Hydroponics reducing effluent’s heavy metals discharge
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ABSTRACT
This paper investigates the capacity of Nutrient Film Technique (NFT) to control effluent’s heavy metals discharge. A commercial hydroponic system was adapted to irrigate lettuces with primary treated wastewater for studying the potential heavy metals removal. A second commercial hydroponic system was used to irrigate the same type of lettuces with nutrient solution and this system was used as a control. Results showed that lettuces grew well when irrigated with primary treated effluent in the commercial hydroponic system. The NFT-plant system heavy metals removal efficiency varied amongst the different elements. The system’s removal efficiency for Cr was more than 92%, Ni more than 85%, in addition to more than 60% reduction of B, Pb, and Zn. Nonetheless, the NFT-plants system removal efficiencies for As, Cd and Cu were lower than 30%. Results show that lettuces accumulated heavy metals in leaves at concentrations higher than the maximum acceptable European and Australian levels. Therefore, non-edible plants such as flowers or pyrethrum are recommended as value added crops for the proposed NFT.

Key words | heavy metals accumulation, nutrient film technique, plants, wastewater

INTRODUCTION
The contamination of surface waters and soils by heavy metals discharge from wastewater treatment plants or storm water may limit the utilisation options of the receiving land or water resource and pose risk on public health. The common reasons for the high levels of heavy metals in effluents are the complexity and unaffordable cost of operation and maintenance of necessary treatment facilities. A major part of the operating cost is due to energy needed for the treatment processes. Moreover, operating and maintaining such treatment processes require skilled people.

The high cost involved in managing the vast quantities of generated sludge from conventional sewage treatment systems in accordance with the current European legislations (Commission of the European Communities 2006a,b) may be a limiting factor in selecting the wastewater treatment facilities. The European Union regulates usage of sewage sludge in agriculture to prevent harmful effects on soil, vegetation, animals and humans (Commission of the European Communities 2002). In particular, it sets limits on the concentrations of heavy metals in sludge, bans the use of sludge in certain cases and regulates the treatment of sludge. According to a European Commission report (Commission of the European Communities 2006a,b), several Member States have set heavy metals concentration limits at levels below those in the European Commission Directive on sewage sludge 86/278/EEC (Commission of the European Communities 2002). Furthermore, most European Union Member States registered an increase in sludge generation, indicating dramatic increase of wastewater treatment cost. Seven Member States report using at least 50% of the sludge they generate in agriculture. The Commission Directive 86/278/EEC considers that using sewage sludge as fertiliser on agricultural soils remains one of the best environmental options provided it poses no threat to the environment, animal or
human health. Hence, alternative or more advanced sewage treatment methods have to be adopted for a safer environment and yet allow sludge utilisation.

Fritioff & Greger (2006) showed that roots of Potamogeton natans accumulated high levels of Zn, Cu, Cd, and Pb when irrigated with stormwater and recommended these plants for remediation of contaminated stormwater.

Weiss et al. (2006) reported that plants grown hydroponically with stormwater accumulated higher levels of heavy metals than plants grown in soils. Therefore, he recommended hydroponics as an alternative remediation technique of stormwater contaminated with heavy metals. Moreover, Ottoson et al. (2005) published results revealing satisfactory microbial removal from wastewater by hydroponic wastewater treatment systems and recommended hydroponics as an alternative to conventional wastewater treatment. Jewell (1994) used roots of many kinds of plants to remove pollutants from sewage. His research findings revealed that plants removed more than 80% of nutrients and 90% of faecal coliforms.

When a primary settled sewage was used in the hydroponic system for wastewater treatment, and for crop production, beans, sunflower and cotton. The system achieved 90% BOD removal, 95% ammonia-N removal, and more than 99% faecal coliforms removal (Bulter & Dewedar 1991). Further work by Ohta et al. in Japan demonstrated a hydroponic system utilising channels in porous blocks of concrete, for the treatment of a small polluted municipal river and for the production of tomatoes. Their system removed more than 99% of total organic carbon (TOC).

