Fruits produced with wastewater treated in stabilization ponds systems: evaluation in a quality prospective

A. B. dos Santos, S. Mota, F. M. Bezerra, B. F. Aquino
[1] Federal University of Ceará, Ceará, Brazil. (Emails: andre23@ufc.br, suetonio@ufc.br, mbezerra@ufc.br, aquino@ufc.br)

Abstract The present paper aimed to evaluate the fruit quality of two food crops - watermelon and papaya, irrigated with sewage treated in stabilization ponds: anaerobic, facultative and two maturation ponds. The experiment was conducted in the Centre of Wastewater Treatment and Reuse, placed in Aquiraz, Ceará, Brazil. The four treatments tested were: raw water with NPKS – T1, treated sewage with NPKS – T2, treated sewage – T3 and treated sewage with ½ NPKS – T4. The results indicated that systems of four stabilization ponds in series produced effluents with good quality for use on agriculture, which were below the limits suggested by WHO; the use of treated sewage on agriculture is feasible, and offers a good prospect mainly for arid and semi-arid regions; and the microbiological evaluation of food crops cultivated with sewage indicated good sanitary condition according to the Brazilian legislation.

Keywords irrigation reuse; *Citrillus lanatus*; *Carica Papaya L.*; stabilization ponds.

Introduction

It is now well recognized that the sustainability of agriculture is directly linked to the efficiency of water use. Fresh water is undoubtedly one of the most limiting factors for agricultural production in arid and semi arid regions. As fresh water becomes scarce and competition with other sectors (i.e. urban, industrial and environmental) increases, farmers find themselves relying more and more on the utilization of marginal water resources - recycled and saline water (AXELRAD and FEINERMAN, 2008).

One of the broad strategies to address the challenge to satisfy irrigation demand under conditions of increasing water scarcity in both developed and emerging countries is to conserve water and improve the efficiency of water use through better water management and policy reforms. In this context, water reuse becomes a vital alternative resource and key element to the integrated water resource management at the catchment scale (ASANO, 2002).

Wastewater if often a reliable year-round source of water and it contains the nutrients necessary for plant growth. The value of wastewater has long been recognized by farmers worldwide. The use of wastewater in agriculture is a form of nutrient and water recycling, and this often reduces downstream environmental impacts on soil and water resources (WHO, 2006).

However, there are health risks of infection from pathogenic microorganism associate with wastewater use in irrigation. Some health-protection measures should be applied to irrigation with recycled water (LAZAROVA and BAHRI, 2005):

- wastewater treatment and storage;
- control of wastewater application by the choice of appropriate irrigation methods and cultivation practices;
- crop restriction for agricultural irrigation and access restrictions for landscape irrigation;
- human exposure control, harvesting measures, education, and promotion of hygienic practices.

According to Almas and Scholz (2006) wastewater treatment in waste stabilization ponds (WSP) is a very efficient, low cost and low maintenance operation. The treated wastewater from WSP should be considered as a valuable resource for reuse by water resources managers.

Waste stabilization ponds are a well established wastewater treatment technology, being considered by World Health Organization as one of the most appropriated technology for domestic wastewater when agricultural reuse is considered, and in special for developing countries (Leite *et al*., 2005).

Waste stabilization ponds and wastewater storage and treatment reservoirs are two excellent treatment options prior to wastewater reuse in agriculture. The can easily achieve the required microbiological quality and, when treating domestic wastewater, also achieve the required physicochemical qualities. In the soil, the pond algae act as 'slow release' fertilizer and so contribute to increase crop yields and soil organic matter, thus improving the water-holdin capacity of the soil (MARA, 2003).

In 1989, the World Health Organization (WHO, 1989) proposed the following limits for treated sewage use on agriculture: $\leq 10^3$ Faecal coliforms per 100 mL (geometric mean); and ≤ 1 Helminth eggs per litre (arithmetic mean).

