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Assessment of wastewater quality for use in crop production: Case studies of Egerton University and Nakuru wastewater stabilization ponds

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Total removal of pathogens in wastewater for agricultural irrigation is not absolutely necessary for the production of clean produce since other risk reduction measures such as hygienic handling of produce and wastewater during irrigation reduce pathogen concentrations significantly. Most of the food contamination by pathogens do not emanate from the fields but rather during their transportation and handling as evidenced from a market survey conducted in Nakuru markets. Vegetables from the market showed high levels of contamination as compared to those grown using wastewater from the trial plot. Though the quality of effluent from the wastewater stabilization ponds showed that it was not suitable for crop production in terms of faecal coliforms and helminths eggs according to WHO guidelines on safe re-use of wastewater for agriculture, the vegetables grown showed almost similar levels of pathogens contamination as the produce in the market.

Introduction

Use of wastewater for crop production has been increasing worldwide due to the increasing food demand and the changing climatic conditions that is making food production through rain-fed agriculture less reliable (Scott et al., 2004). The ever increasing world population, especially in urban areas of the developing economies calls for serious thoughts and approaches in meeting the food demands while taking care of the environment for sustainable development. Formal recycling of wastewater for crop production is hardly practiced in Kenya despite the periodic droughts; its high plant nutrient contents of the wastewater and its utilization in other parts of the world. However, illegal use of raw wastewater for vegetable production despite dangers of faecal pathogens contamination has been observed in major urban centres such as Nairobi and Nakuru where substantial amount of wastewater is produced. The practice is especially common during the dry seasons when vegetables produced through rain-fed agriculture are least available. This calls for serious studies to establish factors limiting its utilization, the quality of the wastewater, and whether the water may be safely used.

The major faecal pathogens associated with wastewater are the faecal coliforms and eggs of some helminths such as *Ascaris lumbricoides* and *Trichuris trichura* whose resistant eggs can be found in the wastewater. Though the World Health Organization guidelines on use of wastewater for irrigation exist, the standards set for the re-use are mostly unachievable by most of the wastewater treatment plants established in most developing economies yet most of the reuse of wastewater in agriculture is done in these countries. To accommodate these regions, the WHO through the Stockholm framework encourages a flexible approach to the setting of regional or national guidelines that would allow countries to adopt procedures that fit their social, cultural, economic and environmental circumstances. Kenya has no specific standards for reuse of wastewater hence a need for research to influence the setting of such standards.

Between March and December 2008, studies were done to establish the quality of vegetables produced through irrigation using wastewater and those produced from rain-fed agriculture on the basis of contamination by faecal pathogens. The quality of the wastewater in the various stabilization lagoons on the

basis of plant nutrient content, faecal pathogens and heavy metals was analysed to establish its suitability for crop production on the basis of WHO guidelines on re-use of wastewater in agriculture. A trial plot was set up in which wastewater irrigation was done to grow the vegetables *Brassicae oleraceae* (kales) and the kales grown were analyzed for faecal pathogens contamination. Other parameters analysed on these vegetables include their quality in terms of size, and the number of leaves produced. The wastewater used was drawn from various ponds to establish the pond from which the best vegetable is produced.

To establish the quality of vegetables sold in the markets and produced using rain-fed agricultural practices, a market survey was conducted for the produce grown conventionally and sold in the markets so as to indicate their quality in terms of pathogen infestation; this was compared to the kales grown using wastewater in terms of pathogen infestation. Further market survey was conducted to establish the sanitary conditions of the municipality markets on the basis of the presence or absence of garbage bins, drainage systems, water availability, display of produce and market cleaning frequency. Observations and questionnaires were used to collect this information. This paper presents the argument that vegetables produced using wastewater irrigation have acceptable quality compared to those produced using rain-fed agriculture at the field level and their contamination by faecal pathogens mainly occurs in the market due to poor handling by the traders.

