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Reuse of Treated Wastewater for Agricultural Irrigation with Its Quality Approach

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ABSTRACT: In most arid and semi-arid regions of the world, including the lands of Iran (above 80%) water crisis is considered as one of the main problems on the path of sustainable agriculture. Due to water restrictions and increased water consumption using low quality water resources (wastewater) is considered as a solution to resolve agricultural water requirements which is pointed out as the largest consumption of water recently. The use of treated municipal wastewater for farming irrigation has been a popular and old practice in agriculture. Due to water restrictions and rising water use in recent years, especially in agricultural sector and increasing pressure on freshwater resources in water-deficit regions, using of non-conventional water sources or lower-quality water resources has been considered as a solution for water requirements in agricultural sector. Heavy metals represent a portion of important environmental pollutants which causes pollution problems by increasing their use in products in recent decades. In spite of gradual accumulation of heavy metals in the soil, the stability of heavy metals in the environment will cause to pollution since they could not be decomposed like organic pollutants by biological or chemical processes.

Keywords: Wastewater, heavy metals, quality, non-conventional water

INTRODUCTION

In many arid and semi-arid countries, water is increasingly scarce; as a result, specialists are thought to provide new water sources, which is effective on agricultural development. Water consumption has increased with increasing world population and rising health levels (Azarpira *et al.,* 2013; Alizadeh *et al.,* 2011). Agriculture is the largest user of water with about 75% of freshwater being currently used for irrigation (Prathapar, 2000). The use of treated municipal wastewater for farming irrigation has been a popular and old practice in agriculture. Due to water restrictions and rising water use in recent years, especially in agricultural sector and increasing pressure on freshwater resources in water-deficit regions, using of non-conventional water sources or lower-quality water resources has been considered as a solution for water requirements in agricultural sector. Wastewater is one of the lower-quality water resources. Also non-conventional water sources, especially treated municipal wastewaters represent complementary supply sources that may be substantial in regions affected by extreme scarcity of renewable water resources (Mousaviand Shahsavari, 2014; Mousavi *et al.,* 2013; Galavi *et al.,* 2009; Al-Jasser, 2011). Therefore, use of treated municipal wastewaters is introduced to prevent environment pollution and as a source for irrigation in agriculture (Scott *et al.,* 2000; Oweis *et al.,*2000). The successful development of this reliable water resource depends upon close examination and synthesis of elements from infrastructure and facilities planning, wastewater treatment plant sitting, treatment process reliability, economic and financial analysis, water utility management, and public acceptance (Azarpira *et al.,* 2014; Friedel *et al.,* 2000; Jimenez, 2005; Fonseca *et al.,* 2007; Mohammad *et al.,* 2007;Choukr-allahand Hamdy, 2008). Asgari *et al.* (2007) reported that total dry matter and leaf area index of maize statistically affected with using treated municipal wastewater, in this study, maximum dry matter and leaf area index were obtained of the treatment that was irrigated with wastewater.

Increasing in crude protein for wheat grain with wastewater irrigation due to the increasing percentage of nitrogen and organic matter in soil has been reported (Ghanbari *et al.*, 2007). The effect of treated municipal wastewater on cabbage yield and quality was significant, as yield and N, P, K, Fe, Mn, Zn, Cu, B, and Mo contents increased by irrigation with treated municipal wastewater (Mousavi *et al.*, 2013; Kiziloglu *et al.*, 2007). Galavi *et al.* (2010) reported that zinc and phosphorus concentrations in soil and sorghum plants increased by irrigation with treated municipal wastewaters and this increase was less than toxicity limit.

A. The importance of treated wastewater quality for irrigation

In most arid and semi-arid regions of the world, including the lands of Iran (above 80%) water crisis is considered as one of the main problems on the path of sustainable agriculture. Due to water restrictions and increased water consumption using low quality water resources (wastewater) is considered as a solution to resolve agricultural water requirements which is pointed out as the largest consumption of water recently. In 1996 the total volume of urban and industrial wastewater produced in Iran was 36.3 billion cubic meters, that urban wastewater formed 5.2 units out of all, 5.4 units in the year of 2001 and it is forecasted about 7 BCM for 2011, Wastewater can have a positive effect on soil and eventually plant growth, due to being rich of organic matter and nutrients such as nitrogen, potassium and phosphorus (Ghanbari *et al.*, 2007;Mohammad and Ayadi, 2004). Discharge of unpurified wastewater into the rivers will pollute and decrease water quality in the rivers and soil pollution occurs while that water is used for irrigation, consequently (Mousaviand Shahsavari, 2014).