In 2006, the WHO conducted a detailed revision on the sanitary limits to use treated sewage on aquaculture, which are in the book **"**Guidelines for the safe use of wastewater, excreta and grey water. Volume 2: Wastewater use in agriculture**"** (WHO, 2006). Table 1 contains the WHO health-based targets for treated wastewater use in agriculture.

Table 1. Health-based targets for treated wastewater use in agriculture. WHO (2006).

Exposure scenario	Health-based target (DALY[a] per person per year)	Log pathogen reduction needed	Number of helminth eggs per litre
Unrestricted irrigation	$\leq 10^{-6}$ [b]		
Lettuce		6	≤ 1[c,d]
Onion		7	≤ 1[c,d]
Restricted irrigation	$\leq 10^{-6}$ [b]		
Highly mechanized		3	≤ 1[c,d]
Labour intensive		4	≤ 1[c,d]
Localized (drip) irrigation	$\leq 10^{-6}$ [b]		
High-growing crops		≤ 2	No recommendation
Low-growing crops		4	≤ 1[e]

a Disability adjusted life years. It is designed to quantify the impact of premature death and disability on a population by combining them into a single, comparable measure.

b Rotavirus reduction. The health-based target can be achieved, for unrestricted and localized irrigation, by a 6-7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other health protection measures, including an estimated 3-4 log unit pathogen reduction as a result of the natural die-off rate of pathogens under field conditions and the removal of pathogens from irrigated crops by normal domestic washing and rising; for restricted irrigation, it is achieved by a 2-3 log unit pathogen reduction.

c When children under 15 are exposed, additional health protection measures should be used (e.g. treatment to ≤ 0,1 egg per litre, protective equipment such as gloves or shoes/boots or chemotherapy.

d An arithmetic mean should be determined throughout the irrigation season. The mean value of ≤ 1 egg per litre should be obtained for at least 90% of samples in order to allow for the occasional high-value sample (i.e. with > 10 eggs per litre). When some wastewater treatment processes (e.g. waste stabilization ponds), the hydraulic retention time can be used as a surrogate to assure compliance with ≤ 1 egg.

e No crops to be picked up from the soil.

The microbiological quality of the water can directly affect the consumer because of the risk of infection from food crops. Shuval *et al.* (1986) defined three levels of risk in selecting a crop to be grown: a) low(est) risk to consumer but field worker protection still needed; b) increased risk to consumer and handler; highest risk to consumer, field worker and handler. They considered as "increased risk to consumer and handler" crops for human consumption, the peel of which is not eaten (melons, citrus fruits, bananas, nuts, groundnuts). Watermelon and papaya can be included in this class.

Papaya production occurs approximately in all Brazilian states. The Northeast region concentrates 72.7 % of the Brazilian area for papaya production, which corresponds to 63.2 % of the national production. The state of Ceará is the fourth biggest Brazilian producer (IBGE, 2004).

The watermelon crop is also very used in the Northeast of Brazil, and its fruits are well accepted in the market and give good economical payback. Because of the above mentioned advantages and due to the fact that watermelon is easily adaptable to the climate conditions, its production has increase the interest.

The present paper aimed to evaluate the fruit quality of two food crops - watermelon and papaya, irrigated with sewage treated in stabilization ponds: anaerobic, facultative and two maturation ponds.

Material and methods

The experiment was conducted in the Centre of Wastewater Treatment and Reuse, placed attached to the Wastewater Treatment Plant of Aquiraz, Ceará, Brazil, owned by the Company of Water and Wastewater of Ceará - Cagece.

Physical-chemical and microbiological analyses of the raw water and treated sewage were done in the Laboratory of Sanitation of the Federal University of Ceará, according to the recommendations of Standard Methods (APHA, 2005).

The fruits microbiological analyses were done according to VANDERZANT & SPLITTSTOESSER (1992). The physical-chemical fruits determinations were pH, total soluble solids (ºBrix) and total acidity, according to the methodology of Adolfo Lutz Institute (1985).

