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The potential use of treated brewery effluent as a water and nutrient source in irrigated crop production

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ABSTRACT

Brewery effluent (BE) needs to be treated before it can be released into the environment, reused or used in down-stream activities. This study demonstrated that anaerobic digestion (AD) followed by treatment in an integrated tertiary effluent treatment system transformed BE into a suitable solution for crop irrigation. Brewery effluent can be used to improve crop yields: Cabbage (*Brassica oleracea* cv. Star 3301), grew significantly larger when irrigated with post-AD, post-primary-facultative-pond (PFP) effluent, compared with those irrigated with post-constructed-wetland (CW) effluent or tap water only ($p < 0.0001$). However, cabbage yield when grown using BE was 13% lower than that irrigated with a nutrient-solution and fresh water; the electrical conductivity of BE (3019.05 ± 48.72 µs/cm^2) may have been responsible for this. Post-CW and post-high-rate-algal-pond (HRAP) BE was least suitable due to their higher conductivity and lower nutrient concentration. After three months, soils irrigated with post-AD and post-PFP BE had a significantly higher sodium concentration and sodium adsorption ratio (3919 ± 94.77 & 8.18 ± 0.17 mg/kg) than soil irrigated with a commercial nutrient-solution (920.58 ± 27.46 & 2.20 ± 0.05 mg/kg). However, this was not accompanied by a deterioration in the soil's hydro-physical properties, nor a change in the metabolic community structure of the soil. The benefits of developing this nutrient and water resource could contribute to cost-reductions at the brewery, more efficient water, nutrient and energy management, and job creation. Future studies should investigate methods to reduce the build-up of salt in the soil when treated BE is used to irrigate crops.

1. Introduction

Brewery effluent (BE) is an organic effluent that contains nitrogen and phosphorus, and a range of organic and inorganic compounds [30,32]. These nutrients are essential for plant growth and health so brewery effluent has the potential to be used as a source of water and nutrients in irrigated crop production [10,26,32]. However, BE also has properties that inhibit the growth of plants and deteriorate soil physical profile and fertility when used to irrigate crops [16,17,8].

Brewery effluent at Ibhayi Brewery (SAB (Pty) Ltd, Port Elizabeth, South Africa) is treated in an anaerobic digester (AD) and activated sludge system before being either piped to a municipal sewer or channelled back to the factory for re-use in non-production activities. A small stream of post-AD BE is fed into an experimental treatment facility, which uses various alternative, sustainable methods of bioremediation including a primary-facultative-pond (PFP), a high-rate-algal-pond (HRAP) and a constructed-wetland

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(CW). Each treatment process results in BE with different water quality parameters such as pH, form and concentration of nitrogen, and the concentration of phosphorus, sodium and other dissolved salts [14]. These parameters have been shown to directly and indirectly affect plant growth and soil fertility ([21], [30]).

Different methods of BE pre-treatment have been found to influence nutrient availability and downstream crop productivity [30]. Furthermore, the sodium concentration of BE negatively affected the physical properties of the irrigated soil [8]. It is therefore essential that the most effective pre-treatment method of BE is found so that the nutrients in the effluent are made accessible to the plants while minimising any negative impacts BE may have on the soil.

1.1. Aims and objectives

The aim of this study was to determine the suitability of different tertiary effluent technologies in making BE suitable for crop irrigation. This was done by comparing the change in soil characteristics and growth of cabbages irrigated with BE drawn at various points from an experimental BE treatment system including post-AD, post-PFP, post-HRAP and post-CW to cabbages irrigated with tap water or a combination of water and inorganic-fertilizer.

2. Methods and materials

2.1. Experimental species and system

Cabbage (*Brassica oleracea*) was used as the test crop because it has similar salt tolerance and nutrient requirements as most vegetables [29]. Two hundred cabbage seedlings (*Brassica oleracea* cv. Star 3301; Starke Ayres Pty Ltd, South Africa) were purchased from a commercial nursery (Moorland Seedlings Pty Ltd, Humansdorp, South Africa). Of these 120 similar size seedlings were used in this experiment.

Cabbage plants were grown out doors in 23 l pots. These pots were filled with an oxidic sandy loam top soil (10% silt, 20–25% clay, 65–70% sand) classified according to Macvicar et al. [22]. One cabbage plant was planted in each pot.

2.2. Treatments

Six irrigation solutions were applied to the cabbages, which included post-AD, post-PFP, post-HRAP, post-CW, a nutrient-solution (NS) and municipal water. The pH of each treatment was either adjusted to 6.5 with 98% sulphuric acid (Protea Chemicals Pty Ltd, South Africa) or left unadjusted (Table 1).

The plants irrigated with tap water served as a control. The nutrient-solution was comprised of a commercially available inorganic-fertilizer (Hygrotech Pty Ltd, South Africa; Registration number K5709; Act 36 of 1947), and calcium nitrate with a composition of 11.7% nitrogen and 16.6% calcium, mixed in a ratio of 1:0.8 and dissolved in municipal water to achieve an electrical conductivity (EC) of 1800 µm (Hygrotech Pty Ltd, South Africa). Each treatment was replicated ten times with a replicate consisting of a single plant in a pot.

2.3. Irrigation regime and pest control

Cabbages were irrigated with one litre two to three times a week. During irrigation care was taken not to wet the cabbage leaves. The maximum volume of water irrigated at one time was one litre. This was done to ensure that leaching did not occur. Water was not observed draining out the bottom of the pots. In total each cabbage plant received 198.1 mm of treatment water and 91 mm of rain during the twelve week growth trial.

One month after planting, diamond back moth larvae were noticed on some of the cabbages. Cabbages plants were sprayed with Malasol (active ingredient: mercaptothion, Efekto Agro-Serve Pty Ltd) to kill the larvae. When a spraying occurred every plant was sprayed, an event that occurred five times during the trial. No plants suffered severe damage from the diamond back moth larvae.

Table 1
Irrigation treatments (T1-T12) that were used to irrigate cabbage plants.

Irrigation solution	pH not adjusted	pH adjusted to 6.5
AD effluent	T1	T7
PFP effluent	T2	T8
HRAP effluent	T3	T9
CW effluent	T4	T10
Municipal water	T5	T11
Municipal water with inorganic fertiliser	T6	T12

Anaerobic digestion (AD), primary-facultative-pond (PFP), high-rate-algal-pond (HRAP), constructed-wetland (CW).