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Utilization of Treated Municipal Sewage Wastewater for Agricultural Irrigation Purpose

Ghassan F. Al-Samarrai
Department of Biology, College of Education, University of Samarra, Samarra, Iraq

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Corresponding author:
Ghassan F. Al-Samarrai
E-mail:
ghfaat76@gmail.com

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ABSTRACT

Industrial water systems produce enormous volumes of effluent wastewater. Properly controlled and managed reuse can provide significant additional resources of good quality water for arable agricultural purposes. Evaluation of using treated wastewater for watering were carried out through the study of accumulation of heavy metals in plant. Four treatment methods, (dilution, filtration, chemical, physico-chemical) were used in treated wastewater effluents with adjusted pH value (5.5, 6.5 and 7.5). The concentrations of Zn, Mn, Cu and were determined by Atomic Absorption Spectrometer (AAS) depended on APHA standard Fe method. The result shows methods using (Physico-chemical, chemical using 20 mg/L $(Al_2(SO_4)^3$ and dilution at 25% ratio methods, with adjusted pH value at 7.5 showed reduction in concentration of heavy metals in seed and fruit planted plants with treated effluents with limited maximum levels residue in fruit depended by World Health Organization The minimum allowable accumulation in plants approved by the World Health Organization (WHO) compared with other treatments. In conclusion treated effluents proud beneficial aspects for ability and potential in using for agricultural purposes.

استخدام مياه الصرف الصحي المعالجة لأغراض الري الزراعي

غسان فارس السامرائي
قسم علوم الحياة، كليه التربية، جامعه سامراء، سامراء، العراق

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للمراسلة:
غسان فارس السامرائي
البريد الالكتروني:
ghfaat76@gmail.com

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الخلاصــة

تنتج الأنظمة الصناعية كميات هائلة من مياه الصرف الصحي السائلة الملوثة التي باتت تشكل مصادر رئيسيه للتلوث البيئي. إعادة استخدام مياه الصرف السائلة بشكل مناسب وأدارتها يمكن ان يوفر موارد إضافية مناسبه من المياه التي يمكن استخدامها للأغراض الزراعية. استخدمت أربع طرق مختلفة للمعالجة (التخفيف، كيميائية، الترشيح، فيزوكيميائية) لتدوير مياه الصرف الصحي مع ضبط قيمة الرقم الهيدروجيني للمياه المعالجة الى (5.5 و 6.5 و 7.5). حددت تراكيز العناصر الثقيلة في الثمار (Zn, Mn, Cu) بطريقة قياس طيف الامتصاص الذري وحسب الطريقة القياسية المتبعة من قبل المؤسسة الأمريكية للصحة العامة (APHA). اظهرت النتائج ان طريقه المعالجة (الكيميو- فيزيائية، الكيميائية) باستخدام جرعة $Al_2(SO_4)^3$ 20 غم/لتر) والتخفيف بنسبه 25%) مع ضبط الرقم الهيدروجيني عند 7.5 سجلت انخفاضا في تركيز المعادن الثقيلة في البذور والثمار المروية بمياه الصرف المعالجة الى الحدود المسموح بها للتراكم في الثمار والمنصوص عليها من قبل منظمه الصحة العالمية WHO مقارنة بالمعاملات الأخرى . النتائج الختامية اشارت الى ان استخدام مياه الصرف الصحي المعالجة بشكل جيد اظهرت امكانيه وقدره على استخدامها لأغراض الري الزراعي.

1.Introduction

Rapid urbanization and industrialization have increased the pressure on a limited existing tap water to meet the growing needs for food production and keeping the environment in a healthy condition. Utilizing efficient irrigation systems with alternative sources of water, such as recycled wastewater, to meet the growing demands would be a positive response to this issue (Hassanli, 2013). The majority of urban water supplies for irrigation are used to maintain vegetation health, appearance and municipal amenities (Nouri *et al*., 2012). Some countries are planning to increase the use of treated wastewater, up to 51% to be used for irrigation. For example, Saudi Arabia intends to increase wastewater use to 65% by 2016 (EPA, 2012).Wastewater from Municipal Sewage and other commercial food service facilities differ significantly from residential wastewater. The pollutants in restaurant wastewater come from the cleaning of dishes, kitchen wares, meat and vegetable. Municipal Sewage wastewater is typically higher in strength than residential wastewater (Klamklang, 2007). The recycling of wastewater for farming irrigation, as an alternative to freshwater, gave the benefits through adding useful plant nutrients as well as organic compounds to the soil. Moreover, it provides a suitable method for disposing waste products (Horswell *et al*., 2003). Several studies revealed that wastewater is enriched with valuable resources including macro-nutrient, micro and organic matter that are necessary for productivity and fertility of the soil (Kiziloglu *et al*., 2008).

