Evaluation of Groundwater Quality for Industrial Using GIS in Mountainous Region of Isfahan Province, Koh-Payeh, Isfahan, Iran

Mohammad Shayannejad¹, Zahra Ebrahim-Zadeh¹,
Mohsen Javaheri-Tehrani², Nastaran Zamani¹, Saeid Eslamian¹,
Maryam Marani-Barzani³, Vijay P. Singh⁴, Masoud Kazemi⁵,
Kaveh Ostad-Ali-Askari⁶*, Zahra Majidifar⁷, Hamid-Reza Shirvani-Dastgerdi⁸

¹Department of Water Engineering, Isfahan University of Technology, Isfahan, Iran
²Department of Water Engineering and Hydraulic Structures, Faculty of Civil Engineering, Semnan University, Semnan, Iran
³Department of Geography, University of Malaya (UM), 50603 Kuala Lumpur, Malaysia.
⁴Department of Biological and Agricultural Engineering and Zachry Department of Civil Engineering, Texas A and M University, 321 Scoates Hall, 2117 TAMU, College Station, Texas 77843-2117, U.S.A.
⁵Civil Engineering Department, Najafabad Branch, Islamic Azad University, Najafabad, Iran
⁶*Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran
⁷Department of Agronomy and Plant Breeding, Lorestan University, Lorestan, Iran

* Corresponding Author: Dr. Kaveh Ostad-Ali-Askari, Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran. Email: Koa.askari@khuisf.ac.ir

Abstract: Groundwater quality is gradually deteriorating due to agricultural activities and its evaluation is there for needed before use. The aim of this study was to evaluate groundwater quality for use in the foundry industry using water quality data, including pH, EC, TDS, Cl and HCO₃, from 26 wells located in Jolgeh and Bon-Rud districts, Iran. Zoning and classification of the area were done, based on groundwater quality, using a GIS software and the existing standards for water use. Results showed that groundwater in the East, North and Southwest of the area was of acceptable quality for use in the foundry industry, but water quality deteriorated from the East to the West of the area. It was found that for foundry industry about 4 percent of area ground water could be used without any limitation, 2 percent with low limitation, 7 percent with moderate limitations, and the rest with high limitation or even unusable. Agricultural activities in the region are having a negative impact on the quality of groundwater.

Keywords: Water quality, zoning, foundry industry, pH, EC, TDS, Cl, HCO₃, Jolgeh and Bon-Rud

1. INTRODUCTION

In recent years, many countries, especially those with dry climate, have been facing water shortages and have therefore resorted to indiscriminate use of groundwater that has led to the deterioration of ground water quality and reduction of groundwater resources. It has been estimated that Iran has 413 billion cubic meters of available water and 56 billion cubic meters are extracted from underground aquifers. In 2001, uncontrolled exploitation of about 5.5 billion cubic meters was recorded. Groundwater is the main source of water supply in dry and semi-dry areas [1-3] as well as for domestic consumption in many cities of Iran and for agricultural use. Therefore, attention should be paid to the quantity and quality of groundwater resources and their management, especially in dry and semidry areas. Given the scarcity of fresh water resources, crop management and decision-making on land use are of particular importance. Isfahan province, like many other parts of the country, has experienced two rare drought periods over the past 18 years since 1999. Droughts, particularly in the East of Isfahan, have led to drying of about 43 thousand hectares of agricultural land, causing huge damages to farmers who are leaving farmland, and migration from the region to other are asin several cases which is leading to negative social, cultural and economic consequences. In some areas, water quality...
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has deteriorated to the extent that groundwater is not usable agriculture. Under these conditions, solutions that can prevent increasing damages to residents are sorely needed. Also careful management of groundwater resources is needed. One of the remedies is land use change that can avert the crisis and help with the subsistence of families. Taking into account the climatic characteristics, topography of the area, the quality and quantity of water resources, area demands, etc., different uses including the construction of industrial workshops can be defined, which are consistent with the existing circumstances and family needs. Because of the water used in industry, water quality in the region should be evaluated and groundwater quality maps of the area should be prepared using GIS Geographical Information System. In the GIS environment, information obtained from various studies can be simultaneously examined. Information on each field forms a layer on the map and the layers can then be combined and analyzed [4-7].