In addition to possible long term efficiency, the hydroponic approach used in this project offers simple and less expensive heavy metals removal from wastewater and commercial plants production. This type of hydroponic system is often refer to as a nutrient film technique (NFT) which was developed in England to grow plants without soil in green houses (Cooper 1996). When wastewater effluents are used for crop irrigation, most trace elements tend to accumulate in the soil, the trace-element contents of the receiving soil could be substantially elevated by the long-term use of the wastewater. Subsequently, the groundwater quality may deteriorate (Pettygrove & Asano 1985).

The proposed treatment technique however, allows plants to grow in a thin film of wastewater in impermeable channels to prevent groundwater pollution and soil salination as biomass is utilised appropriately.

In this work, authors are investigating possible utilisation of one of the most common vegetables (lettuce) as commercial valuable plant trapping effluent’s heavy metals prior to discharge into the environment.

**EXPERIMENTAL MATERIAL AND METHODS**

**Plant selection.** Lettuce fulfilled criteria for the selection of the plant type to be tested with the NFT wastewater treatment system that included:

1. plants grown commonly with NFT hydroponics system to minimise systems modification;
2. concentration on a species requiring large nitrogen and phosphorous inputs;
3. plants able to tolerate the wastewater physical and chemical characteristics;
4. plants growing lights and have a short growth cycle (e.g. 8–10 weeks); and
5. plants with a commercial value.

**Hydroponic systems.** Two hydroponic systems were installed; one utilises primary settled effluent and called the wastewater plot. The second system utilises commercial nutrient solution and called the control plot. Therefore, two series of commercial hydroponic NFT systems (Cat-2530 Accent Hydroponics PTY LTD, Sydney) were modified to study the reduction of heavy metals discharge with primary treated municipal sewage effluent and to produce commercial plants.

The system consisted of components (supplied by Accent Hydroponics PTY LTD, Sydney, unless otherwise mentioned) outlined below and illustrated in Figure 1.

**Supply Pipe Line.** A light 10 mm in diameter PVC pipe was selected to transmit the primary effluent from the circulating tank to the plants.

**Pump.** A Little Giant submersible pump (Model NK1, Trans World Traders Pty Ltd, Sydney) was used. The suitable flow rate of effluent in the supply pipe was 8 L min$^{-1}$.

**NFT Channels.** Two series consisting of five plastic rectangular NFT channels measuring 3 m in length, 100 mm in width, 700 mm in height were used.
Growing Pots. White coloured plastic re-useable growing pots (75 mm £ 46 mm diameter) with a perforated base were used to hold the plants in the NFT channels.

Growing Medium. Perlite and Vermiculite were used as support media for seedlings in the growing pots.

Growing Lights. Lighting systems were used to control light dosage to the control and effluent plots. Six 400 W halide lights with a light intensity of 450 mWm$^{-2}$ and a wavelength around 500 nm were installed overhead of the hydroponics plots. A 400 W light suits an area of 1 m$^2$, which accommodated 10 plants for this study.

Wastewater. Primary settled municipal wastewater free from bulk objects to avoid clogging of the effluent distribution system within the pilot plant was utilised in this study. Moreover, the selected effluents were primary settled without chemical treatment of nutrients that are essential for plants growth.

Methods

The hydroponic NFT-plant system was installed in a glasshouse with a controlled temperature of 22–26°C, where the primary light source was natural light during the months of May to June. The glasshouse provided a controlled environment to grow plants in the adapted hydroponic system at any time of the year under natural light. The growing lights however, were installed and used to give uniform lighting through the experiment for 16 hours a day.

Wastewater plot. The effluent was pumped from the municipal wastewater treatment plant’s primary settling tank into a 1 m$^3$ plastic tank (the recirculation tank). The 1 m$^3$ plastic tank was immediately transported to the glass house and placed near the lower end of the NFT-plant system. This type of configuration allowed direct pumping of the primary effluent from the recirculation tank to the lead of the NFT channels for gravity feed via the roots of lettuce plants in a closed-loop hydroponic-NFT configuration.