On the other hand, regardless of benefits to agricultural products, wastewater and sewage runoffs comprise heavy metals and other materials that could be harmful and poisonous to people (Ali and Shakrani, 2011). According to Pedrero and Alarcon (2009), sewage wastewater could have high concentrations of heavy metals, bacteria, fungi, and salts based on treatment applied and its sources. Heavy metals including Cu, Fe, Zn, and Mn in sewage wastewater effluents could be phytotoxicity, and if accumulated in the fruits and crops it will lead to health risk (Yadav *et al*., 2002). Wastewater irrigation effects on soils have been widely acknowledged, particularly on heavy metal concentrations and toxicity. Constant introduction of heavy metals to the soil can make the plant growth toxic (Ibrahim *et al*., 2013). Constant contamination of irrigated soil with wastewater may increase accumulation and toxicity with respect to heavy metals and uptake by plants. Allowing uptake of the heavy metals by plants increases their damage to different crop tissues (Rattan *et al*., 2005). This is because vegetables cultured on the wastewater-polluted soils could take up heavy metals in adequate considerable and lead to health problems to the consumers (Emongor and Ramolmana, 2004; Khan *et al*., 2008). Moreover, human beings are subjected to direct health hazards by soil pollution due to direct contact with them (Madrid *et al*., 2002).

2.Materials and Methods

2.1 Wastewater Sampling

Sewage wastewater samples were collected from different sites of municipal sewage channels (Glogor area , Penang city, Malaysia) at early in the morning as needed for analysis and irrigation and was kept fresh with short period of storage. The methods of samples collecting was based on Standard Methods of the American Public Health Association (APHA, 2005). The Samples of sewage wastewater were taken in HDPE (high-density polyethylene) bottles. Bottles were thoroughly washed with HNO_3 and rinsed several times with distilled water before sample collection. The sewage wastewater samples were collected at regular intervals and stored at 4°C to avoid any changes in its characteristics. The samples were collected and analysed successively in terms of various physico-chemical parameters following standard procedures, Analytical methods given in the (APHA, 2005). This analysis included (Cu, Zn, Mn and Fe) elements.

2.2 Wastewater Treatment Methods

2.2.1 Dilution

Dilution treatment was carried out by mixing raw wastewater from municipal wastewater with tap water at two different ratios: 1:3 and 1:1. The ratio of 1(wastewater) with 3v/v (tap water), and the ratio of 1 (wastewater) with 1(v/v) (tap water) . This represents a concentrations of 25% and 50% of diluted samples, respectively and the diluted samples were thoroughly stirred.

2.2.2 Filtration

In this study used PP filter cartridge, was used which is made of polypropylene. The size of membrane filters is 1µm and 5µm. (Divya et al,2012) reported that pre-treatment with a micro filter of sizes 5 to 1 µm which completely removed the suspended solids.

2.2.3 Chemical

jar test (Velp Scientific type FC6S- Italy) was used in the chemical experiment procedure to determine the optimal dose in the treatment as reported in procera procedure method by (Domminguez et al., 2004). Six doses of aluminium sulphate [(Al_2 $(SO_4)_3$ including 1, 5, 10, 15, 20 and 25 mg/l plus 0.5mg/l of anionic polymer obtained from SYSTERM/ white powder] were applied in inorganic coagulate to determine the best dosage and pH following jar test procedure to determine the optimum dosage.

2.2.4 Physico-Chemical

The filtered of wastewater used by membrane size (1µm) combined with chemical treatment dose (20 mg/L) plus 0.5 mg/L of anionic polymer combined with disinfection 0.15 mL/L of sodium hypochlorite NaClO. The percent of Removal (%) was determined using the Equation 3.1

$$\text{Removal\%} = \frac{\text{Influent- Effluent x 100}}{\text{Influent}} \qquad \text{Equ.... .1}$$

2.2.5 pH Adjustment of Treated Effluent

The selection of pH adjusted treated effluent based on the suitability of the pH for the growth of the plant in the pH 5.5- 6.5 and 7.5 , and availability of most nutrients ranged between pH 5.5- 7.5 (William *et al.*, 2005), for pH adjustment treated of effluents of wastewater, a $NaOH/H_2SO_4$ solution. The samples stirred for 1-5 min, and the pH (HACH sensiON1 portable pH meter) was determined. The total treatment producers were tabulated as below (Table 1).