Recently, one of the issues that attracted the attention of researchers and environmentalists is wastewater chemicals and heavy metals especially those which can penetrate into soil, plant and finally food chain (Ashworthand Alloway, 2003). Heavy metals represent a portion of important environmental pollutants which causes pollution problems by increasing their use in products in recent decades. In spite of gradual accumulation of heavy metals in the soil, the stability of heavy metals in the environment will cause to pollution since they could not be decomposed like organic pollutants by biological or chemical processes (McBride, 1995). Propagation of heavy metals in biological food chain is one of the important issues of this behavior, as increasing the amount of several heavy metals in higher stages of food chain is many times more than initial levels (Al-Enezi *et al.*, 2005). The storage of heavy metals severely threaten human health, but duo to their long half-life (e.g. 1460 days for lead and 200 days for cadmium), tendency for storing such elements is dramatic (Pescod, 1992). Sorghum crop is important to provide livestock forage and forage health has a direct effect on human health (Al-Jaloud, 1995).

Consequently, the reuse of municipal wastewater will require more complex management practices and stringent monitoring procedures than when good-quality water is used. Treatment and reuse of sewage waters is becoming a common source for additional water in some water scarce regions. Reuse of sewage waters, when properly managed, has the benefit of reducing environmental degradation (Choukr-Allah and Hamdy, 2005). For many of those arid and semi-arid countries, re-use of wastewater may contribute more future water availability than any other technological means of increasing water supplies. Treated wastewater can be used effectively for irrigation, industrial purposes and groundwater recharge and for protection against salt intrusion in groundwater aquifers. Furthermore, the wastewater treatment and possible use of sewage effluents is a health and environmental necessity to the civil society, especially in urban areas. Therefore, for those countries, the use of appropriate technologies for the development of alternative sources of water is, probably, the single most adequate approach for solving the problem of water shortage, together with the improvements in efficiency of water use and adequate control to reduce water consumption. Our water management policy should be fundamentally directed to support that no higher quality, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade". This is what we are challenging for and we have to find the key-recommendations and solutions for action (Choukr-Allah and Hamdy, 2005). There are several benefits of treated wastewater reuse. First, it preserves the high quality, expensive fresh water for the highest value purposes primarily for drinking. The cost of secondary-level treatment for domestic wastewater in MENA, an average of $US $0.5/m^3$, is the cheaper, in most cases much cheaper, than developing new supplies in the region. Second, collecting and treating wastewater protects existing sources of valuable fresh water, the environment in general, and public health. In fact, wastewater treatment and reuse (WWTR), not only protects valuable fresh water resources, but it can supplement them, through aquifer recharge.

Table 1: Reports of the reuse of municipal wastewater and sludge from biological treatment plants on forest species in countries other than those of the Mediterranean Region (Kalavrouziotis and Arslan-Alaton, 2008).

Area of Reuse	Forest Species Used	Method of Application and Results
Experiment at the University of Michigan, USA campus consisting of 14 groupings organized in rows with plant wire of 1.5 × 2.1m. The first group served as the control and was irrigated with ordinary water while the remaining was irrigated with waste water.	*Prunus serotica, Junglans nigra, Populus deltoides, Quercus rubra, Fraxinus americana, Liriodedron tulipefera, Pinus sylvestris, Picea abies, Picea glauca*	The survival of the saplings was not affected by there claimed water. Reduced rates of mortality were observed among *Populus deltoides, Fraxinus americana*, and *Picea glauca* while *Picea abies, Prunus serotica, Junglans nigra*, and *Liriodedron tulipefera* mortality rates increased. *Pinus sylvestris* was not affected by the irrigation. The irrigation resulted in significant growth of *Populus deltoides, Fraxinus americana, Pinus sylvestris, Liriodedron tulipefera*, and *Junglans nigra*. The height and the diameter of *Prunus serotica* and *Quercus rubra* were reduced. The plants *Populus deltoids* and *Fraxinus Americana* exhibited excellent response to there claimed water. The plants irrigated with reclaimed water had higher concentrations of nutrients in their tissues than the controls. *Populus deltoides* was judged the best plant for all the variables studied.
In the areas Horsham, Merbein, Mildura and Robinvale of Australia,1-year old saplings were planted and irrigated with municipal waste water. The plant connector was 1.5 × 3 m.	*Eucalyptus botryoides, Eucalyptus camaldulensis, Eucalyptus globules Labill, Eucalyptus glandis, Eucalyptus saligna, Eucalyptus robusta, Eucalyptus muellerana, Eucalyptus maculate* Hook, *Casuarina cunninghamiana, Pinus elliottii* Engelm, *Araucaria cunninghamii*	The results showed high mortality rates for *Eucalyptus muellerana, Araucaria cunninghamii*, and *Pinus elliottii* Engelm. In the area of Mildura. Low survival rates were also observed for *Eucalyptus saligna*. The growth rates were 50cm/yr for *Pinus elliottii* Engelm., *Araucaria cunninghamii* and *Eucalyptus muellerana*, and 1cm/yr for *Eucalyptus robusta*. The height of the plants was greatest in the Mildura area, followed by that in the Horsham and Merbeinareas. The growth rate in the area of Robinvale was greater than that of the Horsham area and equal to that of Merbein. *Eucalyptus saligna* exhibited problems due to salinity. *Pinus elliottii* Engelm., *Araucaria cunninghamii*, and *Eucalyptus muellerana* were found to be unsuitable for irrigation with municipal waste water, while most suitable were *Eucalyptus glandis, Eucalyptus globulus* Labill, *Eucalyptus camaldu-lensis, Eucalyptus saligna, Eucalyptus botryoides* and *Casuarina cunning-hamiana*.