Control Plot. A commercial nutrients solution (supplied by Accent Hydroponics) diluted in tap water was pumped from a 60-litre tank to the plants in a system similar to the wastewater plot at 8 L min$^{-1}$. The utilised solution flowed back to the 60-litre plastic tank by gravity.

Laboratory Analyses. Trace elements were determined by Inductively Coupled Plasma-AES (ICP-AES) as detailed below (Anderson 1996).

1. Immediately after harvest, tissue samples were washed with P-free detergent and rinsed with milli-Q water to remove dust particle residues. The risk involved in washing plant tissues, however, is that some metals may be leached out of the tissue (Noggle & Fritz 1983). Roots were further washed with 0.06 M CaCl$_2$ for fifteen minutes, then rinsed with milli-Q water. This technique excluded any adsorption contribution to the absorbed metals, but rinsings were collected for analyses.
2. To express the element composition of plant tissues in terms of dry rather than fresh weight, the tissues were dried in a forced draft oven at a temperature of 70°C.
3. The dried tissue was subsequently ground to powder using a ceramic pestle and mortar.
4. After weighing the total mass of powdered tissue, a known weight (50–100 mg) of plant powder was added to a digestion vessel, mixed with 2 ml of 70% nitric acid (HNO$_3$) and digested at 150°C for three hours.
5. After cooling to room temperature, the digest was diluted to form a 2% HNO$_3$ final solution (prepared sample).
6. Two-mL of the prepared sample was analysed via a fully calibrated ICP-AES according to standard methods for Metals by the Inductively Coupled Plasma Method (APHA 1995).
Effluent samples were digested with nitric acid according to the 3030 E. Nitric Acid Digestion Method for Metals according to APHA (1995). The digested sample then analysed via a fully calibrated ICP-AES according to standard method for wastewater (APHA 1995).

RESULTS AND DISCUSSION

Growth rate of the NFT lettuces and heavy metals concentrations in the NFT lettuces are discussed below.

Plant growth

The growth rate of the plants in effluent compared to those grown in nutrient solution are presented in Figure 2.

The plants irrigated with commercial nutrient solution (the control plot plants) were generally larger than those irrigated with municipal primary treated effluent (plants of the effluent plot). The slope of the control plants growth curve is steeper than the slope of the effluent plants growth curve, showing that the control plants grew at a faster rate than the effluent plants until they reached 40 days of age. The lettuces utilising the effluent apparently did not achieve mature growth by 58 days, possibly due to inadequate potassium supply or toxicity. The potassium concentration was about 30 mg L\(^{-1}\) compared to 332 mg L\(^{-1}\) in the nutrient solution (Table 1).

Metal accumulations in lettuce

Translocation of effluent’s heavy metals into NFT lettuces is discussed in this section. Theoretically, roots of the plants in the NFT channels are exposed to different levels of macronutrients and trace elements depending on their location within the NFT channels. Hence, the experimental trials were conducted to investigate element concentrations in each plant grown in the system. Trace elements concentrations were also used to observe metals accumulation in the plant tissues for health risk assessment.

The primary objective of using lettuce in this hydroponic wastewater treatment system was not only to remove or concentrate metals from the wastewater, but also to produce a crop which is both commercially valuable and capable of removing the nutrients nitrogen and phosphorus for acceptable effluent discharge. Nonetheless, excessive heavy metals content would obviously preclude the use of these crops as fodder for animals or humans.

Figures 3 through 5 summarise the results obtained from the ICP analyses conducted on the lettuce plants at various stages in their growth cycle.

