Review

Effects of using wastewater in agricultural production

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The rapid population growth in many municipalities in the arid and semi-arid of the world continues to place increasing demands on limited fresh water supplies. Many cities and districts are struggling to balance water use among municipal, industrial, agricultural, and recreational users. The population increase has not only increased the fresh water demand but also increased the volume of wastewater generated. Treated or recycled wastewater appears to be the only water resource that is increasing as other sources are dwindling. Use of recycled wastewater for irrigating landscapes is often viewed as one of the approaches to maximize the existing water resources and stretch current urban water supplies. Irrigation plays a vital role in increasing crop yields and stabilizing production. In arid and semi-arid regions, irrigation is essential for economically viable agriculture, while in semi-humid and humid areas, it is often required on a supplementary basis. One of the applications of wastewater is its reuse as irrigation water in agriculture. In arid and semi-arid regions, wastewater is considered a valuable source of irrigation water and a fertilizing material (AI-Rashed and Sherif, 2000).

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Expansion of urban populations and increased coverage of domestic water supply and sewerage give rise to greater quantities of wastewater. With the current emphasis on environmental health and water pollution issues, there is an increasing awareness of the need to dispose of these wastewaters safely and beneficially. In arid and semi-arid regions, wastewater is considered a valuable source of irrigation water and a fertilizing material (AI-Rashed and Sherif, 2000).

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INTRODUCTION

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three purposes: (a) complementary treatment method for wastewater (Bouwer and Chaney, 1974), (b) the use of marginal water as an available water source for agriculture (Bouwer and Idelevitch, 1987; Al-Jaloud et al., 1995; Tanji, 1997), and (c) the use of wastewater as a nutrient source (Bouwer and Chaney, 1974; Vazquez-Montiel et al., 1996) associated with mineral fertilizer savings and high crop yields (Smith and Peterson, 1982). In arid and semi-arid regions, wastewater is considered a valuable source of irrigation water and a fertilizing material (Al-Rashed and Sherif, 2000). Although the benefits of wastewater use in irrigation are numerous but precautions should be taken to avoid short and long-term environmental risks related. Earlier studies have shown that the effect of an industrial effluent varies from crop to crop (Kaushik et al., 2005; Tarchitsky et al., 1999; Jiries and Hussain, 2000). Therefore, inappropriate handling and management of wastewater reuse for irrigation can create serious environmental and health hazards (Angelakis, 1999). This encourages most countries to continuously modify and update the standards and guidelines for reuse of wastewater for irrigation (Abu-Rizzaia, 1999; Angelakis et al., 1999). When wastewater is used properly for irrigation it is considered an environmentally sound disposal practice (Papadopoulos, 1998). Such a proper use can relatively minimize pollution of the ecosystem which otherwise would be contaminated by direct disposal of wastewater into surface or ground water (Gori et al., 2000). Protection of environment and public health can be attained through adoption of integrated management practices including wastewater treatment, soil and crop selection, method of application and human exposure control (Gori et al., 2000). Wastewater contains essential nutrients for plant growth like N, P, and K, micronutrients such as iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) and a considerable amount of organic matter (Gori et al., 2000; Weber, 1996). This makes wastewater a good fertilizer and soil amendment that would increase crop yield and enhance soil fertility and productivity.

However, improper management of wastewater irrigation may provide the crops with nutrients beyond their specific requirement and subsequently accumulate them at undesirable high levels in the crop. This would lead to reduction in the yield and its quality (Schalscha, 1999; Gori et al., 2000; Vazquezmontiel et al., 1996). Therefore, management of irrigation with wastewater should consider the nutrient content in relation to the specific crop requirements and the rate of application of wastewater should be adjusted accordingly. Due to diversity in industrial growth there is a considerable variation in the quantity and quality of wastewater generated from industry to industry. Management of such effluents to avoid damage to the environment warrants urgent attention. So it is essential to study the effect of industrial effluents on individual crops before their use in agricultural fields.

