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Full length research paper

The influence of treated waste water and manure on iron uptake and growth of caisim in entisol

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Consumers' demand for better quality vegetables is increasing; however the external morphology of vegetables cannot guarantee safety from contamination. Heavy metals ranks high amongst the chief contaminants of leafy vegetables, especially if using sewage sludge or effluents from wastewater treatment plants for irrigation of agricultural lands. A greenhouse experiment in pots was carried out in order to assess the effect of combination of treated wastewater and dose of poultry manure on the bioavailability of heavy metal Fe in contaminated soils and its uptake from agricultural plants. Caisim/Chinese cabbage (*Brassica sp*) plants were grown. Soil samples were analyzed for determination the content of elements: Fe. Concentration of the same elements was measured also in the leaves and roots of investigated plants after harvesting. The research used completely Randomized Design with two factors. The first factor was water irrigation: a) treated wastewater by slow-sand filtered and b) untreated wastewater irrigated. The second factor was the manure doses: 0%, 5%, 10%, 15%, and 20% of soil weight. The result showed that treated wastewater by slow-sand filtered reduced BOD, COD, suspended solid, Mn and Fe concentration in wastewater. Treated wastewater by slow-sand filtered plus manure application significantly increased plants height, slightly increased dry leaves and roots weight of Caisim/Chinese cabbage, but without manure application has had no different effect. Chinese cabbage which was watered by untreated and treated waste water tended to have high level Fe on leaves and roots, but still below the levels which can be toxic to the plants.

Keywords: Caisim; Entisol; Fe uptake; Manure; Treated waste water

INTRODUCTION

Environmental pollution is an undesirable change in atmosphere, hydrosphere and lithosphere. Advanced industrialization processes have provided comforts to human beings on one hand but it has also resulted in indiscriminate release of gasses and liquids, which pollute the environment of biological system. Nowadays large amount of untreated sewage / industrial water is being discharged into surface bodies for disposal. As there is water shortage in Indonesia therefore, farmers are using this waste water to irrigate their vegetable fields in city conurbations. Such irrigation practices give very good crop yields as it contains large amount of organic material and some inorganic elements essential for plant growth. But it also may contain non-essential heavy metals which when present in large amount could be transferred to animal and human beings through food chain (Ghafoor *et al.,* 1994; Ghafoor *et al.,* 2004).

In suburban areas, the use of municipal and industrial waste water is common practice in many parts of the world (Sharma and Ashwath, 2006; Singh and Agrawal, 2008). Waste waters can be used for the restoration of degraded land and the growth of vegetation having commercial and environmental value (Madejón *et al.*, 2006). Since the deficiency of access to adequate water for irrigation is a matter of increasing concern and limiting factor to develop plantation, therefore municipal waste water could be utilized as an important source of water for expansion of tree plantation in and around the city and industrial complexes (Al-Jamal *et al.*, 2002; Kalavrouziotisa and Apostolopoulos, 2007; Salehi *et al.*, 2007).

