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5 SUMMARY

It is imperative to reuse the treated municipal wastewater in the agricultural expansion to face the scarcity of water resources as well as the rapid population growth in Egypt also, for protecting public health and controlling water pollution. The secondary treated municipal wastewater annual volume of Alexandria city amounts about 1.4 M m^3/d discharge to Maryout Lake and ultimately discharge to the Mediterranean Sea. This treated wastewater can be use as an unconventional resource for irrigating the desert area in the north western coast of Egypt. The most area of these soils is calcareous in nature and depends mainly on rainfall in its cultivation. Using this treated water in cultivating fodder trees will solve the problem of seasonal feed shortage resulted from the unstable rainfall conditions predominated in such areas besides, improving the physical, chemical and biological properties of soils. At the same time save and economic getting rid of this unconventional resource of water instead of wasting it in the sea water. So, the current work was carried out to cast the light on the importance of using secondary treated wastewater, as a source of irrigation water, in cultivating timber trees used as fodder for cattles, particularly sheeps, which encourages the animal wealth in the north western coast area.

The objective of the present work aims to study the effect of secondary treated wastewater on (1) some bio-physicochemical properties of calcareous soil, (2) the growth and some nutrient elements and heavy metals contents of three fodder trees; *Acacia saligna, Acacia stenophylla and Ceratonia siliqua,* (3) the irrigation prolonged for different periods from tree transplant on the accumulation of some nutrient elements and heavy metals in the studied soil and fodder trees.

With this respect, calcareous soil samples were collected from surface layer (0 – 30 cm) of Borg EL-Arab at north western coast area . Physical, chemical and biological analysis were conducted on the studied soil. Secondary treated wastewater used in the present study was obtained from Alexandria West Treatment Plant. Three timber trees used as fodder trees, i.e., ***Acacia saligna, Acacia stenophylla and Ceratonia siliqua***, 9-months-old transplants, were planted and irrigated periodically for 18 months with the secondary effluent.

A pot experiment of complete randomized block design with six replicates was conducted using cylindrical perforated plastic pots (30 cm height x 34 cm diameter) containing 22 kg soil (oven dry weight basis). The experiment was carried out during the period from Sept. 2000 to March 2002 under green- house conditions in the soil salinity laboratory, Agric. Res. Center, Alexandria. The experiment treatments were; (1) irrigation with secondary treated wastewater and tap water for control, (2) three timber tree species used as fodder, i.e., *Acacia saligna, Acacia stenophylla and Ceratonia siliqua*, (3) three prolonged irrigation periods, i. e., 6, 12 and 18 months from trees transplanted. Irrigation water was added periodically with an amount of water at each irrigation event to reach soil moisture content at field capacity. Some soil biological properties, i.e., organic carbon, polysaccharides, microbial biomass, microbial activity and enzymes activity were determined every 1½ months after 6 months from trees transplanting. The studied physical properties; water stable aggregate size distribution, the aggregation parameters, pore size distribution and specific surface area, as well as the chemical properties; pH, EC, soluble cations and anions, CEC, exchangeable cations, ionic strength, SAR, SSP, ESP, some macro and micro- nutrients (N, P, K, Fe, Mn, Cu and Zn) and some heavy metals (Pb, Cd, Cr and Ni) were determined also after 6, 12 and 18 months from trees transplanting.

The obtained results could be summarized as follows:

I- Characteristics of secondary effluent used in irrigation.

1- Electrical conductivity (EC), sodium adsorption ratio (SAR) and pH were in the normal range, they are 1.93 dS / m, 3.05 and 7.8 respectively.

2- Chloride and bicarbonate concentrations were varied between slight to moderate, they were higher than sulfate concentration.

3- The predominate cations were sodium followed by calcium, magnesium and potassium.

4- Concentration of micronutrients (Fe, Zn, Mn and Cu) were generally very low, while those of heavy metals (Pb, Cd, Cr and Ni) were lower than the maximum permissible limits given by FAO (1985).

5- Biochemical oxygen demand (BOD_5) concentration was in permissible limits for wastewater secondary treatment (19 mg/l)

6- Fecal coliform is less than the maximum permissible limits given by WHO, (1989). It was 29/100 ml.