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SEED GERMINATION

An Investigate showed that the germination of kidney bean (Phaseolus aureus) and lady's finger (Abelmoschus esculentus) seeds were affected adversely when 75 and 100% concentrations of the textile effluent were used as compared to water (control). But there was no effect up to 50% effluent concentration (Mohammad and Khan, 1985). Bengal gram (Cicer arietinum) seeds germination was adversely affected even as low as 5% textile effluent concentration (1987). But unlike above said crops, 50% diluted textile effluent increased the seed germination, total sugars, starch, reducing sugars, and chlorophyll than control (distilled water) of groundnut seedlings. These studies showed that the effect of an industrial effluent vary from crop to crop. So it is essential to study the effect of industrial effluents on individual crops before their disposal in agricultural fields. Ramana et al. (2002) reported the effect of different concentrations (0, 5, 10, 15, 25, 50, 75% and undiluted) of distillery effluent (raw spend wash) on seed germination (%) of some vegetable crops, namely tomato, chilli, bottle gourd, cucumber and onion. It was concluded that the effect of the distillery effluent is crop-specific and due care should be taken before using the effluent for pre-sowing irrigation purposes. The distillery effluent did not showed any inhibitory effect on seed germination of low concentration expect in tomato. Irrespective of the crop species, at highest concentration (75% and undiluted) complete failure was observed for germination. Based on the tolerance the crops were arranged in order: cucumber > capsicum > onion > bottle gourd > tomato. Srivastava and Sahai (1987) studied the impact of distillery effluents in various concentrations (1, 2.5, 5, 10, 25, 50, 75 and 100%) on the seed germination, speed of germination, index, growth, leaf area, biomass, net primary productivity, pigment content, reproduction capacity, seed output, seed weight, seed densities and seed protein content of Cicer arietinum. It was concluded that very high BOD load and the presence of excessive concentration of soluble salt could be responsible for the toxicity of the effluents. The effluent at up to 5% concentration was, however, beneficial for the overall
growth parameter and its use as a liquid fertilizer has been suggested. Gulrzaf et al. (2003) evaluated the suitability of different industrial effluents (textile mill, oil refinery, soap and detergent mill, hydrogenated oil mill, and rubber industry) for irrigation purposes in wheat crop. The germination of wheat seeds was most affected by textile mill wastewater followed by soap and detergent, oil refinery, hydrogenated oil and rubber industry wastewater. It was concluded that wastewaters should not be discharged in agricultural crops, water stream etc. It was also recommended that industries should install wastewater treatment plants to protect the crops.

CROP YIELD

Irrigation with wastewater has been studied for several crops and under different climatic conditions (Gori et al., 2000, Weber et al., 1996, Campbell et al., 1983). Many investigators have reported a substantial increase in plant growth and biomass production upon sewage sludge application (Azam and Lodhi, 2001; Chatha et al., 2002; Mohammad and Athamneh, 2004; Dursan et al., 2005; Casado-Vela et al., 2006 and 2007; Jamil et al., 2006). Jamil et al. (2006) reported that sewage sludge increased the yield and straw production of wheat. They mentioned that the maximum yields in both grain and straw were obtained at 40 t ha-1 of sewage sludge application. Azam and Lodhi (2001) indicated that benefits of sewage sludge amendments are derived mainly from a net release of nitrogen from decomposing organic matter with high nitrogen concentration and narrow C/N ratio. Munir et al. (2007) in research on forage crops reported that irrigation with wastewater for two years was caused increasing of barley biomass. Alizadeh et al. (2001) reported that irrigation treatment with wastewater in all the growth stages cause the most biological yield of corn to be achieved. Bouzerzour et al. (2002) reported that the application of sewage sludge increased leaves dimensions, leaf area index, accumulated above ground dry matter, tillering capacity and plant height of barley (Hordeum vulgare L.) and oat (Avena sativa L.) genotypes, evaluated in pots experiment. They noted also that the response of the measured variables to the applied sewage sludge was linear, which corroborated the results of the present study. Antolin et al. (2005) reported that application of sewage sludge increased barley grain yield because the soil amended had improved microbiological properties, which promoted the recycling of nutrients for the crop. Cherak (1999) reported an improvement of the tillering capacity of oat (Avena sativa L.) grown under sewage sludge amended soil, compared to the control. Antolin et al. (2005) reported that application of sewage sludge increased barley grain yield because the soil amended had improved microbiological properties, which promoted the recycling of nutrients for the crop. In another investigations Jamjoum and Khattari (1986) found that corn yield was increased by irrigation with wastewater and they attributed this increase to the enhancement of nutrient uptake and improvement of the physical properties of the soil. Tavassoli et al. (2010) to evaluate the effects of municipal wastewater with manure and chemical fertilizer on yield and quality characteristics of corn forage reported that irrigation with wastewater will increase forage yield. Erfani et al. (2001) showed that utilization of treated municipal wastewater has caused an increase in forage yield and whole plant dry matter of corn as compared to irrigation with the well water. Day and Tucker (1977) also reported high grain yield in sorghum crop irrigated with wastewater. However, Mendoza et al. (2006) reported that when sludge is applied from WSP, it further improved sorghum plant nutrition. Rajput et al. (1983) working with sorghum cultivar Shaheen found that plant height, ear length, ear weight and grain yield increased with N and P application. Similarly, Milam and Hickingbottom (1989), Arya et al. (1997) and Howard and Lessman (1989) also demonstrated that increasing N rate increased grain yield of sorghum. In another study Galavi et al. (2009) in research on sorghum showed irrigation with sewage caused increase of forage yield and reduced of cell wall and cell wall without hemi cellulose.