Materials and method

Study area

Nakuru town is located in the Rift Valley province and is the fourth largest town in Kenya after Nairobi, Mombasa and Kisumu with a population of 289,385 people (CBS, 2001). Its population is much higher during day time, reaching about 500,000 people due to the migration of people from the nearby centres to the town looking for jobs and doing business. The town lies 160 kms North West of Nairobi a semi-arid area due to its low annual rainfall that is estimated at 800mm. The town has two wastewater treatment plants, one for industrial wastes located near the industrial area of the town, and another for domestic wastes both of which comprise of wastewater stabilization ponds consisting of two anaerobic ponds, 2 facultative, 6 maturation ponds with rock and grass filters. The domestic wastewater treatment plant has a treatment capacity of 6,600m³/day (MCN, 2007). The effluent from this plant flows directly into Lake Nakuru where it is the main source of water feeding this lake during the dry season. Though it is a major source of pollution, it supports the wild animals throughout the year in the park. Lying about 25 kms south west of Nakuru Town is found Egerton University, Njoro Campus with a population of about 15,600. The campus is located in an agriculturally endowed area and the produce from the farms in this area are sold in Nakuru town. The University has a wastewater treatment plant is a basic wastewater stabilization pond received through two anaerobic ponds; the old pond that receives about 37 m³day⁻¹ and the new pond that receives an average of 680 m³day⁻¹, one facultative and one maturation pond. The University generates about 717 m³day⁻¹ of wastewater which is released into Njoro River that flows into Lake Nakuru.

Wastewater sample collection and analysis

Three ponds were sampled from Egerton University WSPs, that is, the outlet of facultative, first and second maturation ponds while four ponds were sampled from the Nakuru Kaloleni WSPs from the facultative pond, first, second and third maturation ponds. Samples were collected using sterilized sampling bottles about 10-20 cm below the surface of the ponds and analyzed within six hours after sampling following the modified Bailenger method for helminth eggs and membrane filtration method using lauryl sulphate broth according to Ayres and Mara (1996) for faecal coliforms.

In-situ wastewater temperature, conductivity, dissolved oxygen concentration and pH were determined at each sampling point using hydro lab multi-parameter probes (WTW 340i). Plants nutrient concentration in the wastewater that is, nitrogen (NO₂-N, NO₃-N, and NH₄-N) and phosphorus (SRP and TP) were analysed according to the standard methods as recommended by the American Public Health Association (APHA, 1995). Heavy metals were analyzed in Egerton wastewater using atomic absorption spectrophotometer.

Wastewater irrigation trial plot

The experimental design for the growth of kales used was the completely randomized design with each plot being assigned one of the four different treatments for the type of water supplied for irrigation, that is, clean water, wastewater from the facultative, first and second maturation ponds. Each plot measured 1X3 metres and 0.5 metres between rows with a total of 18 plants and the mid row 4 plants were used as subjects of

analysis. The plants were grown in the green house established using the polythene sheet, with another polythene sheet being placed 20 cm below soil surface so as to separate plots and prevent water seepage from the ground to the plants.

Irrigation of the plants was carried out using a watering can with care being taken to avoid splashing the wastewater on the leaf surface but supplied directly on the soil. The plants were supplied with wastewater twice per day for the initial four weeks with 1 litre of wastewater being used on each crop. Later, the irrigation frequency was reduced to once per day and half litre irrigation water used per crop.

A total of 24 plant samples were taken from the plot at the end of the growing season for analysis. Only recently matured leaves were harvested. The samples were analyzed following standard methods for faecal pathogen contamination level (faecal coliform and helminth eggs) on the surface of the leaves using the membrane filtration method and the Bailenger method according to Ayres and Mara (1996).

Market produce quality survey

The kales sold in the market were randomly collected with care being taken to prevent any contamination in sterile bags. Samples were stored in a cool box and analyzed within 3 hours after collection for faecal coliform and helminth eggs contamination using the membrane filtration technique and the Bailenger method respectively (Ayres and Mara 1996). Further, the sanitary conditions of the markets in terms of drainage conditions, toilets and garbage collection bins availability, water supply, cleaning, packaging and storage of the produce were observed. Observation and questionnaires were used to collect this information with a total of 12 markets being visited within the municipality.

Results and discussion

Wastewater stabilization ponds

While Egerton WSPs show reduction in faecal pathogens as the wastewater flows from the facultative pond to the maturation ponds (Fig. 1), the Nakuru-Kaloleni WSPs showed higher concentrations of faecal pathogens in the third maturation ponds (Fig. 2 and Fig. 3). This is due to the many mammals found around these ponds from the L. Nakuru national park whose droppings may be the source of these pathogens. However from the values of faecal pathogens found in these ponds, none of them could be recommended for use in irrigation of crops. The values are all above the recommended values by the WHO. Though waste stabilization pond technology is the most cost-effective wastewater treatment technology for the removal of pathogenic micro-organisms with the tertiary treatment in the maturation pond is being the point where the removal of pathogens and nutrients (especially nitrogen) is most effective, both Egerton and Nakuru-Kaloleni ponds seem not to achieve this function. Moderate working of the WSPs in Egerton University and the Nakuru Kaloleni Wastewater treatment works was noted. Reduction in the concentration of phosphorus, nitrates and ammonium was observed from the facultative ponds to the second maturation ponds in the Egerton University WSPs (Fig. 4). In the Nakuru-Kaloleni WSPs, higher nutrient levels were observed in the third maturation pond instead of the expected reduction. This is due to the many wild animals from the Lake Nakuru National park, mainly buffalos and water birds that commonly use them for watering.

