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Book Review(S)

Journal of Advances in Environmental Health Research

Daily visual display terminal use and musculoskeletal disorders among Iranian bank tellers

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Original Article

Abstract

Visual display terminals (VDTs) as one of the most important and useful equipment are used in offices and workplaces that may be created some health hazards, including work-related musculoskeletal disorders (WMSDs). The aims of this study were to (i) investigate the prevalence of WMSDs among Iranian bank tellers and (ii) to examine the demographic and work-related characteristics associated with that prevalence rate. In this cross-sectional study, 382 bank tellers who regularly working at VDTs stations were interviewed. The demographic, work characteristics and musculoskeletal disorders (MSDs) data were collected using specific questionnaire and standardized Nordic self-reporting Musculoskeletal Questionnaire. Hence, data analyses were carried out using IBM SPSS for Windows. As a result, 70.2% of participants reported the musculoskeletal problems within 12 past months in at least one of the body regions. The most prevalence was reported in the neck (37.4%) and low back (36.6%) regions, and the elbows (8.3%), and thighs (12.3%) were regions that reported with the least prevalence rate. Mean duration of daily VDT (DVDT) work in 268 subjects with musculoskeletal symptoms was 6.2 h (SD = ±2.2) and in other 114 subjects without symptoms, it was 5.5 h (SD = ± 2.3). There was a positive significant relationship between DVDT work hours with reported musculoskeletal problems (P = 0.005). In conclusion, WMSDs in bank tellers happened in high rate (70.2%) and the most complain reported in neck and low back regions. The most consistently identified risk factor was a duration of DVDT use and inadequate break times.

KEYWORDS: Daily Visual Display Terminal, Musculoskeletal Disorders, Occupational Health, Bank Tellers

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Introduction

Computers as one of the most important and useful visual displays are used in almost all offices and workplaces, and their use is growing.[1] Different sectors, including banks, government offices, private entities, autonomous institutions, etc. have computerized their data systems for easier and faster flow of information. Therefore, the increased use of computers in the modern office setting has raised concern related to its potential health hazards. One of the most complaints in visual display terminals (VDTs) workers is work-related musculoskeletal disorders (WMSDs),[2] which account for approximately one-third of all work absenteeism.[3,4]

In other words, the introduction of VDTs has changed the nature of work and so raised the prevalence of WMSDs among workers in offices; as some studies mentioned that the prevalence of WMSDs is closely associated with the VDT use.[5] Numerous cross-sectional studies of VDT users have reported a prevalence of 10-76.5% of

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musculoskeletal symptoms in the neck/shoulder region among visual display units (VDU) users.[6-10] Some previous studies evaluated the prevalence of musculoskeletal disorders (MSDs) among Iranian workers with VDT stations.[11,12] Mirmohammadi et al. reported that the prevalence of MSDs among VDT users in their study period of 12 months were 46.5%, 20.3%, 5.1%, 12.4%, and 57.6% in neck, shoulder, elbow, wrist, and low back areas, respectively.[11]

Bank working is one of the major occupations with the potential MSDs hazard.[5] Repetitive tasks and awkward postures are known as work-related ergonomic factors while age, gender and psychological characters are known as worker-related risk factors of MSDs among these workers.[13-17] However, there are some controversial discussions about the causes and extent of the problem as well as the work-related reasons and the hazards leading to the symptoms, especially at VDT workstations.[18] Furthermore, according to the results of several systematic reviews, there are limited evidence for an association between computer work and some of the studied MSDs.[19]

Hence, the aims of this study were to (i) investigate the prevalence of work-related MSDs among Iranian bank tellers and compare the findings with other studies and (ii) to examine the demographic and work-related characteristics associated with the prevalence rate.

Materials and Methods

This cross-sectional survey was carried out during April 2010 to Jun 2012 in bank tellers in Sanandaj, Iran. Subjects included 382 tellers regularly working in the banks with VDTs. For participant's selection, a list of all banks and their branches were taken from Provincial Headquarters of banks, and 76 banks were selected randomly, then from every branch offices, five participants were selected randomly. Inclusion criteria were included: ages between 20 and 55 years, employed for at least 3 months or more in the current job (VDTs) and worked for at least 1 h/day for at least 5 days a week.

The following participants were excluded because of not meeting the entrance criteria: those who were not tellers, shift workers, those with more than 13 days off in a month, who had an injury such as disorders caused by unwanted events (e.g., falling down, accidents, etc.) or illnesses like diabetes and finally those who were not willing to cooperate in the study.

The study was explained for the employees and those willing to participate were enrolled, and their informed consent was obtained. The demographic information, Work characteristics such as VDT work experience and duration of daily work with VDTs were collected using specific questionnaires. MSDs data were gathered using standardized different studies, including Persian medium have approved the reliability and validity of the Nordic self-reporting Musculoskeletal Questionnaire.[20,21] This questionnaire deals with the incidence of MSDs during the previous 7 days and recent 12 months as well as their severity and body parts.

After data collection, normality of data was tested by one-sample Kolmogorov-Smirnov. Normally distributed data were analyzed using Student's independent t-tests. Non-normal distributed data were analyzed by chi-square and Mantel-Haenszel tests. The latest test was used to control the effect of confounding factors. All analyses were carried out using IBM SPSS Statistics for Windows (version 20.0, SPSS Inc., Chicago, IL, USA).

Results and Discussion

Of 400 subjects included in the study, 382 completed the questionnaire with the high response rate of 95.5%, which suggested that the tellers were very interested in the subject and the validity and reliability of the questionnaire was approved.

According to the results, 268 (70.2%) participants reported the musculoskeletal problems within 12 past months in at least one of the body regions. The final study group was comprised of 302 males (79.1%) and 80 females

Table 1. Association between some demographic characteristics and musculoskeletalproblems among Sanandaj bank tellers (n = 382)

Variables	Musculoskeletal problems Reported	Musculoskeletal problems Not reported	Total (%)	P
Gender				
Female	57	23	80 (20.9)	0.400
Male	211	91	302 (79.1)	
Age	255 μ = 37.4 ± 6.8	127 μ = 37.1 ± 7.5	382	0.700
Body mass index (BMI)	25.8 ± 3.0	25.4 ± 2.6	382	0.300
Smoking				
Yes	29	19	48 (12.6)	0.080
No	239	95	334 (87.4)	
Duration of employment (year)				
> 5	78	43	121 (31.7)	
5-10	113	36	149 (39)	0.100
10-20	77	35	112 (29.3)	
Working hours/day	8.4 ± 0.9	8.2 ± 1.0	382	0.080
Daily VDT use (h)	6.2 ± 2.2	5.5 ± 2.3	382	0.005*

* Statistically significant; VDT: Visual display terminal

(20.9%) with mean ages of 38.5 ± 6.9 and 32.6 ± 5.3 years, respectively. t-test analysis showed that there was no significant relationship between age and MSDs ($P > 0.05$).

The most prevalence of work-related musculoskeletal symptoms reported in the neck [143 (37.4%)] and low back regions [140 (36.6%)]. This prevalence was not significant between males and females ($P > 0.05$). Furthermore, the results showed that the elbows and thighs were the regions with the least prevalence rate of 32 (8.3%) and 47 (12.3%), respectively. Table 1 demonstrates the association between some demographic variables and reported musculoskeletal problems in the Sanandaj bank tellers.

Mean duration of daily VDT (DVDT) work in 268 subjects with musculoskeletal symptoms was 6.2 h (SD = ±2.2) and in other 114 subjects, without symptoms, it was 5.5 h (SD = 2.3). There was a positive significant relationship between daily VDT work hours with reported musculoskeletal problems ($P = 0.005$). Table 2 presents the prevalence of WMSDS symptoms in the various body regions of the tellers during the last 12 months. As table 2 demonstrates, the most commonly affected regions among the tellers were neck (37.4%) and low back (36.6%). Prevalence at a low back region was related to marital status and working hours at home.

Table 2. Musculoskeletal symptoms in various body regions during the 12 months before their including in the study (n = 382)

Body regions	Number	(%)
Neck	143	37.4
Shoulders	123	31.0
Elbows	32	8.3
Wrists/hands	79	20.7
Upper back	114	29.8
Lower back	140	36.6
Thighs	47	12.3
Knees	99	25.9
Legs/feet	55	14.4

Work experience data demonstrated that 59.7% of the participants worked for 10 years or more 10 or more in banking operations, and 86.1% worked for 8 or more than hours per day. Furthermore, duration of DVDT use showed that 63.9% of respondents worked for 6 h or more, and 29.3% tellers worked for 8 h or more with VDTs. Approximately, 8.2% of subjects were having rest breaks of 5 min/h, which indicates that there are no reinforcement breaks in the actual workplace.

Working in the bank, and any activity related to it is a stressful occupation. Several studies have been conducted in MSDs in office workers in Iran,[11,12] but the assessment of these symptoms among bank tellers, which are important users of the visual display terminals, have not been examined, yet. The 95% of participation rate suggested that the tellers were very interested in the subject. According to the results of several systematic reviews, there is limited evidence for a relationship between computer work and MSDs.[19] Based on our data, the prevalence of musculoskeletal problems was high in bank tellers. It was recognized that there are multiple stressors in bank workers such as; repetitive computer based tasks, awkward and continuous postures, insufficient break times and some other factors.

According to the research, there was no significant relationship between age and musculoskeletal problems prevalence rates since all the subjects were relatively young tellers; the mean age was approximately 37 years old, and most of them were employees with <10 years' experience (70.7%). Similarly, the prevalence of MSDs in all body regions between males and females was not significant ($P > 0.05$), except wrist/hand. The prevalence of MSDs in the recent organ was 26% and 23% in females and males, respectively. The relationship between the incidence and gender was significant ($P = 0.03$). In a similar study, carried out by Klussmann, et al., association between gender and having symptoms in hand/wrist or elbow/forearm was not significant; however, this relation about neck and shoulders was significant.[18]

This study demonstrated that the association between MSDs prevalence and cigarette smoking was not significant ($P = 0.08$). This result was compatible with several previous studies in which sports and smoking habits had no significant effects on symptoms in anybody region.[18]

Our study revealed that compared to other organs, the prevalence of symptoms in neck, lower back, and shoulders was higher during the previous year (37.4%, 36.6%, and 31.0%, respectively), which may be due to changes in the workstation during time. Initially, workstations were designed with ergonomic consideration, but the changes caused by the users make the stations non-ergonomic. For example, the monitor that is too lower than the eye level of the user is a risk factor for increased discomforts in the shoulders and the lower back.[22] Furthermore, lack of adequate rest periods increases the problems.[23,24] This finding is similar to the Aydeniz and Gürsoy which conducted in Turkey. They compared 100 bank workers with extensive computer use with 65 office workers with < 2 h/day of computer use. They founded that the extensive computer users had more positive clinical tests for diagnoses in the shoulder-neck, as well as in the elbow and wrist.[25] Other related studies have shown increased risk in neck and shoulders caused by duration of awkward,[18,26] static and fixed sedentary posture at work.[27]

In this study, the duration of work at VDT stations for all body regions was recognized the most consistent risk factor ($P = 0.005$). We found that 63.9% and 29.3% of tellers worked for 6 and 8 h/day with VDTs stations, respectively. This long uninterrupted exposure may cause the incidence problems arise. In another study, 2000 clerical workers were studied, in Thailand. It was found that there is a significant correlation between daily work hours and MSDs in head and neck regions ($P < 0.001$).[28]

In order to prevent MSDs in bank tellers or those with similar occupations that have to work continuously with VDT stations, we recommend the followings: (1) Having sufficient breaks, (2) respecting the housekeeping and avoiding the disarray, (3) redesigning workstations without consideration of ergonomic principals, and (4) using customer waiting systems for workload control.

Conclusion

WMSDs in bank tellers happened in high rate (70.2%) and the most complains were reported in neck and low back regions. The most consistent risk factor recognized was the duration of DVDT use and inadequate break times. Regarding to the lack of research and its inconsistency, we suggested further studies to be implemented for demonstration of MSDs risk factors among bank tellers.

Conflict of Interests

Authors have no conflict of interests.

Acknowledgements

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Kinetic studies on bioadsorption of arsenate fromaqueous solutions using chitosan

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Original Article

Abstract
Arsenic, one of the most toxic and dangerous elements in the environment affecting millions of people around the world, is associated with several diseases. In this pilot study, we investigated removal of arsenate from aqueous solutions using chitosan under the influences of initial arsenic ion concentrations, pH, contact time, and adsorbent dosages of chitosan. In order to assess the sorption mechanism and the potential rate of controlling steps, the pseudo-first and pseudo-second order kinetic models and the Langmuir and Freundlich isotherm models were used. The obtained results showed that the removal of As(V) by chitosan was found to be pH dependent, with optimum sorption occurring at pH = 4. The kinetics of arsenate adsorption on chitosan is well described by the pseudo-second order model. Furthermore, As (V) sorption isotherm was developed at optimal conditions and sorption equilibrium data were fitted to the Freundlich isotherm model.
KEYWORDS: Adsorption, As (V), Chitosan, Kinetic Models

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Introduction

Arsenic (As), is a widely distributed semi-metallic element found in various compounds in the crust of the earth and it is considered as one of the most important environmental hazards.[1] It is released into the environment mostly through natural processes, such as weathering reactions, volcanic emissions, biological activity, inputs from geothermal sources, and as an outcome of anthropogenic activities, such as mining activities and discharges of various industries.[2-6] The exposure to this semi-metallic element leads to black foot disease, skin cancer, liver, and lung cancer.[7] Therefore, the maximum allowed concentration of arsenic, according to World Health Organization (WHO) and Environmental Protection Agency (EPA), in drinking water equals to 10 µg/l.[8] To remove As(V), many physical/chemical treatment methods have been applied. Among them, adsorption treatment has been widely used. In this method, various adsorbents have been used such as activated alumina, activated carbon, fly ash, ferric hydroxide, and chitosan.[9] Among the adsorbents, chitosan is one of the cationic polyelectrolytes derived from chitin with the chemical name ß-D (1-4) N-acetyl-glucosamine. This material is found in crustacean, insects, and fungi. Chitosan is a natural and linear heteropolysaccharide with high

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molecular weight and has other characteristics such as being soluble in different mediums, degradable, hydrophilic, biocompatible, antibacterial, antioxidant, and an agent for removing metals. This biopolymer is polycationic at pH values under 6 and simply reacts with compounds with negative charge such as anionic polysaccharides, fatty acids, and phospholipids. Chitosan performs coagulation and flocculation through charge neutralization, adsorption, and interparticle bridging.[10-16] The objective of this research is to determine the efficiency level of chitosan, as an effective adsorbent for the removal of arsenate from aqueous solutions.

Materials and Methods

Chitosan with 75-85% deacetyl prepared from shrimp shells was obtained from the GMA Chemical Company. The pilot sorption experiment was performed in 100 ml of arsenate(V) solution in a mixer incubator at room temperature for 120 minutes. To study the influence of pH on the As(V) adsorption capacity of the adsorbent, experiments were conducted at different pH values (3-7). The effect of contact time was studied with an initial arsenic concentration of 1 mg/l and adsorbent dose of 25 mg/l; pH was kept constant at 4 and contact time was varied from 30 to 240 minutes. Isotherm study was conducted by varying initial As(V) concentrations (100–2000 μg/l), fixed adsorbent dose of 25 mg/l, and contact time of 2 hours at pH = 4.

In each set of the experiments, the concentration of arsenate ions was determined using inductively coupled plasma atomic emission spectrometry (ICP-AES), (Ultima 2C, France). Biosorption of the arsenate ions in the sorption system was calculated using the mass balance:

$$q = \frac{(C_0 - C_e)V}{W} \qquad (1)$$

Where C_o and C_e are the initial and final concentrations (mg/l), V is the volume of aqueous solution (L), and W is the mass of absorbent (g).

Results and Discussion

Effect of pH

One of the important parameters for adsorption of metal ions from aqueous solution is pH because it affects the solubility of the metal ions and species of metal in water.[17] Figure 1 shows the effect of pH on uptake capacity of arsenate ions. It can be seen that the adsorption capacity of arsenate ions was decreased as the pH values were increased. This effect can be explained as follows: at low pH values, $H_2AsO^-_4$ is the dominant species, and therefore, $H_2AsO^-_4$ would be easily expected to interact more strongly with the chitosan, which is carrying positive charges.[18] These observations are in agreement with previous works of Gérente et al. and Jeon[9,18]

Effect of adsorbent dosage

Dosage is one of the most important parameters, which should be considered to determine the optimum condition for the performance of chitosan in adsorption. Figure 2 shows the effect of adsorbent dosage on the value of arsenate removal at equilibrium conditions. From figure 3, it can be observed that removal efficiency of the adsorbent generally improved with increasing dose. This is due to the increase in available surface active sites which results from the increase in dose of adsorbent.[18]

Effect of initial metal concentration

The experimental data shown in figure 3 revealed that the metal uptake capacity increases with increase in initial concentration of metal ion while the arsenate removal percentage decreases due to increase in initial metal ion concentration. This effect can be explained as follows: At low concentrations, all arsenate ions present in solution could interact with the binding sites and thus the biosorption percentage was higher for higher initial arsenate ion concentrations. At lower concentrations, lower biosorption yield is due to the saturation of biosorption sites.[19]

Effect of contact time

Figure 4 illustrates the removal percentage of zinc ions by chitosan as a function of the contact

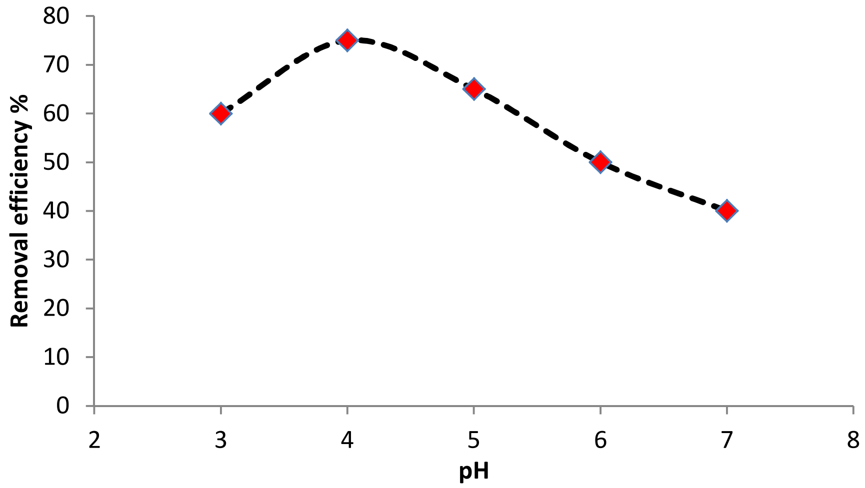

Figure 1. Effect of pH on uptake capacities of arsenate ions using chitosan

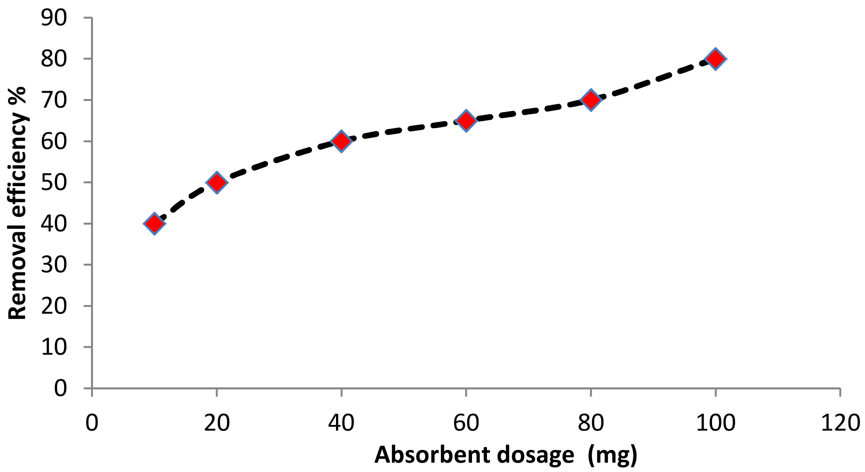

Figure 2. Effect of biosorbent dosage on biosorption of arsenate

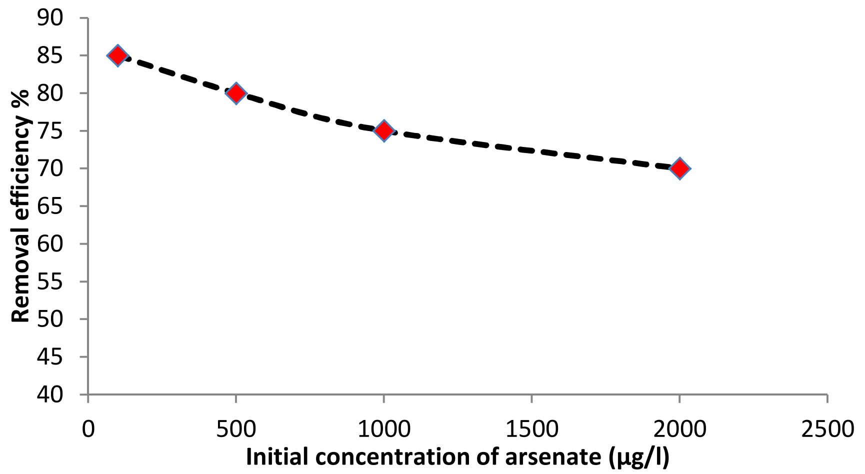

Figure 3. Effect of metal ion concentration on the biosorption of arsenate by chitosan

time in the range of 30–240 minutes. It was observed that arsenate removal (%) increased with time up to about 120 minutes and then the curves became quite level, indicating the attainment of the adsorption equilibrium. Optimum contact time for chitosan adsorbent was found to be 120 minutes. Therefore, the chitosan adsorbent requires a shorter contact time. Greater availability of several functional groups on the surface of chitosan, which are required for interaction with pollutants, significantly improved the binding capacity and the process proceeded rapidly. This result is important, as equilibrium time is one of the important parameters for an economical aqueous solutions treatment system.[20]

Isotherm and kinetics of biosorption

Adsorption isotherm is important to describe how solutes interact with adsorbent. The Langmuir and Freundlich models are often used to describe sorption isotherm equilibrium. Table 1 presents the calculated result of the arsenate sorption equilibrium on the chitosan as a function of the initial concentration of arsenate. Moreover, in order to study the controlling mechanism of the adsorption process, such as mass transfer and chemical reaction, pseudo-first and pseudo-second equations were used to test the experimental data. Table 2 shows the results of the kinetic parameters for arsenate adsorption. As table 1 and 2 indicate, the R^2 values fit with Freundlich isotherm and pseudo-second order kinetics providing a proper model of the sorption system. These results are similar to those reported by Gang et al. and Thirunavukkarasu et al.[21,22]

Comparison of chitosan with other biosorbents for arsenic removal

Arsenate adsorption by chitosan, as quantified in this study from batch experiments, was compared with values of other biosorbents in literature, including natural materials, microbial and algal biomass, industrial and agricultural wastes, activated carbons, and some commercial cation exchange resins (Table 3). Although the data collated in table 3 may not represent equivalent or optimized conditions or various As(V) removal mechanisms in each case, it still provides a useful comparison for engineers in their selection of a suitable biosorbent in engineering practice. According to table 3, the chitosan adsorbent shows a good adsorption capacity when compared with the adsorption capacity of various low-cost adsorbents for arsenate removal.