In Figure 5, concentrations of four macro elements are represented. The average concentrations in mature plants and average standard deviations were about: K, \(1.2 \times 10^5 \pm 1.6 \times 10^4\) mg kg\(^{-1}\); Na, \(3.4 \times 10^4 \pm 7.0 \times 10^3\) mg kg\(^{-1}\); Ca, \(2.3 \times 10^4 \pm 2.8 \times 10^3\) mg kg\(^{-1}\); and Mg, \(1.2 \times 10^4 \pm 687\) mg kg\(^{-1}\). Lettuce plants at 39 days of age seems to show greater difference for Na and Ca than at other ages. The significant difference between the means of K and Na concentrations in plants of different ages was tested according to the null hypothesis tests (Student’s t-test, Miller & Miller 1993). The means of the two macro elements were significantly different (\(p < 0.05\)). However,
following the same approach the means of Mg and Na were not significantly different \((p > 0.05)\).

Concentrations of another group of different trace elements are presented in Figure 4.

B, Fe, Mn and Zn, were all below \(3,000 \text{ mg kg}^{-1}\). The Mn and Zn concentrations and average standard deviations followed similar pattern, but at 58 days concentrations were \(1,454 \pm 219\) and \(2,042 \pm 378 \text{ mg kg}^{-1}\), respectively. At 58 days the concentrations of Fe and B were \(647 \pm 154 \text{ mg kg}^{-1}\) and \(85 \pm 78 \text{ mg kg}^{-1}\), respectively. Neither of the differences between means of Mn and Zn, nor Fe and B were significant \((p > 0.05)\).

Figure 5 shows concentration of the heavy metals Ni, Pb, Cu, Cr and Cd.

Concentration and standard deviation of Ni in mature lettuce plants were \(46.6 \pm 18.8 \text{ mg kg}^{-1}\), lead \(20 \pm 8.2 \text{ mg kg}^{-1}\), copper \(12 \pm 2.5 \text{ mg kg}^{-1}\), chromium \(3.1 \pm 0.4 \text{ mg kg}^{-1}\) and cadmium \(4.8 \pm 0.96 \text{ mg kg}^{-1}\). The average concentration of Cd was lower than the average concentration of either Ni, Pb or Cu (i.e. the average concentration of Cd was significantly different compared to either Ni, Pb or Cu, \(p \leq 0.05\)). Similarly, the average concentration of Cr compared to the average concentration of either Ni, Pb or Cu differ significantly (for \(p \leq 0.05\)) (average Cr concentration < the average concentration of either Ni, Pb or Cu). However, when compared to the average concentration of either Cu or Pb, the average concentration of Ni in plant tissues did not differ significantly \((p > 0.05)\).