In an experimental plot of land, in the Neepi area of India, a variety of forest plant species were planted in groupings under five experimental conditions: municipal waste water, waste water diluted with water in 1: 1ratio,waste water from oxidation tanks, sludge from primary treatment and regular water as control.	*Tectona grandis,* *Bambusa* sp, *Leucaena leucocephala,* *Gmelina arborea,* *Ciselpinnae ciperia*	*Leucaena leucocephala* experienced significant growth with sludge, while both *Leucaena leucocephala* and *Ciselpinnae ciperia* exhibited significant growth with municipal waste water. *Ciselpinnae ciperia* showed the same growth as that with control water under all other conditions, except for sludge under which the growth was less than that under control. *Tectona grandis* showed significant growth with diluted sludge, as did *Gmelina arborea* with waste water, which, however, was not statistically significant. With sludge, the plants had significantly more number of leaves. In general, the use of waste water and sludge had no significant additional effects.
In forested suburban areas of large cities, such as Peking, Shanghai, and Taiwan, China, a specific quantity of sludge from biological treatment plants was mixed with the (surface) top soil where species of forest plants grew.	*Populus* sp, *Pinus*sp, *Arborvitae* sp., *Paulownia* sp., *Robinia pseudoacacia,* *Paeonia suffruticosa*	One year later, the diameter and the height of *Pinus* sp., *Populus* sp. And *Paulownia* sp. had increased 1.092-1.412 times compared to the controls which had increased 1.056-1.206 times. One and one-half year later, the increase was proportional to the quantity of sludge used. Total N, P, organic matter and reactivity of the soil showed much higher values compared to those of the soil where no sludge was used. Significantly improved were also the density, the porosity, the composition, and the water retention capacity of the soil.
In an area, 4 km north of the city of Holinguole, inner Mongolia, the growth of forest plants irrigated with waste water was studied.	*Larix principis rupprechetii Mayr., Pinus sylvestris* var. *Mongolica litv, Populus xoeichenesis*	The plots where waste water from primary treatment was used were found to be inferior. The mean growth increases recorded for *Populus xoeichenesis* and *Larix principis rupprechetii* Mayr. Were 0.5-1.2m and 0.1-0.2m, respectively?
In the area near the Futianswampin China, in a nursery, under conditions similar to those of the natural environ-ment,15 plants were planted and for one year irrigated with municipal waste water and with water enriched with concentrations of metals and total organic loads 5 to10 times greater than ordinary.	*Kandelia candel*	The addition of municipal waste water increased the concentrations of heavy metals in the soil, but did not result in complete saturation. The plants exhibited high concentrations of heavy metals in their trunks varying according to the conditions of the experiment. The highest proportion of the metals was found in the roots of the plants. The metal concentration in the plants, in order, was Zn > Ni > Cd > Pb. Metal concentrations were greater in the plants than in the soil. The low pH increased the solubility of the metals and contributed to their absorption by the plants.
In the vicinity of the University of New Hampshire,USA,1225 × 25m plots were enriched with sludge from a biological treatment plant with a concentration of total N of 200-800kg/ha. The plants used were those endemic in the area. Three of the 12 plots were used as controls.	*Fagus grandifolia L.*	The results showed that the plots where small quantities of sludge were used had lower concentrations of NH_3-N than the control. Significant increase of N in the leaves occurred during the first growing season, but not during the second. The sludge significantly increased the quantity of N in the to p15cm of the soil.