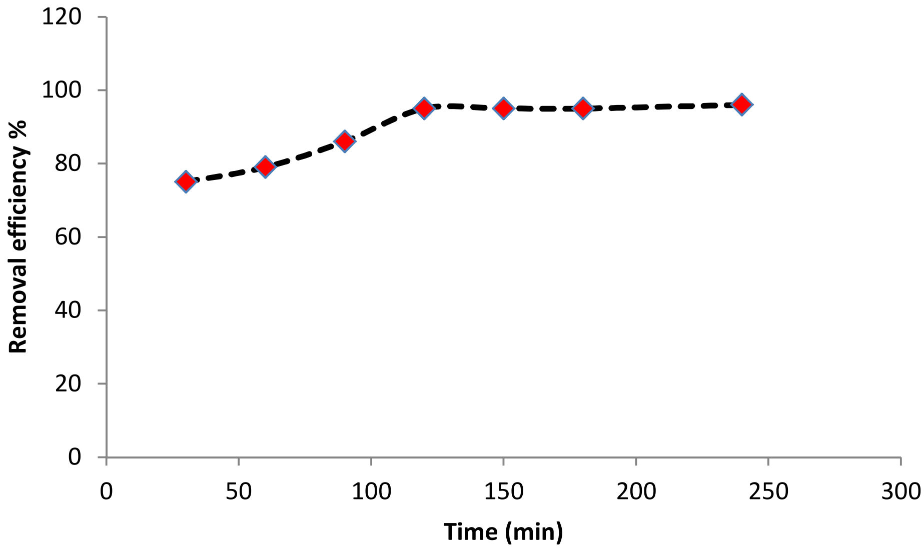

Figure 4. Effect of contact time on biosorption of arsenate by chitosan

Table 1. Langmuir and Freundlich isotherm constants and correlation coefficients

Adsorbent	Freundlich parameters			Langmuir constants		
	K_f	n	R^2	q_{max}	R_L	R^2
Commercial chitosan	0.172	1.315	0.9982	2.458	0.196-0.830	0.937

K_f: Freundlich sorption constant; n: The heterogeneity factor; R^2: The correlation coefficient; q_{max}: Maximum adsorption capacity; R_L: Separation parameter

Table 2. Kinetic constants for arsenate onto chitosan

Adsorbents	q_e (exp) mg/g	Pseudo-first-order kinetics			Pseudo-second-order kinetics		
		K_1	q_e	R^2	K_2	q_e	R^2
Chitosan	0.95	0.0133	0.317	0.9388	0.131	0.928	0.9963

q_e (exp): The sorption capacity determined from the experiment; K_1: First-order rate constant; q_e: The sorption capacity determined from the model; R^2: The correlation coefficient; K_2: Second-order rate constant

Table 3. Comparison of sorption capacities of chitosan and other adsorbents for the removal of arsenate

Adsorbent	Capacity (mg/g)	Reference
Rice polish	0.147	23
Tea fungal biomass	0.310	23
Bone char	1.430	23
Natural iron ores	0.400	24
Natural feldspar	0.208	24
Natural hematite	0.219	24
Bauxsol	1.081	8
Kaolinite	0.230	8
Red mud	0.514	8
Chitosan	2.458	Present study

Conclusion

In this study, we investigated the applicability of the chitosan for As(V) removal. The experiments show that chitosan can absorb arsenate ions from aqueous solution effectively, and the sorption capacity has been improved greatly with a maximum sorption capacity of about 2.458 mg/g. The experimental data of the sorptionequilibrium from arsenate ions solution are well fitted with the Freundlich isotherm equation.

Conflict of Interests

Authors have no conflict of interests.

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Journal of Advances in Environmental Health Research

Estimation of gas emission released from a municipal solid waste landfill site through a modeling approach: A case study, Sanandaj, Iran

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Original Article

Abstract
Sanitary landfill is the common strategy for municipal solid waste management in developing countries. Anaerobic decomposition of disposed wastes in landfill under favorable conditions will lead to the landfill gas (LFG) emissions, considering as emerging air pollutants. The emission of greenhouse gases, including methane, resulting from municipal solid waste disposal and treatment processes are considered as the major source of anthropogenic global emissions. Assessment and prediction of the emission rate are important for planning, proper application of methane as an energy source and determining the contribution of various greenhouse gas emissions to global warming. The purpose of this study was to estimate the amount of gas emissions from Sanandaj sanitary landfill. The data about the quantity and quality of the landfill and waste production were collected based on existing standard methods. Using LandGEM software the landfill emissions were estimated with considering the 50% content of methane, the methane production rate constant of 0.045/year and gas production potential constant of 200 m^3/ton. The results of this study showed that the maximum mass of emitted gas is at the next year after the site closure (2021). It was estimated that total mass of LFG, methane, carbon dioxide and non-methane organic compounds were 23,150, 6184, 16,970, and 266 tons/year, respectively. Effective management in controlling LFGs not only results in air pollution reduction, green energy application for sustainable development, but also can use the financial benefits of the clean development mechanism to Kyoto protocol achievement for developing countries.
KEYWORDS: Municipal Solid Waste, Landfill Gases, Methane, LandGEM

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Introduction

Nowadays, one of the major environmental problems facing our world is climate change. In this regard, the developing countries are faced with the highest damage and threats. Mismanagement of solid waste is among the different reasons of climate change. Today, there

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is a worldwide attention to emission of greenhouse gases (GHGs) from municipal solid waste (MSW) treatment and disposal processes as one of the main sources of anthropogenic emissions.[1,2] Developing countries were responsible for 29% of GHGs emissions in 2000. This amount is expected to be 64% and 76% in 2030 and 2050, respectively. Landfill sites are among the main reasons of such increase.[1] In 2006, in the United States, the contribution of methane emissions from MSW landfill sites were 23% of the total anthropogenic emissions. In addition, the landfill sites were known as the second major source of anthropogenic GHGs in the United States.[1] It is also estimated that 3.8% of the global warming potential (GWP) in the United States is related to methane emissions from landfill sites.[3] In Europe, 30% of anthropogenic sources of methane emissions are from landfill sites.[4] Anaerobic decomposition of wastes in landfills by microorganisms under favorable conditions results in landfill gases (LFGs) emission.

Gas production usually begins 2 months after burial of the wastes and continues up to 100 years. LFG typically contains 45-60% methane (CH_4) and 40-60% carbon dioxide (CO_2). It also contain small amounts of nitrogen (N_2), oxygen (O_2), ammonia (NH_3), hydrogen sulfide (H_2S), hydrogen (H_2), sulfide (S_2), carbon monoxide (CO), and non-methane organic compounds (NMOCs) such as trichloroethylene, benzene, and vinyl chloride.[1,5,6] The amount of methane in the atmosphere has doubled over the last 200 years and this increase, continues, although at a slower pace.[7] In terms of GWP, methane has 25-30 times more effective than CO_2. It is also estimated that the quantitative contribution of CH_4 is about 18% and it has the second rank among GHGs.[4,5,8] Methane has a high heating value, (heating value of a cubic meter of methane is nearly equivalent to that of a liter of kerosene). Thus, it is economically important, too. In addition, when mixed with atmospheric air, methane is explosive in concentrations between 5% and 15% by volume. Therefore, If it is not collected properly and the concentration reaches to the range, it will explode.[2,5] For these reasons, estimation of CH_4 emissions from landfill sites is very important. This estimation also can help to determine the worldwide emissions of different countries. There are several methods for estimating the emissions from landfill sites such as site evaluation, field testing and mathematical modeling.[9,10] In this study, mathematical modeling was applied for LFG emission from the Sanandaj landfill site. LFG modeling is a forecasting model for gas production in the landfill site according to data on waste disposal in past and coming time. Such model will reveal the efficiency of the waste collection system. In addition, the model is an important step in developing a landfill project, which makes it possible to estimate the available recoverable amount of CH_4 as fuel energy over time.[7,11]

Most of these models have been developed based on Monod equation, first-order decay, such as TNO, LFG emissions model (LandGEM), Gassim, Afvalzorg, EBER, IBCC, LFGEEN.[7,11,12] One of the most commonly used and most flexible models is LandGEM. This model that has been developed by the United States Environmental Protection Agency (USEPA), estimates an acceptable amount of produced methane in landfills over time.[13,14] Sanandaj city (the center of Kurdistan province) is located in west of Iran (longitude 47° east and latitude 35° 19' north). The area of the city is about 5023 km^2 and it is 1500 m above the sea level. Its weather is cold and arid. According to the synoptic station in Sanandaj, the city has a mean annual temperature of 14.5° C, annual humidity of about 48.5% and average annual rainfall of about 319 mm. Prevailing wind direction is from south to north of the city. Based on existing statistic data in 2011 the population of the city is about 335,000. The main method for waste disposal is landfilling. The aim of this study is to estimates the methane emissions from Sanandaj sanitary landfill site using LandGEM model.

Materials and Methods

The landfill site of the city has an area of approximately 35 hectares. About 22 hectares of the area have been occupied during operating years. According to the Sanandaj waste management organization (SWMO), this place has been applied as the landfill site since 1993. From 2000 until 2013, about 880,000 tons of waste has been buried in this site. This figure is equivalent to an average of 185 tons of waste per day for a period of 13 years. After 2012, in addition to Sanandaj municipality districts, other wastes from rural areas, industrial and manufacturing centers (within a radius of 20 km from the city) were buried in this site. About 85% of the total produced wastes are disposed at the site, and the rest are recycled or composted. At the site, the wastes are covered by a layer of soil using ramp method as a relatively sanitary landfill. The average depth of waste in the site is approximately 10 meters. In this study, LFG production is estimated based on the assumption of a sanitary landfill that has been launched in 2000 and will be closed in 2020.

Information on the quantity of generated and disposal waste in the landfill is available from 2000 to 2013. The amount of produced waste generation was predicted based on the population growth rate, the rate of waste generation per capita and its changes up to the plan horizon year (2020). To determine the composition of MSW, the necessary data were taken from SWMO. Physical analysis of the waste transported to the landfill site, in the year of 2012, was carried out according to standard methods.[15] Prediction of the changes in the quality and quantity was based on the changes from 2000 to present data, and was compared with changes in the waste components in reliable sources.[2,15]

LandGEM is the most extensively used model for estimating emission rates for total LFGs including CH_4, CO_2, NMOCs and some particular air pollutants. LandGEM is based on a first-order exponential decay rate equation for quantifying emissions from the decomposition of landfilled waste in MSW landfills.[13] The software was developed by Technology Control Center of USEPA. In this study, LandGEM (Version 3.02-USEPA, 2005) was used for estimating LFG emission.[13]

The LandGEM emission methodology can be described mathematically using the following equation:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0,1}^{1} KL_o \left(\frac{M_i}{10}\right) e^{-kt_{ij}}$$

where:

Q_{CH4} = annual methane generation in the year of the calculation (m^3/year)

i = 1 year time increment

n = (year of the calculation) − (initial year of waste acceptance)

j = 0.1 year time increment

k = methane generation rate (/year)

L_0 = potential methane generation capacity (m^3/ton)

M_i = mass of waste accepted in the i^{th} year (ton)

t_{ij} = age of the j^{th} section of waste mass M_i accepted in the i^{th} year (decimal years, e.g., 3.2 years).

According to the equation, the required inputs for estimating the amount of generated LFG are the design capacity of the landfill site, the annual acceptance rate, the LFG generation constant k, the LFG generation potential L_0 and the years of waste acceptance.[13] In this study, the key constants of k and L_0 were calculated. The NMOC concentration for the clean air act default is 4000 ppmv as hexane and methane volume content is 50%.[13,14]

Generation rate (k) value depends on the amount of waste moisture, pH and temperature, and nutrient availability for methanogenic bacteria. Based on USEPA guidelines k values of 0.7 and 0.02 are recommended for humid and dry climates, respectively. The default k value proposed by USEPA is 0.05/year.[13] The World Bank also presents a guideline for estimating the k value. In this method, moisture and the biodegradation rate of waste components is considered.[14] Recommended *k* values of waste components for different conditions are presented in table 1.

With respect to the elements of waste entering the landfill in 2012, and the amount of annual 319 mm of precipitation the constant *k* values were calculated as shown in table 2.

The value of L_0 strongly depends on the organic fraction of the landfilled waste. This parameter is estimated based on the carbon content of the waste, biodegradable carbon, and a stoichiometric conversion factor. If valid data is available on the quantity and quality of the waste, L_0 can be calculated using several methods used in different references. The World Bank recommends a method to estimate the value of L_0 (Table 3).[14]

With regard to table 3 and qualitative characteristics of Sanandaj solid waste in 2012, the minimum and maximum values of L_0 are 200 and 269, respectively. The estimated values of *k* and L_0 have substantial effect on LFG calculation. Since the maximum values of the assumptions will cause invalid results, so the minimum value of L_0 (L_0 = 200) was taken into consideration.[7,14] In this study, for calculating *k* and L_0, the quality of landfilled waste in 2012 was considered as the index for entered waste to the landfill site from 2000 to 2020.

Results and Discussion

Current and future status of generated waste in Sanandaj

The population of Sanandaj in 2006 and 2011 was approximately 315,000 and 335,000, respectively. The generated wastes related to these populations were 265 and 310 tons/day, respectively. Accordingly, the per capita waste production was 840 g/day in 2006 and 925 g/day in 2011. United Nations development

Table 1. Different *k* values (/year) of waste components for different precipitation conditions based on the World Bank recommendation[14]

Annual rainfall	Recommended values for k (/year)		
	Slowly biodegradable	Moderately biodegradable	Rapidly biodegradable
< 250 mm	0.01	0.02	0.03
> 250 to < 500 mm	0.01	0.03	0.05
> 500 to < 1000 mm	0.02	0.05	0.08
> 1000 mm	0.02	0.06	0.09

Table 2. Calculated k values (/year) based on the components of waste in 2012, and annual rainfall of 319 mm in Sanandaj

Materials	Percent	Slowly biodegradable	Moderately biodegradable	Rapidly biodegradable
Putrescible	70.5	-	-	70.5
Paper and paperboard	6.5	4.87	1.63	-
Textiles	2.6	2.60	-	-
Wood	1.1	1.10	-	-
Plastic, glass, metals, etc.	19.3	-	-	-
Total	100	8.57	1.63	70.5
Residual components of each group multiplied by the coefficient (k)	-	0.09	0.05	3.5
Final k value (/year)	-	0.045		

Table 3. Estimation of L0 (m3/ton) based on the waste biodegradability14

Biodegradability	Minimum value of L0	Maximum value of L0
Slowly biodegradable	5	25
Moderately biodegradable	140	200
Rapidly biodegradable	225	300

program suggests a range of 500-900 g/capita/day for citizens of developing countries. The average per capita production of solid wastes in Iran in 2000 was estimated about 850 g/day.[15,16] After 2012 in addition to Sanandaj municipality districts, about 20-50 tons/day waste have been transported to the site from different rural areas, industrial and manufacturing centers (within a radius of 20 km from the city). In general, in 2013, about 300 tons/day waste was transported to the site. With regard to increasing in public welfare, and due to the increase in per capita waste generation in recent years, the average rate of the increase in per capita waste generation is estimated to be 10 g/year. Based on the population growth rate, it is estimated that the population exceeds 350,000 in 2020. Accordingly, it is estimated that solid waste generation exceeds 350 tons/day in 2020. Thus, the average per capita will be 1000 g/day. At the end of the project year (2020), total generation of waste (including 50 tons of waste generated in the surroundings) will be 400 tons/day. After determining the amount of produced waste, the amounts of solid waste disposal site (SWDS) and effective portion of solid waste for gas production must be determined. For this purpose, both the quantity of waste and the condition of landfilling is very important. Since some of the generated waste is recycled or composted, conversion factor of MSW into SWDS is considered to be 0.85.[16]

The input waste to the landfill is not properly disposed and in some points, aerobic conditions can be provided due to inadequate coverage. Therefore, the impact factor of 0.7 is considered for waste products contributing to gas production. Table 4 presents the quantity of waste generated in Sanandaj and the effective values in gas production in recent and upcoming years. To determine the waste composition, data from the previous years were received from the SWMO. The physical analysis of waste entering the landfill in 2012 was carried out according to standard methods. Physical composition of the landfilled waste in 2012 is presented in figure 1. Due to the increase in MSW generation per capita per year and assign an increase of 10 g per capita per year to dry waste stream, it is expected by 2020, about 7.5% of the putrescible organic portion is reduced, and the amount of paper, plastics, etc. will increase.[2,15]

Estimation of LFG production

According to existing data model mass production and gas volume in Sanandaj landfill was estimated using LandGEM from 2000 to 2100 (Figures 2 and 3). As can be seen, emissions start a few months to one year after the waste landfilling. It reaches to peak point after the landfill closure and then declines. Based on the condition this decline continues from forty to hundred years.[1,5,6] As shown in figure 2, the

Table 4. The quantity of generated waste and their effective amounts of gas production in recent and upcoming years

Year	Generated waste (tons/day)	Generated waste (tons/year)	Effective amounts of gas production (tons/year)
2000	210	76,650	53,655
2001	210	76,650	53,655
2002	220	80,300	56,210
2003	230	83,950	58,765
2004	240	87,600	61,320
2005	250	91,250	63,875
2006	265	96,725	67,708
2007	280	102,200	71,540
2008	280	102,200	71,540
2009	290	105,850	73,906
2010	300	109,500	76,650
2011	310	113,150	79,205
2012*	350	127,750	89,425
2013	350	127,750	89,425
2014	360	131,400	91,980
2015	370	135,050	94,535
2016	385	140,525	98,368
2017	390	142,350	99,645
2018	390	142,350	99,645
2019	395	144,175	100,923
2020	400	146,000	102,200
-	-	-	-

* After 2012 in addition to Sanandaj city waste, other wastes from rural areas, industrial and manufacturing centers (within a radius of 20 km from the city) have been buried in this site

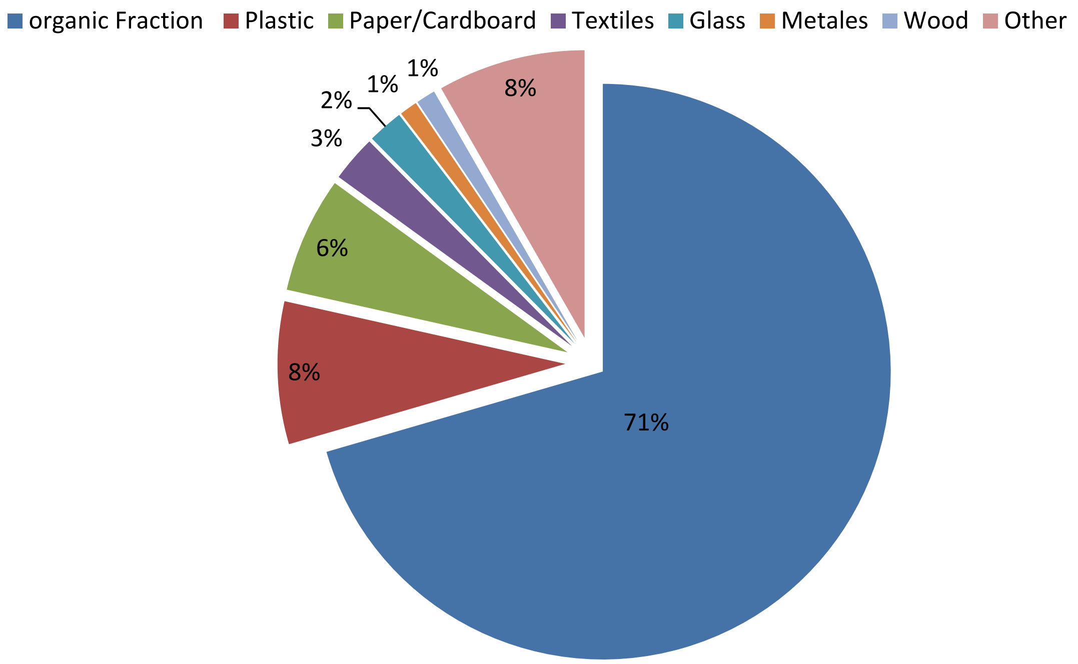

Figure 1. Municipal solid waste component of waste disposed in Sanandaj landfill site in 2012

maximum mass of emitted gas is occurred in 2021. The amount for total LFGs, methane, carbon dioxide and non-methane organic compounds are 23,150, 6184, 16,970, and 266 tons/year, respectively. Also from figure 3, the maximum volume of emitted gas in 2021, volume rates of gas emissions from landfill are 185×10^5, 93×10^5, 93×10^5, 74×10^3 m^3/year for total LFGs, methane, carbon dioxide and non-carbon organic compounds, respectively. Considering that more than 70% of the buried waste is biodegradable organic materials, so the period before the land fill closure year (2020), gas production rate will be very high. Sharp slope of the curves in figures 2 and 3 indicates it clearly. After a year from landfill closure the increase in the gas production rate reaches to maximum level, but with decrease in organic matter content of waste and reduction of biological activity, it declines gradually in the next years.[5] According to the assumptions of the model, the emission volume of carbon dioxide and methane are the same, and the emission volume of total LFGs is twice that of methane (Figure 3).[3] According to the report of Iran environmental protection agency, based on the international panel on climate change (IPCC) methodology, methane emissions from MSW landfills in 2000, was estimated about 497.54 Gg.[16]

