Environmental and chemical study of the applying treated sewage on irrigating urban forested areas

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Abstract

Using treated sewage for irrigation can be a good source of food for plants and enriching agricultural lands due to the presence of fertilizing materials in treated sewage in addition to saving in water consumption. Nitrogen, phosphor and potassium are some of the essential nutrients for the growth and reproduction of plants. This research aims to evaluate the effect of irrigation with urban treated sewage on the chemical characteristics of soil and on the growth of three plant species namely Sempervirns, Buxus Cupressus Arizonica and Pinus Nigra used in green spaces and also on the aggregation of nutritional elements in different parts of plant species in the urban green space of Ghods Town in Tehran. In order to conduct the research, the green space area of Ghods Town in Tehran was selected as the sample area a part of which is irrigated with well water and another part irrigated with waste water. After the precise determination of the geographical and topographical characteristics of the control and experimental areas in this research, three 20x20 cm plots were implemented in a random systematical way. Three sample pieces were selected in each sample with a random systematical transmission. About 70 to 80 sample leaves as well as well water and wastewater samples were collected in four repetitions for analysis. The results of this research show that irrigating green spaces with waste water causes a significant increase in some elements (N, P, K) in the leaf and in the growth of trees in green space.

Keywords: Treated sewage, irrigation, green space, waste water, Tehran.

Introduction

Water shortage and the increasing demand for it, especially in dry and semidry countries, has exerted much pressure on water resources especially underground ones in a way that it caused dramatic reduction of underground water level in these areas and made these countries face water crisis. On the other hand, urbanism development and industrialization caused a considerable amount of water to exit water consumption cycle every year due to quality change as urban sewage and wastewater is one its outstanding examples. Given the enormous amount of produced sewage, effort to reach a suitable method of dumping sewage in the environment will be necessary (Zolfagharan *et al.*, 2008; Soroush and Mosavi, 2007; Saffari, 2008). Researches show that disposing raw sewage in the environment lead to lots of hygienic and environmental dangers. Raw sewage quality control has been highly considered in the form of treating sewage and reusing or releasing it into the environment in recent decades in order for protecting the environment especially from limited water resources in many countries. According to reports issued in Iran, only 9% of the 3.9 billion m^3 of urban sewage is treated and the rest enters absorption wells, rivers and farms (Shaygan and Afshari, 2004). Today, reusing the waste water from sewage treatment is important as one of the sustainable sources in irrigation (Abedi Kopayee *et al.*, 2005). Using treated urban sewage has been also become important for non-domestic purposes like irrigation urban green spaces and parks and foresting. Creating green space especially forest belts

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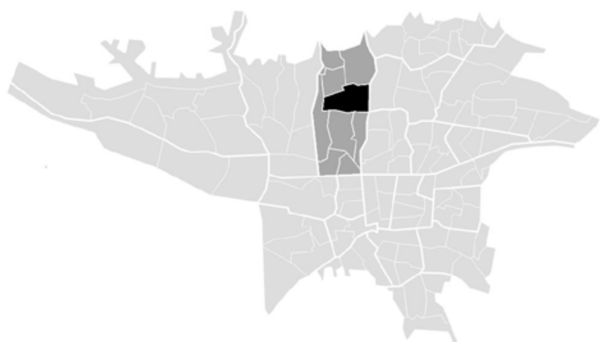
around dry or semidry cities like Tehran, which contains little green space, is very influential in freshen the breathing air. The need to maintain, protect and develop urban green space in Tehran is getting more and more urgent due to numerous reasons and is regarded with higher importance by people and officials. The green space gradually reveals its real significance, concept and value which are directly related to life, respiration, environmental cleanness and hygiene, beauty and air pollution reduction for the people of this mega city. Since water is the restrictive factor to green space creation in these regions and water shortage is one of the main problems of developing and protecting urban and suburban green space in Tehran, urban sewage can be used in foresting and green space creation. Moreover, the amount of necessary elements for growth in urban sewage in more than what agricultural plants need; hence, only trees can transform nutritional abundance to biomass (Matin, 1995). Nitrogen, phosphor and potassium are some of the necessary elements for plants which they should abundantly receive and can receive from urban sewage (Pescod, 1992; Ayres and Westcot, 1994; Bai *et al.*, 2010). Hopmans reported that the biomass production and growth rates and nutritional elements aggregation are different in different tree species. The chemical composition of the polluted water is very important for green space irrigation. The main components of the waste water are dependent on the urban water resource composition and the quantity and types of commercial installations. In most cases, the waste water which has gone through advanced treatment process is suitable for irrigating green space trees (Abdul Hameed *et al.*, 2010). Tougher standards of dumping treated sewage into water resources on one hand, and the motivation of reusing sewage and the substances inside caused extensive researches to be posed once more in late 1960s on using land and plant in complementary urban and industrial sewage treatment (Shaygan, 1998). This research aims to study the possibility and way of using treated urban sewage as an irrigation source in urban green space and also to study some chemical properties of tree leaves irrigated by waste water and its effect on the growth rate of green space trees in Ghods Town in Tehran.

