Application of Geographical Information System (GIS) in Analysis and Detection of Microbial Contamination in Water Supply Network

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Abstract

Background: Nowadays, in the world's optimal management of science and technology, the use of geographical information system (GIS) is a necessity. In this study, GIS was used to analyze and detect microbial contamination in the water supply system of Masiri city.

Methods: A cross-sectional study utilizing spatial analysis techniques was conducted to find out the water quality problems of water supply system. In this descriptive-analytical study, 400 water samples from all groundwater resources of Masiri city were conducted during two periods of dry and wet season. Residual chlorine, MPN and E.coli of the samples were determinate.

Results: Results were compared with national standards and analyzed using SPSS and ArcView software. Concentration distribution map in GIS and the factors affecting Residual chlorine, MPN and E.coli changes were investigated. According to the results obtained in ArcView, it is necessary to improve the microbial quality of Masiri water distribution network in some places, which can be improved by proper management of chlorination and defects.

Conclusion: It is concluded that a combination of water quality parameters and GIS methods is very useful as GIS provides efficient capacity to visualize the spatial data.

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Introduction

Increasing population growth in the country and meeting the needs of the population, environmental pollution, drought, earthquake, climate change, diseases and many other geographical-related crises require a systematic, comprehensive and optimized thinking, in quality control of drinking water.[1, 2] In today's world of optimum management of science and technology, the use of Geographical Information Systems (GIS) is a necessity. GIS comprise a wide range of facilities to manage spatial data and are well established in environmental sciences.[3] The implementation of different and scattered mechanized systems in different sectors as well as the heterogeneity and decentralization between them has become an important factor in the re-workings, high costs and waste of forces and resources. Therefore, a coherent and organized database greatly reduces the cost and number of forces and the amount of resources and information stored, and increases the speed and capabilities of its planning and deployment capability of ArcView software developed by ESRI in many fields including engineering, environmental management, urban public information, forestry, regional development, water, electricity, gas, sewage and irrigation and drainage, natural resources, aerospace, tourism, statistics and most importantly health. Due to the vast amount of research in the quality control sector of water distribution network and increasing knowledge of quality control supervisors, on the one hand, and people's demand for high quality water consumption, many indicators are nowadays included in the quality control of urban water distribution network. Distribution network requires a coherent system with the highest quality in the shortest time and with the fastest and most accurate information processing power possible.[4]

Various studies have been conducted on the use of GIS to detect contamination in the drinking water. Nas and Berktay evaluated the correlation between the depth of the well and nitrate concentrations in Groundwater of Konya using Geographic Information System (GIS) technology.[5, 6] In the study carried out by Zeilhofer et al (2007), GIS methods were successfully applied to create spatial datasets for logistic regression model building and to construct risk maps using regression coefficients.[7, 8] In this study, bacteriological modeling was performed using Arcview GIS software in Masiri.

Methods

Study Area Description

Masiri is a city in the northwest of Fars province in Iran. The minimum east longitude of Masiri city is 57 degrees 6 minutes; the minimum north latitude is 30 degrees 16 minutes and minimum altitude of the city is 850 meters above the sea level. Figure 1 shows the location of the Masiri city on the map.

The climate of the city is relatively warm in summer and relatively cold in winter. Precipitation of this city is in the cold season of September to late May and the average annual rainfall is 550 mm. The average annual temperature is 14.7°C, while the absolute maximum temperature is 41.5°C and the absolute minimum is -2.5°C. The average number of frost days during the year is about 17 days. Water resources of Rostam city are divided into two categories of surface and ground water. The rivers around the city of Rostam are all seasonal, except for the Fahliyan, Pirin and Black Korreh rivers, and only have water when it rains. The city's water supply resources are 4 deep wells in calcareous texture, which are located in residential areas due to the expansion of urbanization and lack of privacy of these wells. This is the city. In recent years, 5% of the samples taken from the municipal water network have been microbial contaminants. The test performed on samples taken from the Masiri water network showed a pH of 7.5, a TDS of 760 mg / L and an EC of 1534 µm / cm.

Sample Collection and Analytical Procedures

According to the topographical map and distribution network of Masiri city, the information on the distribution network including altitude, locations of distribution tanks, and locations of sampling sites were selected from the above information and population. Since chlorination has been carried out at three locations and each facility has been supplying water to a specific part of the city, there has been an attempt to check the chlorinators daily for proper operation.[9, 10] Fixed calibration stations were identified in each area. Samples were taken daily and each sample was assayed for residual chlorine and MPN according to water and wastewater tests. The amount of residual chlorine in each sample was measured in situ and the amount of MPN after transfer to the experiments was tested in lactose medium using a nine-tube method.

