The mega city of Tehran water quantity assessment based on DPSIR model

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Abstract. One of the most important factors of urbanization is healthy water supplement. Tehran as a megacity suffers from not only overcrowding but also lack of water. Tehran water supplements are both groundwater and surface resources. Surface water resources are including Karaj, Lar, Latian, Taleghan Dams and Tehran-Karaj Plain is its groundwater resources. Therefore, Tehran-Karaj Plain is considered as a target area in this study. The target area is located between 51°05' and 51°10' longitude and 35°02' and 35° 57' latitude with approximately 2704Km2. The urban rivers are originated from the Alborz Mountains and received urban runoff, and secondary effluent of Tehran Wastewater Treatment Plants which ultimately collected in Bande Alikhan in the southern part of Tehran. The evaluation of Tehran water quantity by DPSIR Model is considered in this paper. Driving forces, Pressures and the Status of water quantity will represent and their impacts on the city will also investigate.

1. Introduction
Iran with 1748000 Km2 has six primary basins, Central Plateau is the biggest basin which it's average precipitation is 150 mm/year. Although this basin suffers a lack of water, some of the biggest Iranian cities are located in it. Tehran, the capital, is in this dry area. A variety of methods has considered supplying Tehran water demand, for example water transmission from the other basins. Tehran Dams are in Khazan Basin but water transmitted by Tunnels to supply Tehran water demand.

On the other hand, Tehran rapid population growth, high immigration rate to this city and the type of demand and consumption of its citizens have increased the challenges of water supplement. Lack of appropriate humidity and air pollution and air pollution are also two important factors which decrease rainfall in this city. Above all, the amount of existing surface and groundwater resources do not supply water demand appropriately. On the other hand, industries and agricultural demands are also limited water resources in this area. Tehran-Karaj plain is in the Iran central plateau, and is surrounded by Alborz mountain in the north, Bande Alikhan in the south, Jajrood and Sorkhe Hasar in the east and Shoor River in the west. The area of this plain is approximately 2704 Km2. The source of its rivers is Alborz Mountain in the north, then it receives industrial and urban runoff in the southern part of Tehran. They flow to Kavir Markazi in the southern part of Tehran [1]. Tehran suffers from not only the increase in drinking water demand but also an increase in water pollution. Dry hydrological circumstances (250 mm rainfall), overcrowding and climate change has caused some difficulties and complications in Tehran water resources management [2].
2. Material and methods

DPSIR model is used to evaluate Tehran Environmental Status and water quantity is one of the main factors. This model is based on causes and effects chain of data analysis which connect environmental information with a variety of different indexes. Then appropriate responses and solutions will consider improving different aspects of indexes. The framework has 5 main elements, referring to figure 1, which relate processes and environmental status with human factors and the impacts of human activities. Tehran elements are included:

- Driving forces: some main factors which affect the other variables
- Pressures: natural and human elements which directly affect environmental status.
- Status: environmental quality and natural resources quantity affected by pressures.
- Impacts: the results of negative changes in the status of human and ecosystem health and welfare.
- Response: accepted measures to decrease negative impacts

Figure 1. DPSIR model for water quantity of Tehran megacity.

3. Driving force

3.1. Population

Population growth has a direct impact on water demand and consumption in urban areas. The rate of Tehran population growth was 86% from 2006 to 2011.

3.2. Urbanization and water consumption

Urbanization growth in Iran will threat water safety in Iran because rapid urbanization will change water consumption pattern. The rate of Tehran urbanization was 90% in 2011.

3.3. Urban green spaces

Urban green spaces are one of the most important of water consumption in cities [3]. Urban green spaces have a significant role in air pollution treatment and temperature balance of Tehran megacity. Tehran green spaces area was 10139.9 ha in 2011, approximately 16.5% of the city total area.

3.4. Industries

Industries need a great deal of water. The expensive treatment process is needed to treat Industrial wastewater to become appropriate for agricultural or industrial uses [4]. Water allocation to industrial purposes has increased from 2008 to 2010, for example, Latian Dam with 0.47 MCM. [5].

4. Pressures

4.1. Water consumption
Tehran water consumption is depended on surface water resources (Dam reservoir) and groundwater resources (figure 2). The total amount of water has increased from 1019 MCM in 2008 to 1034 MCM in 2010. Use of groundwater resources had 10% decreases in 2009 and it was constant in 2010.