In the area of St. Martin Parish of Louisiana, USA, two test lots which for years had been irrigated with municipal waste water from the city of Beaux bridge, were selected for sampling. Core samples were taken from the tree so f the two area sand analyzed.	*Taxodium distichum*	The results of the study, and the analysis of the samples, showed that the mean annual growth of the trees irrigated with waste water was greater than that o ft he controls. The increase in diameter with age was slightly, and the mean surface area of the perimeter also increased slightly. In general, irrigation with reclaimed municipal waste water had positive effects, although the excess of water over all tended to affect negatively the growth of *Taxodium distichum*.
In southern Sweden, reclaimed water, sludge, and trickling filter liquids were used on a poplar plantation for purposes of comparison with traditional methods of cultivation.	*Salix* sp.	The use of water quantity greater than 20mm/d resulted in the tripling of the growth, with water from secondary treatment exhibiting greater growth effect than that of primary treatment water. Application of 6mm/d of water satisfied the nutrient demands of the plants completely with the exception of K. No negative effectsontheplantswereobservedwiththeapplicationof20tonsofsludge/ha.Theapplica tionmusttakeplaceinthespringforperennialsandafterharvestforannuals.
In an area of marginal soil in eastern Montreal, Canada an experiment was carried out on four 30 × 33 m parcels of l and planted with *Salix* sp. in 5 rows of 20 plants each. The top soil was enriched with wood chips and with constantly increasing N content sludge from biological treatment sewage plants. The height of the plants was monitored and soil, and plant tissues samples were taken and analyzed.	*Acer sacharrinum* L., *Fraxinus pennsylvanica* Marsh, *Salix discolor* Muhl.	The results showed that the survival rates of *Acer sacharrinum* L. and *Fraxinus pennsylvanica* were 96 and 99% respectively. For *Salix* sp., the survival rate was 70% for the first year, reduced to 57% during the second year. During the second year, the height of *Acer sacharrinum* L. increased by 35% and that of *Fraxinus pennsylvanica* by 33%, while the diameter of the two plants increased by 93 and 100 %, respectively. The height of *Salix* sp. increased by 86 %. N and P concentrations in the leaves of the plants were proportional to the concentrations in the sludge added to the soil. The addition of small quantities of sludge had positive effects, while larger quantities were detrimental to the plants.
In the area of Upper-Saint Laurent, south Quebec, Canada, plants were planted in three locations, two clayish and one sandy, enriched with varying quantities of sludge from biological treatment sewage plants.	*Salix viminalis L.*, *Salix discolor Muhl.*	The results showed that *Salix viminalis* L. experienced greater growth than Salix discolor Muhl. The addition of the sludge led to a significant increase in the diameter of the plants as well as high concentrations of N. The addition of the sludge to the sandy soil did not contribute as much to the growth of the plants, as it did in clayish soil. Most productive species was that of *Salix viminalis* L. Lower productivity occurred in the plots without the use of sludge.