The results of a study on three municipal landfill in west of Iran, showed that the averages methane and GHGs emissions in the year of 2010 were about 2244 and 8405 ton/year, respectively.[17] Since the rate and volume of produced gas depend on the age and composition of waste, the moisture, geologic conditions, the amount of leachate, landfill waste mass temperature, presence of oxygen and quality of site coverage, thus, comparing the results obtained from this study with other similar studies does not seem very reasonable.[4,5,18,19] As a whole, compared with some other studies, the amount of 6184 tons/year of methane production in Sanandaj landfill is relatively high. High percentage of biodegradable fraction of wastes, as well as the high values of the *k* and L_0 constants due to the landfill conditions, can be the reasons for such

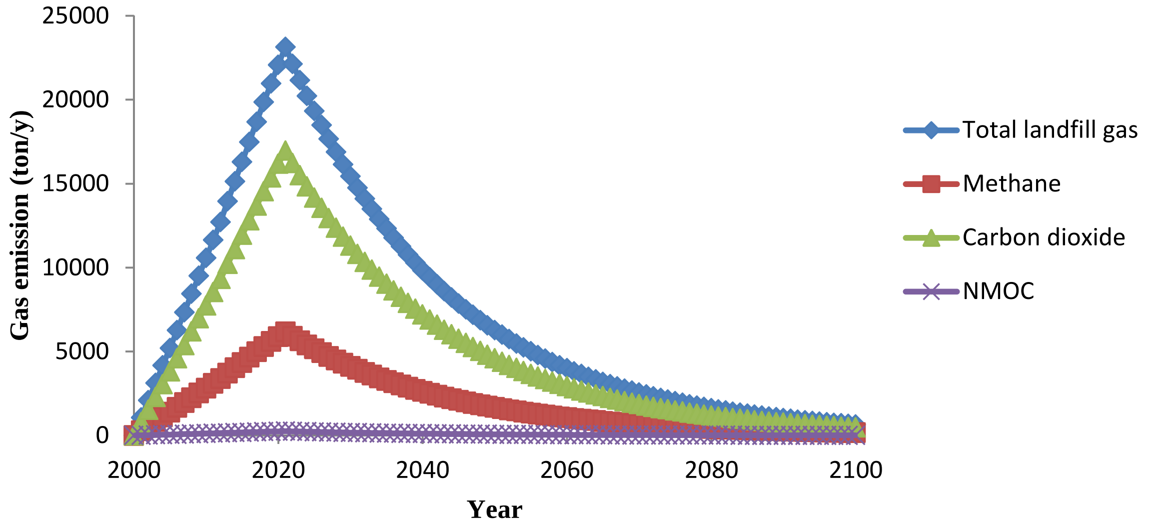

Figure 2. Annual landfill gas mass production provided by LandGEM models (2000-2100) in Sanandaj landfill
k = 0.045 (/year), L_0 = 200 (m^3/ton), non-methane organic compound (NMOC) = 4000 ppmv, methane = 50%

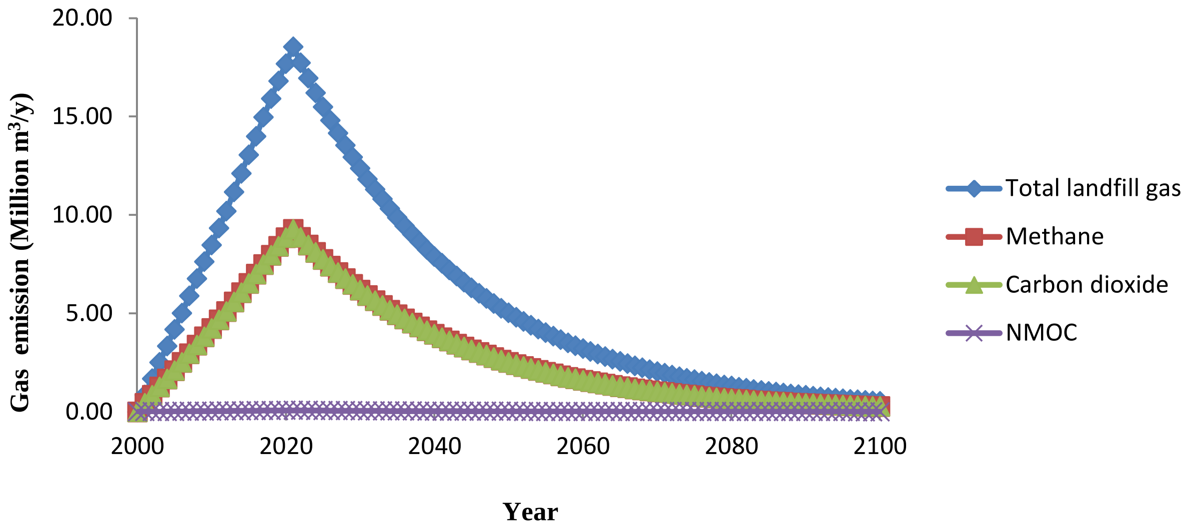

Figure 3. Annual landfill gas volume production provided by LandGEM models (2000-2100) in Sanandaj landfill
k = 0.045 (/year), L0 = 200 (m3/ton), non-methane organic compound (NMOC) = 4000 ppmv, methane = 50%

relatively high gas production. Biodegradability of organic contents is over 70%, while in other studies this value was lower and ranged from 40% to 65%.[3,5] The effect of effective parameters on gas production is considered in terms of *k* and L_0.[7,14] Methane generation rate (*k*) is the rate of waste decay, and the common range is from 0.02/year for dry sites to 0.7/year for wet sites. Values of *k* depend on the moisture, pH and temperature of the waste mass and nutrient availability for methanogenic bacteria. In high levels of *k*, methane production rate increases and after landfill closure gas production declines rapidly.[13,14] In this study, a constant value of 0.45/year was obtained. Similar works reported lower or higher values.[3,5,20] L_0 was actually the potential of methane generated from decomposing a ton of waste calculated based on the carbon content of the waste, waste biodegradability and effect of the stoichiometric conversion factor. Theoretical and operational levels range from 125 to 310 m^3 of methane per ton of waste. The value of this parameter is recommended by the USEPA about 170 m^3/ton of waste. Except dry climates, where methane production is limited, the value of this parameter mainly depends on the composition of the buried waste. Wastes with higher organic matter content have higher L_0 value.[13,14] The values obtained from this study (200 m^3/ton) compared to other studies (average100 m^3/ton) is relatively high.[3,5] NMOCs emission in this study is about 1% of total emissions, which is consistent with its usual emission amount from landfills. In spite of such small amounts, it may be important, because some of these compounds are known as carcinogen and have adverse environmental and health effects.[6] Overall, LandGEM model due to its reliability and close results to actual studies, have been known as the representative of estimating models for LFG emissions.[3,13] However, since this model is unable to consider the differences among various organic contents in MSW, total MSW is taken into consideration. So that, the estimation is slightly higher than that of other models.[11] Obviously, knowledge of the real gas production trend requires accurate knowledge of degradation of waste in landfill condition. Therefore, the work should be conducted in field studies on pilot cells and continuous recording of volume gas production. Along with the environmental conditions, such as ambient temperature, pressure, rainfall, temperature within the waste mass, the pressure of buried waste in cells should be measured and recorded. After a few years, from the trend of changes in gas production the degradation of waste and *k* coefficient can be realized.[1,2,14,15] With regard to high volumes of predicted methane in the landfill site, with good engineering practice in addition to methane recovery, odors, air and of groundwater pollution can also be prevented considerably. By establishing a biogas plant, not only the environmental contaminants are collected, and the public's health is benefited, but also some part of required electrical and thermal energy can be supplied. Thus, production of 5.22 kwh for each cubic meter of waste can be expected.[1,5,10] By controlling and reducing of methane emissions in Iran, we can move up to the sustainable development. In addition, the aim of the clean development mechanism of the Kyoto protocol will be complied, and a part of solid waste management costs will be provided using economic benefit derived from the mechanism.[14,21] Since methane emissions from the waste sector contributed to 10 to 19% of total anthropogenic global emissions; therefore, development of new and environmentally friendly methods is necessary for MSW management.[1,8,22,23]

Conclusion

MSW landfill is one of the major sources of anthropogenic greenhouse gases. If it can be properly managed and emitted gases can be collected and recycled, adverse environmental impacts would be minimized. In this study, the amount of emissions from Sanandaj landfill during 2000 to 2100 was calculated using LandGEM software program. Accordingly, most of the emitted gas mass from the landfill was estimated in 2021. Estimated values for total LFG, methane and carbon dioxide, were 23,150, 6184, and 16,970 tons/year, respectively. Also in this year the rate for total LFG, methane and carbon dioxide were 185×10^5, 93×10^5, 93×10^5 m^3/year, respectively. It is obvious that gas generation in landfill depends on many factors that model does not consider them. Thus, the results of this study are merely estimation. In addition to modeling, more accurate results require some knowledge of the real situation prevailing landfill waste decomposition process through pilot field studies and continuous recording of gas producing.

Conflict of Interests

Authors have no conflict of interests.

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Assessment of chemical quality of drinking water in rural areas of Qorveh city, Kurdistan province, Iran

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Original Article

Abstract

Groundwater aquifers as one of the main sources of water supplies are faced with different risks such as level dropping due to lack of precipitation, and natural and non-natural pollutants. Thus, it is extremely necessary to monitor ground water quality. In the present study, the concentration of cations, anions, and some toxic metals was evaluated in 21 rural water supplies in Qorveh plain in two stages. Data were analyzed with Rockwork and Arc GIS software. Results from Hydro chemical analysis showed that all the studied parameters had lower concentrations than the permitted limits, except for arsenic (As) and selenium (Se) in some of water resources. As concentration in 20% of studied resources were higher than recommended standards. There was a significant difference between nitrate (NO_3^-) concentrations in the two low- and high-water seasons ($P < 0.01$). Bicarbonate (HCO_3^-) and calcium (Ca^{2+}) were the prevalent anion and cation, respectively, meaning that samples type was calcium-bicarbonate. Wilcox diagram classified the samples in C2-S1 and C3-S1 classes. Correlation coefficient between chemical parameters showed that HCO_3^- and Ca^{2+} had the highest correlation. Finally, it can be said that except for As and Se, other water characteristics have a good quality for drinking water application. However, current and uncontrolled application of the studied water supplies, especially in agricultural activities, can change and decrease their quality. Therefore, it is important to prevent the health threats of such process.

KEYWORDS: Water Quality Monitoring, Water Resource, Drinking Water, Heavy Metals, Water Quality Standard

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Introduction

Improper operation of groundwater resources change their quality and introduce either direct or indirect destruction in other resources. Arid and semiarid areas are more vulnerable to such destructive effect because of their higher dependency to groundwater resources.[1] Thus, proper management of water resources in such areas needs to study their quality.[2] To proper operation of ground water in every area, it is necessary to precisely recognize its quantity and quality. Hydrological and hydro-chemical studies can be used for such purpose and to decide on the possibility of mixing waters with different resources. Brackish water, as the most prevalent groundwater pollution that decreases its quality, is going to become a very serious problem worldwide.[3] Therefore, considering increasing use of groundwater and its importance in arid areas such as Iran, qualitative

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assessment of such resources is very important part of ground water studies. Physical and chemical qualitative variation of ground water is a function of geological characteristics and human activities in every area.[4] However, some special compounds, such as heavy and toxic metals in drinking water can be serious threat for consumers' health, making its monitoring more important.

Among water chemical pollutants, arsenic (As) can find its way to water resources through solution in soil layers.[5] Thus, As pollution in water resources is one of the most serious threats for natural ecosystems and human health, which become a big health concern in many countries worldwide:[6,7] South Asia, Bangladesh, West Bengal, India, and Tiwan and some South American countries such as Argentina and Mexico; and also some urban and rural areas in Iran such as Kurdistan and Khorasan, are facing this problem.[8,9] As polluted water in Qorveh and Bijar in Kurdistan province of Iran in some local and limited studies has been reported.[10] Therefore, it is necessary to prevent consumer exposure to As, particularly in areas of potential natural pollution, by continuously monitoring of water. Since the main water supply of Qorveh's rural areas is ground water, and considering that agricultural activities in the area use different types of fertilizers and pesticides, and also the possibility of As pollution of groundwater, this study aimed to assess chemical quality and toxic metal contents in ground water supplies of some rural areas of Qorveh city.

Materials and Methods

In this cross-sectional study, concentration of chemical parameters in drinking water in some drinking water supplies of rural areas of Qorveh city (21 villages covered by Kurdistan Rural Water and Wastewater Company) was investigated. Samples were taken in two low- and high-water seasons in the year 2012, according to standard methods for the examination of water and wastewater.[11] Then, they were transferred to the laboratory under standard conditions and kept in the refrigerator until the examination. Turbidity, temperature, electrical conductivity, and pH were measured in sampling site. Sulfate (SO_4^{2-}), phosphate (PO_4^{3-}), nitrate (NO_3^-), chloride (Cl^-), fluoride (F^-), calcium (Ca^{2+}), magnesium (Mg^{2+}) were determined using an ion chromatograph. Sodium (Na^+), lithium (Li^+), and potassium (K^+) were measured by a flame photometer. All examined parameters were determined according to standard methods for the examination of water and wastewater.[11]

In order to compare the results of two phases of the study SPSS for Windows (version 16.0, SPSS Inc., Chicago, IL, USA) and Wilcoxon test were used. To determine the correlation between the anion and the cation Pearson correlation coefficient was used. Rockwork was used to analyze the results of chemical analysis in the studied samples. Using the results obtained from previous step, ground water type was determined and its application for drinking, agricultural and industrial purposes were assessed. Moreover, ArcGIS was used to study the spatial variation of As and nitrate.

Results and Discussion

Table 1 represents the anions and cations' concentration and other water quality parameters in the studied water supplies. Table 2 shows the statistical characteristics of the chemical parameters.

Results showed that majority of anions and cations are within the standard rages. Hardness survey results showed that the water hardness in all the villages is temporary hardness (no permanent hardness was observed), categorizing as completely hard, hard and slightly hard (9.5%, 66.5%, and 23.8%, respectively). Therefore, hardness in the studied water supplies was lower than the recommended standards and did not have adverse effect on the consumers. However, its continuous increase can be a concern for future. It also, limits such supplies application for industrial purposes.

Table 1. Water quality parameters of groundwater in rural areas (high-water season)

Village	pH	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	F (mg/l)	Cl (mg/l)	TDS (mg/l)	EC (µS/cm)	Alkalinity (mg/L $CaCO_3$)	TH (mg/l $CaCO_3$)
Amir Abad	7.7	69.3	9.7	8.6	36	18.0	16.0	0.40	8.3	460	660	246	210
Chomoghloo	7.3	38.2	8.7	5.6	63	12.9	16.5	0.39	7.6	410	598	216	130
Najaf Abad	7.5	77.5	17.0	1.3	58	7.3	34.6	0.40	5.9	575	847	308	260
Tazeh Abad	7.6	91.0	41.3	8.5	161	1.1	113.0	0.75	50.4	1108	1655	529	393
Bayeh	7.8	59.0	11.0	1.1	58	7.0	51.1	0.38	18.0	465	694	211	190
Zarin Abad	7.4	60.0	13.6	2.6	52	14.6	22.9	0.43	12.0	482	701	250	204
Alahyari	8.0	57.0	3.0	2.5	54	14.5	23.2	0.31	11.9	410	599	201	152
Dirakloo	7.6	49.0	9.2	2.5	53	15.4	26.7	0.25	13.2	406	605	194	158
Muzafarabad	7.7	59.0	11.4	2.5	53	14.4	23.0	0.31	12.0	460	683	235	192
Zivieh	7.5	34.7	5.1	1.1	61	11.7	30.0	0.39	9.7	365	528	175	106
Saeed Abad	7.8	65.3	7.3	0.8	34	20.4	7.7	0.43	6.3	398	583	209	190
Vinsar	7.6	85.7	16.0	2.1	113	38.6	150.0	0.30	28.3	759	1151	255	276
Ghandab Sufla	7.5	79.5	9.5	2.1	114	38.3	165.0	0.31	29.3	711	1061	219	234
Ghandab Olya	7.8	46.9	7.5	4.7	62	38.5	47.2	0.54	27.2	430	627	166	146
Dosar	7.7	79.6	12.2	6.7	95	34.4	64.5	0.49	45.9	682	1021	279	250
Babashaydolla	7.5	75.5	15.8	2.1	110	39.7	167.0	0.26	26.8	700	1078	214	250
Baharloo	7.8	66.0	18.0	2.1	109	36.2	149.0	0.42	32.6	675	1045	225	236
Jodaghyeh	7.8	97.0	23.8	6.8	82	28.3	67.0	0.50	35.7	771	1152	355	336
Miham Olya	7.6	49.0	8.7	0.6	14	16.0	13.9	0.33	11.4	290	407	150	146
Miham Sufla	7.9	34.7	7.3	1.0	34	21.0	13.8	0.39	11.7	310	449	161	115
Gharbelaghkhan	7.9	31.8	11.0	20.0	83	35.0	81.0	0.45	23.2	482	719	164	160
National Standard of Iran[12] (max. permissible)	-	-	-	-	200	50.0	400.0	1.50	400.0	1500	-	-	500

TDS: Total dissolved solids; EC: Electrical conductivity; TH: Total hardness

Table 2. Descriptive statistics of elemental concentration for the studied parameters

Parameter	N	Low-water season				High-water season			
		Mean	Standard deviation	Min	Max	Mean	Standard deviation	Min	Max
EC	21	882.62	335.51	470.0	1820.0	803.00	303.58	407.0	1655.00
TDS	21	585.95	226.86	320.0	1270.0	540.43	196.67	290.0	1108.00
pH	21	7.52	0.22	7.2	7.9	7.65	0.19	7.3	8.00
Ca	21	68.76	18.81	34.0	102.8	62.18	19.14	31.8	97.00
Mg	21	16.23	10.17	2.0	51.5	12.71	8.12	3.0	41.00
Na	21	72.52	37.59	19.0	160.0	71.38	35.08	14.0	161.00
K	21	3.95	4.30	0.6	19.3	4.06	4.44	0.6	20.00
HCO_3	21	315.00	113.80	209.0	744.0	288.20	102.00	183.0	645.00
Cl	21	21.05	17.68	4.2	81.5	20.34	13.05	6.0	50.00
SO_4	21	65.64	59.47	6.6	175.6	61.19	54.72	167.5	7.66

EC: Electrical conductivity; TDS: Total dissolved solids

Ionic frequency, water type and geochemical facies, and the way it developed in the studied villages showed that bicarbonate (HCO_3^-) and Ca^+ are the dominant anion and cation in the studied supplies, respectively, introducing calcic bicarbonate as the water type. Results obtained from Rockwork showed that rock bed in the studied villages, is mainly made up of limestone, dolomite and feldspar. Spread of carbonate rocks in the study area and dissolution of carbonate minerals are the main source of Ca^{2+} and Mg^{2+} ions in the water. The high concentration of HCO_3^- ions in the water is due to erosion and weathering of carbonate and silicate minerals. Table 3 was prepared according to Schuler diagrams (figures not provided), and it was found that the water samples from the studied villages are classified mainly into three groups, ranged from moderate to good. Due to its significant use in agriculture, one of the major issues in the study of water quality in the area is to evaluate its quality criteria for agriculture. To determine the quality of groundwater in agriculture Wilcox diagram was used (figures not presented). Based on its results, 61.9% of samples were in C2-S1 class, classified as slightly salty water for agriculture, and the rest were in C3-S1 class, considering as usable brackish water for agriculture.

Based on sodium percentage, more than 40% of the samples were good and about 50% of them had acceptable qualities. According to the residual sodium carbonate criteria for water quality, more than 90% of the samples had acceptable and the rest had good qualities.

Table 3. Classification of water bodies based on Schuler diagram

Water classification	SO_4	Cl	Na	pH	TH	TDS
Good	80.95	100.00	95.24	85.71	76.19	61.90
Acceptable	19.05	0	4.76	14.29	23.81	33.33
Average	0	0	0	0	0	4.76
Unsuitable	0	0	0	0	0	0
Unpleasant	0	0	0	0	0	0
Non-potable	0	0	0	0	0	0

TH: Total hardness; TDS: Total dissolved solids

Evaluation of water quality for industrial application showed that 4.8% of samples were balanced, 47.6% of them were scale forming and the rest were corrosive waters. Correlation coefficients between the different chemical parameters measured in the studied villages showed the highest correlation exists between HCO_3^- and Ca^{2+} (Table 4). Piper diagram also confirmed that the facies of water was calcic bicarbonate, showing that the main chemical composition of water is $Ca(HCO_3)_2$.

Considering the presence of other cations and anions in the water and existence of the correlation coefficient between them, other chemical compounds are $CaSO_4$, $CaCl_2$, $Mg(HCO_3)_2$, $MgSO_4$, $MgCl_2$, $NaHCO_3$, Na_2SO_4, NaCl, and KCl (depending on the specific terms of the ratio of Ca^{2+} to Mg^{2+} and Na^+ to Ca^{2+} in each of the studied sources).