There have been many studies on groundwater quality in Iran. Shabani 2008 investigated groundwater quality changes in Arsanjan plain using different geo-statistical methods, including ordinary and simple Kriging. Inverse Distance Weighting method (IDW), radial basis function (RBF), and local and general estimator. His results showed that ordinary and Simple Kriging (SK) methods were superior in the preparation of TDS and pH maps [8]. In order to update information and zoning of groundwater in terms of total hardness and total suspended solids, and determination of the most appropriate areas for the exploitation of groundwater considering potable water standards in Shiraz, samples taken from 137 wells were imported to Arc GIS software and using OK, SK, IDW and RBF interpolation methods and spherical, circular, exponential and Gaussian models, zoning maps of groundwater were developed in another study. Results showed that SK method was the best method for determining suitable areas for ground water exploitation.

In a study using 84 wells in Isfahan it was concluded that Krigning and Co-Kriging methods were not significantly different, but because of a lower RMSE value, Co-Kriging was used in Arc GIS for zoning of groundwater quality [9]. Taghi-Zadeh et al. 2008 used Co-Kriging to develop groundwater zoning maps in the Ardakan plain, Yazd[10-11]. Imran et al. 2014 used data from 36 wells in Southwest of Greece to develop water quality maps of the area by using ordinary Kriging. Results showed that the circular Variogram Method best fitted the EC, Cl and sodium adsorption ratio data and the spherical model best fitted the nickel and zinc data [12-13]. Yao et al. 2014 investigated an aquifer surface using 8 methods e.g. ordinary, simple, and universal Kriging, etc. and indicated that the Kriging methods yielded more accurate results than other interpolation methods [13-15]. In another study, Ordinary Kriging (OK) and (IK) index were used to find the spatial and temporal variability and the possibility of increasing groundwater salinity. It was concluded that the Kriging method was a useful technique for observation, evaluation and management of groundwater resources [16-19].

As mentioned before, water crisis, especially in the East of Isfahan including Jolgeh and Bon-Rud areas, has caused a lot of problems. For example, the average groundwater surface in the area has dropped from 16.41 meters in 2002 to 17.29 meters in 2009, and the average groundwater EC has increased from 9.192 in 1995 to 11.453dS/m in 2012 with an approximate increase in salinity of 25%. In this area there are large amounts of low-quality water. Under these conditions, the revival of low-water-consuming industries can help sustain local economy as well as industries for which water quality does not matter much, such as industries in which water is used as a coolant in keeping with regulations.

In this study, considering different geostatistical methods and existing standards of water consumption in industry, the foundry industry was selected for the Jolgeh and Bon-Rud districts in the Southeast of Isfahan province. Therefore, the aim of this study was to investigate the quality and spatial changes in groundwater characteristics, including EC, PH, TDS, and CL, and develop maps and perform feasibility study for application in the foundry industry using the Arc GIS software [20-24].

2. MATERIALS AND METHODS

2.1. Study Area

The study was conducted on the Jolgeh and Bon-Rud districts located in the southeast part of Isfahan province. Jolgeh district with a population of 19,822 is limited to the Kuhpayeh from north, to the Bon-Rud from east, to the central part of Isfahan from west and to the Jarqavieh from south. It includes Rudasht and Emamzadeh Abdol Aziz villages. The area of the district is 1824.6 square kilometers and...
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is located between the eastern lengths of 52°03’58” and 53°03’27” and northern latitudes of 32°09’37” and 32°41’31” with an altitude of 1,540 meter above sea level.

Bon-Rud district with a population of 26,299 is limited to the Kuhpayeh from north, to Yazd province from east and to the Jolgeh from south and west and includes Eastern Rudasht and Gavkhuni villages. The area of the district is 1721.4 square kilometers and is located between the eastern lengths of 52°24’48” and 53°03’33” and northern latitudes of 32°17’09” and 32°37’50” with an altitude of 1,477 meter above sea level. The location of Jolgeh and Bon-Rud districts is shown on the map in Figure 1 [25-32].