Materials and Methods

Environmental section

The research location lies at 1535 m above sea level, at longitude 51:21 east, at latitude 35:46 north and in the northwestern part of Tehran (scheme 1). The average annual rainfall is 405 ml and the average relative annual moisture is 45%. The dominant wind is westward (270 degree) and the average wind speed is 5.5 m/s.

We tried to choose Buxus Sempervirns, Pinus Nigra and Cupressus Arizonica and sample them in the forested area. These conditions were considered to be the same for both areas. The selected trees were 8 years old, lacked pest and diseases and were not also exposed to environmental stress. SPSS 11.5 and Excel 6.0 were used to analyze collected data in the different stages of this research. The non-coupled t-test was compared for comparison in the case of data normality and the Duncan method was used for the overall comparison of the target elements in plant leaves. An addition, the Cane sample test-t was used to compare the parameters measured in irrigation in proportion to world standards. Scheme 1 shows the location of Gharb Town (the black section) and the area of the district 2 of Tehran city hall (the dark grey section).



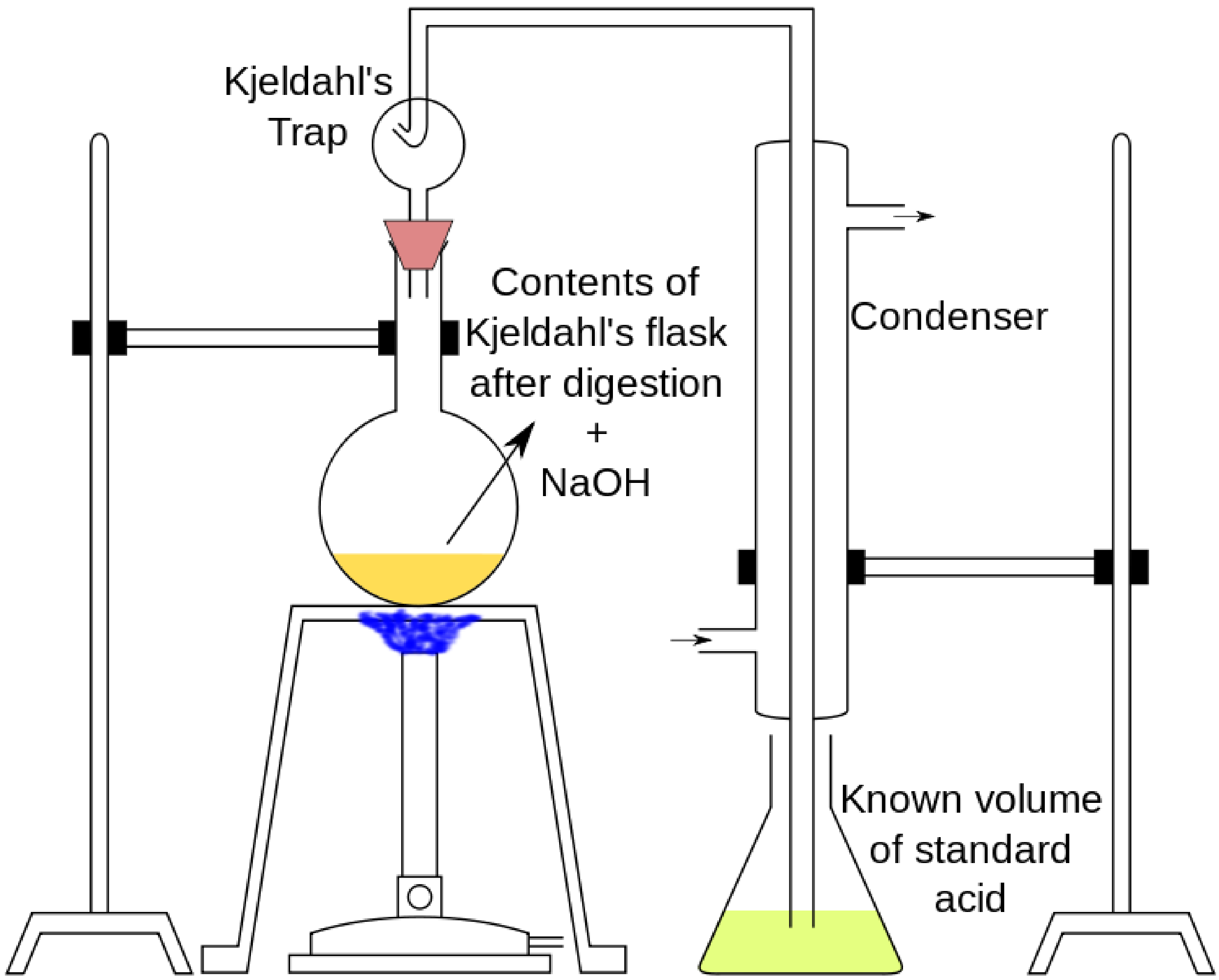
Scheme 1. Gharb Town situation (Black part).

Four hectares of the lands forested with Pinus Nigra and Cupressus Arizonica with 2x2 planting distances were selected. Half of this area has been irrigated by urban waste water for 8 years while the other half was irrigated by well water during the same period. Sampling the well water and used leaves was carried out in 4 periods 20 days after each other in spring 2008. Three 20x20 cm plots were implemented in a systematic random way in the experimental (irrigated with urban treated sewage) and control (irrigated with well water) areas. The height and thickness of the trees at a height of 10 cm above the ground as well as rostrums were measured in these areas (Hopmans *et al.