![Figure 2. Surface and groundwater consumption (MCM), [6], [7], [8], [9].](image)

4.1.1. Dam reservoir water
The maximum use of dam reservoirs water in the target period was related to drinking water, except Taleghan Dam which its agricultural supply was much greater than drinking water supplies. Taleghan Dam supplied a maximum amount of water and Lar Dam the minimum amount of water, 390.19 MCM and 147.893 MCM respectively in 2010 and 2008 [5].

4.1.2. Total consumption and per capita consumption of drinking water
The trend of Tehran total Water consumption shows an increase from 1998 to 2010 and was 886 MCM and 1033 MCM respectively (figure 3). Considering population growth, Tehran per capita consumption has decreased in 2009 and it was constant in the target period. The amount of this index was 351, 347 and 350 MCM in 2008, 2009 and 2010 respectively [4], [2].

![Figure 3. Total water consumption of Tehran, 2008 to 2010. [4], [9].](image)

4.2. Water losses
The average amount of water losses in Tehran Megacity is 29.53% and has a decreasing trend (figure 4). One of the most important factors in water losses, particularly in Tehran, is pipe erosion in the drinking water network, which is approximately 25% to 30%. While based on global standards, water losses are approximately 5%.

![Figure 4. Water losses in Tehran [10].](image)

4.3. Rainfall and evaporation
The investigations on rainfall in basins which supply Water of Tehran dams has shown a decrease in the amount of rainfall in the period of 2008 to 2010 in contrast with the period of 1998 to 2007 period. Taleghan Dam was operated in the recent period. The minimum and the maximum amount of rainfall in Tehran Dam's basins have occurred in 2008 and 2010 with 734.6 mm and 1428.4 mm respectively from 2008 to 2010 (figure 5). Karaj Dam and Taleghan Dam had the maximum rainfall and minimum rainfall with 433.1 mm and 78 mm in 2009 and 2008 respectively. The maximum and minimum amounts of evaporation have occurred in Latian Dam (2013 mm) and Lar Dam (905 mm) in 2009. The total amount of evaporation had its peak in 2010.
5. Status
Karaj, Lar, Latian and Taleghan Dams were responsible for surface water control, drinking, agricultural and industrial water demands. The information of Tehran Dam Reservoir is shown in figure 6.

5.1. Existed water in Tehran water resources dams
Karaj, Lar, Latian and Taleghan Dams were responsible for surface water control, drinking, agricultural and industrial water demands. The information of Tehran Dam Reservoir is shown in figure 6.

5.2. Existed water in groundwater resources
Tehran-Karaj aquifer is located in the central plateau of Iran. The average amount of Tehran aquifer drop is approximately 18 cm per year. The average amount of Tehran aquifer drops in the area of Kan River which supply Tehran drinking water is approximately 1m per year in recent 11 years. It is predicted that the circumstances of Tehran aquifer drop will be much more critical in the future when Tehran wastewater networks will be completed and recharge of the aquifer will decrease. Tehran aquifer supplies 30% of Tehran drinking water in normal years and 60 to 70% in dry years, therefore structural and nonstructural measures should be considered for balances purposes. Using Tehran groundwater for drinking water purposes is approximately 300 MCM and return water from urban uses to Tehran aquifer is approximately 373 MCM [1], [12]. Tehran groundwater level is shown in figure 7. The results of groundwater hydrograph of Tehran-Karaj Plain show groundwater level has a decline of 36.17 MCM and 65.34 MCM in 2009 and 2010 respectively.

6. Impacts
Because of Tehran extend and the huge immigration to this city, there is a growing trend of population growth. Tehran green spaces have also a growing trend. Both of aforementioned factors have a direct impact on water demand.
6.1. The problems of groundwater resources
Excessive usage of groundwater resources has had catastrophic impacts. The mixture of groundwater resources with wastewater, because of uncompleted wastewater networks, caused the aquifer became contaminated. Drinking water allocations caused the increase of illegal wells for agricultural and industrial purposes.

6.2. Decrease of surface water due to the operation of wastewater network
The main source of surface water in the southern part of Tehran is urban and industrial wastewater. Based on Tehran wastewater plan, wastewater networks of 22 areas of Tehran will be completed in 2031. This measure will save groundwater resources from contamination in the future [12].