Table 4. Correlation matrix of studied water quality parameters

	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3	TH	TDS	EC	pH
Ca	1											
Mg	0.661^{**}	1										
Na	0.573^{**}	0.716^{**}	1									
K	$-0.081^{£}$	$0.242^{£}$	$0.268^{£}$	1								
HCO_3	0.738^{**}	0.914^{**}	0.628^{**}	$0.188^{£}$	1							
Cl	0.634^{**}	0.806^{**}	0.877^{**}	$0.354^{£}$	0.852^{**}	1						
SO_4	0.518^{*}	0.455^{*}	0.853^{**}	$0.090^{£}$	$0.265^{£}$	0.697^{**}	1	1				
NO_3	$0.151^{£}$	$-0.142^{£}$	$0.322^{£}$	$0.188^{£}$	$-0.305^{£}$	$0.067^{£}$	0.615^{**}	0.615^{**}				
TH	0.922^{**}	0.889^{**}	0.724^{**}	$0.158^{£}$	0.888^{**}	0.867^{**}	0.561^{**}	0.561^{**}	1			
TDS	0.813^{**}	0.875^{**}	0.917^{**}	$0.225^{£}$	0.841^{**}	0.977^{**}	0.733^{**}	0.733^{**}	0.935^{**}	1		
EC	0.809^{**}	0.868^{**}	0.826^{**}	$0.217^{£}$	0.823^{**}	0.948^{**}	0.755^{**}	0.755^{**}	0.930^{**}	0.999^{**}	1	
pH	$-0.090^{£}$	$0.152^{£}$	$-0.152^{£}$	$0.21^{£}$	$-0.185^{£}$	$-0.277^{£}$	$-0.099^{£}$	$-0.099^{£}$	$-0.100^{£}$	$-0.145^{£}$	$-0.136^{£}$	1

* Correlation is significant at the 0.05 level; £: Non-significant; ** Correlation is significant at the 0.01 level; TH: Total Hardness; TDS: Total Dissolved Solids; EC: Electrical Conductivity

According to table 1, the concentration of fluoride in the most of the water sources (85%) was less than the recommended standard, so this deficiency, especially in children, may lead to health problems.

According to table 1, the mean nitrate concentration in water supplies is 22.06 mg/l with a standard deviation of 12.3 mg/l, and nitrate concentrations in drinking water in all villages were less than the national standard.

However, nitrate concentrations in water supplies of Saeed Abad, Vinsar, Ghandab Sofla, Ghandab Olya, Dosar, Babashaydolla, Baharloo, Jodaghyehand Gharbelaghkhan villages were between 20 and 45 mg/l. Considering the nitrate risks at concentrations higher than 20 mg/l, it is possible that these villages would face with problems caused by nitrates.

The results showed that the nitrate distribution in low-water season, unlike nitrite, had wide variations and in most cases nitrate concentration in the season of high water is higher than the low-water season.

According to the Wilcoxon test and its correlation coefficient, it was found that there is a significant difference between the nitrate ions concentration in samples taken in the two seasons of high and low water ($P < 0.01$). It is due to increased agricultural activities in the high-water season following increased consumption of fertilizers and pesticides, which results in high concentration of nitrate in returned and agricultural drainage waters. Similar results were obtained in Semnan and Kashan.[13,14]

According to the map of nitrate concentrations (Figure 1), the greatest band of the nitrate concentration is in the northern part of the plain's center, which is an agricultural area with a high population. Therefore, the use of nitrate fertilizers in these areas is an important factor in increasing the concentration of nitrate ions in the water. In this regard, high concentrations of nitrate in groundwater of agricultural areas in Bahar (Hamadan) plain (122 mg/l), the agricultural district of Rajasthan, India (70-700 mg/l) and Krishna Delta, India (39% of samples had more than 50 mg/l) confirm the role and impact of agricultural activities on nitrites increase in water.[15-17]

The results of metal concentrations presented in table 5. According to the table, except for the As, concentrations of other metals are in the recommended standard ranges. The mean concentrations of As in water supplies is 16.25 µg/l with a standard deviation of 15.1 µg/l. 66.6% of the villages had the lowest concentration (1 µg/l) and Dosar village had the highest concentration (47 µg/l). According to the Institute of Standards and Industrial Research of

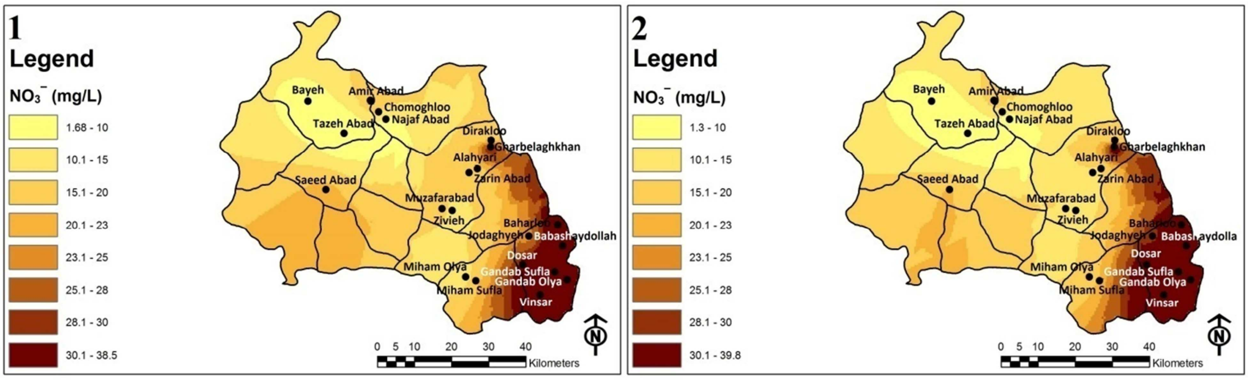

Figure 1. Spatial distribution of nitrate in ground water in low- and high-water seasons

Table 5. Trace metal concentrations (µg/l) in drinking water samples (high-water season)

Village	Cr	Pb	Cu	As	Zn	Se	Fe	Al	Ba
Amir Abad	6.1	0.4	20	10	16	7	2.0	8.6	214
Chomoghloo	7.5	0.4	19	24	65	6	1.3	3.0	93
Najaf Abad	7.0	0.4	20	1<	18	1	6.8	7.3	18
Tazeh Abad	10.0	0.4	22	1<	13	20	6.6	4.5	32
Bayeh	12.4	0.3	17	1<	11	1	34.0	4.2	42
Zarin Abad	9.0	0.4	21	1<	15	5	2.5	1.2	7
Alahyari	8.8	0.4	20	1<	15	8	4.8	2.4	89
Dirakloo	13.0	0.4	17	1<	14	8	54.0	1.3	8
Muzafarabad	8.3	0.4	18	1<	13	1	0.2	0.3	11
Zivieh	9.6	0.4	22	1<	10	1	1.6	2.2	18
Saeed Abad	11.6	0.4	23	1<	25	10	7.0	0.1	11
Vinsar	14.6	0.4	16	1<	17	5	11.4	0.5	6
GhandabSufla	14.6	0.4	18	9	28	10	16.0	53.0	7
GhandabOlya	14.0	0.3	25	12	11	4	4.2	4.0	41
Dosar	13.6	0.4	27	47	50	15	5.3	1.8	13
Babashaydolla	7.5	0.4	25	1<	19	11	246.0	5.5	6
Baharloo	6.0	0.4	27	1<	9	4	96.0	6.3	10
Jodaghyeh	7.0	0.4	20	9	17	1	6.3	4.8	63
MihamOlya	7.6	0.4	21	1<	5	1	3.2	8.5	1
MihamSufla	7.0	0.4	19	1<	21	10	5.7	1.4	9
Gharbelaghkhan	6.7	0.4	23	10	19	1	20.5	5.7	7
National Standard of Iran[12] (Max. Permissible)	50.0	10.0	2000	10	3000	10	300.0	100-200	700

Iran, No. 1053 and also World Health Organization, As concentration in 23.8% of water supplies is higher than recommended concentration and in 9.5% of them As concentration is close to the maximum allowable concentration. Therefore, there is a risk of exposure to As for consumers, and it is essential to determine and monitor its amounts in water.

As and its compounds are great threats to human and other organisms' health, and As-contaminated soils and sediments and water supplies are important sources of food chain contamination. Abundance of As in calcareous soils of the Qorveh basin plain, as the Kurdistan Province's major agricultural region, leads to contamination of agricultural corps and water sources. To obtain sufficient information about the characteristics of As-contaminated regions is a key step to their reform. To assess and manage the risks of As contamination, it is important that the geochemical conditions in the contaminated site be investigated and geochemical data be collected. The stabilization mechanism of As in calcareous soils of the Qorveh basin plain and the effect of soil physicochemical characteristics on more toxic fraction ratios should be considered. Geological formations and soils of Qorveh basin plain, mostly limestone, contain significant amounts of As, resulted from volcanic activity of Tertiary geology, consists of volcanic rocks, hot springs and geothermal activities.

Among the important minerals containing As in soil, arsenopyrite, orpiment, and realgar can be pointed out.[18] Figure 2 shows the As concentration map. It is clear that there is As-contaminated water in different parts of the plain. Such information has also been reported in previous studies.[10] However, in some parts of Kurdistan province, including northern and northeastern parts of Qorveh, As, due to the regional geology and above-mentioned minerals, is an integral part of soil. Furthermore, due to the travertine hot springs and bedrock type, water sources are contaminated with As. From Regional geology and As appropriate distribution maps, extracted from Geological Survey of Iran, it can be seen that there is a risk of land structures containing As. Thus, the inclusion of As in drinking water in rural areas shows that there are specific problems for consumers facing As. Depending on the circumstances of each village, measures need to be considered in accordance with US Environmental protection agency guidelines, such as replacement of water supply, safe water distribution among consumers, use of home methods with the capability of As removal for water purification or water treatment methods in small areas.

Conclusion

In this study, the concentrations of water quality parameters in a number of villages Qorveh city were measured using Piper, Schuler, and Wilcox graphical diagrams, for drinking, agricultural, and industrial applications. Results from hydro-chemical analysis showed that, apart from As and Se in a number of sources, concentrations of other quality parameters are less than the allowable limit. Nitrate concentration in some of the resources was close to its maximum allowable amount, which is mostly due to agricultural activities in the area, application of different fertilizer and pesticides. It was found that in 23.8% of the studied water supplies As concentration of water is higher than the recommended standard, and in 9.5% of them, it is close to the maximum allowable amounts. Thus, there is a risk of exposure to As for consumers, and it is necessary to evaluate and monitor the As in water. In summary, though, except As and selenium, other properties of the studied water supplies are suitable for drinking, but the continuation of the current trend, particularly in the agricultural activities and uncontrolled use of groundwater resources in agriculture, will lead to change and declining of water quality. Hence, in order to prevent health hazards resulting from the process (especially NO_3^- and As), preventive measures are necessary.

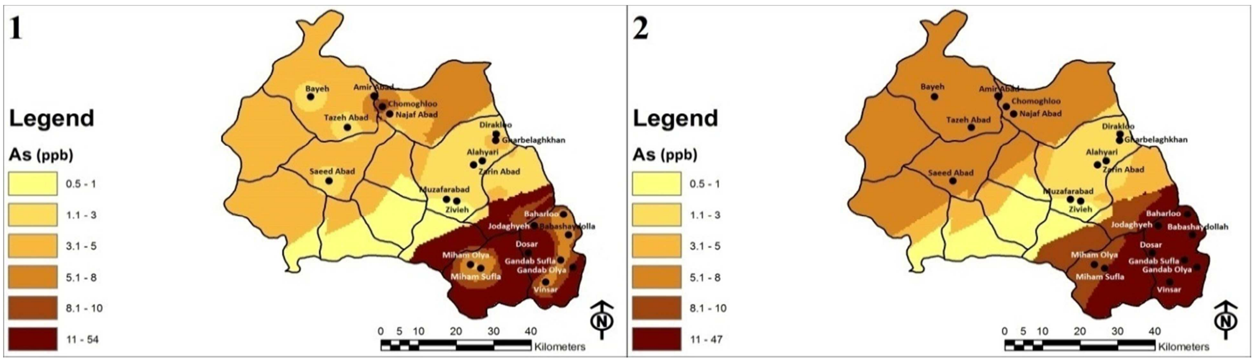

Figure 2. Spatial distribution of arsenic in ground water in low- and high-water seasons

Conflict of Interests

Authors have no conflict of interests.

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Journal of Advances in Environmental Health Research

Spatial epidemiology and pattern analysis of childhood cancers in Tehran, Iran

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Original Article

Abstract

Identification of cancer clusters may have an important value to the study of disease etiology in cancer surveillance. We aimed to determine the spatial pattern of childhood cancer cases (CCCs) from 2007 to 2009 in Tehran, Iran. Records of 176 childhood cancer counts (children younger than 15 years old) for 2007-2009 were obtained from Iran's Ministry of Health and Medical Education. Thereafter, they were successfully geo-coded within a geographic information system based on their residence phone number or postal code. We used two distinct techniques, namely average nearest neighbor index (ANNI) and Quadrat analyses, to measure the spatial pattern of CCCs in Tehran. The count of childhood cancers for 2007-2009 in Tehran was 117.3 per 1,000,000 children. The ANNI analysis suggested that there was a clustered pattern for the CCCs in 2007-2009. There was less than 1% likelihood that this pattern could be the result of random chance (nearest neighbor ratio = 0.73; Z-score = –6.8 standard deviations; $P < 0.01$). In the Quadrat analysis, the largest absolute difference between the observed and expected cumulative proportions in the frequency table was 0.2778 while the critical value of Kolmogorov-Smirnov test was 0.1649. Therefore, the Quadrat analysis confirmed that the CCCs had clustered pattern in 2007-2009 in Tehran. Both used methods suggested that childhood cancers in Tehran had clustered pattern in 2007 and 2009. We believe further research is needed to study the etiological factors, especially environmental factors, which made this cluster.

KEYWORDS: Childhood Cancers, Cluster Analysis, Geographic Information System, Iran, Medical Geography, Spatial Epidemiology, Tehran

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Introduction

Cancer is one of the leading causes of mortality and disease burden, globally.[1-3] According to the latest global burden of disease (GBD) study,[4] leukemia ranks 12th amongst the top 25 global causes of death for children 5-14 years old (see the heat map from permanent online link).[5] For Western Europe region of the GBD, brain cancer, leukemia, non-Hodgkin's lymphoma, liver and kidney cancers rank, respectively, 2nd, 3rd, 10th, 22nd, and 25th amongst the top 25 causes of death for the same age group (see permanent online link).[6] In the North Africa and Middle East region, leukemia and brain cancers rank 6th and 11th, respectively (see permanent online link).[7] In addition, the GBD 2010 study reported that

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leukemia and brain cancers rank 4th and 10th amongst the top 25 causes of death for children 5-14 years old in Iran, respectively (see the heat map from permanent online link).[8]

The etiology of childhood cancers is largely unknown.[9] Although genetic factors play an important role in the development of childhood cancers, the role of environmental factors, infectious agents, maternal cigarette smoking and alcohol consumption, and socioeconomic status are also substantial.[10-13] So far, few environmental risk factors, such as exposure to air pollutants and radiation have been suggested to be associated with the development of childhood cancers.[13-15] However, these risk factors describe only a small proportion of childhood cancers. Nevertheless, environmental risk factors play an important role in the incidences of childhood cancers.[13,14,16]

In cancer surveillance, identification of areas with increased risk, mapping, and detection of cancer clusters may have an important value to the study of disease etiology.[17-21] There have been numerous studies to date that reported geographic and spatiotemporal variations in variety of cancers, such as childhood cancers.[22-29] A more recent study from Tehran, Iran, also reported clusters of childhood cancers within diverse administrative areas of this megacity.[30]

Currently, many methods have been developed and introduced to detect clusters in spatial point patterns.[31,32] These include average nearest neighbor index (ANNI) analysis, Cuzick and Edwards' method, gradient analysis, *K* function or Ripley's function, kernel intensity function, Kulldorff's scan statistic, mean center standard distance, Quadrat analysis, standard deviational ellipse, variance mean ratio test, etc.[33-36] Each of these methods has its specific advantages and limitations, which are described elsewhere.[18,21]

In this study, the authors aimed to determine the spatial pattern and probable clusters of childhood cancer cases (CCCs) in the Middle Eastern city of Tehran, Iran from 2007 to 2009 using ANNI and Quadrat analyses.

Materials and Methods

Tehran is a large metropolis with a population of more than 8.2 million residents. It is noteworthy that based on latest census report (2011), more than 36% of Tehran's population is less than 25-year old and the population of childhoods (children younger than 15 years old) is about 1.5 million children (19%). The city is located in a large area, roughly 613 km^2 and has diverse configuration. The altitude in the southern parts of the city is about 1000 m above the sea level and in the northern parts of the city is approximately 3800 m (Figure 1).[37-40]

Records of 176 childhood cancer counts (children younger than 15 years old) for 2007-2009 were obtained from Non-Communicable Disease Center of Iran's Ministry of Health and Medical Education (MOHME). Thereafter, they were successfully geo-referenced within Tehran megacity by Geographic Information System Bureau of Iran's Post Office based on their postal code.

We used two methods, namely ANNI and Quadrat analyses within geographic information systems (GIS) to measure the spatial pattern and clustering of CCCs as discrete point features from 2007 to 2009 in Tehran.[18,41]

In the ANNI analysis, we calculated the distance between each CCC and the nearest CCC. Thereafter, we calculated the average distance between CCCs and compared with the distance of random cases within the study area. If the observed average distance of the CCCs was smaller than expected average distance of random distribution (nearest neighbor ratio), we considered the CCCs to have cluster pattern. Statistically, the null hypothesis says that the CCCs are randomly distributed. If the CCCs have a spatially random distribution, then the NNI would have a normal distribution. Thereafter, we can calculate the Z-score and compare the distributions. If the Z-score was positive, it indicates that the pattern is dispersed;

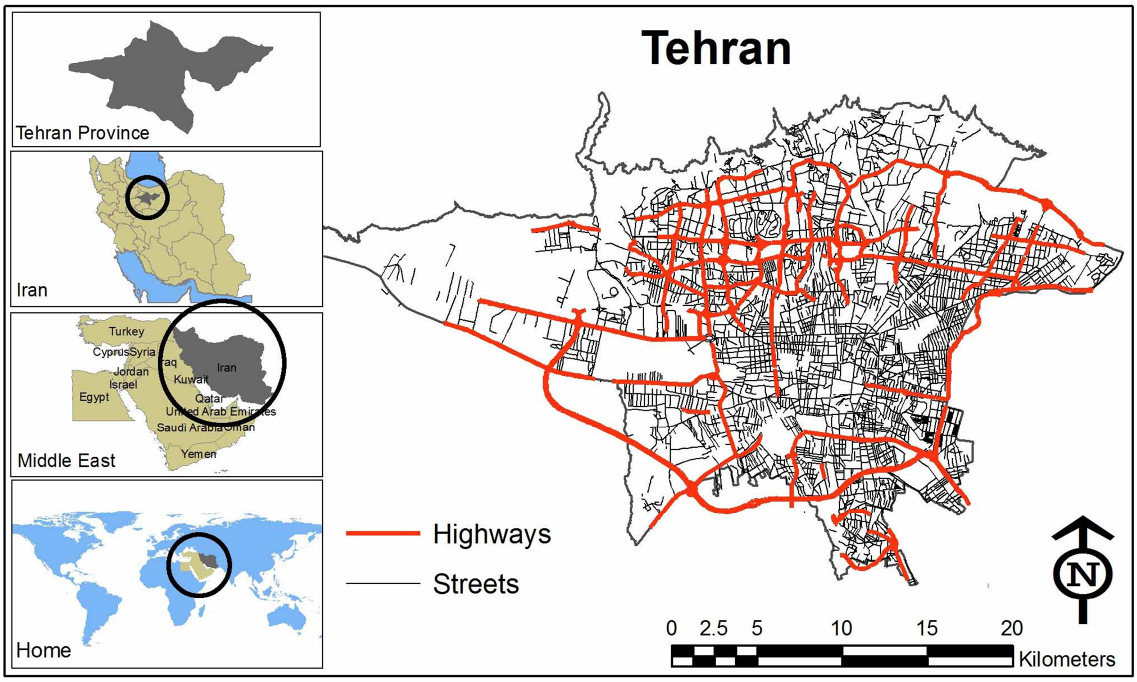

Figure 1. The study area of Tehran, Iran

if it was negative, then the pattern is clustered. Meanwhile, at a confidence interval of 95%, the Z-score > 1.96 or < –1.96 would be considered statistically significant.[42,43]

In this analysis, we have overlaid the areas of equal size on the study area—known as quadrats or quads—and counted the number of CCCs in each square quadrat. One of the most important points in this analysis is the size of the used quadrats. Traditionally, the size of quadrats is identified as twice the size of the mean area per feature.[44] Thus, we have applied the following equation to calculate the length of a side of each quadrat:

$$L = \sqrt{[\{2 \times \left(\frac{A}{N}\right)\}]}$$

Where the L denotes the length of a side of each quadrat, A denotes the area of extend for CCCs, and N denoted the total observed number of CCCs.

Thereafter, we have calculated the expected counts of CCCs for a random distribution in the study area based on Poisson distribution. We first calculated the probability of the x number of CCCs occurring in any given quadrat or $P(x)$ as the following equation:

$$P(x) = \frac{e^{-\lambda}\lambda^{X}}{X!}$$

where e is the Euler's constant, X is the observed number of CCCs, and λ is the average number of CCCs per quadrat. In addition, the λ was calculated based on the following equation:

$$\lambda = \frac{n}{k}$$

where n denotes the total number of CCCs, and k denotes the total number of quadrats.

We then multiplied the $P(x)$ results by the total number of CCCs to get the number of quadrats expected to contain that number of CCCs. Therefore, we created two frequency tables; one for observed distribution, observed proportion, and observed cumulative proportion; and the other one for expected distribution, expected proportion, and expected cumulative proportion based on Poisson distribution. In quadrat analysis, if more square quadrats contain few or no CCCs than expected, and fewer square quadrats contain most of the CCCs than expected, the CCCs form a clustered pattern. The most common statistical test that has been used to find out how much the two frequency tables and patterns differ is Kolmogorov-Smirnov test. In summary, we calculated the absolute difference between observed and expected cumulative proportions for each line in the frequency tables. Then, we found the largest absolute difference between these and compared this value with critical value of Kolmogorov-Smirnov test, which was calculated as the following equation:

$$C = \frac{Z_\alpha}{\sqrt{n}}$$

where C is the critical value of Kolmogorov-Smirnov test, n is the number of quadrats, and Z_α is the constant for a confidence interval. We have applied the confidence interval of 0.05 and therefore $Z_\alpha = 1.36$ as it is frequently used (Table 1).

We compared the largest absolute difference of the observed and expected cumulative proportions with the critical value of Kolmogorov-Smirnov test. If the largest absolute difference was greater than the critical value, we considered the difference statistically significant and rejected the null hypothesis that CCCs have random distribution over the study area.