II- Effect of irrigation with secondary effluent on some soil physical properties.

1- Distribution of water stable aggregates and aggregation parameters.

a- Water stable aggregates significantly affected by irrigation with secondary effluent compared with tap water (control).

b- Percentage of the macro water-stable aggregates (> 2mm) significantly increased by using secondary effluent as a source of irrigation water compared with the tap water. The increment percentage under the tree species was in the following trend:

Acacia saligna > Acacia stenophylla > Ceratonia siliqua

c- Percentage of the fine aggregates (< 0.25 mm) significantly decreased by using secondary effluent as a source of irrigation water . The decrement percentage was in the following trend under the studied trees :

Acacia stenophylla > Ceratonia siliqua > Acacia saligna

d- A significant increase in optimum size aggregate (OSA) (2-0.5 mm) caused by using secondary effluent as a source of irrigation water comparing with tap water. The increment was in the following trend :

Acacia stenophylla > Acacia saligna > Ceratonia siliqua .

e- Aggregation parameters i.e. structure coefficient (S.C) and mean weight diameter (M.W.D.) significantly increased by using secondary effluent as a source of irrigation compared with tap water, by prolonged irrigation period up to 18 months. The increment was in the following trend: ***Acacia stenophylla > Acacia saligna > Ceratonia siliqua***

2- Pore size distribution: Quickly drainable pores (Q.d.P.) decreased significantly by prolonged irrigation with secondary effluent up to 18 months compared with tap water meanwhile, slowly drainable pores (S.d.P.) increased by using secondary effluent as a source of irrigation water, compared with tap water as well as by the prolonged irrigation period up to 18 months. On the other hand, prolonged use of the secondary effluent up to 18 months had no marked effect on the total drainab pores (T.d.P.) of the soil cultivated by ***Ceratonia siliqua***, while T.d.P. increased under both ***Acacia stenophylla*** and ***Acacia saligna***

The water holding pores (W.h.P.) significantly increased by prolonged irrigation with secondary effluent up to 18 months compared with tap water. The increment of the W.h.P indicates more plant available water in the soil irrigated with secondary effluent. Also,irrigation with secondary effluent led to an increment in fine pores (F.P.) compared with tap water (the control treatment). The increment under the trees species was in the following trend: ***Acacia stenophylla > Acacia saligna > ceratonia siliqua .***

3- Specific surface area (SSA) The results revealed that secondary effluent application as a source of irrigation significantly decreased the specific surface area (SSA) comparing to using tap water for irrigation. The SSA decreased from 287.6 m^2/g soil before plantation to 283.5 m^2/g by prolonged using secondary effluent as a source of irrigation up to 18 months, while using tap water in irrigation increased SSA to 305.6 m^2/g soil during the same period.

III- Effect of irrigation with secondary effluent on some soil chemical properties

1- Secondary effluent application decreased soil pH by 0.37% , 1.26% and 2.54 % after 6,12 and 18 months from trees plantation, respectively, while soil pH almost unchanged by using tap water for irrigation. Also, results reveal that tree species have no effect on soil pH.

2- Soluble salts values of soil expressing in (EC) values increased owing to using secondary effluent for irrigation by 6.5% , 9.18% and 10.32% after 6,12 and 18 months from trees plantation, while it still 3.05 dS / m in that irrigated with tap water. Also, results indicated that tree species had no effect on soluble salts of soil.

3- Ionic strength (IS) values, represented the intensity of the electrical field increased by 4.5%, 9.4% and 10.37% after 6.12 and 18 months from trees plantation when using secondary effluent as a source of irrigation water. Ionic strength values unchanged by using tap water and it was 41.7 mmole / L. The increment of the IS for the soil solution under tree species was in the following order :

Ceratonia siliqua = Acacia stenophylla > Acacia saligna

4- Soluble sodium percentage (SSP) values increased by using secondary effluent comparing with tap water for irrigation. The SSP values increased to 29.95 %, 30.38% and 30.50% after 6,12 and 18 months from trees plantation, respectively. While SSP was about 28.8% and unchanged by using tap water for irrigation. The tree species had no effect on SSP.