*, 1990). Sampling the plant leaves was conducted from 4.4.2009 to 6.6.2009 for 2 month and in 4 periods. Three sample pieces were selected with 2 systematic random distribution in each of the two experimental and control areas as well as three trees were selected in each area and 70-80 mature leaves were picked randomly from the middle of the rostrum (Sadeghi, 2002). Samples were immediately taken to the laboratory and were dried at 70-80 C for 72 hours (Bahati and Singh., 2005; Liu *et al.*, 2000).

Chemical section

In the recent years, chemistry has found the important roles in various fields of research and industry (Koohyar *et al.*, 2012). In other words, we can say chemistry is the central science playing a key role in virtually all sciences, including biology, biomedical science, environmental science, geology and many others

The chemical elements can be detected and measured with various methods. The total nitrogen quantity was determined using Kjeldahl method. This method consists of heating a substance with sulfuric acid, which decomposes the organic substance by oxidation to liberate the reduced nitrogen as ammonium sulfate. In this step potassium sulfate is added to increase the boiling point of the medium (from 169°C to 189°C). Chemical decomposition of the sample is complete when the initially very dark-colored medium has become clear and colorless. The solution is then distilled with a small quantity of sodium hydroxide, which converts the ammonium salt to ammonia. The amount of ammonia present, and thus the amount of nitrogen present in the sample, is determined by back titration. The end of the condenser is dipped into a solution of boric acid. The ammonia reacts with the acid and the remainder of the acid is then titrated with a sodium carbonate solution by way of a methyl orange pH indicator (Amin and Flowers, 2004).