Table 1. The constant values (Zα) for calculating the critical value of Kolmogorov-Smirnov test by different confidence intervals

Alpha	Zα
0.2000	1.072749
0.1000	1.223848
0.0500	1.358099
0.0200	1.517427
0.0100	1.627624
0.0010	1.949475
0.0001	2.225251

Results and Discussion

The count of childhood cancers for 2007-2009 in Tehran was 117.3/1,000,000 children younger than 15 years old. Figure 2 illustrates the spatial distribution of CCCs for 2007-2009 in Tehran.

Results of ANNI analysis

There was a clustered pattern for the CCCs in 2007-2009. There was < 1% likelihood that this pattern be by random chance (nearest neighbor ratio = 0.73; Z-score = –6.8 standard deviations; P < 0.01).

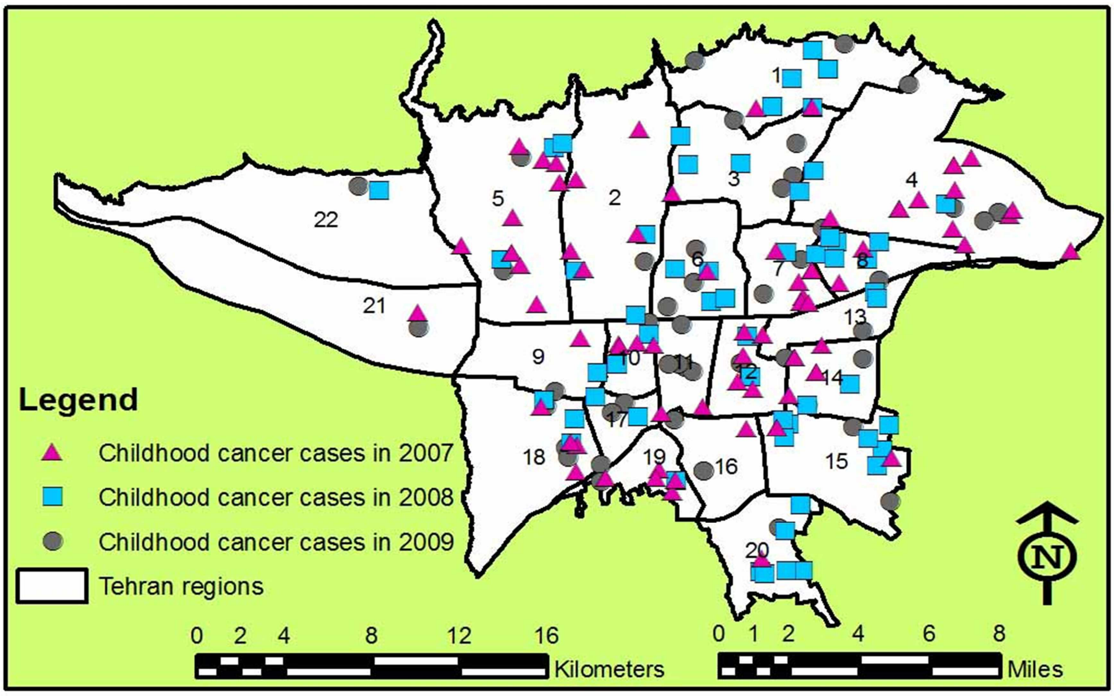

Figure 2. The spatial distribution of childhood cancer counts from 2007 to 2009 in Tehran, Iran

Results of Quadrat analysis

The length of the quads for 2007-2009 was 3396 m. For 2007-2009, the largest absolute difference between observed and expected cumulative proportions in the frequency table was 0.2778 while the critical value of Kolmogorov-Smirnov test was 0.1649.

In this study, the authors tried to map and analyze the spatial pattern of childhood cancer counts in Tehran, Iran, for a 3-year period from 2007 to 2009. We used two distinct techniques, namely ANNI and Quadrat analyses, to identify the probable clusters of CCCs, and to verify that the results are reliable.

Studies of the disease mapping especially cluster analysis of childhood cancers are not rare and there are numerous studies globally.[22,24,25,30,45-47] However, the majority of studies on clustering of childhood cancers investigated the leukemia, as it represents about 25% of childhood cancers.[48] Unfortunately, in case of our study, the MOHME provided us the data of childhood cancers without detail information on the type of registered cancers, but it seems that the majority of cases be leukemia as the prevalence of leukemia is more than other childhood cancers in Iran based on the GBD 2010 study.[8] One of the famous studies related to the cluster analysis of childhood cancers is EUROCLUS project. The EUROCLUS is a European collaborative study to identify spatial clustering of cancer cases and to detect whether these clusters could be explained by environmental risk factors. This study analyzed spatial pattern of 13,351 childhood leukemia cases diagnosed between 1980 and 1989 in 17 countries. The EUROCLUS revealed that childhood leukemia cases had statistically significant clusters within small census areas. However, the study also indicated that the phenomenon of intense clusters is rare and needs careful surveys.[22,45] Bellec et al. analyzed spatiotemporal pattern of childhood acute leukemia cases for two periods from 1990 to 1994 and from 1995 to 2000 for all the French territory. Indeed, they have found a statistically significant cluster pattern in the incidence of acute leukemia cases over 1990-1994, but neither over 1995-2000 nor over the whole period from 1990 to 2000.[49] Gustafsson and Carstensen also reported clustering of 1020 childhood acute lymphatic leukemia and malignant non-Hodgkin's lymphoma for Sweden from 1973 to 1996. They have found a statistically significant excess of case-pairs (25 observed, 14.9 expected, P = 0.01) in the 4-14 year age group for acute lymphatic leukemia. However, they have found no statistically significant clustering when the cases of leukemia, and the non-Hodgkin's lymphomas were assembled.[50] Noteworthy, we have found statistically significant clusters for combination of all CCCs in Tehran for 2007 and 2008, but not in 2009. Knox and Gilman (1996) analyzed data of (a) all childhood leukemia and non-Hodgkin lymphoma cases registered between 1966 and 1983 in England and Wales based on enumeration districts, and (b), all childhood leukemia and cancer deaths between 1953 and 1980, in England, Wales, and Scotland based on their post codes. They have found short range spatial clustering for both leukemia at a place of registration, and leukemia and cancer (separately and jointly) at both birth and death addresses.[46] Wheeler used several cluster analyzes techniques in Ohio, USA, to identify clusters of childhood leukemia incidences from 1996 to 2003. Wheeler found some evidence of significant local clusters in childhood leukemia using kernel intensity function, but no significant overall clustering by other used methods.[21] Alexander et al. analyzed data of childhood leukemia incidences during 1984-1990 for evidence of variation between small areas in Hong Kong and reported that there was evidence of spatial clustering for acute lymphoblastic leukemia at ages 0-4 year.[47] On the other hand, Dockerty et al. analyzed spatial clustering of childhood leukemia and lymphoma cases in New Zealand and found little evidence for spatial clustering. In fact, they have reported significant clustering in a specific subgroup of acute lymphoblastic leukemia aged 10-14 years, which believed may have been real or a chance association.[51] Schmiedel et al. worked on spatial clustering of 1168 childhood leukemia cases diagnosed during 1980-2006 in Denmark and have found spatial clustering at time of diagnosis for children aged 2-6 years (observed/expected [95% confidence interval]: 1.35 [1.15-1.54]).[52] Schmiedel et al. also worked on another study in Germany. They have obtained data of 1946 children with leukemia diagnosed during 1987-2007 from the German Childhood Cancer Registry and tried to identify probable clusters. As a result, they have declared no evidence of a tendency to clustering neither for the whole study population nor in the sub-groups.[53] In case of Tehran, we have found only one study that has tried to map and analyze the spatial pattern of childhood cancers during 1998-2002. In fact, Mosavi-Jarrahi et al. reported marginally statistically significant clustering (P = 0.056, RR = 1.3) for all childhood cancers in Tehran; however, they have found no statistically significant clusters for cancer categories.[30]

One of the limitations of this study is that we have obtained the data of CCCs only from MOHME, while there may be some CCCs that have not been registered by MOHME. Meanwhile, the Quadrat analysis usually has been applied to evaluate point patterns for clustering based on density of features as it counts the number of features per unit area. In fact, it does not consider the arrangement of points and their proximity to each other.[18] Therefore, we have tried to use another method—ANNI—that analyze cluster patterns based on the proximity of features. Both used methods are also biased by the fact that they assume the population is homogenous over the study area.

Conclusion

In our study, both methods suggested that childhood cancers in Tehran had clustered pattern. We believe further research in the future is needed to study the etiological factors, especially environmental factors, which made this clusters.

Conflict of Interests

Authors have no conflict of interests.

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Journal of Advances in Environmental Health Research

Assessing landfill leachate heavy metal effect on the surface water quality: A case of Gheshlagh River, Sanandaj City, Iran

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Original Article

Abstract
Pollution resulted from the leachate of the Sanandaj City landfill into Gheshlagh River is an important environmental and health issue, which has endangered the river. Having a population of more than 400,000 and four municipality districts, the solid waste generation rate is approximately more than 300 tons/day in Sanandaj City. The wastes generated are disposed of at the Sanandaj City landfill with an area of approximately 35 hectares located on the off-road at the Sanandaj-Kamyaran highway. The leachate formed is discharged into the Gheshlagh River through seasonal Kilak River during the succulence (winter and spring) seasons due to the un-sanitary conditions of the landfill. In this study, we investigated the effects of the heavy metals [mercury (Hg), lead (Pb), zinc (Zn), and copper (Cu)] existing in the leachate on the Gheshlagh River and its autopurification capacity. For this purpose, we selected five stations and performed random sampling during two above-mentioned seasons and analyzed the samples. The data were analyzed using one-way analysis of variance and t-test. In general, our results showed that the concentration of the measured elements was more at the leachate confluence station compared with the control station. The mean concentration of the heavy metals in different sampling times and stations was observed in the order of Cu > Zn > Pb > Hg. However, the autopurification of the river resulted in statistical insignificancy of the data, except for Hg.

KEYWORDS: Leachate, Chemical Quality, Contamination, Gheshlagh River, Heavy Metals

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Introduction

Solid waste disposal is an important environmental issue in both developed and developing countries.[1] In spite of efforts to find alternatives for municipal solid waste disposal, landfills are still the most common waste disposal option in many countries.[2,3] Leachate is a hazardous liquid produced in landfills as a result of decomposition of organic materials in municipal solid wastes by microorganisms, and its volume is influenced by surface and ground water excess rainwater penetrating through the waste layers.[4] Landfill leachate mainly consists of organic matter, inorganic macro-components, and heavy metals.[5,6]

Heavy metals distribution in landfill leachate has shown that significant fraction of them is associated with waste-derived dissolved organic matter. The mobility of the heavy metals may

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enhance leachate-polluted waters.[7,8] In recent years, most of the current concerns with regards to the environmental quality were focused on the water quality, because of its importance in maintaining the human and ecosystem health.[9] Landfill leachate can severely influence the quality of water. Maqbool et al. reported that landfill leachate might affect the sustainability of the aquatic life. Therefore, the solid waste dumping site must be kept away from the natural water resources.[10] At the moment, there is no sanitary landfill in Iran. Therefore, moving leachate through soil, groundwater, and surface water is highly possible.

Surface waters contamination by leachate can transmit the heavy metals. Therefore, the effluence of heavy metals into the environment is great concern due to their serious effects on the food chain and furthermore on animal and human health.[11] The aim of this investigation was to assess mercury (Hg), zinc (Zn), lead (Pb), and copper (Cu) concentrations in Gheshlagh River before and after landfill leachate entrance at different times and stations.

Materials and Methods

Sanandaj landfill site located at latitude of 35°10' North and longitude of 46°59' East has an area of about 3.5×10^5 m^2 and receives approximately 300 tons of municipal solid waste per day. Gheshlagh River located with a distance of 1250 m in the downstream of the studied landfill is one of the four major branches of the Sirvan River. The unsanitary landfill does not have daily soil coverage. Therefore, a substantial part of the leachate may leak into the Gheshlagh River.

In this study, five sampling stations were selected. Figure 1 shows the location of sampling stations. The most important criterion in selecting the sampling stations was the Gheshlagh River distance from the landfill. Sampling was carried out 6 times during January-June, 2012.

Water samples were collected 0.1-0.2 m below water surface[12] using 1.5 L polyethylene bottles. The bottles were first washed with nitric acid,

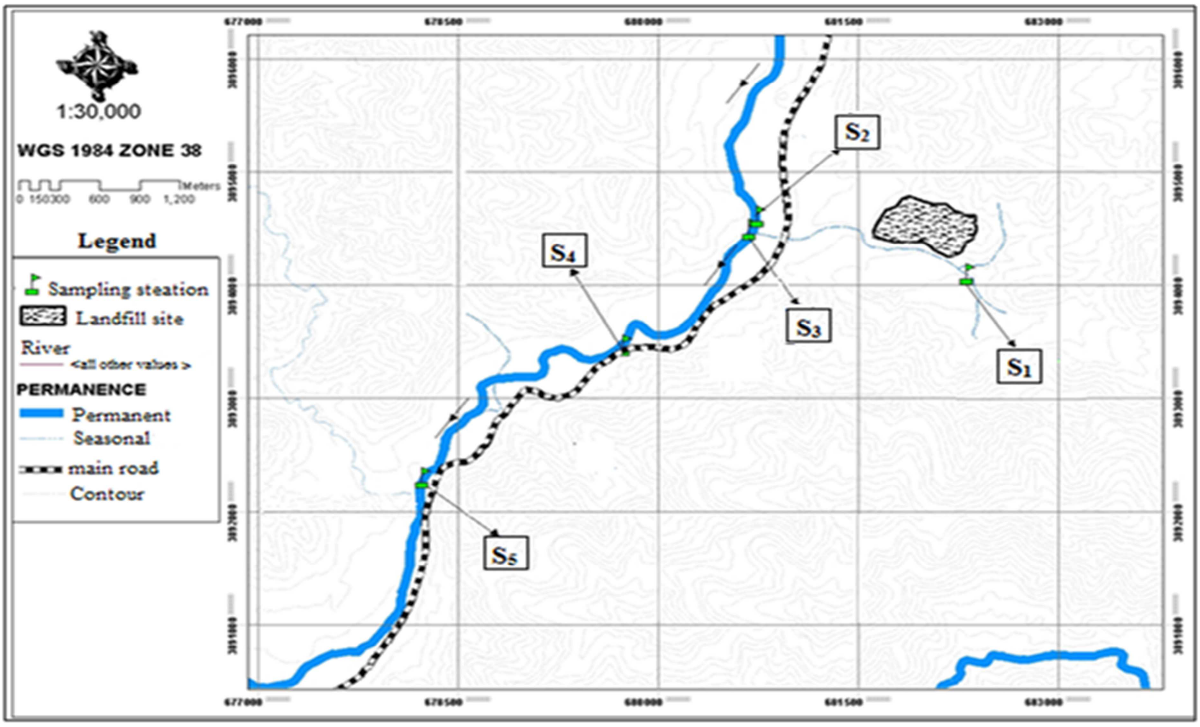

Figure 1. Location of sampling stations in the study area

detergent, and hot water respectively and finally rinsed with distilled water.[10] Samples for heavy metals were first digested using nitric-acid-sulfuric digestion method[12] and then analyzed by atomic absorption spectrometry 220 (Varian model).

Various statistical analyses were done to check whether changes in the concentrations at the studied times and stations are statistically significant. One-way analysis of variance (ANOVA) (for normal data) and Kruskal-Wallis (for nonparametric data) tests were used to compare the heavy metal concentrations in samples collected in different dates and stations. Turkey multiple comparisons tests were used to compare means of heavy metals in leachate among studied times and different sampling stations.

One sample t-test (for normal data) and one sample Wilcoxon (for nonparametric data) tests were used to compare respectively the mean and median of the studied heavy metals with World Health Organization (WHO) standards for heavy metals in surface water. Statistical computations were undertaken with SPSS for Windows (version 20, SPSS Inc., Chicago, IL, USA).

Results and Discussion

The mean concentration of the heavy metals in different sampling times and stations was observed in the order of Cu > Zn > Pb > Hg (Tables 1 and 2). We compared our results with the standard values determined by WHO (Tables 3 and 4). The results for each of the metals investigated are discussed in the following sections.

Hg

Hg had its lowest and highest concentrations on January and June, respectively. Kruskal-Wallis test results showed that there is a significant difference between Hg concentrations at different sampling times ($P < 0.05$) (Table 1). On the other hand, Hg concentration changed by the variation of stations. Since the first station that is, upstream of leachate-Kilak confluence point in Kilak stream, had the lowest, and the fourth station that is, 2 km downstream of the Kilak-Gheshlagh confluence point in Gheshlagh River, had the highest concentration of Hg. According to ANOVA test results, these variations at different stations were not statistically significant ($P > 0.05$) (Table 2). According to tables 3 and 4, one sample t-test and one sample Wilcoxon test results for Hg showed that Hg concentrations at all sampling times and stations were significantly lower than WHO standards for Hg in surface water ($P < 0.05$); thus, Hg might not pose any significant health problems. James et al. in a study showed that Hg and lead (Pb) concentrations at all of stations leachate above standard values.[13] The lowest concentrations of Hg were observed in the month of January after heavy rainfall flushing and dilution of metal may have occurred, but the highest concentrations were in June that are attributed to the high temperatures, increase evaporation and low precipitation at the site that results in concentrating of pollutant. Watananugulkit et al. reported that the comparison of surface water quality showed that the quality in the rainy season is much better than in the dry season. Surface water Hg was analyzed in both seasons (rainy and dry), and the results showed that Hg concentration is lower in the rainy season.[14] Table 2 shows that Hg concentration was higher at site 4 than the other site, which implied that the contamination might have occurred due to pesticides and fertilizers used in the adjacent field areas. Magombeyi and Nyengera showed that the concentration of Hg is higher at stations downstream from the landfill compared with upstream locations. The difference in Hg concentrations between upstream and downstream indicates the contribution of the landfill to stream pollution.[12]

Zn

Table 1 shows that Zn concentration do changed at different sampling times. Samples taken on January had the lowest (28.70 µg/l) and those of February had the highest (48.97 µg/l) mean concentrations of Zn. Significant difference

Table 1. Descriptive and analytical results of the investigated heavy metals

Heavy metals	Number of samples	Mean ± SD (μg/l)							Kruskal-Wallis	
		January	February	March	April	May	June	Total	Chi-square	P*
Hg	30	0.00 ± 0.00	0.89 ± 0.50	0.72 ± 0.36	0.66 ± 0.36	1.03 ± 0.02	1.10 ± 0.02	0.73 ± 0.45	15.81	0.007
Zn	30	28.70 ± 1.57	48.97 ± 13.12	46.93 ± 5.43	44.73 ± 2.45	43.51 ± 1.54	43.59 ± 1.64	42.74 ± 8.62	13.68	0.018
Pb	30	11.65 ± 1.26	46.21 ± 19.84	28.32 ± 25.16	27.58 ± 36.14	11.89 ± 1.04	9.75 ± 1.12	22.57 ± 22.3	9.52	0.09
Cu	30	45.17 ± 3.18	76.70 ± 18.44	80.72 ± 13.70	68.18 ± 14.83	55.12 ± 8.26	40.85 ± 2.80	61.12 ± 18.78	20.07	0.001

* P-value < 0.05 is considered as significant; SD: Standard deviation, Hg: Mercury, Zn: Zinc, Pb: Lead, Cu: Copper

Table 2. Descriptive and analytical results of the investigated heavy metals in studied stations

Heavy metals	Number of samples	Mean ± SD (μg/l)						ANOVA	
		S_1	S_2	S_3	S_4	S_5	Total	F	P*
Hg	30	0.60 ± 0.53	0.68 ± 0.46	0.79 ± 0.48	0.80 ± 0.47	0.79 ± 0.46	0.73 ± 0.45	0.204	0.934
Zn	30	40.97 ± 10.62	43.08 ± 8.50	42.69 ± 6.36	44.24 ± 11.64	42.71 ± 7.94	42.74 ± 8.62	0.097	0.982
Pb	30	31.76 ± 34.48	18.49 ± 18.16	26.22 ± 22.74	18.17 ± 19.4	18.18 ± 17.27	22.57 ± 22.30	0.426	0.788
Cu	30	59.66 ± 21.60	63.94 ± 16.32	67.17 ± 24.06	58.57 ± 16.43	56.27 ± 19.28	61.12 ± 18.78	0.295	0.879

*P-value < 0.05 is considered as significant; SD: Standard deviation, ANOVA: Analysis of variance, Hg: Mercury, Zn: Zinc, Pb: Lead, Cu: Copper

among Zn concentrations in different sampling times was proved by Kruskal-Wallis test (P < 0.05). Table 2 reveals that the first and fourth stations had the lowest and highest concentrations of Zn, respectively. This table also shows that based on ANOVA test result variation of Zn is not significant (P > 0.05). Tables 3 and 4 show that Zn concentrations at different sampling times and stations were significantly lower than WHO standards for Zn in surface water (P < 0.05). Therefore, Zn might not pose any significant health problems. Kar et al. showed that the highest concentration of Zn was observed in monsoon, which may be due to a sudden rainfall followed by high discharge from upstream environment into the river,[15] while in this study the highest concentration of Zn was observed in winter. Zn concentration was higher at site 4 than the other site, which implied that the contamination might be due to the agricultural effluents.

Pb

Table 1 shows that Pb concentration was in its lowest in June and highest in February. Kruskal-Wallis test revealed that Pb concentration at sampling period did not significantly change (P > 0.05). It also revealed that fourth and fifth sampling stations had the lowest concentration, and the first sampling station showed the highest concentration for Pb (Table 2). Moreover, table 2 shows that there is not any significant difference among the Pb concentrations at different sampling stations (P > 0.05). Pb concentration in January, February, April, and May, and also stations 1, 3, and 5 were significantly higher than the WHO standards for Pb in surface water (P < 0.05) (Tables 3 and 4); thus, Pb might has significant health problems. When water is contaminated with leachate containing Pb, the mechanism leading to health hazards is bioaccumulation. Many living organisms are capable to accumulate Pb in their bodies.[13,10] In this study, the highest concentration of Pb was observed in the month of February. It implied that waste either consist of the sources of Pb such as batteries, photography, old based paints and Pb pipes or the erosion of Pb containing deposits in the landfill occurred in February. Moreover, acidity in leachate can cause Pb to be extracted from waste and move through in it. Maqbool et al. reported that the high Pb concentration was in the month of December, and the low concentration of Pb was observed in the month of September after heavy precipitations in this month.[10] Pb concentration was higher at site 1 than the other sites, which implied that the contamination might have occurred due to exist in residual sediments of Pb in bottom seasonal Kilak stream.