5- Sodium adsorption ratio (SAR) did not varied by using both secondary effluent and tap water as a source of irrigation. Results indicate that tree species have no effect on SAR.

6- Application of secondary effluent as a source of irrigation progressively increased exchangeable cations i.e. calcium, magnesium, sodium and potassium, comparing to using tap water for irrigation. Furthermore, results indicated that both cation exchange capacity (CEC) and exchangeable sodium percentage (ESP) increases with prolonged irrigation period from 6 months till 18 months comparing with the control treatment. Also, results revealed that tree species have no effect on SAR or ESP.

7- Available nitrogen, phosphorus and potassium in soil increased with using secondary effluent comparing to using tap water for irrigation. In addition, soil content of these elements increased with extended irrigation period from 6 months to 8 months. Also, iron, manganese, zinc and cupper in soil increased by using secondary effluent comparing to using tap water for irrigation. These micronutrients increased in soil as follow: Cu > Mn > Fe > Zn .

Heavy metals. Namely Pb, Cd, Cr and Ni contents in soil different in affection by irrigation water type and the extended irrigation after seedling plantation . Furthermore, heavy metals increased by using secondary effluent as a source of irrigation compared with tap water and increased with the prolonged irrigation peroid from 6 months to 18 months. Also, the concentration of these heavy metals increased in soil in the order: Pb > Cd > Ni >Cr

IV –Effect of irrigation with secondary effluent on some organic constituents in soil.

Both organic carbon and total polysaccharides in the investigated soil increased by using secondary effluent comparing to using tap water (control) for irrigation. They, also increased with prolonged irrigation periods from 6 to 18 months. The increment in total polysaccharides under tree species was in the following trend:

Acacia saligna > Acacia stenophylla > ceratonia siliqua .

V- Effect of irrigation with secondary effluent on some soil biological properties.

1-The results revealed that soil biological properties were the most one affected by using secondary effluent as a source of irrigation water compared with tap water (control).

2 - Results also revealed that tree species clearly affected biological properties of investigated calcareous soil where the highest values were under *Acacia stenophylla* followed by *Acasia saligna* then *Ceratonia siliqua*

3- In general, data showed that prolonged irrigation period, and hence the age of trees had an effective role on soil biological properties, where both of microbial biomass and soil respiration rate values decreased after 6 months from transplanting as follow: 6 > 7.5 > 9 > 10.5 months, after that there was an increment in the order: 10.5 <12 < 13.5< 15 < 16.5 < 18 months after tree transplanting.

4- Values of microbial biomass-C, -N and – P increased in soil irrigated with secondary effluent compared with control (tap water). In general, the ratios of these microbial elements C : N : P were 6.7 :1.3 : 1.

5- Soil basal respiration rate results were consistent as microbial biomass.

6- Metabolic quotient (qCO_2) was almost constant or tended to decrease slowly (starting from 6 months after tree plantation) every 45 days in case of irrigation either by secondary effluent or by tap water.

7:- Oxidoreductases (Catalase, dehydrogenose), hydrolases (acid and alkline phosphatases, inorganic pyrophosphatase and invertase) and amidohydrolases (urease, amidase, glutuminase, asparaginase) activities increased by using secondary effluent as a source of irrigation water comparing with tap water (control).

VI – Effect of irrigation with secondary effluent on growth of fodder trees and its mineral contents

1- Vegetative growth increased with prolonged irrigation period by secondary effluent comparing with tap water (control). Increment percentage average of height and diameter were 248.2 % and 332.3 %, for ***Acacia stenophylla,*** 106.3% and 712.3 %, for ***Acacia salign*** and 145.6% and

2- 43.1% for ***Ceratonia siliqua,*** respectively. Consequently, the response of trees growth in height and diameter to irrigation with secondary effluent was in the order :