Scheme 2. Apparatus of Kjeldahl method.

Degradation: Sample + $H_2SO_4 \rightarrow (NH_4)_2SO_4(aq) + CO_2(g) + SO_2(g) + H_2O(g)$ (1)

Liberation of ammonia: $(NH_4)_2SO_4(aq) + 2NaOH \rightarrow Na_2SO_4(aq) + 2H_2O(l) + 2NH_3(g)$ (2)

Capture of ammonia: $B(OH)3 + H2O + NH3 \rightarrow NH_4^+ + B(OH)_4^-$ (3)

Back-titration: $B(OH)_3 + H_2O + Na_2CO_3 \rightarrow NaHCO_3(aq) + NaB(OH)_4(aq) + CO_2(g) + H_2O$ (4)

The phosphorus of plant samples was determined using colorimeter (Mortensen *et al.*, 1989) and atomic absorption machine with a 470 nm wavelength and the potassium was also determined using atomic absorption machine with a 766.5 nm wavelength. In analytical chemistry the atomic absorption machine is used for determining the concentration of a particular element (the analyte) in a sample to be analyzed. This machine can be used to determine over 70 different elements in solution or directly in solid samples employed in pharmacology, biophysics and toxicology research.

Scheme 3. Images for atomic absorption machine.

Results

Water

The quantity of elements measured in urban treated sewage was higher than in well water for urban green space irrigation. This difference is statistically significant. The different letters (a) and (b), indicates the statistically significant difference on the basis of non-coupled t-test. As it is presented in Table (2), the quantity of phosphorus, nitrogen and potassium present in the waste water use in irrigating urban green space was higher than the quantity of the same elements in the well water used for the same purpose. This difference is significant at a 99% probability level (sig<0.0.1).

Table 1. A comparison of the qualities of urban sewage and well water in terms of measurable parameters (average ± standard deviation).

Measured Parameters	Irrigation source	Measured Amounts
K(ppm)	Effluent	a 9.55 ± 0.064
	Well Water	b 0.53 ± 0.014
N (ppm)		a 2.9 ± 0.700
	Well Water	b 0.015 ± 0.002
P (ppm)		a 3.8 ± 0.2 00
	Well Water	b 0.12 ± 0.020

The chemical properties of plant leaf

The quality of waste water is terms of its physical and chemical properties is important in waste water usage in green space section; and among these factors, those elements which cause sensitivity in plants are important and should be precisely measured (Bandari, 1998). The elements N, K and P in the plant leaves of the involved areas were measured in this research. The elements were found to be present in various quantities in the experiments carried out on tree leaves as these elements in leaves are analyzed below. The non-coupled t-test was used to compare the measured elements in the two parts. Moreover, the one-sided variance analysis test was used (for overall comparison) to compare three groups and the Duncan test was used (for one-by-one comparison) to compare groups. The achieved results are shown in Tables 2, 3 and 4 separately. The concentration of nutritional elements, namely nitrogen, phosphorus and potassium measured in the leaves of Buxus Sempervirns, Pinus Nigra and Cupressus Arizonica irrigated by waste water was more than the quantity of these elements in leaves of the control area trees irrigated by well water. As it can be seen in Table 2, this difference in the leaves of Pinus Nigra was statistically significant for nitrogen and phosphorus at 99% probability level but was not significant for potassium. The difference in the concentration of nutrients (K, N and P) was 95%, 99% and 99% respectively (Table 3). Statistically, the difference in concentration of nitrogen and phosphorus measured in the leaves of Cupressus Arizonica was significant at 99% and 95% reliability level respectively but was not significant for potassium similar to Pinus Nigra leaves.

Table 2. A comparison of nutrients measured in Pinus Nigra leaves (average ± standard deviation).