Table 3. Statistical results of comparing the investigated heavy metals in studied times with the standards determined by World Health Organization

Heavy metals	WHO standard value (μg/l)	P*											
		January		February		March		April		May		June	
		OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test
Hg	1	-	-	-	0.0420$^{\downarrow}$	-	0.0430$^{\downarrow}$	-	0.0430$^{\downarrow}$	< 0.0001$^{\downarrow}$	-	-	0.0390$^{\downarrow}$
Zn	500	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	-	0.0430$^{\downarrow}$	< 0.0001$^{\downarrow}$	-
Pb	10	0.0430$^{\uparrow}$	-		0.0430$^{\uparrow}$	-	0.2250	-	0.0430$^{\uparrow}$	0.0150$^{\uparrow}$	-	0.6400	-
Cu	2000	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-

* P-value< 0.05 is considered as significant; OST-test: One sample t-test; OSW-test: One-sample Wilcoxon test; WHO: World Health Organization; Hg: Mercury, Zn: Zinc, Pb: Lead, Cu: Copper

Table 4. Statistical results of comparing the investigated heavy metals in studied stations with the standards determined by World Health Organization

Heavy metals	WHO standard value (μg/l)	P*									
		S_1		S_2		S_3		S_4		S_5	
		OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test
Hg	1	0.0010$^{\downarrow}$	-	0.0010$^{\downarrow}$	-	-	0.0270$^{\downarrow}$	-	0.0280$^{\downarrow}$	-	0.0270$^{\downarrow}$
Zn	500	< 0.0001$^{\downarrow}$	-	-	0.0280$^{\downarrow}$	< 0.0001$^{\downarrow}$	-	-	0.0280$^{\downarrow}$	< 0.0001$^{\downarrow}$	-
Pb	10	-	0.0460$^{\uparrow}$	-	0.0750	-	0.0460$^{\uparrow}$	-	0.2250	-	0.0280$^{\uparrow}$
Cu	2000	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-

* P-value < 0.05 is considered as significant; OST-test: One sample t-test; OSW- test: One-sample Wilcoxon test; WHO: World Health Organization, Hg: Mercury, Zn: Zinc, Pb: Lead, Cu: Copper

Cu

Cu, which had the highest concentration among the studied heavy metals, had its lowest and highest concentrations in June and March, respectively. This result was not matched with findings of Kar et al. (Pb > Zn > Cu).[15] Differences among the Cu concentrations in the studied times were significant (Table 1). Table 2 reveals that station number 3, that is, Kilak-Gheshlagh confluence point, had the highest and station number 5 that is, 5 km downstream of the Kilak-Gheshlagh confluence point had the lowest Cu concentrations among other stations. ANOVA test result showed that the changes in Cu concentration in the different stations were not significant (P > 0.05). According to tables 3 and 4, one sample t-test results revealed that compared with WHO standard for Cu in surface water, Cu concentration in all sampling times and stations, was significantly low (P < 0.05), showing that Cu might not pose any significant health problems. Table 2 shows that Cu concentration was higher in March than the other months, which implied that the contamination might have occurred due to pesticides and fertilizers used in the adjacent field areas in this month. Cu concentration at station 3 was the highest that implied probably waste has contaminations consist of Cu. The lowest Cu concentration was in station 5 that showed the river has self-purification capacity high. According to tables 3 and 4, Cu might not pose any significant health problems.

We collected the water samples only in two seasons due to finance constraints. This might affect our results. On the other hand, it is suggested to monitor the river at least for 1 year through weekly randomized sampling and analyzing river water quality and leachate characteristics is recommended to be determined, at least, seasonally in order to interpret results achieved more precisely and scientifically.

Conclusion

The investigation evaluated the heavy metal concentration (Hg, Zn, Pb, and Cu) of Gheshlagh River before and after entrance of Sanandaj landfill leachate. For comparison purpose, we considered to stations as monitoring stations to check whether the river itself or the tributary seasonal river contain heavy metal. The results showed that Pb concentration in January, February and April, and stations number 1, 3, and 5 exceed the standards, which present a potential hazard to the public and environmental health. Moreover, it was found that the autopurification capability of the Gheshlagh river could to somewhat reduce the heavy metal concentration. Therefore, Gheshlagh river water should be treated prior to use for any domestic purposes in the downstream.

Conflict of Interests

Authors have no conflict of interests.

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Removal of parachlorophenol from the aquatic environment by recycled used tires as an adsorbent: Characterization, adsorption, and equilibrium studies

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Original Article

Abstract

Parachlorophenol has an extended usage in refineries, petrochemical industries, insecticide, and herbicide manufacturing industries. Tire a solid waste, which is disposed in large amounts each year, a large number of them in landfills can cause irreparable environmental impacts. Consequently lots of efforts were done to produce activated carbon from used tires. Activated carbon was made in laboratory conditions by using pyrolysis furnace. Scanning electron microscopy was used for determining structural characteristics of the activated carbon produced from recycled used tires and Brunauer, Emmett, and Teller isotherm was used to find out its special surface. The structure of produced activated carbon in this study has a special surface of 111.702 m^2/g. The internal diameter of holes was 1.54 nm, and the total volume of them was 0.124 ml/g. The removal efficiency was reduced from 88.59% to 69.25% by changing the pH from 3 to 9. In addition, the efficiency was reduced from 88.59% to 75.95% when the primary concentration of parachlorophenol increased from 10 to 60 mg/L. On the other hand, changing the temperature from 10°C to 30°C increased it from 65.86% to 74.53%. Moreover, contact time had direct impacts on the removal efficiency. The results conform Freundlich isotherm (R^2 = 0.9958). The efficiency of parachlorophenol removal would be decreased by increasing pH and concentration of the pollutant, and would be increased by adding temperature and contact time. As a conclusion, since the recycled tires are cheap, the produced activated carbon from them can be used as an effective and low-cost method for parachlorophenol removal from aqueous solutions.

KEYWORDS: Activated Carbon, Isotherm, Parachlorophenol, Recycling, Used Tires

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Introduction

Chlorophenols are made by replacing one or more chlorine on the benzene loop. Solubility of chlorophenols in water is low, and its insolubility would be increased by raising the number of chlorine atoms.[1] The main sources of chlorophenol are: paper pulping factories, coal factories, chemical materials factories, petroleum refinery, plastic productions, and the leachate of urban solid wastes.[2] Parachlorophenol (C_6H_5ClO) is one form of chlorophenol in which

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the hydrogen in the benzene loop are replaced with a chlorine atom. Parachlorophenol has an extended usage in refineries and petrochemical industries, insecticide and herbicide manufacturing, and environmental antimicrobial agents producing.[3,4] Parachlorophenol with a molecular weight of 128.6 is yellow solid, and soluble in water and in the normal conditions it is almost acidic.[5,6] It enters to the body through skin, breathing and digesting system, and as a toxic and corrosive chemical cause's irritation for eyes, skin, nose, increasing cough, wheezing, and breathing problems. Long time exposure can cause headache, tiredness, impatience, adverse effects on the liver and kidney, muscle weakness, nausea and in the end, coma and death.[7-9] Some of the other health hazards related to these compounds are high toxicity, being carcinogen, destroying water quality and making it unsuitable for routine consumption and drinking.[10-12] Various methods have been used for removing parachlorophenol from aqueous solutions, such as: electrochemical oxidation, using photocatalysts, chemical oxidation, wet oxidation, and biological treatment.[13] Applications and expansions of the mentioned methods have been limited by the problems such as high cost, producing hazardous by-products, and low efficiency.[14,15]

Adsorption may potentially avoid producing minor materials while it brings about high efficiency. Activated carbon is the most common substance for adsorption. The high price of commercial types is a big obstruction for using them in processes.[16,17] Therefore, lots of efforts have been made for producing activated carbon from low cost materials in the recent years, which the main parts of these materials are commercial and industrial waste products. As an example, Stavropoulos and Zabaniotou produced activated carbon from olive-seed and removed methylene blue dye from aqueous solutions in 2005.[18] Rahman et al. produced activated carbon from rice hunks and removed green malachite from aqueous solutions in 2005.[19] Valix et al. derived activated carbon from sugarcane dregs and removed blue acid 80 from water in 2004.[20] Bansode et al. could produce activated carbon from almond shell and removed volatile organic carbon in 2003.[21] Kadirvelu et al. could make activated carbon from coir and removed heavy metals from industrial wastewater.[11]

Tire is a solid waste, which is disposed in large amounts each year. As an example, about 299 million tires were manufactured in United States in 2005; large number of them in landfills can cause irreparable environmental impacts.[12] Consequently lots of efforts were made to produce activated carbon from used tires, because they are almost free raw materials. For instance, Amri et al.,[22] Troca-Torrado et al.,[7] Tanthapanichakoon et al.,[6] Ariyadejwanich et al.,[23] Ko et al.,[24] Alexandre-Franco et al.,[25] produced activated carbon from tires and reported high quality of their products in removal of different substances.

Also in Iran, thousands of used tires are being disposed to the environment uselessly; these tires can be free raw materials to produce activated carbon. The produced activated carbon is beneficial for the removal of various contaminants from aqueous solutions, including parachlorophenol, thereby it decreases polluted water treatments' cost and somehow it causes recycling of used tires. Thus, it preserves the environment from being polluted by such extremely hazardous materials. The purpose of this study to investigate the removal of parachlorophenol from water by adsorbing it on the used tires derived activated carbon. The effect of contact time, temperature, pH, and the concentration of contaminant were evaluated in this study. Determining the adsorption isotherms in designing the pollutant treatment systems, which are working by adsorption method has a great importance.[26] Langmuir, Freundlich, Redlich-Peterson, and Temkin models were used for analyzing the result of adsorption and its isotherm.

Materials and Methods

Tests were done in a batch reactor by changing pH, temperature, contact time, and parachlorophenol concentration. Adsorption process was surveyed in each step by adding 20 mg activated carbon derived from used tires in a reactor with the volume of 50 ml (0.4 g/l), which was put in the incubator (for temperature adjusting). It is worth noting that to avoid the probability of evaporation of parachlorophenol and causing errors in the test results, all the reactors were completely closed during the test.

The used parachlorophenol in this research was purchased from Merck Company and 4-aminoantipyrine was bought from Fisher Company. During the different steps of the test, pH of the samples was measured by WTW unit, Inolab pH 720 pH meter. After testing and sampling at the determined time, parachlorophenol concentration was measured by colorimeter 4-aminoantipyrine method according to the standard methods for examination of water and wastewater (5530A) with a set of UV-Visible HACH DR 5000 spectrophotometer.

Chemical activation and carbonation methods were used for producing activated carbon from waste tires. Therefore, first waste tires were shredded to 3-4 mm pieces. Then in order to activate them, the rubbery pieces were put in contact with thick potassium hydroxide in a glass container for 3 h; the temperature was adjusted on 85° C. During the reaction process, a magnetic stirrer was mixing the mentioned mixture at the rate of 150 rpm for a better reaction between potassium hydroxide and pieces of tire. Mass ratio was considered as 4:1 potassium hydroxide to tire. After a 3-h contact time with potassium hydroxide, tire pieces were taken out of mentioned solution and were put in the oven with 110° C for 24 h. After drying, tire pieces were heated in an Argon furnace with 85 cm^3/min gas stream up to 750° C for carbonation. The rate of temperature increase in the furnace was 5° C/min. The intended samples were put in the furnace (25-750° C) for approximately 2.5 h. After reaching this temperature, the furnace was turned off immediately, and it was allowed to become cool slowly. Then the produced activated carbon was rinsed with distilled water, until pH comes to 7; then the derived activated carbon was put in 110° C oven for 24 h to become completely dry, and after passing from a standard 100 mesh sieve, it was maintained in desiccators.[27,28] The effective factors in performing the intended processes were: detention time (5, 20, 60, and 90 min), pH (3, 5, 7, 8, and 9), the amount of used activated carbon (0.4 g/l), parachlorophenol concentration in water (10, 20, 40, and 60 mg/l), and test temperature (10° C, 20° C, and 30° C).

The percentage of produced activated carbon was estimated by using Eq. 1:

$$\text{Carbon yield}\,\% = \left[\frac{W_{ac}}{W_{ti}}\right]\times 100 \quad (1)$$

In this equation, W_{ac} is the weight of produced activated carbon and W_{ti} is the weight of used tire. Scanning electron microscopy (SEM) was used for surveying the surface of activated carbon. The special surface of the activated carbon was measured by Brunauer, Emmett, and Teller method.

Results and Discussion

Specifications of adsorbent

The percentage of produced activated carbon was estimated to be 36.46%. The SEM image is shown in figure 1. The structure of the produced activated carbon in this study has a special surface of 111.702 m^2/g. The internal diameter of the hole was 1.54 nm, and the total volume of them was 0.124 ml/g.

The effect of temperature

One of the effective factors in adsorption process is the temperature of the reaction. For surveying the effect of this factor on the removal efficiency, adsorption was evaluated at temperatures of 10° C, 20° C, and 30° C. In order to adjust temperature, all the experiments were performed in a chamber incubator with adjustable temperature. Figure 2 shows the result of temperature effect on the removal efficiency. As it shows removal efficiency is increased by temperature rising. In this way, changing temperature from 10 to 30 increased the removal efficiency from 65.86% to 74.53%.

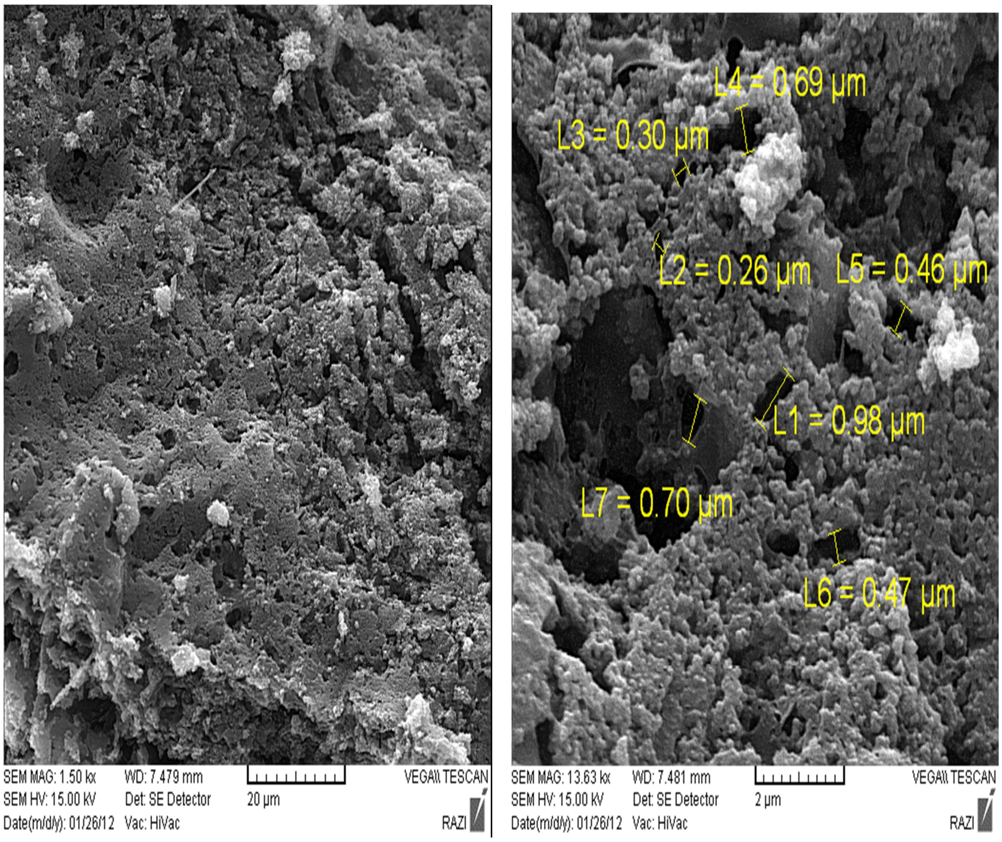

Figure 1. Scanning electron microscopy images of activated carbon produced from used tire

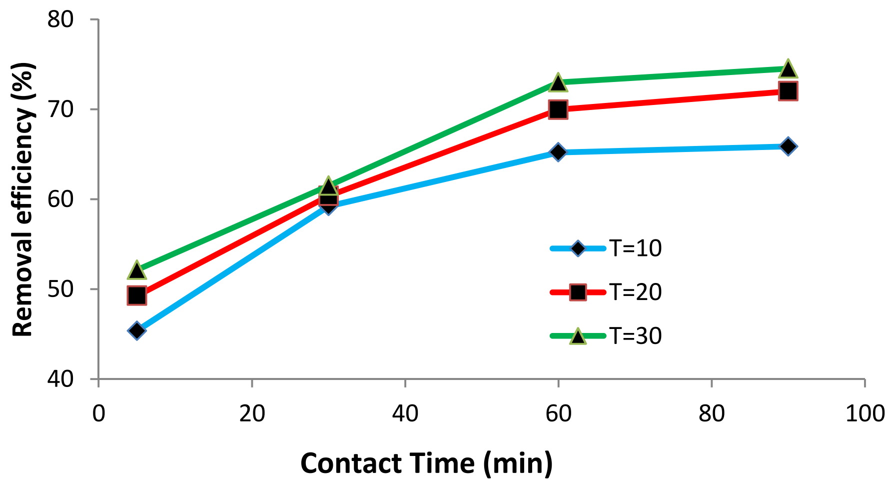

Figure 2. Effect of temperature on parachlorophenol removal (the amount of adsorbent 0.4 g/l, pH = 7)

Hence, it can be said that temperature can have a great effect on adsorption capacity of the adsorbent. In general, adsorption process is an exothermic process, and adsorption should be decreased by increasing the temperature. But in some cases, that the amount of adsorption is under control by emission process, temperature increase will cause an increase in the amount of adsorption. Therefore, according to found data, temperature process is controlling adsorption of phenol on the produced adsorbent. This study which is done by Srivastava et al. approves this result.[29]

The effect of pH

Figure 3 shows the effect of pH on the removal efficiency of parachlorophenol. It shows that the removal efficiency decreases by increasing pH, in a way that by changing pH from 3 to 9, removal efficiency decreases from 88.59% to 69.25%, in contact time of 90 min. In adsorption systems, pH of the intended solution is very important, because it affects chemical characteristics of the adsorbent attribute of self-absorption.[30] This study which was done by Wan Ngah and Hanafiah shows that the produced adsorbent from tires and the optimum pH for the highest adsorption was 5.[31] In other study by Fan et al., it was found that the most chlorophenol adsorption amount was achieved in the pH of 2 and the removal percentage was decreased by increasing pH.[32]

As it is observed in figure 3, the percentage of parachlorophenol removal is higher in lower pHs, which is because of the protonation of existing phenol in solution. This point is approved by the result of the studies, which were done by Blanco-Martinez et al.[33] and Srivastava et al.[29]

The effect of contact time

The effect of contact time on the removal efficiency was studied by changing it from 5 to 90 min in pH = 3, with surveying the effect of concentration changes in the removal efficiency of adsorbent. As it is observed in figure 4, when the contact time is increased from 5 to 90 min, the removal efficiency by 10 mg/l primary parachlorophenol concentration increases from 60.28% to 88.59%. This contact time (90 min) is equilibrium time in tests. This point is also true in the concentration of 20, 40, and 60 mg/l parachlorophenol. In the study done by Chen and Chen, it was observed that increasing the contact time will increase the amount of Cu^{2+} removal.[34] In the other study, which was done by Fan et al., results showed that with an increase in the contact time, the removal

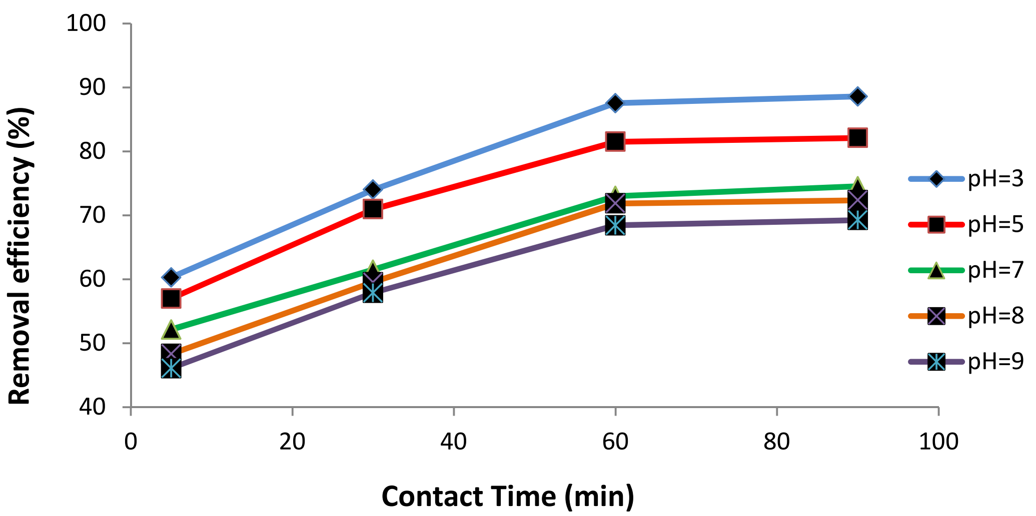

Figure 3. Effect of pH on parachlorophenol removal (amount of adsorbent = 0.4 g/l)

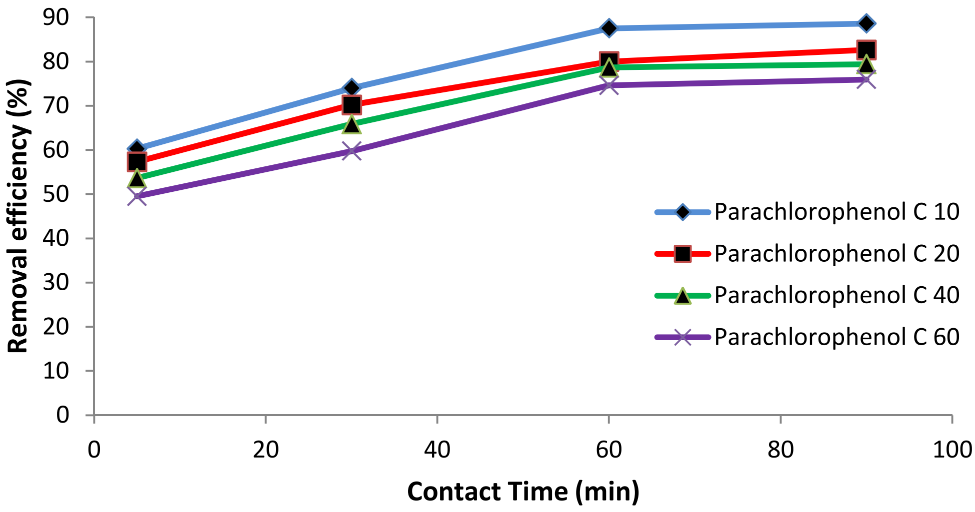

Figure 4. Effect of contact time on parachlorophenol removal (pH = 7 and 30° C)

efficiency of dielderin increased. Especially in the first 4 h when the adsorption rate is higher.[32]

The effect of different parachlorophenol concentration

The effect of primary phenol concentration in the intended study was surveyed by changing the phenol concentration (10, 20, 40, and 60 mg/l) in pH = 3 and 0.4 mg/l adsorbent and 90 min contact time. pH = 3 was chosen because in surveying the effect of pH changes on the amount of pollutant removal, it was determined that the adsorbent has the best removal of pollutant in pH = 3. So that, in surveying the effect of concentration changes on adsorption efficiency, the temperature of 30° C was chosen as the best temperature. As shown in figure 5, the effect of primary parachlorophenol concentration on the removal efficiency. It can be observed that removal efficiency is decreasing by increasing primary parachlorophenol concentration. So when the primary parachlorophenol concentration is increased from 10 to 60 mg/l, the removal efficiency will be decreased from 88.59% to 75.95%, in the contact time of 90 min.