![Figure 1. Location of the Jolgeh and Bon-Rud districts on the map of Isfahan province](image)

2.2. Methodology

Data was collected by the Isfahan Regional Water Company in 2012 and consists of UTM coordinates of wells and PH, EC hydraulic conductivity, TDS (Total Dissolved Solids), CL and HCO3 values for each well. To map groundwater quality changes in the area, the GIS software was used. The GIS software can produce, process, analyze and manage geographic information spatial information. It is a computer software to manage and analyze spatial information with the ability to collect, store, analyze and display geographic spatial information. The ultimate goal of a GIS is to support decision-making, based on spatial information and its basic function is to obtain information from a combination of different layers of data obtained with different methods and with different perspectives [33-39].

Data was entered into the GIS and the zoning of study area was initiated. The normality of the data was examined by using the histogram. Then, zoning of the groundwater quality was done using three interpolation methods of IDW, Radial Basis Function and ordinary Kriging methods, as in the study of Zahedifar, Mousavi and Rajabi who used Ordinary Kriging for the zoning of groundwater quality [40-52]. Then, based on the lowest Root Mean Square Error RMSE and Mean Error ME values, the best interpolation was selected. However, results showed that in some of the interpolations, concentration ranges exceeded the minimum and maximum values. Therefore, an accurate estimate of the area was not achieved, since the above-mentioned methods were used for areas with normal data. However, Jahanshahi, Moghadam and Dehvary used Kriging in a study and obtained accurate results, because the data in the study area was normal [53-59]. Finally, groundwater quality interpolation was done again using the Topo to Raster interpolation method and EC, PH, TDS, Cl and HCO3 changes maps were developed separately. The maps were then classified and evaluated using Reclassify and Weighted sum functions in terms of water quality using Table 1 standards which was an estimation of the American standards for the industrial units’ construction as well as European, Malaysian and Korean Standards [60-78], to be used in the foundry industry.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>No limitation</th>
<th>Moderate to low limitation</th>
<th>High limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC (dS/m)</td>
<td>&lt; 3/5</td>
<td>3.5-8</td>
<td>&gt;8</td>
</tr>
<tr>
<td>TDS (mg/L)</td>
<td>&lt; 1500</td>
<td>1500-3500</td>
<td>&gt;3500</td>
</tr>
<tr>
<td>Na⁺ (meq/L)</td>
<td>&lt; 5</td>
<td>&gt; 5</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1. Standards of water quality for use in the foundry industry
3. RESULTS

Zoning results of groundwater quality for the foundry industry:

Figure 2 shows the EC changes in the study area. In addition, Table 2 shows the area classification based on the foundry industry standards.

![Figure 2. EC changes of the Jolgeh and Bon-Rud groundwater](image)

| Na⁺ (mg/L) | < 115 | > 115 | - |
| CL⁻ (meq/L) | < 4.75 | > 4.75 | - |
| CL⁻ (mg/L) | < 285.5 | > 285.5 | - |
| HCO₃(meq/L) | < 1.5 | 1.8-5.5 | > 8.5 |
| HCO₃(mg/L) | < 400 | 400-620 | > 620 |
| PH | Normal value (6.8 - 5.4) |

![Table 2. Area corresponding to each EC class](image)

<table>
<thead>
<tr>
<th>Area percent</th>
<th>Area</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.2</td>
<td>31526.5</td>
<td>&lt; 3.5</td>
</tr>
<tr>
<td>28.4</td>
<td>87912.214</td>
<td>3.8-5</td>
</tr>
<tr>
<td>61.4</td>
<td>190200</td>
<td>&gt; 8</td>
</tr>
</tbody>
</table>

As can be seen from Figure 2, the EC ranged from 0.43 to 21.51 dS/m with the highest value in the south and northwest of the area.

According to Table 2, most parts of the area had an EC over 8 dS/m and the average EC was 7.15 dS/m.