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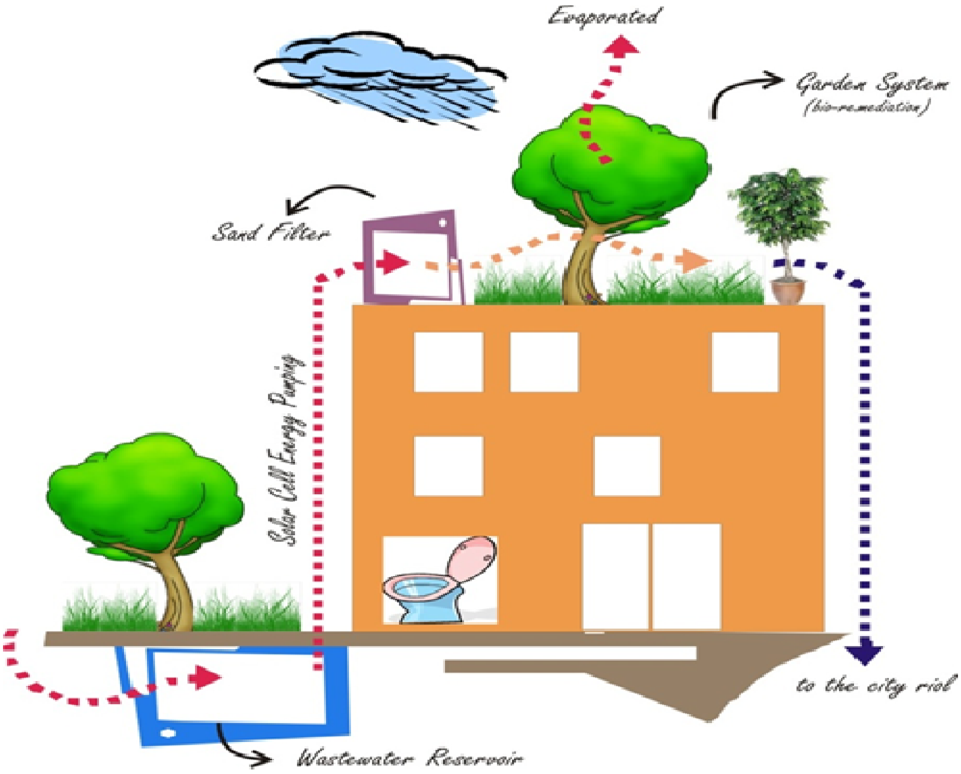

Figure 1. Wastewater treatment installation

Again, waste waters carry appreciable amounts of toxic heavy metals (Brar *et al*., 2000; Yadav *et al*., 2002; Salehi and Tabari, 2008) and concentrations of heavy metals in waste waters vary from city to city (Rattan *et al*., 2002; Aghabarati *et al*., 2008). Important sources of heavy metals in waste water are urban and industrial effluents. Elevated concentrations of heavy metals in soil may cause phytotoxicity, direct hazard to human health, indirect effects due to transmission through the food chain or contamination of ground- or surfacewaters (Clijsters et al., 1999; Cuypers et al., 1999; Berglund et al., 2002; Quartacci et al., 2003). Heavy metals cannot be degraded or destroyed, but it is possible to alter their chemical form and change their solubility in water and hence availability to plants (Pulford et al., 2002; Nakova, 2002, Sharma *et al*., 2007). Long-term use of waste waters on lands often results in the build-up of the elevated levels of heavy metals in soils (Rattan *et al*., 2002; Larchevêque *et al*., 2006). Hence waste water irrigation is known to contribute significantly to the heavy metals content of soils (Nyamangara and Mzezewa, 1999; Nan *et al*., 2002; Singh *et al*., 2004; Mapanda *et al*., 2005). When the capacity of the soil to retain heavy metals is reduced due to repeated use of waste water, soil can release heavy metals into ground water or soil solution available for plant uptake (Sharma *et al*., 2007). In fact, the main problem for utilizing waste water in plantations is existence of the heavy metals, because these materials are accumulate in soil and absorbed in plant organs. High concentration of heavy metals affects mobilization and balanced distribution of the fundamental elements in plant organs via the competitive uptake (Schat and Ten Bookum, 1992). Thus, if waste water is to be recycled for irrigation the problems associated with using it need to be known (Emongor and Ramolemana, 2004). Iron is an essential micronutrient element, which plays a significant etabolic role, but in high doses it can be toxic for the plants. What is the correlation of elevated Fe concentrations in the soil with the Fe uptake and growth of Chinese cabbage is one of the main objects of this study. An investigation of the interaction between heavy metal pollution and manure application also would be interesting, especially for the agricultural practice.