Surveying the correspondence of results with linear adsorption isotherms

Langmuir model is one of the most widely used models, which is valid for monolayer adsorption onto a completely homogeneous surface.[35] In the Langmuir equation (Eq. 2), q_e (mg/g) is the rate of the adsorbed phenol per weight unit of the prepared activated carbon, q_{max} (mg/g) is the maximum adsorption capacity of the prepared activated carbon, C_e (mg/l) is the equilibrium concentration, and K_L is the Langmuir constant.[36]

Langmuir model:

$$q_e = \frac{q_{\max} K_L C_e}{1 + K_L C_e} \quad (2)$$

Freundlich is a widely used isotherm model that assumes a heterogeneous adsorption surface with sites that have different energies of adsorption.[37] In this model, K_F and n are the Freundlich constants characteristic of the system. K_F ($mg^{1-1/n}\ l^{1/n}\ g^{-1}$) and n are indicators of adsorption capacity and adsorption intensity, respectively (Eq. 3).[38] The results showed that the found data are in accordance with Freundlich model (R^2 = 0.9958).

Freundlich model:

$$q_e = K_F C_e^{1/n} \quad (3)$$

Redlich-Peterson model contains three parameters and integrates the features of the Langmuir and the Freundlich isotherms (Eq. 4).[39]

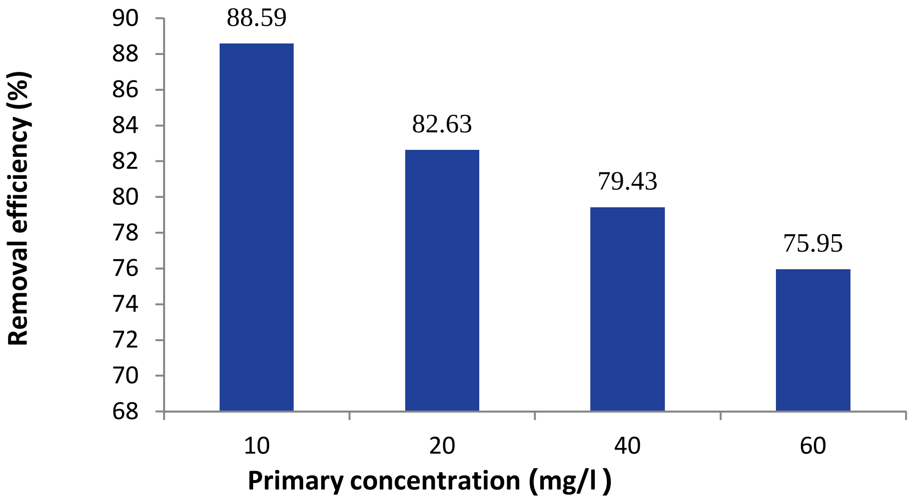

Figure 5. Effect of different concentration on parachlorophenol removal (the amount of adsorbent 0.4 g/l, pH = 3 and 30° C)

Redlich-Peterson model:

$$q_e = \frac{K_r C_e}{1 + a_r C_e^{\beta}} \quad (4)$$

The Temkin equation (Eq. 5) shows the effects of some indirect adsorbate/adsorbate interactions on adsorption isotherm. The heat of adsorption of all the molecules in the layer would decrease linearly with coverage.

Where in this model *A* is the Temkin isotherm constant (L/mg), b_T is the Temkin constant related to the variation of adsorption energy (J/mol), *R* is the universal gas constant [8.314 J/(mol K)], and *T* is the absolute temperature (K).[40]

Temkin model: $$q_e = \frac{RT}{b_t}\ln(a_t C_e) \quad (5)$$

Parameters calculated related to adsorption isotherms are provided in table 1. Different models of adsorption isotherms are shown in figure 6.

Conclusion

The special surface of produced activated carbon in this study was 111.702 m²/g and the total volume of the internal diameter of the hole was 0.124 ml/g. The percentage of parachlorophenol removal achieved at a higher temperature in lower pH. Results of this research showed that the produced activated carbon from used tires can be used as an effective and low-cost adsorbent for removing parachlorophenol from aqueous solutions.

Table 1. Parameters and contents adsorption isotherms

Parameter		Content
Langmuir	q_{max}	126.58
	B	181
	R^2	0.975
Freundlich	1/n	6534
	N	1.5304
	K_F	19.62
	R^2	0.9958
Redlich-Peterson	β	3794
	a_r	79.13
	K_r	130
	R^2	0.9828
Temkin	A	9.3447
	B	82.1045
	R^2	0.9331

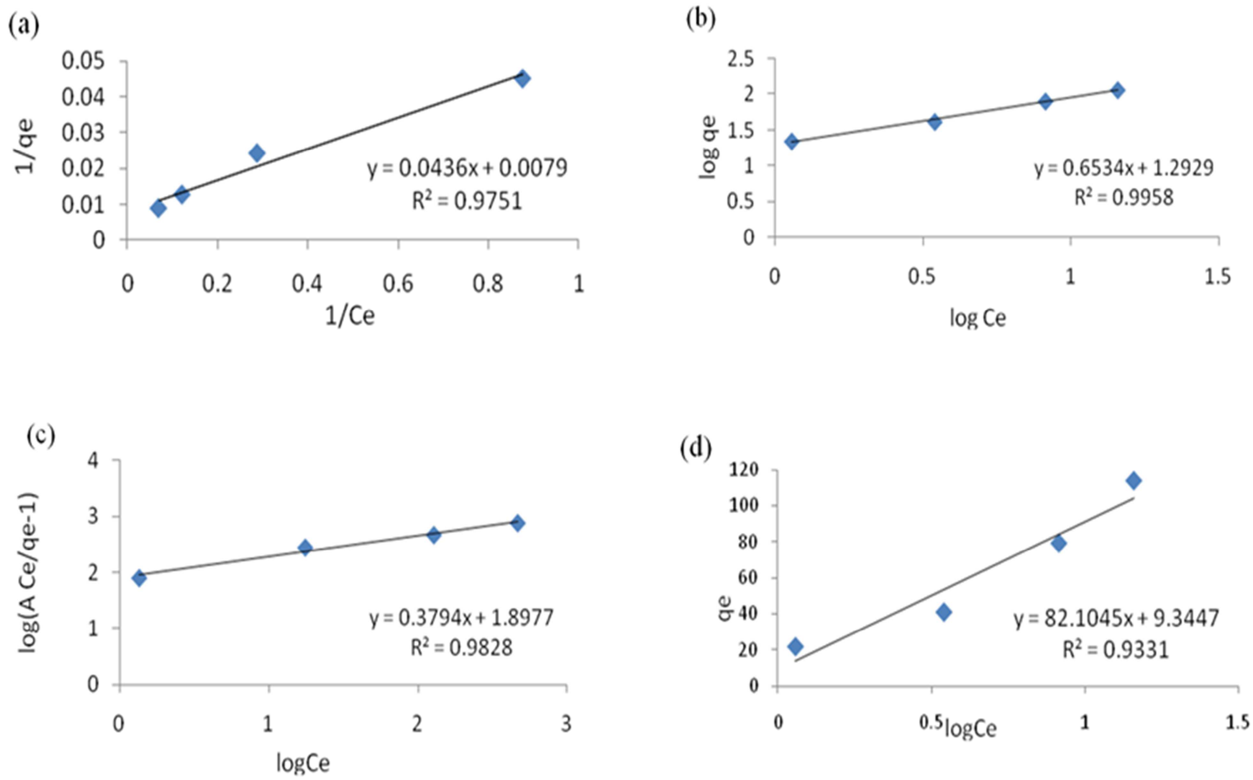

Figure 6. Adsorption isotherms for parachlorophenol whit activated carbon produced from used tires: (a) Langmuir model, (b) Freundlich model, (c) Redlich-Peterson model, and (d) Temkin model

Conflict of Interests

Authors have no conflict of interests.

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Journal of Advances in Environmental Health Research

Health impact assessment of particulate matter in Sanandaj, Kurdistan, Iran

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Original Article

Abstract

Air pollution is a major environmental issue in all regions of the world. We aimed to assess the health impacts of particulate matter with an aerodynamic diameter < 10 µm (PM_{10}) in Sanandaj, Kurdistan, Iran. The air pollution data were obtained from Sanandaj Department of Environment Protection. The annual mortality and morbidity, including cardiovascular and respiratory diseases attributable to PM_{10} exposure were estimated using AirQ model, which is the proposed method for health impact assessment of air pollution by World Health Organization. The annual, winter, and summer averages of PM_{10} in 2013 were 81.5, 64.7, and 98.3 µg/m^3, respectively. The total mortality, cardiovascular mortality, respiratory mortality, hospital admissions due to cardiovascular diseases, and hospital admissions due to respiratory diseases, respectively, were estimated 228, 120, 23, 118, and 305 cases. Approximately 11.7% of total mortality was associated with concentrations more than 20 µg/m^3. This study was the first attempt to assess the health impacts of air pollution in Sanandaj, Kurdistan, Iran. In summary, we found increased mortality and morbidity attributable to PM_{10} exposure.

KEYWORDS: Air Pollution, AirQ Model, Health Impact Assessment, Morbidity, Mortality, PM_{10}

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Introduction

Air pollution is a major environmental issue in all regions of the world.[1,2] Foundational epidemiologic studies have found a variety of chronic and acute health effects attributable to ambient air pollution.[3,4] These include hospitalizations, respiratory, and cardiovascular diseases.[5-12] The World Health Organization (WHO) estimated that the annual global burden of these health outcomes is roughly 865,000 premature deaths.[3] Furthermore, almost 150,000 lost lives in 2003 were attributed to ambient air pollution exposure in South Asia.[9]

One of the air pollutants that can penetrate deep into the human lung is particulate matter with aerodynamic diameters < 10 µm (PM_{10}). The health impacts of PM_{10}, such as asthma, bronchitis, impaired lung function and cardiopulmonary diseases are well-recognized.[13-16]

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In addition, many studies reported that short- and long-term exposure to PM_{10} can lead to elevated mortality and morbidity risks.[6,17-21]

Sanandaj is the capital city of Kurdistan province in North West of Iran. In recent years, the annual mean PM_{10} concentrations increased dramatically and there are many public concerns regarding this issue. Therefore, in this study, the authors aimed to assess the health impacts attributable to PM_{10} exposure in Sanandaj, Iran.

Materials and Methods

Sanandaj is the capital city of Kurdistan Province in North West of Iran. Based on the latest census report, the population is about 450,000 persons.[22] Meanwhile, it is located in the longitude and latitude of 47°00′ E and 35°32′ N and the altitude is about 1450-1538 m above sea level. The city is developing and non-industrialized (Figure 1).

The complete mean daily PM_{10} data from January 01, 2013 to January 01, 2014 were obtained from Sanandaj Department of Environment Protection. The data were for Azadi square monitoring station, which is a traffic station (Figure 1).

AirQ 2.2.3 software and its used approach has been proposed by WHO to estimate the impacts of short-term exposure to air pollutants on the health of the population. It has been developed to estimate the health impacts of exposure to specific air pollutants on a resident population in a certain area and period. In this software, health impact assessment of air pollutants is standing on the calculation of attributable proportion (AP) in which AP is the fraction of health consequences in a specific population that can be attributed to a specific air pollutant exposure with this notion that there is proven causative correlation between health consequences and air pollutant exposure. The AP can be easily calculated with the following formula:[21,23,24]

$$\mathrm{AP} = \frac{\sum\{[\mathrm{RR}(c)-1]\times P(c)\}}{\sum[\mathrm{RR}(c)\times P(c)]} \tag{1}$$

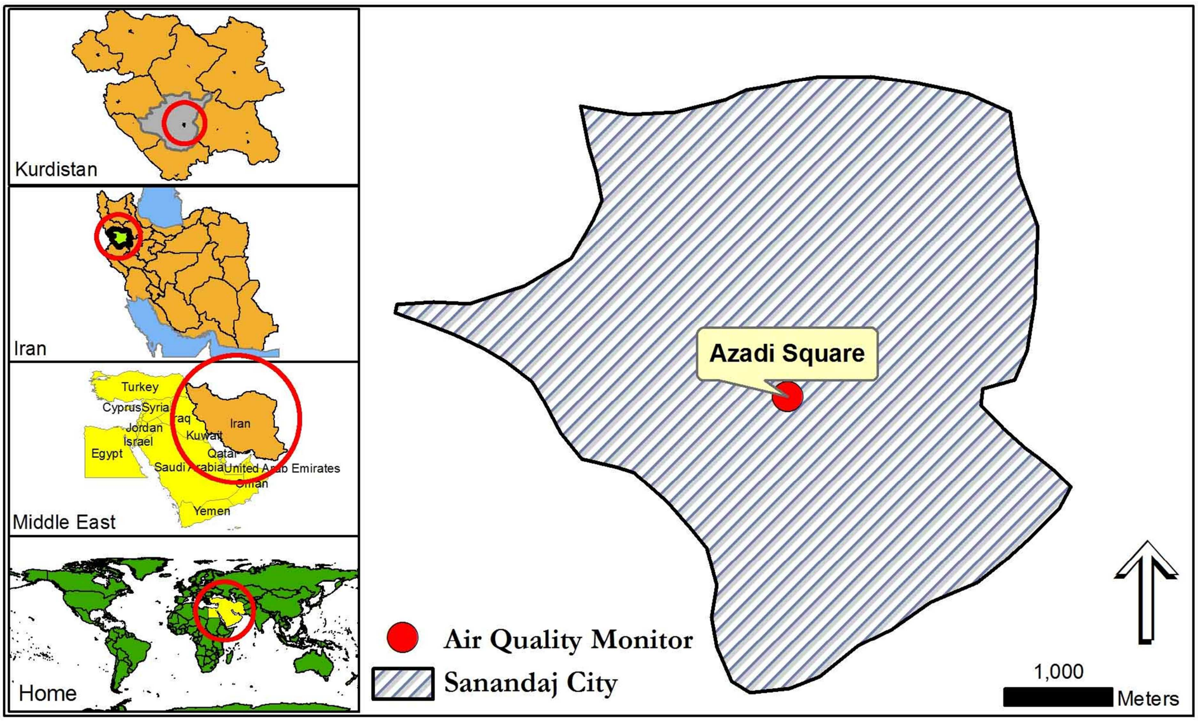

Figure 1. This study area of Sanandaj, Iran, and location of the air quality monitoring station in 2013

where RR denotes the relative risk for a given health endpoint, in category "c" of exposure, obtained from the concentration–response functions derived from wide literature (i.e., current existent epidemiological studies) and $P(c)$ denotes the proportion of the population in category "c" of exposure.

The rate attributable to the exposure can be calculated as the following equation if the baseline frequency of the health endpoint is known in the population:

$$\mathrm{IE} = I \times \mathrm{AP} \quad (2)$$

where IE denotes the rate of the health outcome attributable to the exposure, and I denotes the baseline frequency of the health endpoint in the population.

Finally, the number of cases attributable to the exposure can be estimated as the following equation knowing the size of the population:

$$\mathrm{NE} = \mathrm{IE} \times N \quad (3)$$

where NE denotes the number of cases attributed to the exposure and N denotes the size of the population investigated.[21,23,24]

In this research, mean daily PM_{10} data and exposed population were entered to the software for the period of January 2013 to January 2014. Afterwards, number of cases for total mortality, cardiovascular mortality, respiratory mortality, hospital admissions due to cardiovascular diseases, and hospital admissions due to respiratory diseases were calculated using relative risk and baseline incidence of WHO.[25]

Results and Discussion

This paper is a case study, which assesses the effects of PM_{10} on human health for people living in Sanandaj using a method developed by WHO. Figure 2 shows a summary of PM_{10} concentrations measured in Azadi Square Station in 2013. The annual average PM_{10} was 81.5 μg/m^3, which is two-fold of the European Union standard and much higher than WHO air quality guideline (20 μg/m^3). The highest PM_{10} concentration with a maximum value of 666.9 μg/m^3 was measured during summer.

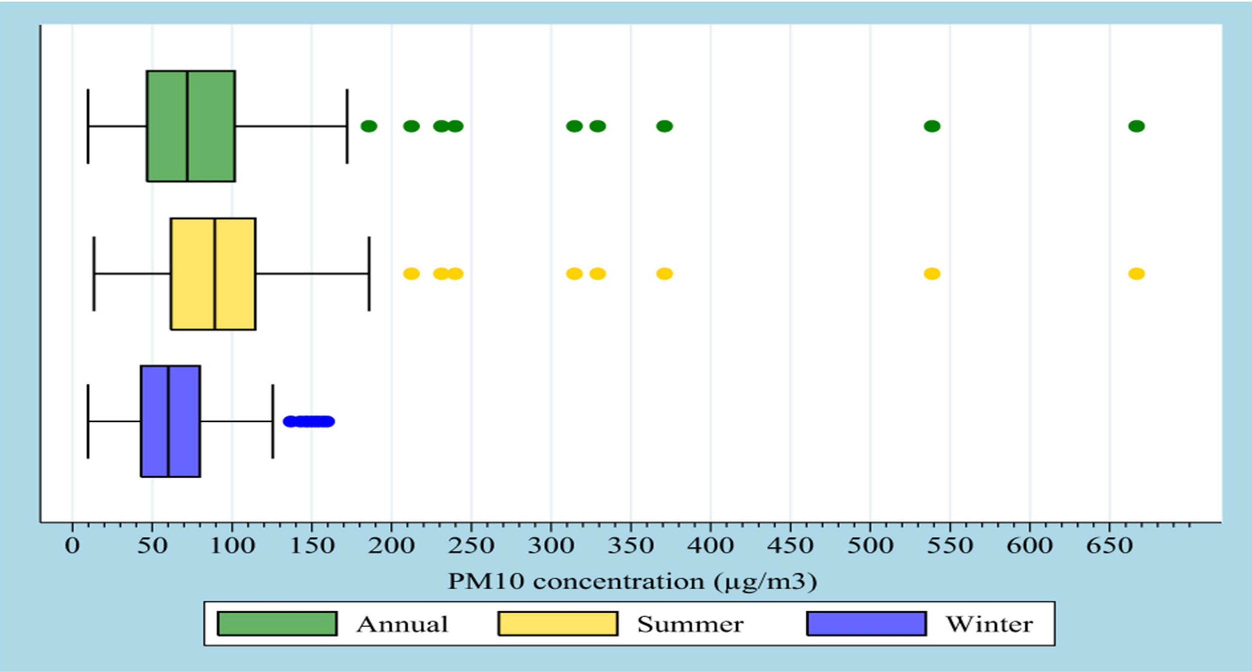

Figure 2. Descriptive statistics of measured particulate matter with aerodynamic diameters <10 μm concentrations in Sanandaj, Iran, in 2013

Figure 3 shows the percentage of time that people were exposed to PM_{10} concentrations. These data are used to estimate the short-term health effects. The highest percentage of person-days was associated with 40-49 µg/m³ of PM_{10}, which shows that maximum exposure days to PM_{10} were at these concentration ranges. In addition, this diagram demonstrates that with the increase in PM_{10} concentration the number of exposure days reduces.

The excess cases and estimated AP to PM_{10} for total mortality, cardiovascular mortality, respiratory mortality, hospital admissions due to cardiovascular diseases, and hospital admissions due to respiratory diseases are shown in table 1.

Figure 4 shows percentage of the cases related to aforementioned effects at different PM_{10} concentrations. Although a higher percentage of person-days was associated with 40-49 µg/m³ of PM_{10} (Figure 3), percentage of the cases related to health end points is relatively low; however, its maximum was occurred at 70-79 µg/m³ (Figure 4).