2.2.6 Wastewater Utilization for irrigation

A pot of experiment to evaluate the effect of the wastewater on selected plants was established at the green house. Seed of mung bean and okra were planted in plastic pots (20 cm height x 30 cm diameter) have been filled of amounts of sandy loam soil. After the establishment of seedlings in the pots, the treated wastewater was applied to each pot after making different methods of wastewater treatment. The treated wastewater was applied soon after sampling and carried to green house in order to avoid any change in characteristics and to minimize microbial activity. The irrigation was scheduled to keep the soil moisture content and seedlings were irrigated at intervals of once a day to eight weeks of each experiment. After the plants reached maturity stage, the fruits were harvested , brought to laboratory, then washed and dried well for next use

2.2.7 Assessment of Heavy Metals in Plants Parts

Assessment of the heavy metals content in plant parts was done following the methods proposed by FAO (2000). Fruits of each plant were washed under running water in order to get rid of the dirt, insects and plankton, followed by washing samples with distilled water. The samples were dried for 2 days in the laboratory at 40^{o}C using an oven. The dried materials were then pulverized using a blender (electric mixer) and passed through 2 mm sieve before use to obtain powder forms of each sample. The concentrations of Zn, Mn, Cu and Fe were determined by Atomic Absorption Spectrometer (AAS) (APHA (2005).

2.2.8 Statistical Analysis

Statistical analysis was carried out using statistical software SPSS version 19- (SPSS Inc., Chicago, USA, 2012). Variety ANOVA was used to analyze the experimental results of dependent variables. Significant differences between mean values were determined using Duncan's Multiple Range test (DMRT) ($P \leq 0.05$) following ANOVA statistical analysis one way, which were performed using SPSS. All data presented were expressed as mean ± standard error.

Table 1. Total of treatment methods and control

Control	Details
T1	Tap water
T2	Raw Wastewater
Treatments	Dilution treatments
T3	1 Wastewater: 3 tap water, pH 5.5
T4	1 Wastewater: 3 tap water, pH 6.5
T5	1 Wastewater: 3 tap water, pH 7.5
T6	1 Wastewater: 1 tap water, pH 5.5
T7	1 Wastewater: 1 tap water, pH 6.5
T8	1 Wastewater: 1 tap water, pH 7.5
	Filtration treatments
T9	Membrane size 1µm, pH 5.5
T10	Membrane size 1µm, pH 6.5
T11	Membrane size 1µm, pH 7.5
T12	Membrane size 5µm, pH 5.5
T13	Membrane size 5µm, pH 6.5
T14	Membrane size 5µm, pH 7.5
	Chemical treatments
T15	Alum /15 mg/L + Polymer 0.5 mg/L + Chloride 0.15 mL/L, pH 5.5
T16	Alum /15 mg/L + Polymer 0.5 mg/L + Chloride 0.15 mL/L, pH 6.5
T17	Alum / 15 mg/L + Polymer 0.5 mg/L + Chloride 0.15 mL/L, pH 7.5
T18	Alum / 20 mg/L + Polymer 0.5 mg/L + Chloride 0.15 mL/L, pH 5.5
T19	Alum / 20 mg/L+ Polymer 0.5 mg/L + Chloride 0.15 mL/L, pH 6.5
T20	Alum / 20 mg/L + Polymer 0.5 mg/L + Chloride 0.15 mL/L, pH 7.5
	Physico-chemical treatment
T21	Filter with 1µm + Alum / 20 mg/L + Polymer 0.5 mg/L + Chloride 0.15 mL/L, pH 6.5

3. Results

3.1 Accumulation of Heavy Metal in Fruits

Concentration of heavy metals in fruits of irrigated plants with untreated and treated effluent of municipal was presented in figure (1, 2, 3 and 4). Maximum concentration of heavy metals (Cu, Zn, Mn and Fe) recorded in plant fruit, that received untreated wastewater (T2). The averages concentration were [(2.36, 3.39, 1.39 and 2.9) and (2.45, 3.7, 1.52 and 3.07)] in fruits of Mung bean and Okra and the above mentioned heavy metal respectively.

