainy season.

The river water used is acidic in both seasons (Table 2). The NO_3^- and SO_4^{2-} are predominant in the dry season why $PO_4^{2-,}$ K^+, COD and DBO_5 are higher in rainy season (Table 2). The nutrient level of the wastewater is higher than that of the river water.

The soil profile is characterized as "Fairly organic hydromorphic soil" of French classification, (Humaquept of soil taxonomy, Humic Gleysol of FAO classification). The rustic reddish yellow spots correspond to iron in the oxidized state. The soil is saturated with water in the rainy season and the water level drops to a few centimetres in dry season. Its pH is acidic and it is very rich in nitrogen and organic matter (Table 3) due to the accumulated years of fallow. This soil is deficient in major mineral elements P, K, Ca, and Mg. Its CEC is average

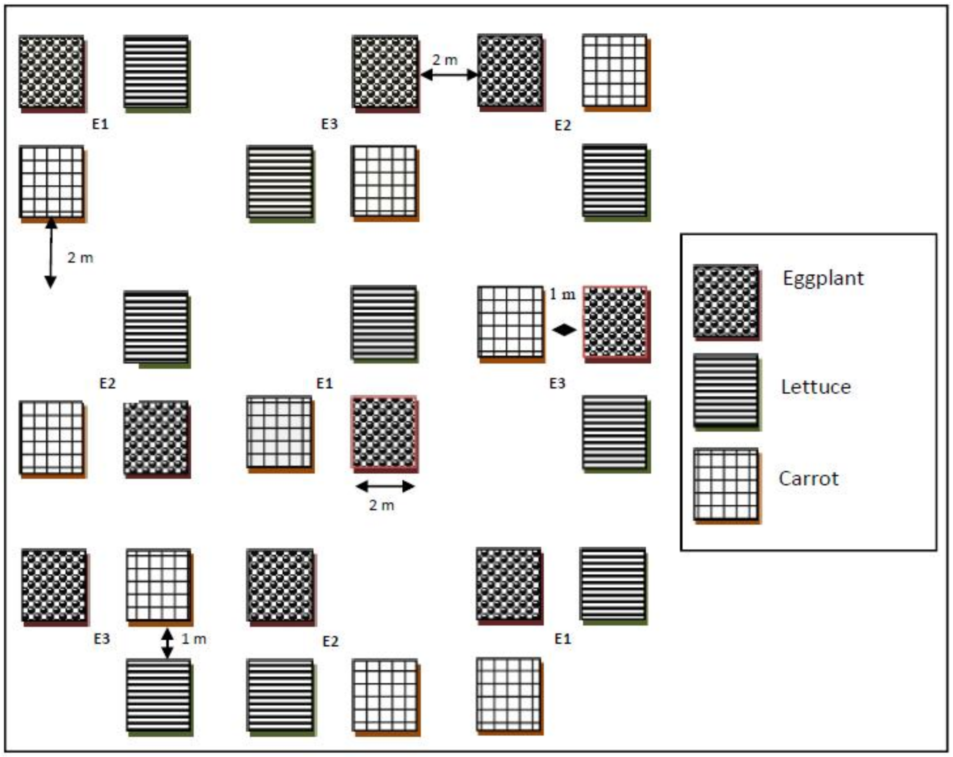

Fig. 2. Experimental layout showing the arrangement of the different blocks
E1= Block that received raw waste water; E2= Block that received urban surface water; E3= Control block (block that received drinking water)

Table 1. Characteristics of the raw wastewater

Parameters	Rainy season	Dry season	Standards (15, 16)
pH	7.90 ± 0.26	7.70 ± 0.39	6,5-8,5
CE (µS/cm)	72.7± 4.52	71,8 ± 5.26	< 7000
NO_3^- (mg/L)	20.00 ± 4.88	29.00 ± 7.07	< 50
PO_4^{2-} (mg/L)	238.00 ± 19.83	137.00 ± 35.48	//
K^+ (mg/L)	69.00 ± 7.43	53.00 ± 9.11	0.5-5
SO_4^2 (mg/L)	48.00 ± 15.00	86.00 ± 22.24	24-240
COD (mg/L)	1005.00 ± 450.20	1369.00 ± 450.59	< 90
BOD_5 (mg/L)	316.00 ± 94.00	272.00 ± 73.80	< 30