The four treatments tested were: raw water with NPKS – T1, treated sewage with NPKS – T2, treated sewage – T3 and treated sewage with ½ NPKS – T4.

Watermelon (*Citrullus lanatus*), variety *Crimson Sweet,* was one of the crops used in the experiment (spacing 2.0 x 1.0 m), tested with the irrigation methods dripping and furrow. Papaya (*Carica Papaya L.*), variety Formosa, was the other crop used (spacing 2.5 x 2.0 m), tested with the irrigation method micro-sprinkler. The experimental setup was random blocks, with four treatments and four repetitions.

Results and discussion

Quality of the water and treated sewage used in irrigation

The physical-chemical and microbiological results of the raw water and treated sewage can be found in Table 2. They showed good physical-chemical and microbiological quality for agriculture, in which the faecal coliforms and helminth eggs concentrations were below the limits suggested by the WHO.

Table 2. Physical-chemical and microbiological analyses of raw water and treated sewage used in irrigation systems. Aquiraz, Ceará, Brazil.

Parameter	Water	Treated sewage
BOD (mg O_2 L^{-1})	17	60
COD (mg O_2 L^{-1})	56	215
Sodium (mg Na^+ L^{-1})	35	89
Potassium (mg K^+ L^{-1})	8	22
Conductivity (µS cm^{-1})	236	751
Chlorine (mg Cl^- L^{-1})	40	67
Ammonium (mg N-NH_3 L^{-1})	0,2	5,3
Phosphorus (mg P L^{-1})	0	3,4
E. coli (MPN $(100mL)^{-1}$)	2,6 x 10^2	7,6 x 10^2
Helminth eggs (eggs L^{-1})	0	< 1

Papaya fruit quality

The papaya fruit quality in terms of physical-chemical and microbiological aspects is shown in Tables 3 and 4. There was a pH increase due to the irrigation with treated sewage (Table 3). Treatment T2 not only provided the highest productivities but also gave the highest value for Brix degree, in other words, the highest dissolved solids content, which is related to the final product quality. For the parameter total acidity, all treatments gave close responses, except treatment T4 that was very different from the others.

Table 3. Physical-chemical pulp quality of papayas collected in the different treatments

Parameter	Treatment			
	T1	T2	T3	T4
pH	3.98	4.11	4.30	4.28
Brix degree	9.30	11.60	8.50	11.05
Total acidity	1.58	1.54	1.53	1.37

T1 - raw water with NPKS; T2 - treated sewage with NPKS; T3 - treated sewage; T4 - treated sewage with ½ NPKS

The microbiological quality of the fruit pulp, in terms of pathogens detection, is shown in Table 4. The results indicated absence of *Salmonella,* faecal coliforms below the limit of 5 x 10^2 MPN/g, mesophiles and bolors/yeast below 10^6 CFU/g, which were independent of the irrigation water used. This indicated that the pathogens concentrations were below the concentrations limited by Anvisa (Agência de Vigilância Sanitária, Brazilian sanitary control agency, 2001). Therefore, the reuse of treated sewage on papaya production did not compromise de product quality, which could be used for human consumption.

Table 4. Microbiological pulp quality of papayas collected in the different treatments.

Sample	Determination					
	Coliforms at 35ºC (MPN/g)	Coliforms at 45ºC (MPN/g)	*E. coli* (MPN/g)	*Salmonella* sp. (in 25g)	Mesophiles counting (CFU/g)	Bolors and yeast (CFU/g)
T_1B_1 (water)	< 3	< 3	< 3	Absence	< 10	10^3
$T_1B_2 + T_1B_3$ (water)	< 3	< 3	< 3	Absence	1.7×10^3	< 100
$T_2B_1 + T_2B_2$ (treated sewage)	< 3	< 3	< 3	Absence	< 10	< 100
T_3B_1 (treated sewage)	< 3	< 3	< 3	Absence	< 10	< 100
$T_3B_3 + T_3B_4$ (treated sewage)	4	< 3	< 3	Absence	< 10	< 100
$T_4B_1 + T_4B_2$ (treated sewage)	< 3	< 3	< 3	Absence	< 10	< 100
T_4B_4 (treated sewage)	< 3	< 3	< 3	Absence	4.4×10^3	1.4×10^3