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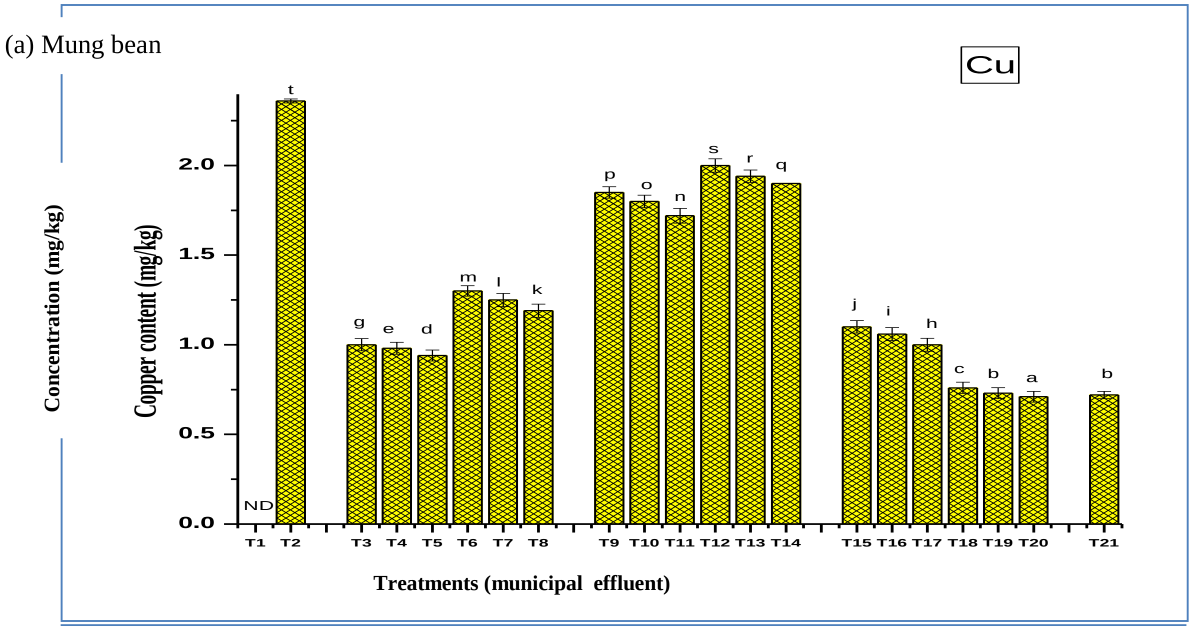