Vegetable quality

The market survey for the produce quality showed that kales sold in the market showed contamination by the faecal pathogens with the degree of contamination depending on the sanitary conditions of the market and how the produce are displayed (Table 1), whether on the ground or stalls. The markets having stalls, toilets and water had their produce less contaminated than those markets that lacked these facilities. The produce had faecal coliforms contamination within the range of 60-400 FC/g. This was attributed to poor sanitary conditions in the markets and lack of clean water for cleaning and “freshening” the produce.

The vegetables produced through wastewater irrigation had their leaves contaminated with faecal pathogens, though the degree of contamination was lower than those in the produce sold in the markets. The levels of pathogens analyzed from the leaves ranged between 0-10 FC/g and while the number of helminth eggs ranged between 0-2 eggs/g with most of the leaves having no helminth eggs. Though the effluent from the stabilization ponds did not meet the required microbial quality according to WHO guidelines, the kales grown using this wastewater showed minimal contamination hence the faecal coli forms and helminthes eggs is not an issue since other measures like avoiding contact of the plant's surface with the soil and wastewater greatly reduce contamination.

Conclusions and recommendations

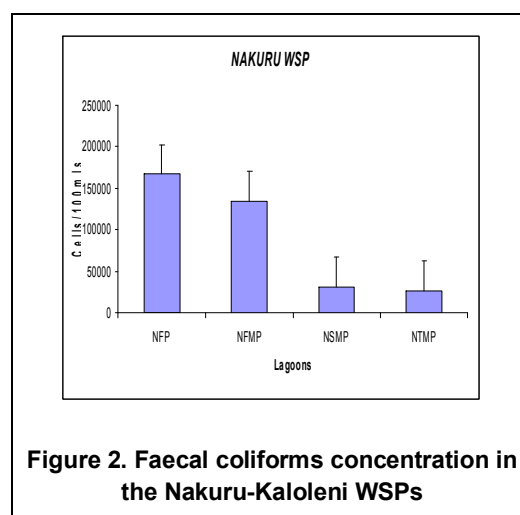
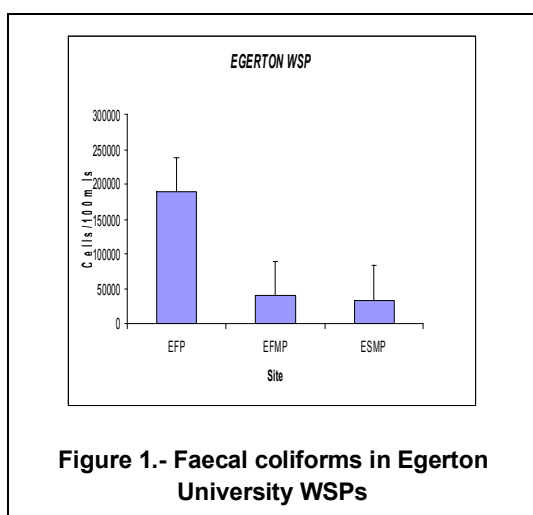
Use of wastewater for crop production is becoming increasingly important due to water scarcity especially in the semi and arid areas in the developing countries. Despite its various benefits coupled with the continuous availability in the urban areas, there has been little reuse of wastewater in Kenya in a formal way. Wastewater may be used for crop irrigation but cautiously with risk reduction strategies like localized irrigation, proper hygiene that include washing of produce, cooking of food and proper food handling among others, may be applied. Limited data exist on the Egerton University and Nakuru WSPs performances on the basis of the effluent quality for agricultural use. Other reports including Murage (2003) show that wastewater from Egerton University stabilization ponds also have heavy metals especially cadmium at a concentration above the acceptable level as recommended by the WHO on the reuse of wastewater for agriculture.

The results from produce survey shows high contamination of vegetables occur during food handling in the market. This is attributed to poor sanitary conditions in the market, the handling of the produce and whether produce are displayed on the stalls or on the ground. Markets with poor drainage had a higher faecal contamination of the produce recorded than those with good drainage system.