Fifty-one percent of short-term effects were happened at the time of concentrations not

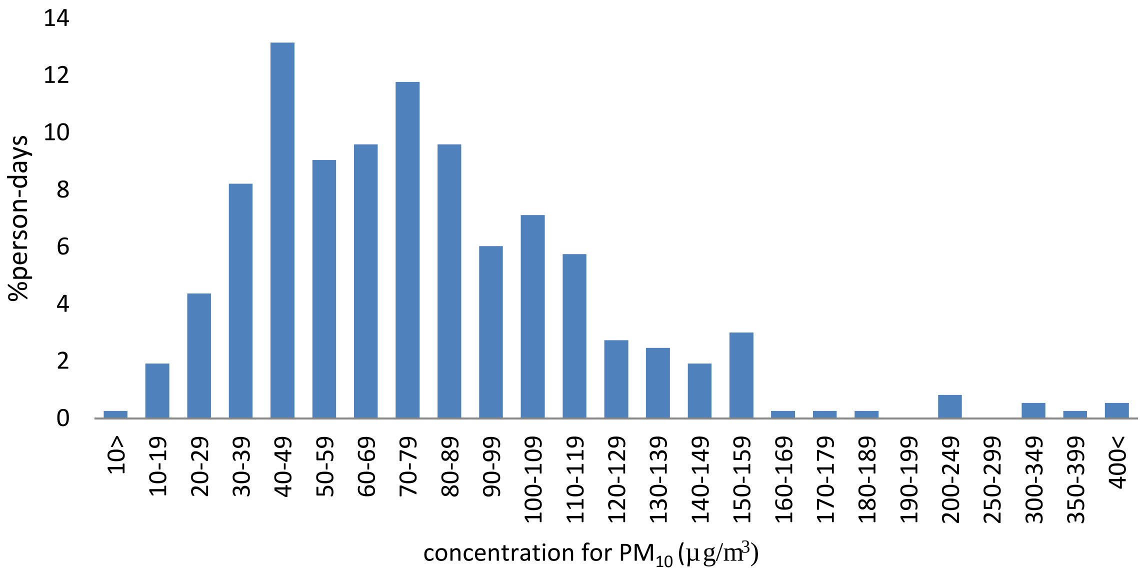

Figure 3. Percentage of days on which people in Sanandaj are exposed to different concentrations of particulate matter with aerodynamic diameters <10 µm

Table 1. Baseline incidence, relative risk, estimated attributable proportion, and number of annual excess cases due to short-term exposure to particulate matter with aerodynamic diameters <10 µm above 10 µg/m³

Health endpoints	BI*	RR	Attributable proportion in percent (uncertainty range)**	Number of excess cases (uncertainty range)**
Total mortality	1013	1.0074 (1.0062-1.0086)	5.0 (4.2-5.8)	228 (193-263)
Cardiovascular mortality	497	1.0080 (1.0050-1.0180)	5.4 (3.4-11.4)	120 (77-254)
Respiratory mortality	66	1.0120 (1.0080-1.0370)	7.9 (5.4-20.9)	23 (16-62)
Hospital admissions due to cardiovascular disease	436	1.0090 (1.0060-1.0130)	6.0 (4.1-8.5)	118 (80-166)
Hospital admissions due to respiratory disease	1260	1.0080 (1.0048-1.0112)	5.4 (3.3-7.4)	305 (187-419)

* Crude rate per 100,000 inhabitants; ** Obtained using the lower and upper RR values; BI: Baseline incidence; RR: Relative risk

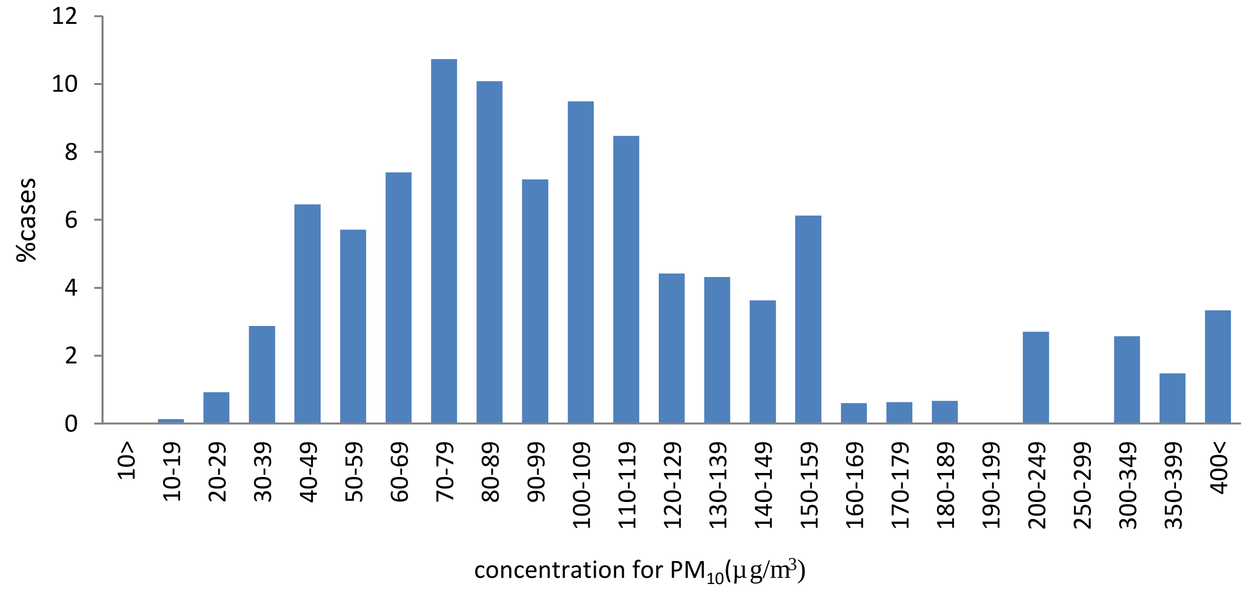

Figure 4. Percentage of a number of cases that are exposed to different concentrations of particulate matter with aerodynamic diameters <10 μm

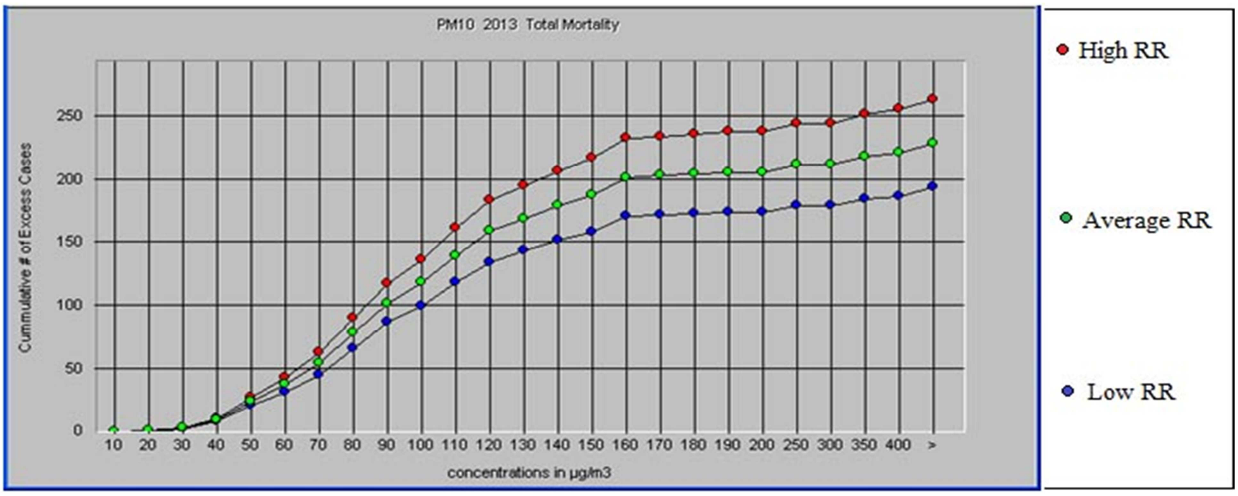

Figure 5. Estimated cumulative number of total mortality cases attributable to particulate matter with aerodynamic diameters <10 μm comparing concentration intervals by means of the model (Sanandaj, Iran, 2013)

RR: Relative risk

exceeding 99 μg/m³. In Sanandaj, with a population of 450,000, the total non-accidental mortalities were 1936 cases in 2013. Figure 5 also shows that the cumulative number of total mortalities were 228; therefore, based on this model 11.7% of them were related to concentrations over 20 μg/m³ of PM_{10}.

Another study conducted by Goudarzi et al. in 2008, showed that 4% of the total mortalities in Tehran were related to concentrations above 20 μg/m³.[26] In 2005, Tominz et al. utilized AirQ model, in order to measure health effects of PM_{10} in Trieste, Spain. They concluded that 1.8% of cardiovascular and 2.5% of respiratory mortalities were related to concentrations above 20 μg/m³.[27] A comparison between the results of the present study and other studies conducted in Tehran and Trieste shows that higher rate of mortality in Sanandaj can be related to higher mean concentration of PM_{10} or extent of days with high PM_{10} concentration in Sanandaj. In another studies on 29 European cities, 20 American cities, and some Asian countries, it was revealed that adverse health effects of short-term exposure to PM_{10} in cities of different developing and developed countries are identical and mortality rate increases by 0.5% after PM_{10} daily increase of 10 µg/m^3.[28-31]

Cumulative cases of different health end points attributed to PM_{10} concentrations are illustrated in figures 6-9. Figures showed three ranges of relative risk based on model's default, which were considered for assessing health effects of PM_{10}. The total number of cases for total mortality, cardiovascular mortality, respiratory mortality, hospital admissions due to cardiovascular diseases, and hospital admissions due to respiratory diseases in relative average risk were 120, 23, 118, and 305 persons, respectively. Seventy-three percent of them were related to the PM_{10} concentrations lower than 129 µg/m^3.

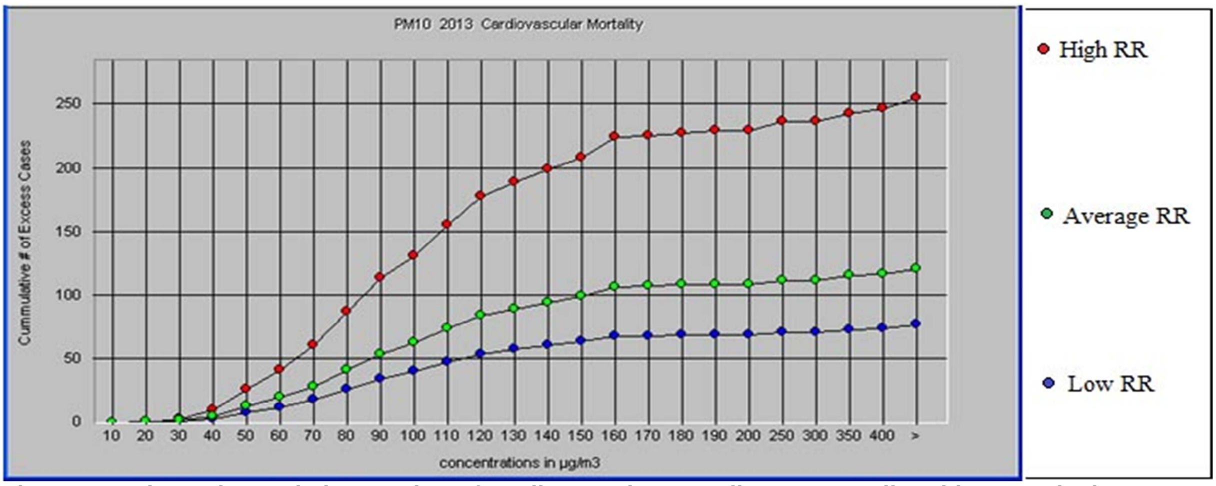

Figure 6. Estimated cumulative number of cardiovascular mortality cases attributable to particulate matter with aerodynamic diameters <10 µm comparing concentration intervals (Sanandaj, Iran, 2013)
RR: Relative risk

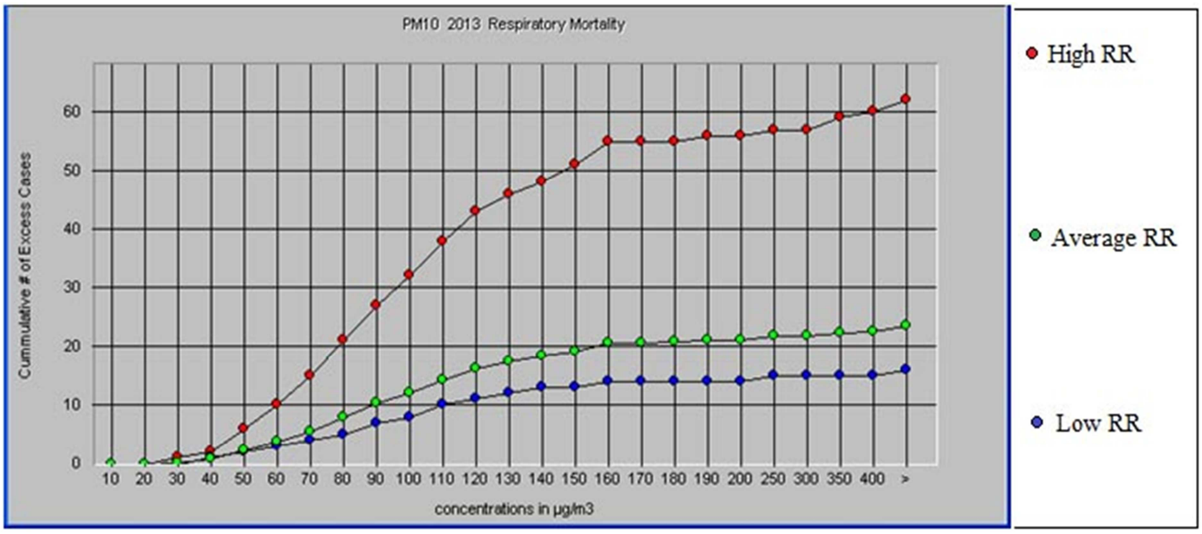

Figure 7. Estimated cumulative number of respiratory mortality cases attributable to particulate matter with aerodynamic diameters <10 µm comparing concentration intervals (Sanandaj, Iran, 2013)
RR: Relative risk

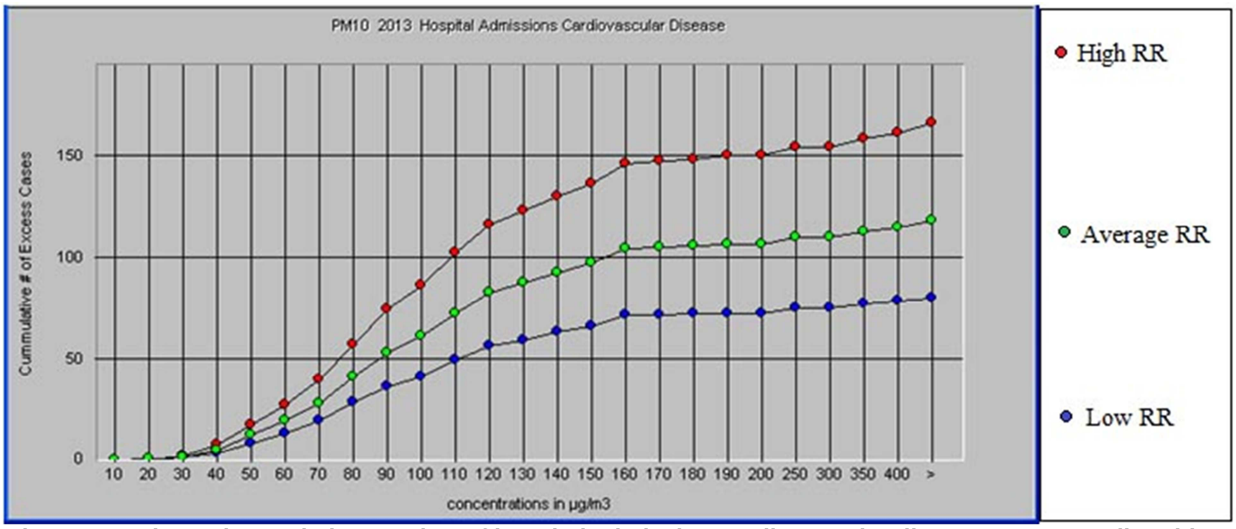

Figure 8. Estimated cumulative number of hospital admission cardiovascular diseases cases attributable to particulate matter with aerodynamic diameters <10 µm comparing concentration intervals (Sanandaj, Iran, 2013)

RR: Relative risk

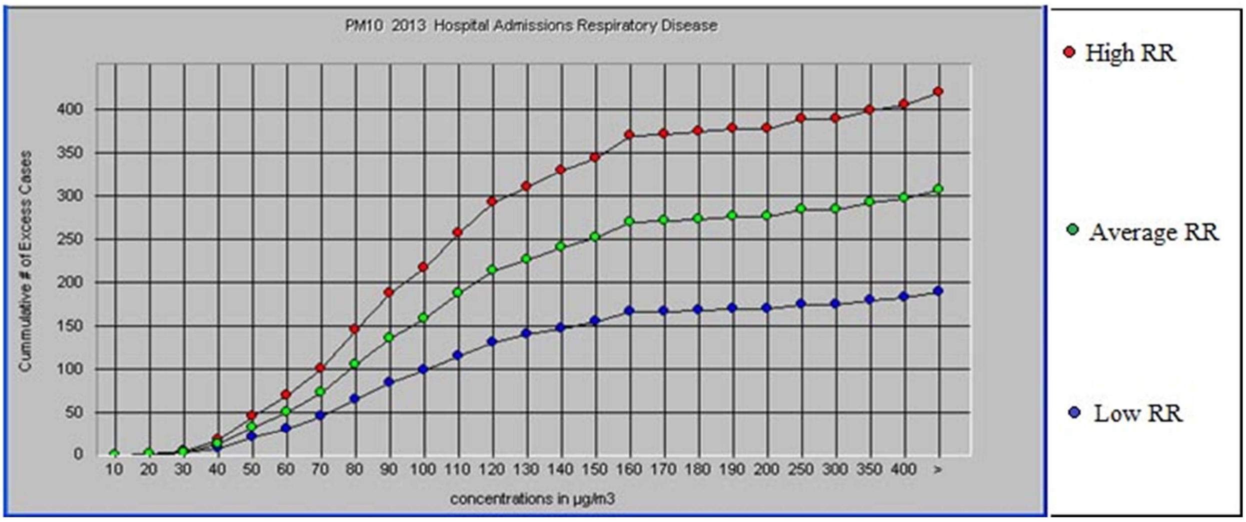

Figure 9. Estimated cumulative number of hospital admission respiratory diseases cases attributable to particulate matter with aerodynamic diameters <10 µm comparing concentration intervals (Sanandaj, Iran, 2013)

RR: Relative risk

Conclusion

The objective of this study was to measure the adverse health effects of PM_{10} on the Sanandaj people using AirQ software, which shows the effects of pollutants on residents of a certain area. The results of the present study are in line with other studies and reveal that 11.7% of mortality rates in Sanandaj are related to concentrations of PM_{10} above 20 µg/m^3. A comparison between the results of the present study and other studies conducted in Tehran and Trieste shows that higher mortality rate in Sanandaj is due to higher average PM_{10} or higher number of exposure days. Consequently, the health impact estimated for the city of Sanandaj underscores the need for urgent action to reduce the health burden of PM_{10}.

Conflict of Interests

Authors have no conflict of interests.

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Journal of Advances in Environmental Health Research

Pollution: Treating environmental toxins

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Book Review

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Environmental pollution resulted from toxic chemicals is a worldwide issue due to their toxicity, persistence, bioaccumulation, and biomagnification in the food chain. Therefore, in order to decrease toxicity of these materials, using a suitable strategy is crucial to find sources of pollution, to detect types of pollutants, and treating diseases caused by toxins. Selected topics have been clearly and logically arranged in "Pollution: Treating Environmental Toxins". The book contains eight chapters; each dealing with different aspects of environmental pollution resulted from the toxins entrance from the urban environment to the natural environment. After a general description of the importance of environmental medicine to diagnosing and treating illnesses caused by toxins in the environment in Chapter 1, the author gives details about environmental diseases and tools used in diagnosing diseases in Chapter 2. In this chapter, finding the source of an environmental toxin, the most important step in epidemiology of environmental diseases is presented. The basic information about environmental medicine and epidemiology of environmental diseases have been descripted in Chapters 1 and 2. The illustration of uptake mechanisms and toxin elimination by each tissue is very important in diagnosing diseases and their effects on the body; such aspects have been neglected in these two chapters. Chapter 3 deals with classifying toxins, entry mechanisms to the body, and body detoxification mechanism of toxic chemicals. The author presents general information about toxic metals; however, such information is not comprehensive about environmental toxins. This chapter needs to describe two sections: (1) use of toxic metal bioindicators such as fish, bird, and mosses species and (2) biomarkers of metal toxicity in living organisms such as metallothioneins, phytochelatins, and antioxidant enzymes. These two parts are useful in assessing metal exposure and the prediction of potential detrimental effects induced by environmental metal contaminants. Now-a-days, researchers are interested in biomonitoring the fate of novel materials to assess the environment contamination. Chapter 4 briefly focuses on three subjects: (1) air quality and pollutants in air, (2) electromagnetic fields, and (3) noise pollution. These kinds of pollution are growing

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rapidly in developing countries and have become an emerging environmental pollution. The illustration of tables and figures about related subjects in this chapter are very good and strength for this chapter. However, the author could give a brief introduction to new tools used to measure selective pollutants in the environment and suggest methods to reduce the amount of pollutants. Moreover, indoor air pollution consists of polyscale particles and toxic gases that can harm the human body such as tobacco smoke, organic chemicals, respirable particles and so on. In Chapter 5, contamination of food and water, their routes, and importance of water and food quality are explained. One of strongest points of this chapter is the illustration of major food-borne and water-borne illnesses, infections, and main sources of these illnesses. However, this chapter suffers from not illustrating the prevention routes. The author could give methods of treating water polluted by pollutants such as heavy metal, persistent organic pollutants, algae, bacteria, etc. under critical conditions such as flood, typhoon, earthquake, and so on. Regarding food section, it was better to present route of pollutants into the food web and the way pollutants affect the organisms, especially humans. Chapter 6 explains effective factors (such as age, health, inhabit place, and job) related to the populations at risk. Chapter 7 discusses about the use of environmental medicine in veterinary as a critical role protecting the diversity of life against environmental toxins. Finally, Chapter 8 refers to the importance of environmental medicine to human and animal as a tool to find sources of pollutions, to monitor organisms, and to improve methods for treating humans or animals' related diseases. Thus, providing general information on environmental pollution with reference to the toxicological aspects makes this book a valuable text for those concerned about environmental issues. Hence, we recommend the materials presented in this book be read by environmental scientists, researchers, and students of environmental sciences.