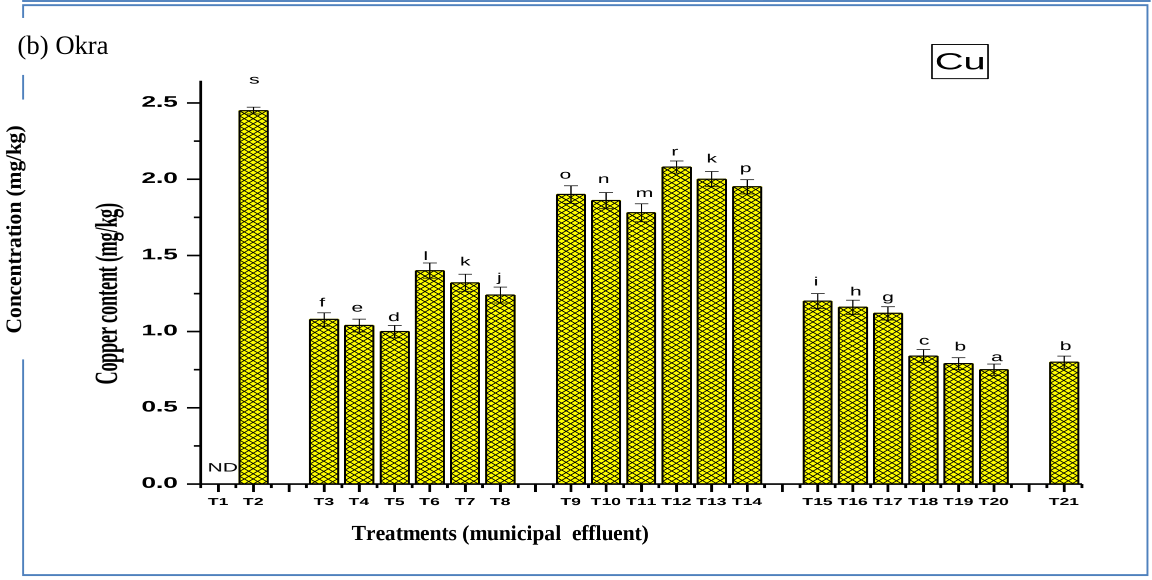
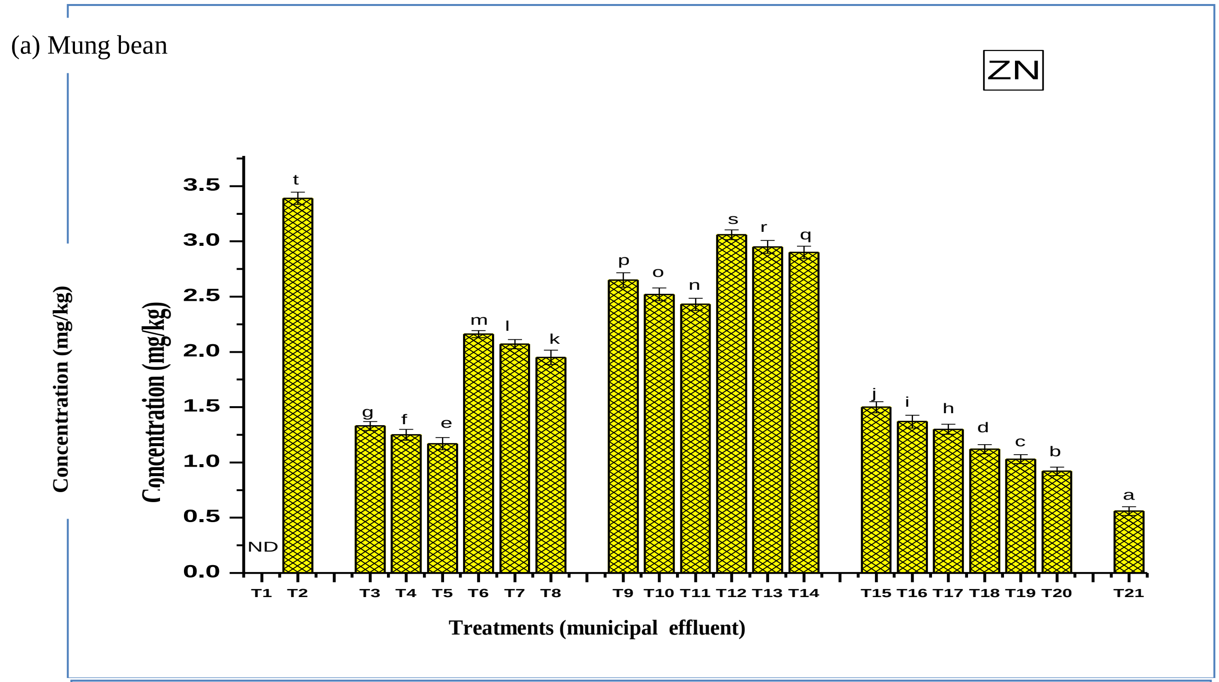
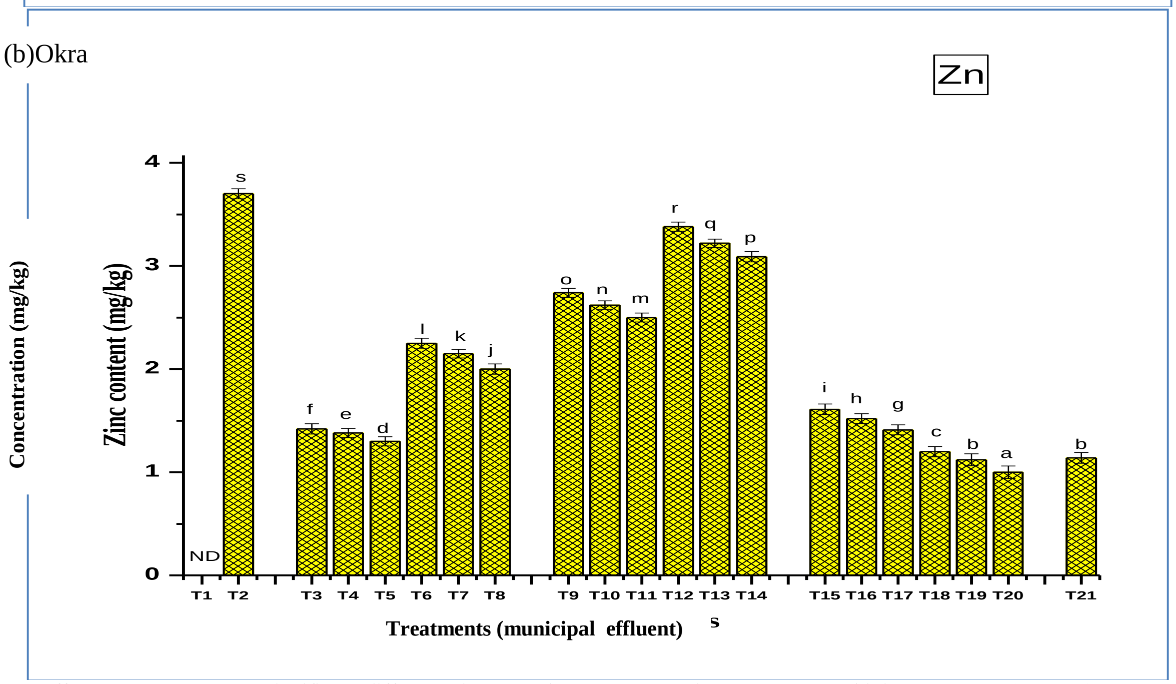