7. Responses
7.1. The last period responses
- Organizing groundwater resources committee in Tehran municipality in 2003 to improve the circumstances of Tehran Aqueducts
- Identification of groundwater resources
- The project of geographical positioning of Tehran Aqueducts (751 wells)
- Mapping project and producing database location of Tehran Aqueducts (6 Aqueducts), and preparing GIS layer

7.2. Guidelines, regulations and adopted strategies
- The studies of urban and rural wastewater treatment plants, in construction or operation, which is imparted in 2008
- The guideline of identification of free, banned and critical banned plains, which is imparted in 2008
- The studies of surface water and wastewater projects, which is imparted in 2010

7.3. Measures and studies
Wastewater networks have a vital role to improve the groundwater quality. The number of wastewater subscriptions (installed and sold) shows an increasing trend in the target period [4]. Figure 8 shows the number of installed and sold wastewater subscriptions [4].

7.3.1. Comprehensive plan of Tehran raw water
This plan is implementing in 640ha in 22 Tehran areas. Its targets are mentioned below:
- Separation of drinking water network from the raw water network
- Improvement of drinking water quality
- Reduction of drinking water consumption (approximately 35%)
- Using modern irrigation systems.
- Using secondary effluent of wastewater treatment plants for irrigation of green spaces

8. Conclusions and suggestions
Nowadays in our modern world, healthy water supply and urban wastewater treatment and its disposal are considered as an important factor to analyze urban community’s development. There are different methods to evaluate water quantity status in megacities. The status of water quantity with the DPSIR model has considered in this paper. Driving forces, pressures, status, impacts and related responses have also considered. Solutions for different indexes have considered in table 1.
Table 1. Solutions for different indexes of water quantity.

| Sector                  | Index                  | solutions                                                                 |
|-------------------------|------------------------|--------------------------------------------------------------------------|
| Driving Force           | Population             | Transfer activities from Tehran to the other cities                      |
|                         |                        | Improvement the facilities of the other provinces                        |
|                         |                        | The policies of encouraging people from Tehran to the other cities         |
|                         |                        | Increasing public awareness about changing consumption method           |
|                         |                        | Increase water cost and remove subsidies                                 |
|                         | Urbanization and       | Using appropriate flora species in green spaces area with low water demand|
|                         | overconsumption        | Using secondary effluent treatments for green spaces irrigation          |
|                         | Green spaces           | Improvement of irrigation systems and using pressured irrigation systems  |
|                         |                        | to increase water efficiencies                                            |
|                         | Industries             | Transfer industries from Tehran to the other cities                      |
| Pressures               | Using surface and      | Improvement of water consumption pattern                                 |
|                         | groundwater water      | Using facilities which decrease water consumption                         |
|                         | consumption Major      | Water consumption management in Tehran major water consumers with using modern irrigation systems |
|                         | consumers              |                                                                          |
|                         | Water losses           | Improvement of water distribution systems and prevention of water losses  |
| Status                  | River and surface water flow | A revival of water river and urban water runoff                          |
|                         | The existed water in dam water resources | Preventing water losses in the dam water reservoir, considering environmental water flow in the river downstream |
|                         | Wastewater secondary treatment effluents | Improvement of water and wastewater treatment plant facilities Compl | |
|                         | Groundwater level      | Preventing groundwater level drop and land subsidence with discharge water to aquifer and aquifer protection Identification and improvement of Tehran Aqueducts and groundwater resources |
| impacts                 | The impacts of lack of water | Environmental flow in dam downstream Decr | |
|                         |                        | ease of water consumption with correction of water use pattern              |

References

[1] K., Mohammadi, "Preparation of Tehran-Karaj Aquifer vulnerability, Tarbiat Modares University, 2006
[2] A., Salavitabar, M., Zarghami, A., Abrishamchi, "Dynamic Model in Urban Drinking Water", Water and Wastewater Journal, (2006)
[3] A., Abdolghafoorian, M., Tajrishi, A., Abrishamchi, "Urban water resources Management, considering secondary treatment effluent and runoff as new water resources", Water and Wastewater Journal, (2011)
[4] Tehran statistics, Information and Connection Organization of Tehran municipality, (2010)
[5] Statistics Reports, Water Supplement Facilities Operation Office, Iran Water Resources Management Co., (2012)
[6] Tehran statistics calendar, Information and Connection Organization of Tehran municipality, (2008)
[7] Tehran statistics calendar, Information and Connection Organization of Tehran municipality, (2009)
[8] Tehran statistics calendar, Information and Connection Organization of Tehran municipality, (2010)
[9] Tehran State of Environment Report (SoE) (1998-2007), Tehran Municipality, (2011)
[10] Statistics Reports, Tehran Water and Wastewater Co, (2011)
[11] Statistics Reports of Tehran Dams, Tehran Regional Water Co., (2013)
[12] Improvement of runoff water in the southern part of Tehran, Iran Water Resources Management Co., (2011)