### Table 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Australia(^1) on all soils ((\text{mg L}^{-1}))</th>
<th>California on Sandy soil(^2) ((\text{mg L}^{-1}))</th>
<th>Primary effluent Concentration ± standard deviation ((\text{mg L}^{-1}) n = 3)</th>
<th>Nutrient Solution(^3) Concentration ((\text{mg L}^{-1}) n = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>5.0</td>
<td>5</td>
<td>Not measured</td>
<td>Not measured</td>
</tr>
<tr>
<td>As</td>
<td>0.1</td>
<td>0.1</td>
<td>(0.435 \pm 0.439)</td>
<td>Not measured</td>
</tr>
<tr>
<td>B</td>
<td>3.0</td>
<td>0.75</td>
<td>(2.7 \pm 0.96)</td>
<td>0.3</td>
</tr>
<tr>
<td>Ca</td>
<td>NGR</td>
<td>NGR</td>
<td>(41.4 \pm 28)</td>
<td>168</td>
</tr>
<tr>
<td>Cd</td>
<td>0.01</td>
<td>0.01</td>
<td>Not measured</td>
<td>Not measured</td>
</tr>
<tr>
<td>Co</td>
<td>0.05</td>
<td>0.05</td>
<td>Not measured</td>
<td>Not measured</td>
</tr>
<tr>
<td>Cr</td>
<td>0.1</td>
<td>0.1</td>
<td>Not measured</td>
<td>Not measured</td>
</tr>
<tr>
<td>Cu</td>
<td>0.2</td>
<td>0.2</td>
<td>(1.29 \pm 0.79)</td>
<td>0.06</td>
</tr>
<tr>
<td>Fe</td>
<td>1.0</td>
<td>NGR(^3)</td>
<td>(1.97 \pm 1.14)</td>
<td>5.6</td>
</tr>
<tr>
<td>Hg</td>
<td>NGR</td>
<td>0.01</td>
<td>Not measured</td>
<td>Not measured</td>
</tr>
<tr>
<td>K</td>
<td>NGR</td>
<td>NGR</td>
<td>(30.7 \pm 3.15)</td>
<td>332</td>
</tr>
<tr>
<td>Li</td>
<td>2.5</td>
<td>2.5</td>
<td>Not measured</td>
<td>Not measured</td>
</tr>
<tr>
<td>Mg</td>
<td>NGR</td>
<td>NGR</td>
<td>(15.4 \pm 3.9)</td>
<td>49</td>
</tr>
<tr>
<td>Mn</td>
<td>0.2</td>
<td>0.2</td>
<td>(0.03 \pm 0.01)</td>
<td>2.2</td>
</tr>
<tr>
<td>Mo</td>
<td>0.01</td>
<td>0.01</td>
<td>Not measured</td>
<td>Not measured</td>
</tr>
<tr>
<td>S</td>
<td>NGR</td>
<td>NGR</td>
<td>Not measured</td>
<td>65</td>
</tr>
<tr>
<td>Se</td>
<td>0.02</td>
<td>0.02</td>
<td>Not measured</td>
<td>Not measured</td>
</tr>
<tr>
<td>Be</td>
<td>0.1</td>
<td>0.1</td>
<td>Not measured</td>
<td>Not measured</td>
</tr>
<tr>
<td>Ni</td>
<td>0.02</td>
<td>0.2</td>
<td>Not measured</td>
<td>Not measured</td>
</tr>
<tr>
<td>Pb</td>
<td>0.2</td>
<td>5.0</td>
<td>Not measured</td>
<td>Not measured</td>
</tr>
<tr>
<td>Zn</td>
<td>0.20</td>
<td>1.0</td>
<td>(0.18 \pm 0.12)</td>
<td>0.06</td>
</tr>
<tr>
<td>Conductivity ((\mu\text{s.cm}^{-1}))</td>
<td>Not available</td>
<td>Not available</td>
<td>(1325 \pm 215)</td>
<td>(2850 \pm 320)</td>
</tr>
<tr>
<td>pH</td>
<td>Not available</td>
<td>Not available</td>
<td>(6.2 \pm 0.8)</td>
<td>(6.9 \pm 1.1)</td>
</tr>
</tbody>
</table>

\(^1\)NSW RWCC (1993).

\(^2\)Chang et al. (1996).

\(^3\)Accent Hydroponics PTY LTD (2006).

\(^4\)NGR = no guidelines recommended.
The concentrations of the five metals (Ni, Pb, Cu, Cr, Cd) in the plants generally decreased after 39 days of age. Personal consultations with Dr Barrow (CSIRO) concluded that the decrease in concentration with plant age was due to the fact that these concentrations were diluted by the faster rate of mass increase than the rate of absorption. Furthermore, young plants have greater capacity to take up metals per unit of root growth than older plants.

Average levels of trace elements found in the edible part of plants grown in the NFT system are listed in Table 2 for the purposes of comparisons with standards. Four values for heavy metals were regulated in Food Standards Australia New Zealand (FSANZ) Act 1991 (FSANZ 2007) as guidelines for the acceptable levels of metals in vegetable plants. Table 2 also shows European maximum allowable levels of three elements that are currently regulated by the European Commission (Commission of the European Communities 2001).

Examining obtained concentrations in Table 2, the NFT-grown lettuce in effluent concentrated K, Mg, Zn, Pb, Mn, Fe, Cr, and Na in the lettuce leaves.