The overview is as follows:
a. Mapping the topography of the area in Auto Cad with dwg extension and importing it into GIS environment. Study area base map was digitized using ArcGIS 10.2 software.
b. Mapping the area distribution network in a way that is compatible with the GIS.
c. Coordination, the use of a point to find all the parts and

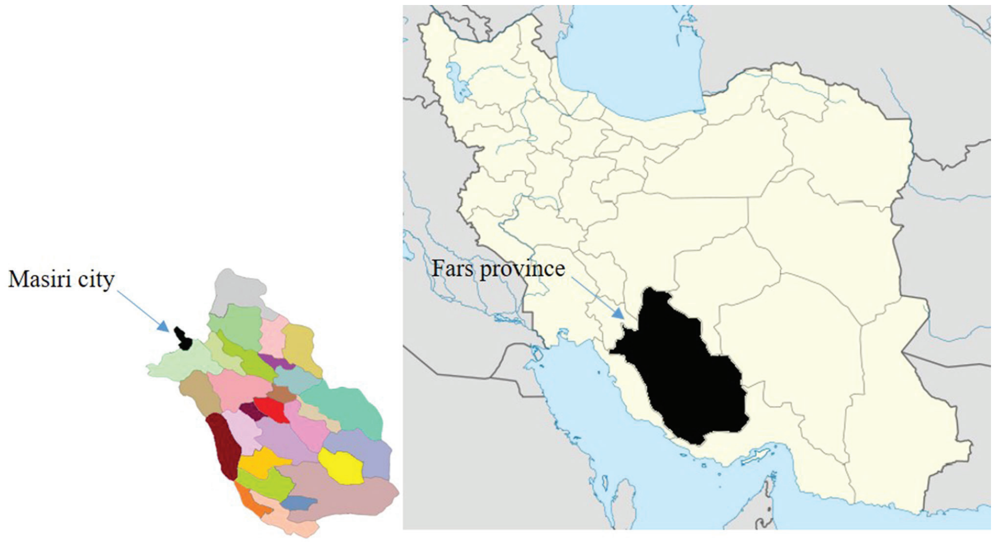

Figure 1: Location map of the study area.

vice versa. That is, using GPS, we found the coordinates of a spot, and by entering the coordinates into the region on a topographic map, topographic maps, distribution network and other complications were identified to be overlapped.

Chlorometry and MPN testing were performed daily, at different times and temperatures and data entry. Terefore, the city was divided into 10 regions. Then, using proportional stratified sampling with sufficient information, the share of each class was determined.

Then, within each floor, branches of the water meter were selected using systematic sampling method. Then, the sampling points were identified and transferred to the map with hydraulic characteristics.[11]

At the end of each day, the coordinates of the selected point were measured by the device and CPS and matched to the map in dwg format in Auto cad environment. It was then converted to ArcInfo environment by converting the dwg format to the shp format.[12]

An acceptable mathematical model with normal accuracy was adapted to the matrix model and the topology of the sequences was designed. Creating solidarity in GIS environments is of great importance, which helps us to prepare query maps and various analyses. It can also be used to create a color zoning based on the captured parameters.[13, 14]

After preparing the spatial model from the distribution network map of Masiri city in ArcInfo, it was transferred to ArcView and connected to the relevant locations from the field data bank. In ArcView, three layers of information were formed and the results were defined in three ranges of standard, low and high. After interpolation and creation of the desired layers, question maps were created and color zoning was formed. Then, statistical indices (mean, standard deviation, etc.) were determined and the optimum percentage of free residual chlorine in the area was determined.[15, 16]

Results

The residual chlorine with standard value in two seasons on the basis of one sample t-test in both residual chlorine seasons was less than standard value of 0.8 (Table 1). Results of chi-square test showed significant differences in two different seasons and regions for percentage of samples with E.coli. The results can be seen in Table 2.

Discussion

Evaluation of residual chlorine content in drinking water distribution network in two seasons of dry and wet based on independent t-test showed a significant difference between residual chlorine in two seasons ($P<0.001$). According to one-way ANOVA, residual chlorine in different regions showed a significant difference, which was lowest in zone 6 and highest in zone 10.

Comparison of residual chlorine with standard amount (0.5-0.8 mg / L) in different regions, based on one sample t-test, showed a significant difference, so that in all regions the difference was less than the standard level.

According to the Kruskal-Wallis test, the comparison of MPN in 10 regions showed a significant difference, and independent t-test showed no significant difference for comparison of residual chlorine with E.coli and MPN with E.coli.

Locative analysis of MPN and E.coli was performed using Thiessen polygonation method. This method is a geometric method based on polygonation independent of the amount and type of data and is only dependent on location. Since this method is needed to identify the trends in MPN and E.coli values, trend analysis and locative variability analysis were used. After microbial sampling, MPN, E.coli and chlorination tests were performed on all samples. The results were analyzed by Excel and SPSS software. Figures 2, 3 and 4 show the zoning of residual chlorine, MPN and E.coli in dry and wet seasons, respectively.

The results of the residual chlorine assay and positive ocular samples for each of the dry and wet season were investigated as follows:
a. Zero residual chlorine samples
b. Residual chlorine greater than zero and less than 0.5.
c. Residual chlorine at the desired level of 0.5-0.8 ppm.
d. Residual chlorine above 0.8 ppm.