Table 2. Characteristics of the river water

Parameters	Rainy season	Dry season	Standard (15, 16)
pH	6.43±0,3	6.49± 0.22	6,5-8,5
CE (µS/cm)	58,4±4,9	56±4,5	< 7000
NO_3^- (mg/L)	11.25± 1.20	28.00 ± 2.30	< 50
PO_4^{2-} (mg/L)	4.50 ± 0.20	2.50 ± 0.41	//
K+ (mg/L)	0.70 ± 0.16	0.40 ± 0.06	0.5-5
SO_4^{2-}(mg/L)	0.48±0.08	0.52± 0.02	24-240
COD (mg/L)	99.70 ± 22.40	50.50 ± 10.84	< 90
DBO_5 (mg/L)	49,20 ± 11.20	38.00 ± 9.17	< 30

Table 3. Characteristics of soil of the experimental site. ***CEC= Cation Exchange Capacity, C/N= Carbon/Nitrogen***

Parameter	0-10 cm
Sand (%)	17.31
Silt (%)	31.96
Clay (%)	50.73
pH water	5.33
pH KCl	4.46
CEC (cmol$^+$/kg)	4.19
Available phosphorus (mg/kg)	4.19
Organic Carbon (%)	4.48
Total Nitrogen (%)	0.32
C/N	13.86

3.2 Effect of Different Treatments on Crop Yield

3.2.1 Lettuce yield

There is a significant difference ($p < 0.01$) between the yields of the different treatments during the two cycles. . In the rainy season, lettuce yield from treatment E1 was 3.29 times higher than the yields from treatment E2 and 7.46 times higher than the yield from treatment E3 (Table 4). The yield of treatment E2 was 2.2 times that of treatment E3. In the dry season, however, lettuce yield from treatment E1 was 3.25 times higher than that of treatment E3 and 1.49 times higher than treatment E2. The yield of E2 was 2.17 times that of E3 in the dry season and 2.2 times that of E3 in the wet season.

3.2.2 Carrot yield

The difference between the yields of the various treatments during the two cycles was significantly different ($p < 0.01$). In both dry and rainy seasons, the yield of treatment E1 was the highest, followed by treatment E2 (Table 4). The yield of treatment E1 was three times higher than that of treatment E3 in the dry season. It was more than one and a half times higher than the wet season performance of treatment E3. Treatment E1 performed 1.4 times and 1.75 times better than treatment E2 in the wet and dry seasons, respectively. The performance of E2 was 1.1 times that of E3 in the wet season and 1.76 times that of E3 in the dry season. For all treatment types, carrot yield was higher in the wet season.

3.2.3 Eggplant yield

There was a significant difference ($p < 0.01$) between the eggplant yields of the different treatments during the two cycles. The eggplant yield of treatment E1 in the rainy season was 1.83 times higher than that of treatment E2 and 1.8 times higher in the dry season (Table 4). In contrast, it was 2.2 times higher than that of treatment E3 in the wet season and 4.38 times higher in the dry season. The performance of treatment E2 was 2.43 times better than treatment E3 in the dry season and 1.2 times better than treatment E3 in the wet season. Like carrot, for all types of treatments, the yield in the wet season was higher.

4. DISCUSSION

4.1 Wastewater from the City of Dschang has Fertilizing Power

It has been reported [6] that differences in pH of irrigation water play a vital role in nutrient availability in soils and makes the uptake of these nutrients by the plants very difficult. This could partly explain the high yield obtained in E1 due to their alkaline pH and higher nutrient status that contribute in enriching the soil. Overall, the stream water is less rich in fertiliser, but is the one whose characteristics (e.g. BOD5) meet the WHO standards. The river water shows slightly acidic to neutral pH in both season and very low COD. The low COD is a result of dilution and low oxygen demand required by microorganisms to breakdown the organic matter in the water. Several authors [2,3,5] have already put into evidence the effect of irrigation water quality on crop performance. Neutral to alkaline pH values are suitable for the availability of basic cations such as Ca, Mg and K as well as for optimum activity of micro-organisms necessary for organic matter decomposition [7,10]. Such pH values will make micronutrients like Cu, Fe, Mn and Zn unavailable to plants [5]. Also, crops will not run the risk of aluminum toxicity due to excessively low soil pH.