*Alphabets above different columns shows significant difference between the treatments using Duncan's Multiple Range test (P≤ 0.05). The average was calculated from three replicates

Figure 1. Effect of irrigation with untreated and treated municipal effluent of on Cu accumulation in fruit of Mung bean (a) and Okra (b) with varies pH.

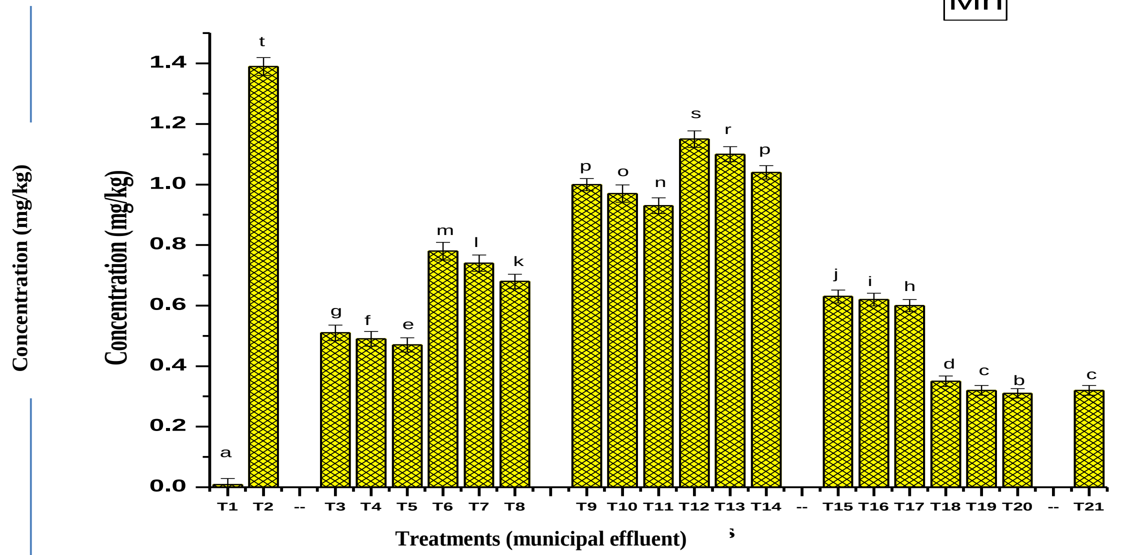




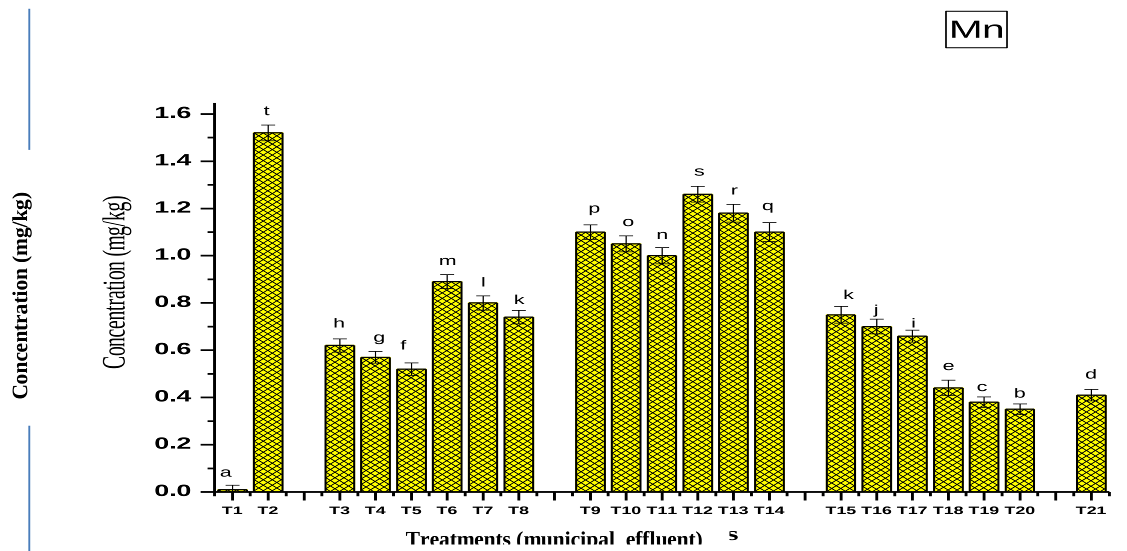
*Alphabets different columns shows significant difference between the treatments using Duncan's Multiple Range test (P≤ 0.05). The average was calculated from three replicates

Figure 2. Effect of irrigation with untreated and treated municipal effluent on Zn accumulation in fruit of Mung bean (a) and Okra (b) with varies pH.