MATERIAL AND METHODS

Domestic wastewater is pumped to the top of building using solar cell energy. Two units of slow-sand filter which is installed on the top of building are operated to filtering the wastewater (Figure 1.). The treated wastewater thus is used to irrigate the vegetable (Caisim/*Brassica rapa var. parachinensis L*.**).** The water quality parameters has been analyzed including pH, TDS,

Table 1. The domestic waste water quality before and after treatments

Parameter	Before treatment	After treatment
pH	6.75	6.98
Electrical conductivity µS.cm-1	150.4	148.2
Ferrum (Fe) mg.L^{-1}	21.06	0.26
COD mg.L^{-1}	28.62	2.15
Suspended Solid (SS) mg.L^{-1}	418	0.08
BOD	9.79	0.78
Mangaan (Mn) mg.L^{-1}	5.91	0.025

DHL, COD, BOD, Fe, and Mn. The research was used Completely Randomized Design with two factor. The first factor was irrigated by water from domestic wastewater which was filtered by slow-sand and non filtered wastewater irrigated. The second factor was the poultry manure doses application: 0%, 5%, 10%, 15%, and 20% of the soil weight. In order to maintain the moisture content of the soil at approximately field capacity throughout the duration of the experiment, water was added daily. Caisim was planted till 6 weeks. At physiological maturity (Jones, 1997), caisim was harvesting. Then, leaves and roots were prepared to plant analysis according to Jones *et al.* (1991). The measurement of the Fe concentrations in the leaves and roots were performed by atomic absorption spectrometry method. The obtained data were processed by the statistics software. The testing of the presence of significant differences between the two average values in both cases was determined by the Duncan's test for the level of significance at 95%.

RESULT AND DISCUSSION

Wastewater Treatment Quality

Table 1 showed the mean quality of wastewater after treatment. The water pH (7.5 – 7.7) and CEC (1.40-1.50 dS/m) was good enough as water irrigation (Ayers & Westcost, 1994; Bauder et al., 2011). The wastewater recycling installation increasing wastewater quality through slow sand filter. Slow sand filter significantly decreased total density (tds), Carbon Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Fe, and also Mn.

According to guideline for safe limits of heavy metals in soil, plants, and water (FAO, 2007), the Fe and Mn in wastewater was several fold higher but after treated by slow- sand filter the Fe and Mn concentration was drastically decreased. The COD and suspended solid also decreased.

Caisim (Chinese cabbage) growth

There were significant differences in plants height among the treatments. The lower plants height found in untreated waste water with low dose manure application, while the highest plants height due to treated wastewater with high level (15% dry weight) manure application, but increasing manure dose application till 20 % dry weight of soil did not increase plant height significantly. (Table.2.).

Significant differences were detected between average fresh and dry leaves of caisim as influenced by manure application and treated waste water. The lowest fresh and dry weight leaves were found on untreated waste water with lowest manure treatment, while the highest dry weight leaves were found on treated wastewater with 15 % dry weight of manure application. The highest dry leaves weights were found on untreated wastewater + 20% nanure. The untreated waste water was still rich of nutrients and addition poultry manure enhanced the caisim growth. The highest dose manure application significantly increased dry leaves weight but but not for fresh leaves weight (Table 3.).

For root dry weight partitioning variables, fresh roots weight showed slightly significant differences among the treatments. The highest fresh and dry roots weight was found on untreated wastewater + 20% manure. While the lowest fresh and dry roots weight was detected on untreated wastewater with lowest manure dose application (5%) (Table 4.).

Significant differences were detected between Fe concentration in soil and soil pH after treatments (Table 5.). The lowest Fe concentration in soil was found on treated wastewater without manure application, while the highest Fe concentration in soil was detected on untreated wastewater with highest manure dose application (20%).