Figure 3 and Table 3 show Cl changes and classification of the area based on the foundry industry standards.

![Figure 3. Changes of groundwater Cl in Jolgeh and Bon-Rud districts](image)
Table 3. Area of each class CL

<table>
<thead>
<tr>
<th>range</th>
<th>Limitations</th>
<th>area</th>
<th>Area percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;285.5</td>
<td>No limitation</td>
<td>225.2</td>
<td>0.07</td>
</tr>
<tr>
<td>&gt;285.5</td>
<td>Moderate to low limitation</td>
<td>309400</td>
<td>99.95</td>
</tr>
</tbody>
</table>

According to Fig. 3, Cl changes from 0 to 6871.71 meq/L and the highest value was observed in the center and northwest of the area.

According to Table 3, most parts of the area had a Cl concentration over 285.5 meq/L and the average Cl concentration was about 290 meq/L.

Figure 4 and Table 4 show Na changes and classification of the area based on the foundry industry standards.

Table 4. Area of each Na class

<table>
<thead>
<tr>
<th>range</th>
<th>Limitations</th>
<th>area</th>
<th>Area percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;115</td>
<td>No limitation</td>
<td>5897</td>
<td>1.9</td>
</tr>
<tr>
<td>&gt;115</td>
<td>Moderate to low limitation</td>
<td>303700</td>
<td>98.1</td>
</tr>
</tbody>
</table>

According to Fig. 4, Na changed from 0 to 3816.88 mg/L and the highest value was observed in the center and west of the area.

According to Table 4, most parts of the area had a Na concentration over 115 mg/L and the average Na concentration was 124 mg/L.

Figure 5 and Table 5 show HCO3 changes and classification of the area based on the foundry industry standards.

Table 5. Area of each HCO3 class

<table>
<thead>
<tr>
<th>range</th>
<th>Limitations</th>
<th>area</th>
<th>Area percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>357.83</td>
<td>13.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>385.67</td>
<td>13.5</td>
</tr>
<tr>
<td>&gt;385.67</td>
<td></td>
<td>303700</td>
<td>98.1</td>
</tr>
</tbody>
</table>

According to Fig. 5, HCO3 changes from 0 to 385.67 mg/L and the highest value was observed in the center and west of the area.

According to Table 5, most parts of the area had a HCO3 concentration over 357.83 mg/L and the average HCO3 concentration was 385.67 mg/L.
Table 5. Area of each HCO₃ class

<table>
<thead>
<tr>
<th>Range</th>
<th>Limitations</th>
<th>Area</th>
<th>Area percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;400</td>
<td>No limitation</td>
<td>250800</td>
<td>81.01</td>
</tr>
<tr>
<td>400-620</td>
<td>Moderate to low limitation</td>
<td>58789</td>
<td>18.9</td>
</tr>
</tbody>
</table>

According to Fig. 5, HCO₃ changed from 13.5 to 557.83 mg/L and the highest value was observed in the center, south and west of the area.

According to Table 5, most parts of the area had an HCO₃ concentration less than 400 mg/L and the average HCO₃ concentration was 340 mg/L.

Figure 6 and Table 6 show PH changes and classification of the area based on the foundry industry standards.

Table 6. Area of each PH class

<table>
<thead>
<tr>
<th>Range PH</th>
<th>Area (ha)</th>
<th>Area percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5-8.4</td>
<td>309634.9</td>
<td>100</td>
</tr>
</tbody>
</table>

According to Fig. 6, PH changes from 6.9 to 7.93 mg/L and the highest value was observed in the north and east of the area.

According to Table 6, whole groundwater of the area can be used in the foundry industry with no limitation.