(a)Mung bean

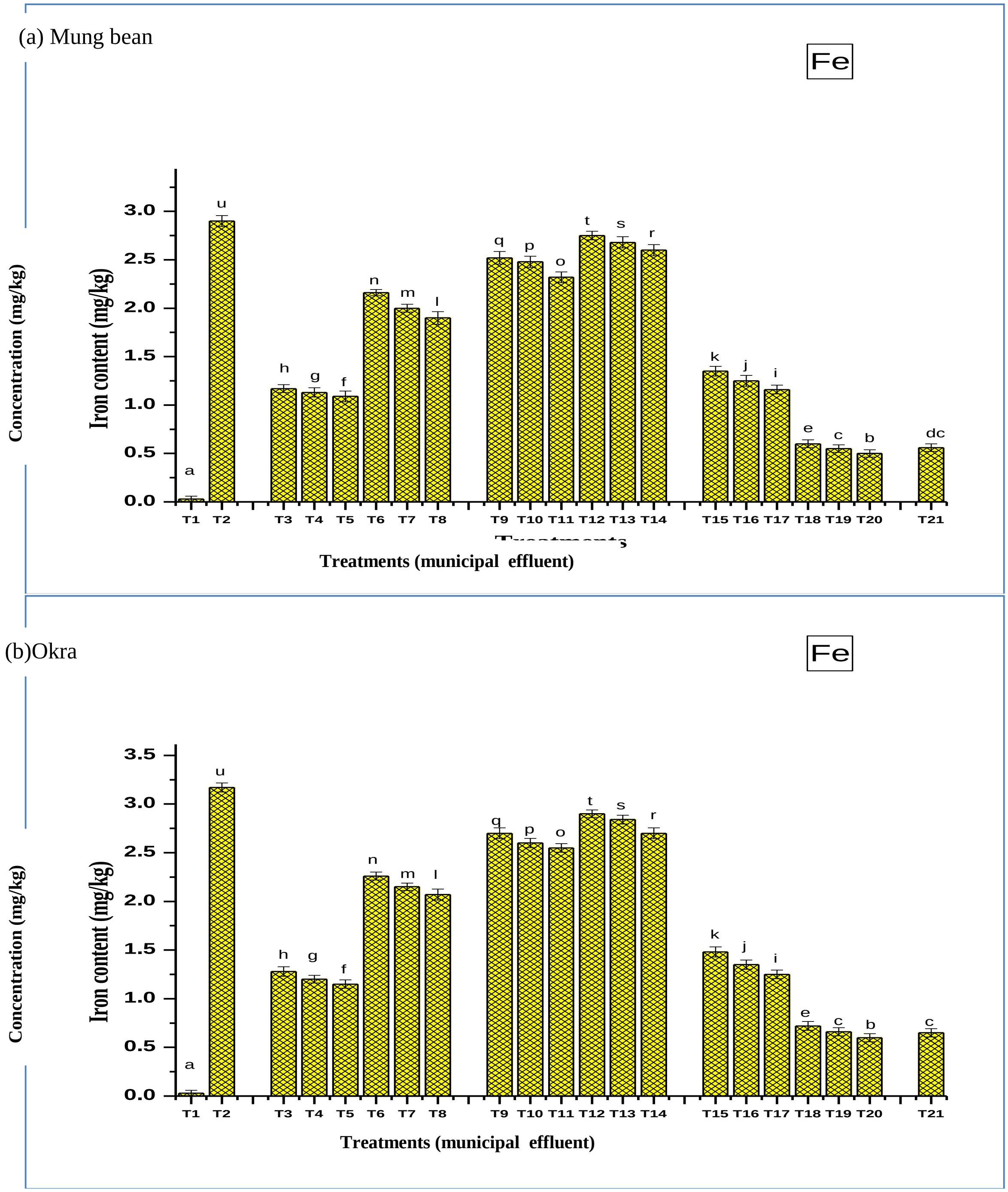


(b) Okra



*Alphabets different column show significant difference between the treatments using Duncan's Multiple Range test (P≤ 0.05) and average was calculated from three replicates

Figure 3 Effect of irrigation with untreated and treated municipal effluent on Mn accumulation in fruit of Mung bean (a) and Okra (b) with varies pH.



*Alphabets different columns shows significant difference between the treatments using Duncan's Multiple Range test (P≤ 0.05). The average was calculated from three replicates

Figure. 4 Effect of irrigation with untreated and treated municipal effluent on Fe accumulation in fruit of Mung bean (a) and Okra(c) with varies pH.