Treated wastewater may enhance urban food production since proper treatment lowers faecal pathogen content and this coupled with proper handling of the produce will lower the chances of produce contamination. Proper handling of wastewater during irrigation is also important so as to minimize health risks to the farmers. Localised irrigation, particularly when the soil is covered with plastic sheeting or other mulch, uses nutrients and water from the wastewater more efficiently leading to higher crop yields and certainly provides greater degree of health protection for farm workers and consumers (FAO, 1992).

Table 1. Market produce quality on the basis of faecal coliforms and helminth eggs contamination

Market type	Vegetable	FC/g	Helminthes' eggs/g
Closed market	Kales	61	1
Open market	Kales	247	2
Closed market	Spinach	139	9
Open market	Spinach	132	3



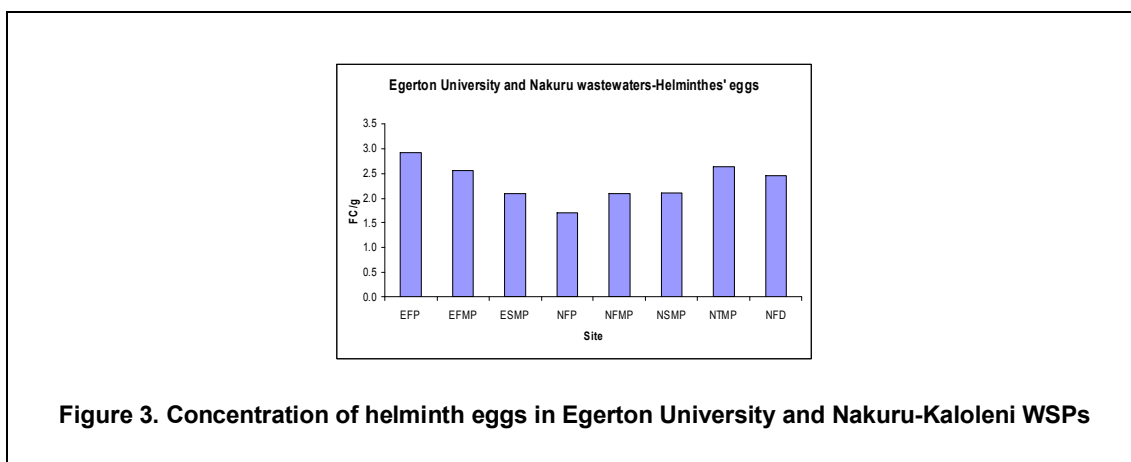


Figure 3. Concentration of helminth eggs in Egerton University and Nakuru-Kaloleni WSPs

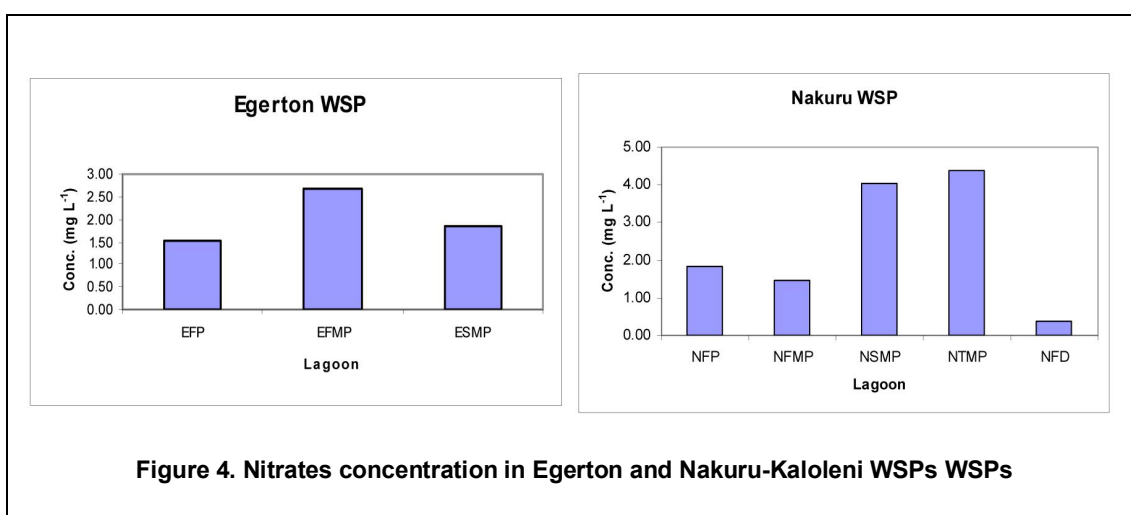


Figure 4. Nitrates concentration in Egerton and Nakuru-Kaloleni WSPs WSPs

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Keywords

wastewater, water quality, irrigation, water treatment, WHO guidelines.

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