The plants grown in the NFT experimental set up contained As, Cd, Cu, Pb and Zn in excess to what may be considered an acceptable level even though some (e.g. Zn) were within limits set for irrigation. This is one of the main reasons to recommend the use of non-edible plants such as flowers or pyrethrum as value added crops for the proposed system.

Below is a summary discussion related to results of selected elements and effluent suitability for irrigation purposes.

**Arsenic.** Arsenic concentrations in primary effluent exceeded the recommended levels for irrigation waters (Table 1). The As content of lettuce plants grown in the experimental NFT pilot plant was also well over the Commission of the European Communities (2001) and FSANZ (2007) recommended values (Table 2).

**Boron.** Effluent containing boron may be suitable for growing lettuce, because the plant could tolerate higher levels than those found in effluent (Table 1).
Cadmium. Lettuce plants grown in the NFT experimental pilot plant accumulated Cd in their leaf tissues at concentrations typical for leaves of foliage plants (Table 2).

Copper. Lettuce plants grown in the adapted hydroponic system accumulated Cu at concentration higher than the recommended value (Table 2).

Lead. About 20 mg kg\(^{-1}\) of Pb was accumulated in the leaves of the lettuce plants grown in the experimental NFT pilot plant with primary effluent which contain 0.2 mg L\(^{-1}\) of Pb. Though, the maximum recommended concentration of Pb in irrigation water is 0.2 mg L\(^{-1}\), which is equal to the concentration in the utilised effluent (Table 1). This elevated content of Pb in the grown lettuce in the NFT system neither complies with the European standards nor with the FSANZ.

Nickel. About 47 mg kg\(^{-1}\) of Ni was accumulated in the leaves of lettuce grown in the NFT channels irrigated with primary effluent. Typical plant content of Ni is between 8 and 14 mg kg\(^{-1}\). Nickel concentration in primary effluent was about 2.0 mg L\(^{-1}\) which is higher than the American and the Australian recommended maximum concentration for irrigation waters.

Zinc. Lettuce plants accumulated about 2.042 mg kg\(^{-1}\) of Zn which is over an order of magnitude higher than the FSANZ maximum recommended concentration for crops (150 mg kg\(^{-1}\)). The European Commission does not set limits for Zn in Lettuce. The Zn concentration in primary effluent averaged 0.18 mg L\(^{-1}\), being slightly less than the maximum recommended concentration by for irrigation water 0.2 mg L\(^{-1}\).

<table>
<thead>
<tr>
<th>Element</th>
<th>Initial concentration and standard deviation (mg L(^{-1}))</th>
<th>Final concentration and standard deviation (mg L(^{-1}))</th>
<th>NFT-plant system removal efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>Not measured</td>
<td>Not measured</td>
<td>5.0</td>
</tr>
<tr>
<td>As</td>
<td>0.435 ± 0.439</td>
<td>0.403 ± 0.278</td>
<td>7</td>
</tr>
<tr>
<td>B</td>
<td>2.7 ± 0.96</td>
<td>1.08 ± 1.14</td>
<td>60</td>
</tr>
<tr>
<td>Cd</td>
<td>0.061 ± 0.067</td>
<td>0.045 ± 0.06</td>
<td>26</td>
</tr>
<tr>
<td>Co</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
<td>–</td>
</tr>
<tr>
<td>Cr</td>
<td>0.026 ± 0.018</td>
<td>&lt;0.002</td>
<td>&gt;92</td>
</tr>
<tr>
<td>Cu</td>
<td>1.29 ± 0.79</td>
<td>1.022 ± 0.464</td>
<td>21</td>
</tr>
<tr>
<td>Ni</td>
<td>2.02 ± 1.38</td>
<td>0.3 ± 0.28</td>
<td>85</td>
</tr>
<tr>
<td>Pb</td>
<td>0.214 ± 0.102</td>
<td>0.08 ± 0.15</td>
<td>63</td>
</tr>
<tr>
<td>Zn</td>
<td>0.18 ± 0.12</td>
<td>0.0608 ± 0.063</td>
<td>66</td>
</tr>
</tbody>
</table>

Reduction of effluent’s heavy metals discharge

Concentrations of common elements in the utilised effluent before and after one week of treatment in the NFT system are summarised in Table 2.