Ahmad et al. (2003) studied the response of sugarcane to treated wastewater of oil refinery. The sugarcane growth was better when irrigated with treated wastewater of oil refinery than control. Dongale and Savant (1997) found a significantly higher yield of sugarcane and increase in available N content of soil (300 kg N per ha) through applied spent wash and also thought that spent wash was a good source of potassium for sorghum.

NUTRIENT ACCUMULATION IN CROP

Wastewater contains essential nutrients for plant growth like N, P, and potassium (K), micronutrients such as iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) and a considerable amount of organic matter (Gori et al., 2000). This makes wastewater a good fertilizer and soil amendment that would increase crop yield and enhance soil fertility and productivity. However, improper management of wastewater irrigation may provide the crops with nutrients beyond their specific requirement and subsequently accumulate them at undesirable high levels in the crop. This would lead to reduction in the yield and its quality (Schalscha et al., 1999). Therefore, management of irrigation with wastewater should consider the nutrient content in relation to the specific crop requirements and the rate of application of wastewater should be adjusted accordingly. Sewage sludge releases the nutritive elements slowly, which remain available to the plant along the crop cycle. This source is rich with macro nutrients, such as nitrogen, potassium, phosphorus and magnesium, and trace elements like iron, zinc and manganese (Elsokary and Sharaf, 1996; Jafarzadeh, 1996; Kabatapendias and Padias, 1992).
Some researchers found that heavy metals and micro nutrients can be accumulated in the soil and the plants after long term wastewater application (Schalscha et al., 1999), Harati (2003), during a study of wastewater effects on corn, concluded that macro (N, P and K) and micro elements in the wastewater improve growth and yield of maize, while accumulation of heavy metals such as cadmium and lead in corn was more than the standard limits and critical step for animal feeding, stated that a weekly application of 25 mm of wastewater was enough to supply 40-80% of the corn N requirements and all P needed. Other researchers reported similar results (Elliott and Stevenson, 1977). Ouazzani et al. (1996) found that meadows irrigated with wastewater received N and P in amount equivalent or superior to the recommended dose of fertilizers for meadows. With ray grass (Lolium perenne L.), Guiraud et al. (1977) observed an improvement of nitrogen concentration of tissue of plants grown in sewage sludge amended soils. Smith (1996) showed that there are other unexpected factors, such as heavy metals, which lead to changes in natural ecosystem balance, agricultural lands and changes in structure and characteristics of plants and animals fed by wastewater through contaminated food chain (Alloway, 1995). With ray grass (L. perenne L.), Guiraud et al. (1977) observed an improvement of nitrogen concentration of tissue of plants grown in sewage sludge amended soils. Effects of wastewater in south of Tehran on vegetables and crops were investigated by Hariri et al. (2005) and Akbari et al., (1995). They concluded that in some of these plants, heavy metals are accumulated in the roots and they are not transported into the shoots. The amount of some heavy metals, particularly lead, cadmium and nickel reached the critical level for man and livestock.

**SOIL CHARACTERISTICS**

In many countries, even raw sewage water is used for crop production as it considered the only recycling option. Such practice has resulted in accumulation of heavy metals in the soil (McBride, 1995; Bansal, 2004). Heavy metals in soils beyond certain limits may pose serious environmental problems due to their effect on crop production and animal or human health. For example, high rates of Cu, Zn and Ni will cause crop injury before concentration in the crops is high enough to be toxic to consumers of the crops (Arar, 1988). In contrast, Cd can accumulate to concentrations, which are not harmful to the crop but may represent a hazard to consumers of the crop (Arar, 1988). Pb and Cr are un-available to crops so entry into the food chain through crop up-take is slight. If they enter the food chain, it would be directly by indigestion of contaminated plant material (Arar, 1988). Plant species varied in their ability to absorb the macro and micro-elements from soils and applied water depending on the selectivity phenomenon (McGrath et al. 1997). Abdellah (1995), Lone et al. (2003) and Tapan-Adhikari et al. (2004), in different investigates reported that wastewater increased these heavy metals in different plant species. The greatest values of these elements were obtained in the tissues of S. durra plants irrigated with raw sewage waste-water while they recorded in the tissues of S. dochna plants irrigated with 1% treated sewage water. Sharma et al. (1990) found that Fe$^{3+}$ was decreased by wastewater in Sesamum indicum and Phaseolus vulgaris. The depression of Fe$^{3+}$ may be due to the formation of CaCO$_3$, which reacts with Fe$^{3+}$ resulting in Fe$^{2+}$ (CO$_3$)$_{2-}$, thus Fe$^{3+}$ becomes unavailable for root absorption (Dahiya and Singh, 1980).

