ABSTRACT

Scarcity of water for irrigation is a serious hindrance for small-scale farmers in sub-Saharan Africa. The use of good quality water for irrigation has resulted in increasing pressure on such water which has prompted sourcing of wastewater as an alternative. One possibility, being investigated by eThekwini Water and Sanitation (Durban, South Africa), is to install anaerobic baffled reactors within local communities to treat wastewater to allow its use for agriculture. The success of wastewater irrigation depends on the ability of the soil to assimilate the water, nutrients and any other contaminants that are applied to it. The aim of this project was to investigate the potential of an anaerobic baffled reactor (ABR) effluent as both an irrigation and nutrient source for use in peri-urban agriculture.

The effluent was slightly alkaline (pH 7.40–7.60) and in class C2S1 (medium-salinity/low sodicity water) according to the United States Soil Salinity Laboratory classification for irrigation waters. It was very low in heavy metals, values being below permissible levels according to the Food and Agricultural Organisation (FAO) of the United Nations and the South African Department of Water Affairs and Forestry (DWAF) guidelines for water use in agriculture. The total solids were low thus particulate matter was minimal with a greater concentration of the major elements found in solution. An investigation was carried out to ascertain the behaviour of the effluent when applied to soil and how the soil was able to adsorb plant nutrients from it. A soil column study was undertaken in the laboratory with three contrasting soil types namely a sandy soil (Longlands, E horizon), an organic soil (Inanda, A horizon) and a clayey soil (Sepane, A horizon). The effluent was leached through the soil while distilled water was concurrently used as a control. Results indicated that after application of 16 pore volumes, leachates from the columns contained concentrations of Na, equal to that in the incoming effluent for all soils. The concentrations of Ca and Mg were lower in the leachates than in the original effluent indicating adsorption in the soils. Phosphorus was the element that was most strongly adsorbed in all soils. While its adsorption in the Ia could be attributed to organic matter and the presence of iron oxides and oxyhydroxides, the clay type and amount in the Sepane was likely to have been responsible for P adsorption. The NO_3-N, which was initially low in the effluent, increased as leaching

progressed, while the NH_4-N decreased. In the water-leached columns, elements were leached out of soil because none were added with the water.

At the end of leaching, columns were allowed to drain and then sectioned into 2 cm segments. The 0-2 cm, 8-10 cm and 14-16 cm segments representing the top, middle and bottom parts of the column were analysed for inorganic-N, phosphorus and potassium. The elemental content of the 0-2 cm segment was significantly higher ($p<0.05$) than the lower segments in all columns for soluble P in all soils. This reflects the immobile nature of P in soils and confirmed the high amounts of P retained by the soils. There were significant differences between the effluent and the water-leached soils in terms of P retention. The amount of inorganic-N and K in the top layer was not significantly different from the other layers. In the Ia 0–2 cm segment, a pH increase of about 1.3 pH units was recorded in the effluent-leached columns when compared to the equivalent segment in the water-leached columns.

A glasshouse study was undertaken to assess the availability to maize of nutrients from the effluent. Maize was grown for 6 weeks in pots filled with the same soil types used in the columns study except that a similar sandy soil, Cartref (Cf, E horizon), replaced the Lo due to inadequate availability of the latter. Fertilizer (N, P and K) was applied at the full recommended rate, half the recommended rate and zero fertilizer for each of the three soils used. This corresponded to 0, 100, 200 kg N ha^{-1} for all soils; 0, 40, 80 kg P ha^{-1} and 0, 50, 100 kg K ha^{-1} for the Cf; 0, 10, 20 kg P ha^{-1} and 0, 102.5, 205 kg K ha^{-1} for Ia; and 0, 30, 60 kg P ha^{-1} and 0, 5, 10 kg K ha^{-1} for Se. Lime was applied to the Ia soil at the rate of 10 t ha^{-1}. Plants were watered with either effluent or tap water. Dry matter yield and nutrient concentrations for effluent-irrigated maize were significantly higher ($p<0.05$) than for all equivalent fertilizer applications in the water-irrigated plants. The unfertilized effluent-irrigated plants were not significantly different from the fertilized water-irrigated plants, but performed as well as the water-irrigated plants at half fertilization irrespective of soil type. Phosphorus deficiency was observed in the Ia and Se soils but not in the Cf soil, irrespective of fertilizer treatment. Plants grown on the Cf soil irrigated with effluent and fully fertilized had the highest above-ground dry matter yield (4.9 g pot^{-1}) and accumulated the most nutrients namely N, P, K, Ca and Mg than all other treatments. After harvest the most marked changes had occurred in the Cf soil for P as the effluent-irrigated soils were significantly higher ($p<0.05$) than the water-irrigated soils reflecting the P input from the effluent.

The effect of effluent on soil and plants was further investigated by planting maize on the Ia soil without lime application. Plants that received effluent irrigation and no lime had significantly higher ($p<0.05$) dry matter yields and accumulated more N, P and K than the water-irrigated with no lime as well as the equivalent limed treatments. This suggests an interaction effect between the lime and the effluent with its effects obvious on above-ground dry matter yield and plant N, P and Mg.

A soil column experiment using the Cf, Ia and Se soils and planted with maize was conducted to assess the ability of plants to take up nutrients with concurrent leaching. Plants from the Cf soil recorded the lowest above-ground dry matter yield which was observed from the less vigorous growth as compared to plants in the Ia and Se soils. This growth pattern could also be explained by the low N accumulation in the plants from the Cf soil. Unlike N, P in plants grown on the Cf soil was significantly higher ($p<0.05$) than in the plants on the Ia and Se soils, despite having the least P gain from the effluent. The readily available P triggered both more uptake and also greater losses through leaching. The rate at which P was being supplied from the effluent was greater than its uptake by the plants and with limited capacity to hold onto P in this sandy soil there was inevitably loss though leaching.

A pot experiment was conducted to investigate the interaction effects between lime and effluent. Lime type (calcium hydroxide or dolomite) was applied to two acidic top soils namely Inanda and Avalon at 0%, 25%, 50%, 75% and 100% of the recommended rates for these soils. Maize was planted and after 6 weeks it was harvested and evaluated for above-ground dry matter yields and plant nutrient concentrations. Non-significant effects were recorded for above-ground dry matter, N, P and K as a result of altering the liming rate and type within each soil. The effects of lime application were apparent in the soils after harvest as increasing the lime rate caused an increase in pH and an inverse relationship with the exchangeable acidity and acid saturation in soils, as expected. Although the unlimed treatments did not impact on the acidity as much as the limed treatments, effluent irrigation was shown to reduce soil acidity after harvest when compared to the soils at the beginning of the experiment. Phosphorus accumulation in plants was also unaffected by either lime rate or type which showed that effluent irrigation could influence P availability and further liming would not accrue benefits to the soil so as to influence plant P uptake.

Based on these data, ABR effluent could be perceived as a resource rather than a waste product. It could conveniently be used for irrigation provided there is soil and plant monitoring to assess build-up of elements especially in the long term. Further investigations have to be carried out on other crop types both in the field and glasshouse to ascertain nutrient uptake and effect on different soil types.