Sludge from a biological treatment plant, in the amount of 20 t/ha, was applied on groves of *Pinus sylvestris* trees, 50-60 years old, at four different locations (Brosarp, Jadraas, Vindeln and Jukkasjarvi) in Sweden, followed by a study of the concentration of different macroelements before and after the application of the sludge in the soil and the plants.	*Pinus sylvestris L.*	The results indicated higher concentrations of N, Ca, Mg and Na in the locations where the sludge existed within the first 10 cm of the soil. P concentrations increased also. The concentration of K increased greatly. The concentration of Mg increased at first, but decreased subsequently in the needles of the plants, since there seemed to exist a strong correlation between Mg concentration and the quantity of sludge applied. In general, a correlation between the sludge added and the concentration of the various chemicals in the needles of the pines was noted.
In the area of Ojinaga, Chihuahua, Mexico, saplings were planted with fencing 2x2 m in groups of seven rows and were irrigated with municipal wastewater 1-1.36 times more than the quantity required by the controls.	*Eucalyptus camaldulensis, Populus sp., Robinia sp.*	The samplings exhibited very good growth, in general, except for those destroyed by low temperatures. The trees later experienced good height and diameter increases. Small differences were recorded both in height and in the diameter among the trees. In general, the model used, correctly predicted the values actually recorded.
In the areas of Bromolla and Kagerod, Sweden, suckers were planted in rows 0.75-1.5 m apart and at a distance of 0.5-0.6m between plants within each row. In Bromolla, water from tertiary treatment was used for irrigation, while in Kagerod the wastewater used came from the local biological treatment plant.	*Salix viminalis L., Salix dasyclados*	The results showed that the growth of the new sprouts was greater near the sprinklers of irrigation than that of the sprouts more away from them. In the area of Kagerod, very little difference was observed in the dry weight of the sprouts near the sprinklers and that of sprouts away from the sprinklers. In general, the application of reclaimed wastewater had more of a positive effect on sprout growth along the length of the rows than across their width. The sprouts within 1-2 m of the sprinklers grew at a rate four times greater (faster) than those 5 m or further away from them.
In an area, 3 km south of the city of Guyla in south Hungary, a plantation was established and was irrigated with municipal wastewater.	*Populus euramericana, Populus robusta, Populus sp.*	The results showed that the growth of the trees was big and fast. Wood production was just about the same with the control. The growth of the trees irrigated with wastewater was 4-7 times bigger than the control.

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In the area of Upsala, Sweden plants were planted in eight lysimeters, of which one pair was irrigated with municipal wastewater, while the other two pairs were irrigated with water containing the same concentration of nitrogen as that of the treated waste water. Halves of the lysimeters contained clay and sand.	*Salix viminalis*	The plants in the lysimeters with clay showed greater growth than those with sand; as a result, wood production was doubled in the lysimeters with clay. Higher concentrations of NH3-N were observed in the lysimeters with clay. Organic carbon concentrations were nearly the same as those of nitrogen. The plants were not harmed by the high concentrations of N and NH_3. Wood production was greater in the plots with the added nutrients than in those where municipal wastewater was used. With sand, however, the exact opposite was the case.
In the area at Rabbit Island near Nelson city, New Zealand, treated municipal sludge was applied in the 1000 ha plantation. The plots consisted of an untreated control, sludge with 300 kg/ha N and sludge with 600 kg/ha N.	*Pinus radiate*	The results showed that there was a significant growth in the diameter and basal area and volume, and a lesser but still significant response in height growth. For volume and branch diameter, the response to the sludge over the control treatment was highly significant. Both sludge treatments produced significantly larger branches than the control treatment. Mortality was negligible. The trees with the sludge treatment had the same growth with the control in a smaller period of time. Land application of sludge can significantly increase the economic returns.

If the true, enormous, benefits of environmental and public health protection were correctly factored into economic analyses, wastewater collection, treatment and reuse would be one of the highest priorities for scarce public and development funds. Third, if managed properly, treated wastewater can sometimes be a superior source for agriculture, than some fresh water sources. It is a constant water source, and nitrogen and phosphorus in the wastewater may result in higher yields than freshwater irrigation, without additional fertilizer application. Research projects in Tunisia have demonstrated that treated effluent had superior non-microbiological chemical characteristics than groundwater, for irrigation. Mainly, the treated wastewater has lower salinity levels (Choukr-Allah and Hamdy, 2005).

B. Treated waste water reuse in irrigation

Water supply and water quality degradation are global concerns that will intensify with increasing water demand, the unexpected impacts of extreme events, and climate change; for this reason, worldwide, marginal-quality water will become and increasingly important component of agricultural water supplies, particularly in water-scarce countries. One of the major types of marginal-quality water is the wastewater from urban and peri-urban areas. The wastewater has been recycled in agriculture for centuries as a means of disposal in cities such as Berlin, London, Milan and Paris. However, in recent years wastewater has gained importance in water-scarce regions. In Pakistan 26% of national vegetable production is irrigated with wastewater. In Hanoi 80% of vegetable production is from urban and peri-urban areas -. In Ghana, informal irrigation involving diluted wastewater from rivers and streams occurs on an estimated 11,500 ha, an area larger than the reported extent of formal irrigation in the country. In Mexico about 260,000 ha are irrigated with wastewater, mostly untreated. In the most of these cases, the farmers irrigate with diluted, untreated, or partly treated wastewater. The failure to properly treat and manage wastewater generates adverse health effects. Farmers and their families using untreated wastewater are exposed to health risks from parasitic worms, viruses and bacteria (Pedreroa *et al.,* 2010; Mousavi and Shahsavari, 2014).

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