In addition, the antagonistic effect of Mn$^{2+}$ and Zn$^{2+}$ on Fe$^{3+}$ absorption (Hatem et al., 1990; Dahdoh and Hassan, 1997), may also contribute to the depressed Fe$^{3+}$ under sewage water treatment. Sauerbeck and Hein (1991) found that the largest Ni$^{2+}$ contents were found in the roots whereas the higher content of Fe$^{3+}$, Mn$^{2+}$ and Cu$^{2+}$ were found in the shoots. This could be attributed mainly to the trans-cation and thus the tendency to accumulate these ions in the leaves (Jones, 1972). The relatively low Zn$^{2+}$ and Ni$^{2+}$ content in the upper parts of the plants may indicate that their translocation from the roots to the shoots was low (Eissa and El-Kassas, 1999). Dongale and Savant stated that tannery effluent caused deflocculating of soil particles and increase in the N, P and K levels of soil. Similarly, deleterious effects, such as increase in pH, salinity and EC in soils due to use of textile effluent have been reviewed by Chhonkar et al. (2000). But the adverse effects of these could be reduced by diluting the effluent. Salinization and alkalization of groundwater due to application of these effluents are also reported. Ahmad et al. (2003) stated that the soil receiving wastewater did not show any changes in physicochemical characteris-tics. The soil accumulated all the heavy metals but the sugarcane accumulated Ni, Pb and Zn only whose values were much lesser then the permissible limits. Other researchers found that heavy metals and micro nutrients can be accumulated in the soil and the plants after long term wastewater application (Schalscha et al., 1999).

The evaluation of soil nutrients for the three soil layers indicated their accumulation with increasing irrigation dose (Mosab, 2000). The objective of Mancino and Pepper (1992) was to determine the influence of secondarily treated municipal wastewater irrigation on the chemical quality of bermudagrass (Cynodon dactylon L.) turf soil (Sonota gravelly sandy loam: coarse-loamy, mixed, thermic Typic Hapludalf) when compared to similarly irrigated potable water plots. Research plots were irrigated using a 20% leaching fraction. After 3.2 yr of use, effluent water increased soil electrical conductivity by 0.2 ds m$^{-1}$, Na by 155 mg kg$^{-1}$, P by 26 mg kg$^{-1}$, and K by 50 mg kg$^{-1}$ in comparison to potable irrigated plots. Soil pH was not significantly affected by effluent irrigation.

The concentrations of Fe, Mn, Cu, and Zn were found to be within the range considered normal for agricultural
soil. It has been reported that the use of treated wastewater also increases the total carbon, total nitrogen concentration along with the microbial activity in soil (Friedel et al., 2006; Barton et al., 2005; Ramirez-Fuentes et al., 2002). Mekki et al. (2006) reported that the use of treated wastewater tends to increase the density of soil microorganisms including bacteria, fungi and actinomycetes that helps in nutrient availability of plants. Agunwamba (2001) also reported elevated mineral content of soils irrigated with wastewater.

CONCLUSIONS

There are agronomic and economic benefits of wastewater use in agriculture. Irrigation with wastewater can increase the available water supply or release better quality supplies for alternative uses. In addition to these direct economic benefits that conserve natural resources, the fertilizer value of many wastewaters is important. Wastewater effluent from domestic sources could supply all of the nitrogen and much of the phosphorus and potassium that are normally required for agricultural crop production. In addition, micronutrients and organic matter also provide additional benefits. Rarely, however, is a scheme laid out or planned on the basis of nutrient recycling. The primary constraint to any wastewater use project is public health. Wastewater, especially domestic wastewater, contains pathogens which can cause disease spread when not managed properly. In addition sewage sludge is often a source of ground water pollution, when their content is high in nitrate, a source of soil salinity (Tasdilas, 1997), heavy metals pollution. The primary objective of any wastewater use project must therefore be to minimize or eliminate potential health risks. There are numerous agronomic practices that can assist in lowering the risk from wastewater use but most of these are individual site decisions that are normally made by the farmer to increase agricultural production and not to lower the overall disease infection risk. The choice of crops for wastewater use areas depends upon a number of factors. The crop grown must be suitable to the agronomic conditions in the area. Determining factors include climate, soils, available water, pest control, marketing and farmer skills. These and other general agronomic problems are discussed in numerous publications and will not be discussed in detail here. Another factor of importance for wastewater use areas is water quality. The impact can be on the soil, on crop growth, or it can affect the consumer of that crop. The microbiological quality of the water can directly affect the consumer of that crop because of the risk of infection from that crop. There are important orders in use of wastewater in agricultural production.

1. Crops not for human consumption (for example cotton, sisal).
2. Crops normally processed by heat or drying before human consumption (grains, oilseeds, sugar beet).
3. Vegetables and fruit grown exclusively for canning or other processing that effectively destroys pathogens.
4. Fodder crops and other animal feed crops that are sun-dried and harvested before consumption by animals.
5. Landscape irrigation in fenced areas without public access (nurseries, forests, green belts).

REFERENCES