Nutrients measured in leaf	Irrigation source	
	Irrigated with well water	Irrigated with Effluent
N (ppm)	b 2.44 ± 0.31227	a 5.15 ± 0.309569
P (ppm)	b 0.17 ± 0.03122	a 0.47 ± 0.047775
K (ppm)	b 0.50 ± 0.56921	a 0.65 ± 0.118797

Table 3. A comparison of nutrients measured in Buxus Sempervirns leaves (average ± standard deviation).

Nutrients measured in leaf	Irrigation source	
	Irrigated with well water	Irrigated with Effluent
N (ppm)	b 2.44 ± 0.31227	a 5.15 ± 0.309569
P (ppm)	b 0.17 ± 0.03122	a 0.47 ± 0.047775
K (ppm)	b 0.50 ± 0.56921	a 0.65 ± 0.118797

Table 4. A comparison of nutrients measured in Cupressus Arizonica leaves (average ± standard deviation)

Nutrients measured in leaf	Irrigation source	
	Irrigated with well water	Irrigated with Effluent
N (ppm)	b 0.89 ± 0.11449	a 1.68 ± 0.13735
P (ppm)	b 0.12 ± 0.02105	a 0.26 ± 0.03708
K (ppm)	b 0.48 ± 0.895.3	a 0.61 ± 0.09793

The overall comparison of elements measured in plant species irrigated by waste water

As Figure (1) shows, potassium aggregation rate in Buxus Sempervirns irrigated by waste water is more than in the two other plant species. This difference is significant at 99% probability level. However, nitrogen aggregation rate in Pinus Nigra and Cupressus Arizonica irrigated with waste water does not reveal a significant difference.

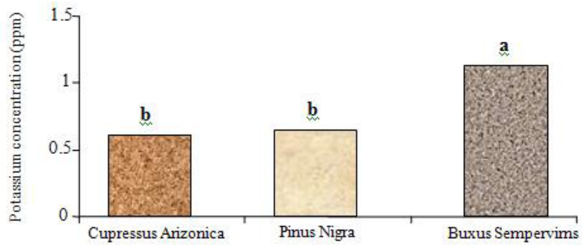


Figure 1. The overall composition of potassium aggregation rate in three plant species irrigated by waste water.

As it is presented in Figures 2 and 3, the quantity of nitrogen and phosphorus measured in the leaves of the involved trees (of all three species) does not show a significant difference in comparison to each other. The aggregation rate of nitrogen (Figure 2) and phosphor (Figure 3) in the involved trees irrigated by waste water is significant at 99% difference probability level. The highest rate of nitrogen aggregation was found in Pinus Nigra while highest rate of phosphor aggregation was found in Buxus Sempervirns irrigated by waste water.

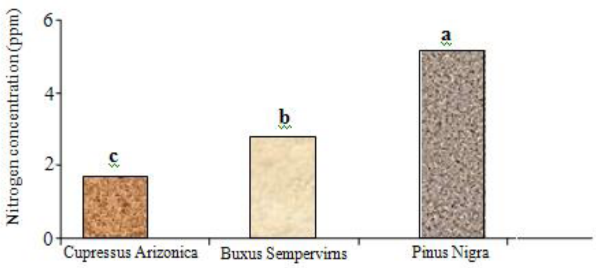


Figure 2. The overall composition of nitrogen aggregation rate in three plant species irrigated by waste water.

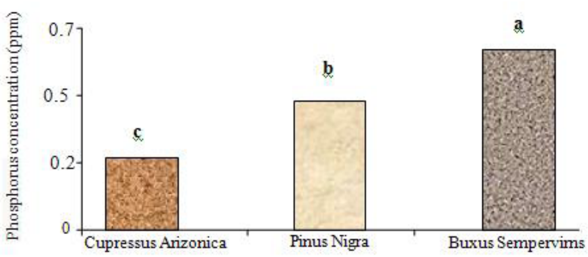


Figure 3. The overall composition of phosphorus aggregation rate in three plant species irrigated by waste water

The overall comparison of elements measured in plant species irrigated by well water

In this part, the quantity of each of the elements (K, N and P) in the plant species of the control area irrigated by well water are compared which are presented in Figures 4, 5 and 6 respectively. The aggregation rate of other elements was not significantly different among the involved species. Duncan test was used to compare the three groups. As Figures 4 and 5 shows, the aggregation rate of potassium and phosphorus does not reveal a significant difference among the three plant species irrigated by well water. The highest potassium and phosphorus aggregation rates belonged to Buxus Sempervirns and Pinus Nigra respectively. Moreover, nitrogen aggregation rate in Pinus Nigra irrigated by well water was higher that the two other species; this difference was significant at 99% probability level. However, nitrogen aggregation rate does not indicate a significant difference in comparing Buxus Sempervirns and Cupressus Arizonica irrigated by well water.