Table 4. Lettuce, carrot and eggplant yields in (tons/ha) according to treatments

	Yield ± standard deviation (rainy season)	Yield ± standard deviation(dry season)
	Lettuce	
Lettuce E1	11.2 ± 0.37	13.0 ± 5.11
Lettuce E2	3.4 ± 0.42	8.5 ± 2.19
Lettuce E3	1.5 ± 0.52	3.9 ± 1.05
	Carrot	
Carrot E1	19.00 ± 1,77	14.03 ± 1,01
Carrot E2	13.53 ± 1,08	8.03 ± 1,76
Carrot E3	12.23 ± 0,39	4.56 ± 1,4
	Eggplant	
Eggplant E1	61.37± 3.01	45.50± 12.38
Eggplant E2	33.62± 1.10	25.21± 6.13
Eggplant E3	27.90± 0.61	10.38± 2.90

E1: raw waste water; E2:urban surface water; E3: drinking water

The levels of the fertilising constituents as Nitrate (NO_3^-), phosphorus (PO_4^{2-}) and potassium????, five days Biological Oxygen Demand (BOD_5) are very high in the wastewater of the city of Dschang and therefore can be a nutrient input for plants. As a consequence of the high global food demand, it is not surprising that the largest user of wastewater (treated or untreated) worldwide is the agricultural sector [15,16,3]. A well-established advantage of wastewater reuse is its nutrient content. Even when treated, wastewater recycles organic matter and offers a greater diversity of nutrients than any commercial fertiliser can provide, making available many trace elements that are essential for optimum plant growth [3,17]. In the light of the global phosphorus crisis, wastewater can be an essential source of phosphorus [18]. Numerous studies have shown that wastewater does not only improve yields, but also make agriculture possible and more lucrative during the dry season, and farmers can sell their produce at three to five times the seasonal kharif (monsoon) price [16,19,20]. The reliability of the wastewater also provides the possibility of multiple cropping cycles and the flexibility in the crops planted [3,21,22]. Similar situations have been reported for Haroonabad in Pakistan, Accra in Ghana, and Dakar in Senegal [23,24]. It is important to note that the BOD5, COD and potassium in the wastewater from the University's wastewater treatment plant is higher than the acceptable level by the standards in force, which reflects the poor state of this treatment plant. Users should take these levels into account and therefore reduce the quantities to be applied for fear of damaging the soil at long term

According to [25], irrigation with wastewater effluent has been practised successfully over a long period. The earliest documented wastewater farms were those of Bunzlom, Germany, and Edinburgh, Scotland, which went operational in 1531 and around 1650 respectively. Many other farms, such as in London, Paris (1868), Berlin (1876) and Melbourne (1892), were established later. The pH is an indicator of the degree of alkalinity or acidity of the water, and the electrical conductivity (EC) is an indicator of the salinity index. The ionic concentration of the solution is closely related to the salinity index [26], and this affects some crops. Perez-Diaz et al. [26] show that most of the water samples analyzed (89.74%) in the Lerma River water can reduce the water soil infiltration by their application in agricultural irrigation. This is due to the high sodium absorption rate values, since it was found that the Lerma River water has a predominance of Na^+ and HCO_3^-; therefore, irrigation with this water could have caused the accumulation of sodium salts and risk of a variable soil sodification. This research found that Waste water and stream water had EC values below 0.0007 dS m^{-1}. Also, Na^+ and HCO_3^- appear very low in the studied milieu [27]. These are reasons why the used wastewaters are not a hazard to water availability for crops and have no use restrictions considering only salt content.