The chemical treatments dosage of 20mg/l (T20) exceeded other treatments in reduction the concentration of heavy metals in fruit. Concentration of Cu, Zn, Mn and Fe in (T20) were (0.71, 0.92, 0.31 and 0.5) in fruits of Mung bean and (0.75, 1, 0.35 and 0.6) in fruit of Okra. Physico-chemical treatment (T21) tailed (T20) in the reduction of content of Cu, Mn, Zn and Fe with averages of [(0.72, 1.05, 0.32 and 0.56) and (0.80, 1.14, 0.41 and 0.65) in fruits of Mung bean and Okra sequentially. In dilution treatments, the optimal dilution optimal found to be with 25% ratio (T5). In (T5) the average of Cu, Zn, Mn and Fe reached [(0.94, 1.17, 0.47 and 1.09), and (1, 1.3, 0.52 and 1.15)] Cu, Zn, Mn and Fe in fruits of Mung bean, Okra respectively. The chemical treatment of 15 mg/l (T17) alum and a pH 7.5 gave on averages reading of [(1, 1.3, 0.60 and 1.16) in fruits of Mung bean and (1.12, 1.41, 0.66 and 1.25) in fruits of Okra respectively for the mentioned metals . Higher concentration of heavy metals in filtration treatments gave on averages concentration of Cu, Zn, Mn and Fe [(1.9, 2.9, 1.04 and 2.7) and (1.95, 3.09, 1.1 and 2.7)] in fruits of Mung bean and Okra, respectively

4. Discussion

Arora *et al*.(2008) found out that substantial build-up of manganese, copper and zinc in vegetables was observed in irrigated plants using raw effluent compared with treated effluents of wastewaters. Erfani *et al*. (2001) found that plants growth were negatively affected by the use of untreated wastewater and a high accumulation of heavy metals was detected in the soil and plant. This could explained that, untreated irrigation water which contains certain ions at concentrations above threshold values can cause soil and plant toxicity problems. There may be a clear relationship between the rates of accumulation of heavy metals in plant parts and the concentration of heavy metals in the soil irrigated with wastewater و which led accumulation of heavy metals with higher percentage in plant Prabu (2009) .

According to results it could be indicated that the effect of chemical treatment can reduce the accumulation of Cu, Zn, Mn and Fe in the treated effluents and irrigated soil, thus there was a reduction in the concentration of heavy metals in plant parts. This coincide with findings of Mustafa *et al*. (2006) showed that the heavy metals contents remained at normal levels in the plant structure. However, plants growing in polluted environment can accumulate metals at high concentrations, through heavy metal uptake the plants grown in polluted soil. Previous studies by (Sedlak, 2005and Pauline *et al*., 2008), found out that using doses of aluminium sulphate plus polymer reduced the accumulation of heavy metals in treated wastewater. Accordingly there was a reduction in the accumulation of heavy metals in the soil and parts of the plant. In dilution treatments using a large amounts of clean water compared with amount of raw wastewater may reduce the pollution of wastewater including concentration of heavy metals. These results are in agreement with studies by Assadin *et al.* (1998) and Vazquez-Montiel *et al.* (1999), which found that, the dilution treatments of wastewater with clean water helps in the reduction of the accumulation of heavy metals in soil and plants to a safety level. This makes the current results acceptable with dilution ratio using clean water and wastewater to get solution with lower concentration of Cu, Zn, Mn and Fe depending on the percentage ratio of mixture 3:1 (Water: wastewater).

The result showed that the pH values of treated effluents which were used in the irrigation effected the accumulation of heavy metals in plants. A higher value of the accumulation of Cu, Zn, Mn and Fe was found in plants leaves and fruits irrigated with treated effluents adjusted at pH 5.5. Minimum levels of heavy metals concentration in plants leaves and fruits were recorded in the irrigation treated effluents that was adjusted to pH 7.5. This is because these elements become more available at a lower pH value and are precipitated in soil at high pH values (Ann et al.,2009). Perhaps the adjusted pH of treated effluents may be impacted on the soil pH which made the elements more available and absorbed in the soil solution by plants. Current results is in agreement with work carried out by McBride *et al*. (1997) in that soil pH has great effect on metal bioavailability of elements. Ann *et al*. (2009) reported that majority of micronutrients (B, Cu, Fe, Mn, Ni, and Zn) are more available within a pH range of 5 to 7. The current result support report Parker *et al.* (1998) in that, plant uptake of Mn, Fe, Cu and Zn enhanced at low soil pH. Also current results are in agreement with funding by Davis-Carter and Shuman, (1993) reported that, the concentration of Zn was increased in shoots of *Arachis Typography* (peanut) with lowered soil pH. The quality of effluents hashed an important role in the accumulation of heavy metals in plants. Application of irrigation using untreated wastewater led to serious contamination and accumulation of heavy metals exceeding the permissible limit.

5. Conclusions

This study indicates that, treated effluents from human activities (municipal sewage waste) have high content of pollutants metals exceed the recommended limits in wastewater. The heavy metals concentration of plants grown with irrigated treated effluents showed relatively lower concentration than those irrigated by untreated wastewater. All the observed concentrations of heavy metals in the studied plants were within the recommended levels of heavy metals in food. The use of treated effluents in agricultural lands may not pose potential environmental and health risks with respect to the accumulation of heavy metals using the proper treatment methods.

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