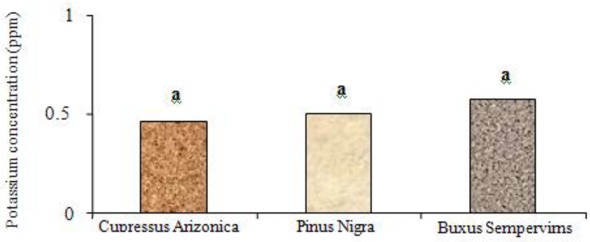


Figure 4. The overall composition of potassium aggregation rate in three plant species irrigated by well water.

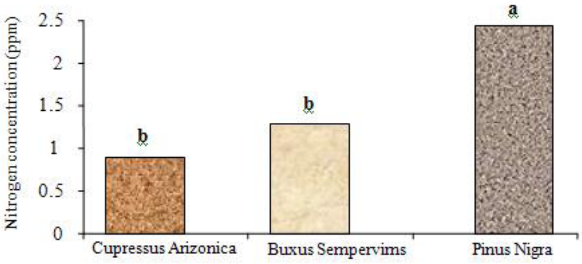


Figure 5. The overall composition of nitrogen aggregation rate in three plant species irrigated by well water

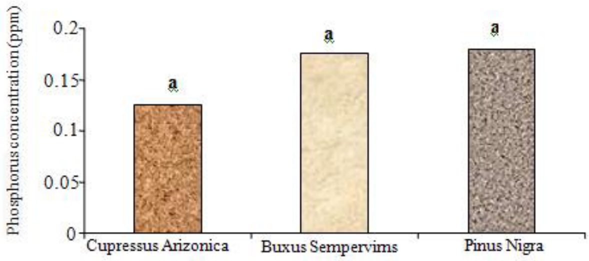


Figure 6. The overall composition of phosphorus aggregation rate in three plant species irrigated by well water.

Discussion and Conclusions

It seems that urban treated sewage can be used as a reliable source of irrigation in green space section especially in dry and semidry areas facing water shortage. Tehran is also one of the semidry areas of the country with insufficient water supply. There would be much waste water available through the establishment of sewage collection and treatment system. Hence, if this waste water is used to irrigate green space, essential nutrients for plants like nitrogen, phosphorus and potassium will be available in solution form which will also cause economizing chemical fertilizers. The potential value of this source can be appropriately and suitably used through using waste water on the basis of a correct management, adapting its physical, chemical and microbial properties with international standards, studying and recognizing absorptive elements, studying the topographical status of the land and also the substance in soil and its pollution sources. Using urban treated sewage for green space irrigation increases the amount of nutritional substances in plant leaf which is significant for elements but not so for some others. The growth rate of leaf samples of the trees irrigated by waste water was higher than in trees irrigated by well water. Urban treated sewage increased the performance of plant leaves due to containing different nutritional elements and had no adverse effect on the trees. Plant decomposition results showed that the concentration of nutritional elements in the aerial organs (leaf and trunk) of the involved plant species in urban green space increased in all experimental samples in proportion to the control one. Given all Figures and the concentration change trend of the elements in tree leaves, Buxus Sempervirns, Pinus Nigra and Cupressus Arizonica were more successful in terms of purification degree respectively which indicates the higher aggregation of elements in Buxus Sempervirns that in other species. Finally, regarding the achieved results, we can conclude that Buxus Sempervirns is the best choice among the involved plant species to be used in Phytoremediation method.

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