4.1.1 Promoting the use of wastewater in agriculture in the city of Dschang could be an alternative for environmental management

The use of wastewater in the city of Dschang could partly solve not only the problem of fertiliser, the price of which has been rising over the years in Cameroon, but also the management of liquid waste in this Municipality. In fact, in Cameroon, the public authorities pay little attention to the liquid waste sector, both for household water and industrial water in urban areas [28]. Grey water is channelled into drains where it often mixes with rainwater, solid waste and excreta from open defecation [29,30]. In Yaoundé, for example, out of 13 identified wastewater treatment plants, 11 of which use the activated sludge process for water treatment, 10 have been out of order for more than 20 years and discharge raw effluent directly into the receiving environment [29,31,32]. These discharges are the cause of permanent faecal contamination of the environment and accelerate the eutrophication of the aquatic environments concerned [31]. In Dschang, the only municipal sludge and wastewater collection truck has been out of order for over 15 years [33]. This unavailable and malfunctioning of wastewater treatment plants results in very high levels of environmental pollution. The protection of the environment from this pollution can be achieved through the use of wastewater in agriculture (except for fruit and vegetables eaten raw). It is important to note that while this practice will not provide a general solution to the fertilizer problem in the country, it will help solve the problem in part. In Cameroon, wastewater should no longer be seen as a waste, but as a raw material of economic, agricultural and environmental importance.

4.1.2 Crop yields variation according to farming practices

In the rainy season, as in the dry season, for all types of vegetables tested, the difference between the yields of the different treatments during the two cycles is significant ($p < 0.01$). Overall, crops that received wastewater from the treatment plant only once (treatment E1) showed the best yield followed by those that received water from the watercourse several times (treatment E2). These results confirm those of many authors on the interest of using wastewater for soil fertilization as seen in Table 5. As show in Table 5 the yields obtained in the present work are much lower than those of other authors. This might be due to differences in the frequency of watering. Indeed, in this study, raw wastewater was applied only once while several works report multiple wastewater applications. Yields for crops that received water from the stream in the dry season were higher than in the wet season. Multiple wastewater applications could have provided additional nutrients. Compared to the control, lettuce showed the best adaptation to wastewater, followed by carrot and then eggplant.

An increase in yield has been observed in cereal crops such as sorghum as well as in vegetable crops [34,35]. However, [36] point out that vegetables such as spinach, cabbage or cauliflower are better adapted to watering with wastewater than root vegetables such as carrots, turnips or radishes. Results of Khuda and Sarfraz [36] allow to draw the conclusions on the poor adaptation of root crops irrigated with wastewater into perspective [37].

Table 5. Yields of crops irrigated with wastewater in Dschang and several cities around the world

Crop	Treatment	Yield (t ha-1)	Source
Eggplant (SS)	EU/ECD/T	45.5/25.2/10.4	This study
Eggplant (SP)	EU/ECD/T	61 .4/33.6/27.9	This study
Eggplant	EUT / T+Eng.	56.3 / 28.5	[38]
Eggplant	EUT / EUT+Eng.	60.6 / 65.4	[39]
Eggplant	T / T+Eng.	61.1 / 65.1	[39]
Eggplant	EUT / EUT + Eng / T	28.6 / 27.5 / 14.9	[40]
Red cabbage	EU / EUTP / EUTI / T	46.9 / 41 / 40 / 32	[41]
Cabbage flower	EU / EUTP / EUTI / T	28.5 / 25 / 23 / 21	[41]
Shuttle	EU / EUT / T	34.4 / 25.9 / 4	[42]
Tomato	EU / EUT / T	34.8 / 26.6 / 11	[42]
Tomato	EUT / EUT+Eng. / T	33.1 / 36.9 / 25	[43]
Lettuce (SS)	EU/ECD/T	12.7 / 8.5 / 3.9	This study
Lettuce (SP)	EU/ECD/T	11.2 / 3.4 / 1.5	This study
Lettuce	EUT / EUT+Eng. / T	26.4 / 25.9 / 27.4	[44]
Lettuce	EUT / EUT+Eng. / T	40.5 / 55.4 / 11.8	[40]
Carrot (SS)	EU/ECD/T	14.03 / 8.03 / 4.56	This study
Carrot (SP)	EU/ECD/T	18.99 / 13.53 / 12.23	This study
Carrot	EUT / EUT+Eng. / T	64.4 / 71.7 / 37.5	[40]