Figure 7 and Table 7 show TDS changes and classification of the area based on the foundry industry standards.
Table 7. Area of each TDS class

<table>
<thead>
<tr>
<th>range</th>
<th>limitations</th>
<th>area</th>
<th>Area percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1500</td>
<td>No limitation</td>
<td>11871.9</td>
<td>8.3</td>
</tr>
<tr>
<td>1500-3500</td>
<td>Moderate to low limitation</td>
<td>21263</td>
<td>6.9</td>
</tr>
<tr>
<td>&gt;3500</td>
<td>High limitation</td>
<td>276500</td>
<td>89.3</td>
</tr>
</tbody>
</table>

According to Fig. 7, TDS changes from 0 to 17134.0 mg/L and the highest value was observed in the center and west of the area.

According to Table 7, most parts of the area had a TDS concentration over 3500 mg/L and the average TDS concentration was 3872.5 mg/L.

Figures 8 and 9 show the classification of the area based on all mentioned components’ standards. In Figs. 8 and 9, the same and different factors of the impact can be observed, respectively.

In Fig. 9, the impact factor of HCO₃ and TDS was considered as 3 because of the possible clogging of pipes, and the impact factor of Cl was considered as 2 because of the possible corrosion of pipes, and the remaining impact factors were considered as 1. As can be seen because of different classification bases of the two figures, different limitations were observed, but in both cases the area was divided into 5 classes based on the software standards. Table 8 shows the area corresponding to different classes in Fig. 8.

Table 8. Area corresponding to different classes in Figure 8

<table>
<thead>
<tr>
<th>row</th>
<th>Limitation</th>
<th>area</th>
<th>Area percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No limitation</td>
<td>8084.51</td>
<td>2.61</td>
</tr>
<tr>
<td>2</td>
<td>Low limitation</td>
<td>3750.31</td>
<td>1.21</td>
</tr>
<tr>
<td>3</td>
<td>Moderate limitation</td>
<td>13574.21</td>
<td>4.39</td>
</tr>
<tr>
<td>4</td>
<td>High limitation</td>
<td>17589.08</td>
<td>5.68</td>
</tr>
<tr>
<td>5</td>
<td>Rejected</td>
<td>266553.87</td>
<td>86.11</td>
</tr>
</tbody>
</table>

Table 9 shows the area corresponding to different classes in Figure 9.

Figure 9. Classification of the area considering standard ranges of all the components with different impact factors.
According to Table 8, most parts of the area cannot be used for the foundry industry and generally, 8.21 percent of the area has no limitation to low limitation for use in the foundry industry. However, according to Table 9, most parts of the area have high limitation for use in the foundry industry and generally, 12.24 percent of the area has no limitation to moderate limitation for use in the foundry industry.

4. CONCLUSIONS

Due to corrosion and clogging potential of pipes, a higher impact factor should be considered for the Cl, HCO3 and TDS parameters. Therefore, according to Table 9 only 4 percent of the total area groundwater can be used in the foundry industry with no limitation, which is too small. It is recommended to treat low limitation groundwater of other areas using water treatment devices so that can be used for industrial use.

The very small percentage of the area groundwater with no limitation for use in industry suggests that no agricultural activities should be undertaken in the area, because of 26 wells only 3 wells have an EC less than 3 dS m. This is against what Chitsazan, Botvandi and Majedi indicated in their research on zoning groundwater quality of Ghal’e Khaje plain, Khuzestan that the majority of the plain has a good to average groundwater quality for agricultural purposes, and just a small amount of the area groundwater quality is not suitable.

Not only the area groundwater is not suitable for agriculture purposes, but also just a small amount thereof is suitable for industrial use. Therefore, management practices must be considered to prevent further contamination of the area groundwater in the future as well as removing the current contamination to an acceptable level in order to render suitable for use in industry.

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Evaluation of Groundwater Quality for Industrial Using GIS in Mountainous Region of Isfahan Province, Koh-Payeh, Isfahan, Iran


AUTHORS’ BIOGRAPHY

Dr. Mohammad Shayannejad, is an associate professor in the Department of Water Engineering, College of Agriculture, Isfahan University of Technology, Iran. He was awarded a PhD in irrigation and drainage engineering from the University of Tarbiat Modarres, Tehran, Iran. He has more than 17 years of research, teaching, and technical consulting experiences in irrigation and drainage engineering.