Table 1: Chlorometric results in dry and wet seasons

Season	Total chlorometers	Favorites	Higher standard	Lower standard
Dry	200	52	20	128
Wet	200	108	1	91

Table 2: Contamination results of the samples taken in dry and wet seasons

Season	MPN	Ecoli
Dry	42	29
Wet	11	7

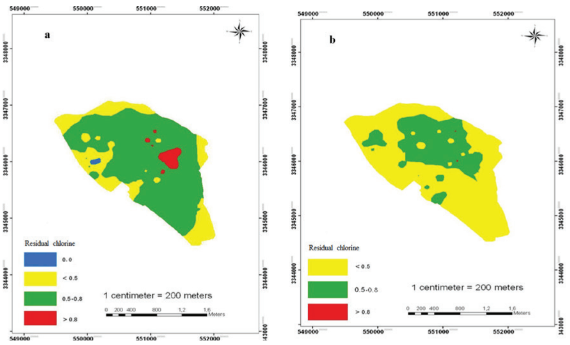

Figure 2: Zoning of residual chlorine values in dry (a) and wet (b) seasons

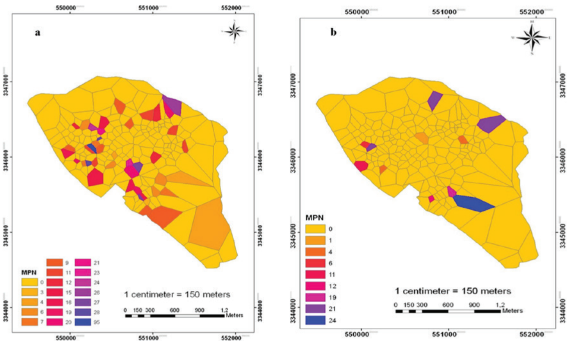

Figure 3: Zoning of residual MPN in dry (a) and wet (b) seasons

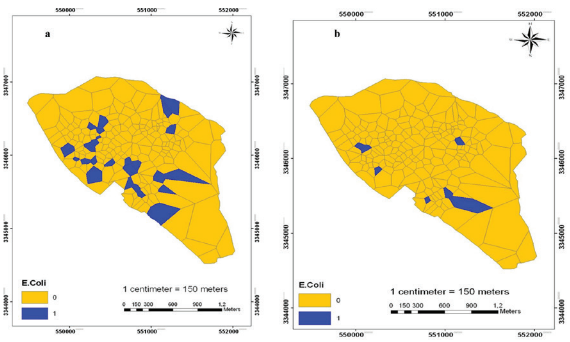

Figure 4: Zoning of residual E.coli in dry (a) and wet (b) seasons

Raw water enters a network of approximately 93 km after chlorination. Chlorination of water is done at three points as follows.

1) Facility 1: The water supply resources of the southern part of the city, which are stored in three reservoirs, enter the network after being chlorinated by the liquid chlorinator.

2) Facility 2: These facilities have 4 tanks for water chlorination in this section manually and perform central watering of the city.

3) Facility 3: Supply of water to the northern part of the city, where the network is chlorinated by a gas clinker.

Chlorination is carried out at stations 1 and 2 in three shifts (morning, afternoon and night).

In addition to the above results, considering the color zoning and also by examining the points where residual chlorine is below the permissible level, one can find the endpoints and blind spots of the network, low water pressure points, pipe permeability, network length, fracture of the old woofer distribution network, etc... By matching the color zones obtained in Arcview GIS, there was a significant relationship among residual chlorine, MPN and Ecoli.

Chlorination of water with gaseous chlorine with the least fluctuation in the amount of residual chlorine, lack of exhaustion and renewal of the water distribution network can be considered as the reasons in the networks with appropriate zero residual chlorine. Investigations showed that the points located in end and blind areas of the network, or with old, worn textures, lack of timely chlorination of workers, and the presence of biofilms caused a rapid decrease in the residual chlorine content and increased MPN. According to the results obtained in ArcView, it is necessary to improve the microbial quality of Masiri water distribution network in some places, which can be improved by proper management of chlorination and defects.

Conclusions

Monitoring of water resources and water distribution network is essential in detecting the pollution and designing and applying sustainable management strategies. In this study, GIS software was used to detect microbial contamination in the water supply network of Masiri city in two dry and wet seasons. The results of this study showed that pollution in Masiri water resources in the dry season was much higher than in the wet season, and MPN and E. Coli were more abundant in the water resources. According to the results obtained in Arcview, the necessity of washing the grid has been proved in some instances, which has greatly improved the microbial quality of the Masiri water distribution network by proper management of chlorination and elimination of the mentioned defects. In order to improve it, we need to continue monitoring and microbial monitoring of the Masiri distribution network.

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Conflict of Interest: None declared.

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