EUT: treated wastewater; EU: wastewater (untreated); EUTP: preliminary treatment; EUTI: primary treatment; ECD: river water; T: control water; Eng: fertilizer at recommended rates for plant needs

The agricultural valorization of wastewater should be part of the water resource management and poverty alleviation policies in Cameroon. It is already integrated into the water resource management policies of many countries [10,45]. Fertilizer prices have risen drastically in Cameroon. The price of chemical fertilizers, for example, rose from 2500 FCFA/50kg bag in 1984 to 13000 FCFA in 2006, 15000 FCFA in 2007 and 25000 FCFA in 2008. The use of wastewater does not require an additional input of chemical fertilizer; the addition of chemical fertilizer sometimes becomes inefficient or even counterproductive [40,46,47]. It is estimated that 1,000 cubic metres of municipal wastewater used to irrigate one hectare can provide 16 to 62 kg of total nitrogen, 4 to 24 kg of phosphorus, 2 to 69 kg of potassium, 18 to 208 kg of calcium, 9 to 110 kg of magnesium and 27 to 182 kg of sodium [48]. They can therefore reduce the demand for chemical fertilizers, especially when wastewater is not diluted, and thus making crop nutrients more accessible to poor farmers. There are numerous scientific developments related to wastewater reuse in agriculture [43,49,50]. This practice would not only solve the fertilizer problem, but would also prevent the over-contamination of urban surface water and the phenomenon of eutrophication.

Contrary to all the countries of the Sahelian strip, where wastewater produced in homes, hospitals and industries is often the only perennial and accessible water resource, in Dschang, wastewater is only used through the waters of the rivers that receive and dilute it. As a result, its fertilizing power is reduced. In some countries, the state takes charge of the mobilization and distribution of wastewater used in agriculture. The perimeters receiving this wastewater are often penalized by the costs of the adductions, pumping stations and storage tanks necessary for wastewater management. Bazza [50] reports that this cost varies between 0.060 and 0.200 Tunisian Dinars/m^3 (18 and 60 FCFA/m^3) in Tunisia. The mobilization of treated wastewater for agriculture is cheaper than water from dams [50].

Countries that reuse wastewater generally have guidelines or codes of good practice to protect the health of consumers and workers [43,51]. Indeed, in the context of wastewater reuse, public health and environmental protection are the main concerns. This is why strict control measures are imposed [48,52,53]. Despite the benefits of wastewater use in agriculture, important socio-cultural and religious factors influence the feasibility and acceptability of wastewater reuse plans [30]. In Asia, the agricultural use of raw excreta is a very old and widely accepted practice, so that pre-treatment may seem unnecessary [51]. In the Muslim world, contact with human excreta is prohibited by religion [53,54].

5. CONCLUSION

The waste waters of Dschang (West Cameroon) are dumped into streams meanwhile they could be used to fertilize garden crops. The purpose of this study was to promote sanitation, by using wastewater in agriculture in the Dschang Municipality, through evaluation of its fertilizing potential. The crops of the plots that received "raw" wastewater from the wastewater treatment plant showed the best yields followed by those of the plots that received water from the river. The raw wastewater was applied only once, but the yield was significant. Due to these characteristics, the stream water contains much less fertilizer than the wastewater, but the multiple applications also provide the fertilizer; the crop yield of the plots receiving this water was higher than that of the plots receiving drinking water. These results confirm the fertilizing power of wastewater. Since the city of Dschang like most cities in Cameroon, has no wastewater treatment system, promoting this practice will help protect the environment while also improving crop production. While ensuring compliance with standards, the public authorities should promote this practice, in order to partially solve the environmental and fertilizer problem which is becoming more and more critical.

DISCLAIMER

The materials used for this research are commonly and predominantly used products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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