T: treatment and B: block; T1 - raw water with NPKS; T2 - treated sewage with NPKS; T3 - treated sewage; T4 - treated sewage with ½ NPKS

Watermelon fruit quality

The watermelon fruit quality in terms of physical-chemical and microbiological determinations is shown in Tables 5 and 6. The microbiological tests (Table 5) also indicated absence of *Salmonella,* faecal coliforms below the limit of 5×10^2 MPN/g, mesophiles and bolors/yeast below 10^6 CFU/g, which were independent of the irrigation water and irrigation methods of dripping and furrow used. The results were all below the limits of Anvisa, Brazil (2001).

The physical-chemical quality of the fruit pulp (Table 6) showed a decrease of the total soluble solids concentration (TSS or ºBrix) in treatments 2 and 3, and an increase in treatment 4 for the dripping system; there was a decrease in treatments 2 and 4 for the furrow system. Such a difference was influenced by the crop period, precipitation, irrigation and soil fertilization. Water variation or absence, mainly during the plant growth and fruit maturation, increases the TSS concentration. High TSS values are desired because they give a better fruit taste. Amongst the pulp samples analyzed, treatment T4 with the dripping system, presented the highest TSS values.

Table 5. Microbiological pulp quality of watermelons collected in the different treatments and irrigation methods.

Sample		Determination					
		Coliforms at 35ºC (MPN/g)	Coliforms at 45ºC (MPN/g)	*E. coli* (MPN/g)	*Salmonella* sp. (in 25g)	Mesophiles counting (CFU/g)	Bolors and yeast (CFU/g)
Dripping	T_1B_2	< 3	< 3	< 3	Absence	Nd	Nd
	T_2B_2	< 3	< 3	< 3	Absence	Nd	Nd
	T_3B_2	< 3	< 3	< 3	Absence	Nd	Nd
	T_4B_2	< 3	< 3	< 3	Absence	Nd	Nd
Furrow	T_1B_2	< 3	< 3	< 3	Absence	Nd	Nd
	T_2B_2	< 3	< 3	< 3	Absence	Nd	Nd
	T_4B_2	< 3	< 3	< 3	Absence	Nd	Nd
	T_3B_2	< 3	< 3	< 3	Absence	Nd	Nd

T: treatment and B: block; T1 - raw water with NPKS; T2 - treated sewage with NPKS; T3 - treated sewage; T4 - treated sewage with ½ NPKS.

Table 6. Physical-chemical pulp quality of watermelons collected in the different treatments and irrigation methods.

Parameter	Dripping				Furrow			
	T1	T2	T3	T4	T1	T2	T3	T4
pH	5.28	4.99	5.06	5.34	5.47	5.15	-	5.20
Brix Degree	8.9	7.9	7.5	9.5	10.2	8.1	-	6.3
Total Acidity	0.101	0.127	0.074	0.074	0.095	0.097	-	0.083

T1 - raw water with NPKS; T2 - treated sewage with NPKS; T3 - treated sewage; T4 - treated sewage with ½ NPKS

Conclusions

The main conclusions of the present research are:

- Systems of four stabilization ponds in series produced effluents with good quality for use on agriculture, which were below the limits suggested by WHO.
- The use of treated sewage on agriculture is feasible, and offers a good prospect mainly for arid and semi-arid regions.
- The microbiological evaluation of food crops cultivated with sewage indicated good sanitary condition according to the Brazilian legislation.

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