Acacia stenophylla > ***Acacia saligna*** > ***Ceratonia siliqua***

The maximum average fresh weight for roots, stem and leaves was 154.1, 173.4 and 191.2 g / plant for ***Acacia stenophylla***, 104.1, 107.9 and 115.1 g / plant for ***Acacia saligna*** and 42.1, 50.2 and 52 g / plant for ***Ceratonia siliqua*** ,respectively, after 18 months irrigation period with secondary effluent and the maximum average dry weight for roots, stem and leaves was 136.3, 144.6 and 147.8g / plant for ***Acacia stenophylla***, 91.9, 95.6 and 87.6 g / plant for ***Acacia saligna*** and 24.4, 27.2 and 26.2 g / plant for ***Ceratonia siliqua,*** respectively. Consequently, the tree growth response for secondary effluent irrigation was in the following order: ***Acacia stenophylla***> ***Acacia saligna*** > ***Ceratonia siliqua***

2-Irrigation with secondary effluent showed a clear increase in concentrations of macro- nutrients, namely, nitrogen , phosphorus, potassium, calcium, magnesium and sodium in leaves, stems and roots of tree species compared with using tap water in irrigation. The increment of aforementioned macro- nutrients in tree species followed the order :

Ceratonia siliqua* > *Acacia stenophylla* > *Acacia saligna

Generally, the concentrations of nitrogen, phosphorus, potassium, calcium, magnesium and sodium in leaves of the three tree species was in the following order : nitrogen > magnesium > potassium > calcium > phosphorus > sodium .

Also, nitrogen and phosphorus concentration in tree parts followed the descending order : Leaves > stems > roots .

Potassium concentration in tree parts had the following order:
stems > roots > Leaves.

While, calcium concentration in tree parts followed the order:
roots > stems > Leaves.

Magnesium concentration in tree parts had the following order: Leaves > stems > roots

Sodium concentration almost, had the same concentration in the different parts of both ***Acacia saligna*** and ***Acacia stenophylla*** ,while in ***Ceratonia siliqua*** was in the following order : roots > Leaves >. Stems.

3-Micronutrients (Fe, Zn, Mn and Cu) percentage increased in leaves, stems and roots of tree species by using secondary effluent as a source of irrigation water comparing with tap water (control). Iron concentration increased in tree parts by the order: roots > stems >Leaves

Furthermore, iron concentration in ***Ceratonia siliqua*** leaves was higher than in that of both ***Acacia stenophylla*** and ***Acacia saligna***. Also, zinc concentration in ***Ceratonia siliqua*** was the highest while, ***Acacia stenophylla*** and ***Acacia saligna*** contained the same concentration. ***Acacia stenophylla*** stems contained the highest zinc concentration, while, ***Acacia saligna*** and ***Ceratonia siliqua*** contained the same concentration.

Furthermore, zinc concentration in the roots of tree species followed the order : ***Acacia saligna > Acacia stenophylla > Ceratonia siliqua***

Manganese concentration in ***Acacia saligna*** was higher than in both ***Acacia stenophylla*** and ***Ceratonia siliqua***. Also, copper concentration increased in the tree species by the following order :

Acacia stenophylla > Acacia saligna > Ceratonia siliqu

4-Heavy metals (Pb, Cd, Ni and Cr) concentrations in leaves, stems and roots of tree species increased by using secondary effluent as a source of irrigation water compared with tap water (control). The concentration of heavy metals in tree species was less than the permissible limits. The concentration of heavy metals in tree species was in the following the order:

Acacia saligna > Acacia stenophylla > Ceratonia siliqua

Also, the the heavy metals concentration in different tree parts was in the following order: roots > stems > leaves.

CONCLUSION

From the above mentioned results it could be conclude that:

1-The secondary treated wastewater used in this study is safely in irrigation purposes and have no harmful effects on the soil of the studied area.

2- Using secondary effluent in irrigation have an improving effect on soil physical, chemical and biological properties, which enhanced fodder trees growth (*Acacia saligna, Acacia stenophylla* and *Ceratonia siliqua*).

3- Tree growth increased by using secondary effluent in irrigation 3 and 2.5 times for *Acacia stenophylla*, one and three times for *Acacia saligna*, and 0.5 and 1.5 times for *Ceratonia siliqua*, respectively, for stem diameter and hight.

4- Content of both macronutrients and heavy metals in tree species were within the permissible limits and below the toxic level, which encourage using of such water for fodder trees irrigation.

5-*Acacia stenophylla* is the most responded tree for irrigation with secondary effluent so, it is recommended to be planted in calcareous soil in western coastal region, instead of wasting such water in the sea.