Zahra Ebrahim-Zadeh, Department of Water Engineering, Isfahan University of Technology, Isfahan, Iran

Mohsen Javaheri-Tehrani, Department of Water Engineering and Hydraulic Structures, Faculty of Civil Engineering, Semnan University, Semnan, Iran.

Nastaran Zamani, Department of Water Engineering, Isfahan University of Technology, Isfahan, Iran

Professor Saeid Eslamian, is a full professor of water system engineering in the Department of Water Engineering at Isfahan University of Technology, Iran, where he has been since 1995. He received his PhD from Civil and Environmental Engineering School, University of New South Wales, Sydney, Australia, under the supervision of Professor David Pilgrim. His research focuses mainly on water resources planning, management, and sustainability and statistical and environmental hydrology in a changing climate. Formerly, he was a visiting professor at Princeton University, New Jersey, and University of ETH Zurich, Switzerland. On the research side, he started a research partnership in 2014 with McGill University, Montreal, Quebec, Canada. He has contributed to more than 770 publications in journals, books, or as technical reports. He is the founder and chief editor of both the International Journal of Hydrology Science and Technology (Scopus, Inderscience) and the Journal of Flood Engineering. Professor Eslamian is also associate editor of the Journal of Hydrology (Elsevier) and Hydrology and Hydrobiology (Elsevier). He has authored more than 250 book chapters and books. Recently, Professor Eslamian published eight handbooks with Taylor & Francis Group (CRC Press) as chief editor: a three-volume Handbook of Engineering Hydrology (2014), Urban Water Reuse Handbook (2015), a three-volume Handbook of Drought and Water Scarcity (2017), and Underground Aqueducts Handbook (2016).

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**Professor Vijay P. Singh**, Ph.D., D.Sc., D. Eng. (Hon.), Ph.D. (Hon.), D.Sc. (Hon.), P.E., P.H., Hon. D. WRE, Academician (GFA), Distinguished Professor, Regents Professor, Caroline and William N. Lehrer Distinguished Chair in Water Engineering
President, FARA, President, G.B.S. Board, Editor-in-Chief, Water Science and Technology Library Book series, Editor, Global Water Resources Book Series, Editor-in-Chief, Journal of Ground Water Research, Editor-in-Chief, Open Agriculture, Editor, Journal of Agricultural Research, Department of Biological and Agricultural Engineering &Zachry Department of Civil Engineering, Texas A and M University.

**Masoud Kazemi**, M.Sc. student of Civil Engineering, Civil Engineering Department, Najafabad Branch, Islamic Azad University, Iran. He has been an expert in various projects of Civil Engineering and technical software such as AutoCAD and MATLAB® programming

**Dr. Kaveh Ostad-Ali-Askari**, is a PhD of civil engineering, Department of Water Resources Engineering, Faculty of Civil Engineering. His topics of interest include Groundwater Hydrology, Irrigation and Drainage Engineering, Sustainable Development and Environmental Assessment, Climate and Integrated and Sustainable Water Resource Management, Water System Engineering, Water Resources Planning, Artificial Neural Network, and Genetic Algorithm. He has contributed to more than 125 publications in Journals, Books and Technical Reports. He collaborates as Editorial Board Membership in more than 45 Journals and as reviewers in more than 30 Journals. Currently, he is a Faculty Member of the Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Iran. He is Editor-in-Chief of International journal of Rural Development, Environment and Health Research (IJREH) and Associate Editorial Board Membership of International Journal of Environmental Sciences & Natural Resources (IJESNR) and Civil Engineering Research Journal (CERJ), Juniper Publishers. He was a Visiting Assistant Professor at Canadian University Dubai (CUD), Dubai, UAE, and American University in Dubai (AUD), UAE. On the research side, he started a research partnership in May 2017 with Concordia University in Montreal, Quebec, Canada.

**Zahra Majidifar**, She has a Bachelor in Agronomy and Plant Breading from Lorestan University, Iran. Her interested topics are GIS AND Agronomy.

**Hamid-Reza Shirvani-Dastgerdi**, M.Sc. of Civil Engineering, Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran.


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