Samples from the utilised effluent were analysed for different elements before and after being used to irrigate the plants. Concentrations of arsenic 0.435 ± 0.439, Boron 2.7 ± 0.96, cadmium 0.061 ± 0.067, lead 0.214 ± 0.102 and copper 1.29 ± 0.79 exceeded the maximum concentration (Table 1) and need to be reduced to acceptable levels before reusing effluent for growing edible plants.

Table 2 shows that the simple and low cost NFT-plants system has reduced effluent’s discharge of Cr by more than 92%, Ni by more than 85%, in addition to more than 60% reduction of B, Pb, and Zn. The removal efficiency of NFT plant system for the As, Cd and Cu was lower than 30%.

Concentrations of As, B, Cd, Cr, Cu and Ni in NFT treated effluent exceeded maximum allowable levels outlined in Table 1. This indicates that treatment of primary effluent in the experimental NFT-plant system for one week is not sufficient to reduce heavy metals level to acceptable limits allowing effluent applications on soil. These weekly treatment results however, may be used in a mathematical model to scale up the size of the experimental of NFT-plant system for field applications installations. Therefore, future pilot plant experimental design and growth trials may be modified to achieve higher reduction rates at different treatment durations.

Furthermore, future experimental trials would also focus on lettuce accumulating pharmaceuticals and organic...
toxins, with particular reference to polycyclic aromatic hydrocarbons (PAHs) that are known endocrine disrupters, carcinogens and mutagens.

**Cost of commercial hydroponic systems**

Most of wastewater treatment plants installations rely heavily on steel. Steel prices have recently achieved record high and continuously rising at accelerated rates. Commercial hydroponic systems however, are readily available at considerably lower cost compared to the conventional wastewater treatment plants (CWTP). Energy cost is also increasing at record rates during the last a few years. Commercial hydroponic systems do not require energy for aeration which is one of the major operational costs in wastewater treatment systems. Furthermore, CWTP produce vast quantities of sludge that need stabilisations and treatment prior to disposal. Commercial hydroponic systems however, produce but a fraction of CWTP-sludge volumes, making operational and maintenance cost of hydroponic systems attractive for small communities.

**CONCLUSION**

This paper investigated the possibility of utilising hydroponic NFT-plant systems to grow plants with primary effluent as well as to control heavy metals concentrations in the effluent prior to discharge into the environment. Research results revealed that NFT-Plants grew well with effluent, indicating that nutrient film technique is suitable to grow vegetables with primary treated wastewater. Nonetheless, plants irrigated with commercial nutrient solution (the control plot plants) were generally larger than those irrigated with municipal primary treated effluent, possibly due to inadequate potassium supply or toxicity.

Results also showed that heavy metals (As, Cd, Cu, Pb) were accumulated in NFT plants at levels that may cause health problems if consumed by humans or animals.

The capacity of the NFT-plants system to control heavy metals effluent's discharge into the environment varied. Cr removal efficiency was more than 92%, Ni more than 85%, in addition to more than 60% reduction of B, Pb, and Zn. Nonetheless, the NFT-plants system removed less than 30% of As, Cd and Cu.

The record high prices for steel and energy make the cost for hydroponic systems attractive for small communities. Future experimental trials would focus on different treatment durations and on lettuce accumulating pharmaceuticals and organic compounds.

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www.accenthydroponics.com


FSANZ (Food Standards Australia New Zealand) 2007 Food Standards Australia New Zealand Act 1991 Prepared by the Office of Legislative Drafting and Publishing, Attorney-General’s Department, Canberra. 