The total concentrations of heavy metals in the soils

Table 2. Average height of Chinese cabbage (caisim) influenced by manure application and treated waste water

Treatments	Average height (cm)
Treated wastewater without manure	21.13 bc
Treated wastewater + 5% manure	24.15 abc
Treated wastewater + 10% manure	27.62 a
Treated wastewater + 15% manure	28.18 a
Treated wastewater + 20% manure	26.77 a
Untreated wastewater without manure	22.17 bc
Untreated wastewater + 5% manure	21.37 bc
untreated wastewater + 10% manure	20.27 c
Untreated wastewater + 15% manure	24.67 ab
Untreated wastewater + 20% manure	26.32 a

Numbers in each column by common letters are not significantly at 5% Duncan's multiple range test

Tabel 3. Average fresh and dry leaves weight of cabbage/caisim as influenced by poultry manure application and treated waste water

Treatments	Fresh leaves weight (g)	Dry leaves weight (g)
Treated wastewater without manure	25.61 abcd	2.65 bc
Treated wastewater + 5% manure	33.80 abc	3.16 abc
Treated wastewater + 10% manure	32.40 abcd	3.08 abc
Treated wastewater + 15% manure	37.60 a	3.26 abc
Treated wastewater + 20% manure	34.25 abc	3.11 abc
Untreated wastewater without manure	25.21 bcd	2.94 abc
Untreated wastewater + 5% manure	21.31 d	2.26 c
untreated wastewater + 10% manure	23.85 cd	2.64 bc
Untreated wastewater + 15% manure	36.38 ab	3.72 ab
Untreated wastewater + 20% manure	36.02 ab	4.06 a

Numbers in each column by common letters are not significantly at 5% Duncan's multiple range test

from which vegetables were sampled were below the maximum permissible limits (MAFF, 1993). Soil pH (in water) was almost the same among the treatments (7.45-7.62), while the concentrations of Fe tested were lower on the treated wastewater than on the treated wastewater. The increasing manure dose application increased Fe concentration in soil significantly (Table 6.).

There were significant differences for leaves Fe concentrations among the treatments. However, no significant differences were detected between Fe roots concentration of caisim among the treatments (Table 6.) Concentrations of Fe in plant tissues (dry weight) averaged 1257.3 -1690.5 mg kg^{-1} on roots and 122.45-354.97 mg kg^{-1} on leaves. No significant differences (P >0.05) in plant Fe were found between the roots, but there were significantly difference between the leaves of untreated wastewater and treated wastewater samples. All samples' Fe concentrations were below the permissible limit of 200 mg kg^{-1} dry wt. (Food Standards Committee, 1950). According to Jones *et al.*, (1991), a critical concentration of Fe in leaves ranges from 20 to 100 ppm for most plants. High levels of Fe can be toxic to plants. Concentrations of Fe on the order of 500 to 800 ppm can result in toxicity in many crops. From data table 6, the plant tissue analyses data showed that all caisim which were irrigated by untreated and treated waste

Tabel 4. Average fresh and dry roots weight of cabbage/caisim as influenced by poultry manure application and treated waste water

Treatments	Fresh roots weight (g)	Dry roots weight (g)
Treated wastewater without manure	3.37 bc	0.63 b
Treated wastewater + 5% manure	4.20 ab	0.93 ab
Treated wastewater + 10% manure	3.22 bc	0.93 ab
Treated wastewater + 15% manure	3.46 bc	1.01 ab
Treated wastewater + 20% manure	3.03 bc	0.88 ab
Untreated wastewater without manure	3.38 bc	0.89 ab
Untreated wastewater + 5% manure	2.79 bc	0.69 ab
untreated wastewater + 10% manure	2.91 bc	0.65 ab
Untreated wastewater + 15% manure	3.26 bc	0.77 ab
Untreated wastewater + 20% manure	4.91 a	1.16 a

Numbers in each column by common letters are not significantly at 5% Duncan's multiple range test

Tabel 5. Average Fe in soil and soil pH as influenced by poultry manure application and teated waste water

Treatments	Fe in soil (%))	pH H_2O
Untreated wastewater without manure	0.012 de	7.57
Untreated wastewater + 5% manure	0.016 cde	7.51
Untreated wastewater + 10% manure	0.019 cd	7.49
Untreated wastewater + 15% manure	0.022 bc	7.54
Untreated wastewater + 20% manure	0.038 a	7.60
Treated wastewater without manure	0.010 e	7.40
Treated wastewater + 5% manure	0.017 cd	7.62
Treated wastewater + 10% manure	0.018 cd	7.51
Treated wastewater + 15% manure	0.022 bc	7.47
Treated wastewater + 20% manure	0.033 a	7.45

Numbers in each column by common letters are not significantly at 5% Duncan's multiple range test

water tended have high level Fe on leaves and roots, but still below the levels which can be toxic to plants. The data also showed that treated waste water still gave result in high Fe concentration in plants. Al samples treatments showed high level Fe concentration on roots (> 1000 ppm), but the Caisim/Chinese cabbage roots are non edible part.

In fact, the main problem for utilizing waste water in plantations is existence of the heavy metals, because these materials are accumulated in soil and absorbed in plant organs. High concentration of heavy metals affects mobilization and balanced distribution of the fundamental elements in plant organs via the competitive uptake (Schat and Ten Bookum, 1992). Thus, if waste water is to be recycled for irrigation the problems associated with using it need to be known (Emongor and Ramolemana, 2004).

Leafy vegetables have greater potential of accumulating heavy metals in their edible parts than grain or fruit crops. Studies on the uptake of heavy metals by plants have shown that heavy metals can be transported passively from roots to shoots through the xylem vessels (Kirkham, 1977; Krijger *et al.*, 1999). In addition, plant organs such as fruit and seed that have low transpiration rates (e.g. fruits and seeds) did not accumulate heavy metals because the storage organs are largely phloem-loaded and heavy metals are generally poorly mobile in the phloem. Zheljazkov and Neilsen (1996) found that the concentrations of heavy metals in vegetables per unit dry matter generally follow the order: leaves >fresh fruits >seeds. Contamination of the human food chains by heavy metals is not directly affected by the plants' total uptake, but rather by the concentration in those parts that are directly consumed (Bieleski and Launchli, 1983).

Table 6. Fe concentration on roots and leaves of cabbage/caisim as influenced by poultry manure application and teated waste water

Treatments	Fe roots concentration (mg.kg^{-1})	Fe leaves concentration (mg.kg^{-1})
Untreated wastewater without manure	1690.5 a	192.15 ab
Untreated wastewater + 5% manure	1510.1 a	354.97 a
Untreated wastewater + 10% manure	1438.7 a	122.45 b
Untreated wastewater + 15% manure	1391.2 a	173.81 ab
Untreated wastewater + 20% manure	1257.3 a	166.37 ab
Treated wastewater without manure	1589.7 a	163.79 ab
Treated wastewater + 5% manure	1564.9 a	155.47 ab
Treated wastewater + 10% manure	1478.4 a	172.13 ab
Treated wastewater + 15% manure	1266.6 a	146.35 ab
Treated wastewater + 20% manure	1393.6 a	137.62 b

Numbers in each column by common letters are not significantly at 5% Duncan's multiple range test

Thus, in assessing exposure risks, heavy metal contents in roots of Chinese cabbage (*Brassica sp*) are of less importance than those in the edible leaves. According to Alloway and Ayres (1993), sensitivity of organisms to heavy metal toxicity depends on heavy metal accumulation rate in plants, intake rate (in animals) and age of the consuming organism amongst other factors.

CONSLUSION

Treated wastewater by slow-sand filter reduced BOD, COD, suspended solid, Mn and Fe concentration in wastewater.Using treated wastewater by slow-sand filtered as water irrigation to Chinese cabbage without manure application decreased plant height, fresh and dry weight biomassa. Using untreated wastewater with 20 % manure application increased plant height, fresh and dry weight biomassa of Chinese cabbage.The lowest Fe concentration in soil was found on treated wastewater with 15 % manure application, while the highest Fe concentration in soil was detected on untreated wastewater. Increasing dose manure application did not give significant differences to Fe concentration in soil till 10% weight application, but increasing dose manure application till 20 % drastically decreased Fe concentration in soil significantly. Chinese cabbage which were irrigated by untreated and treated waste water tended have high level Fe on leaves and roots, but still below the levels which can be toxic to plants.

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