A GIS-Based Approach for Representation of Air Pollution A Case Study: Tabriz City

Davood Parvinnezhad Hokmabadi
Marand Faculty of Engineering
University of Tabriz
Tabriz, Iran
dparvinnezhad@tabrizu.ac.ir

Arash Rahmanizadeh
Marand Faculty of Engineering
University of Tabriz
Tabriz, Iran
arahmanizadeh@tabrizu.ac.ir

Shahla Taghizadeh Sufiani
Faculty of Environment and Energy
Islamic Azad University, Science and Research Branch
Tehran, Iran
sh.taghizade@gmail.com

***Abstract*— Pollution from urban transport has a big impact on community health. Environmental organizations in different countries of the world have installed sensor devices of air pollutants in different parts of their cities for informing the air pollution and its necessary and timely warnings and these devices record pollutants data in 24 hours of everyday. Today, these data are presented on large display boards installed in the important places of big cities. In this research, the results of pollutant data are presented visually on Tabriz map by GIS that it is better than statistical presentation.**

Keywords- Air Pollutants; Air Particles; Air Quality Index; GIS.

I. Introduction

Transportation is one of the vital components in modern human daily life. However, it has both productive effects on human developments and detrimental effects on public health. The number of motor vehicles is estimated to be over 800 million worldwide and is increasing almost everywhere at higher rates than human population, and road traffic may be growing even more rapidly. The number of private cars worldwide rose to 500 million in 1990 from 50 million in 1950. Road traffic is related to undesirable health effects caused by air pollution, noise and accidents. This wide range of negative health effects includes increased mortality, cardiovascular, respiratory and stress-related diseases, cancer and physically injuries. The negative effects are felt not only by transport users but also by the whole population especially in the vulnerable group of children and elderly people, pedestrians and cyclists. The effect of air pollution on public health depends on factors such as: the chemical composition of a particular pollutant, the level of concentration; the presence of other pollutants; the existing health of individuals; and periods of exposure [3].

Environmental organizations in different countries of the world installed sensor devices of air pollutants in different parts of their cities for informing the air pollution and its necessary and timely warnings and these devices record pollutants data in 24 hours of day. In our country, Iran, the Environmental Organization has installed 13 pollutant stations in Tehran and a few stations in other big cities. In Tabriz city 5 stations have been installed and we used all of them. More stations have best results and we can do best and complete analyses by GIS and then authorities can take decisions more effectively. Unfortunately due to the low monitoring stations in Tabriz, it is not possible we can perform GIS famous analyses such as Geostatistical analysis. Therefore, another GIS tools are used for visual presentation the results instead of statistical presentation. In this paper, a program has been developed in ARCObjects^{TM} [2] that it first calculates AQI values for whole of pollutant data and selects the maximum of them, then merges these values properly to attribute information of pollutant monitoring stations. Finally, based on these attribute information, the pollution status on the relevant maps or satellite images is represented as daily, monthly and yearly with various tools.

II. Air Pollutants and Their Role in human Health

The main air pollutants are ozone, particles, CO, Nitrogen oxides, Sulfur dioxide and lead. In Table I, one can see these pollutants and their effects on society health [4].

TABLE I. THE MAIN AIR POLLUTANTS AND THEIR EFFECTS [4]

Pollutant	Impact
Ozone	Burning nose and watering eyes; Tightening of the chest Coughing, wheezing and throat irritation; Rapid, shallow, painful breathing; Susceptibility to respiratory infections; Inflammation and damage to the lining of the lungs; Aggravation of asthma; Fatigue; Cancer

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Particles	Stuffy noses, sinusitis; Sore throats; Wet cough, dry cough, phlegm; Head colds; Burning eyes; Wheezing; shortness of breath; Lung disease; Chest discomfort or pain
CO	Toxicity of the central nervous system and heart; Headaches, dizziness, nausea and unconsciousness; Loss of vision; Decreased muscular coordination; Abdominal pain; Severe effects on the baby of a pregnant woman; Impaired performance on simple psychological tests and arithmetic; loss of judgment of time;
NOx	Increased incidence of respiratory illness; Increased airway resistance; Damage to lung tissue; Chronic obstructive pulmonary disease, or COPD (narrowing of the airways); Emphysema (as part of COPD); Pulmonary edema; Infant and cardiovascular death
SO2	Irritation of eyes, nose, throat; Damage to lungs when inhaled; Acute and chronic asthma; Bronchitis and emphysema; Lung cancer
Lead	Mortality; Hypertension nonfatal coronary heart disease;

III. STUDY AREA

Tabriz is located in the north-west of Iran and its population is about 1.5 millions. Tabriz is the fourth most populous city in Iran after Tehran, Mashhad, and Esfahan, and is also a major Iranian heavy industrial and manufacturing center. Some of these industries include automobile, machine tools, oil and petrochemical and cement production. Therefore, we used pollution data of it that were observed from 5 ground stations in 2011. These stations geographically located in Rahahan, Rastekouche, Baghshomal, Abrasan, and Hakimnezami zones (Fig. 1). Ground pollution monitoring stations collect daily amounts of pollutants in different parts of the city. In this work, all of pollutant data for determining the emergency situation are used. For example in Table II there is a sample data of air pollutants for one of pollutant stations during 5 hours a day. Based on pollution data, the Air Quality Index is calculated from Equation I and then emergency situation is warned.

TABLE II. A SAMPLE DATA OF AIR POLLUTANTS FOR ONE OF POLLUTANT STATIONS

Date	Time	PM_{10} [μg/m^3]	SO_2 [ppb]	NO_2 [ppb]	CO [ppb]	O_3 [ppb]
2011/07/23	00:00	40.5	5.4	10.1	1.2	5.4
2011/07/23	01:00	247.9	6.1	12.2	1.3	6.1
2011/07/23	02:00	45.8	6.3	12.1	1.3	6.3
2011/07/23	03:00	104.3	4.7	6.0	0.7	4.7
2011/07/23	04:00	478.4	5.6	12.4	1.4	5.6

IV. AIR QUALITY INDEX

Air quality indices (AQI) are numbers used by government agencies to characterize the quality of the air at a given location. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects [1].

To compute the AQI everyone requires an air pollutant concentration from a monitor or model. The function used to convert from air pollutant concentration to AQI varies by pollutant, and is different in different countries. Air quality index values are divided into ranges, and each range is assigned a descriptor and a color code. Standardized public health advisories are associated with each AQI range. An agency might also encourage members of the public to take public transportation or work from home when AQI levels are high [1].

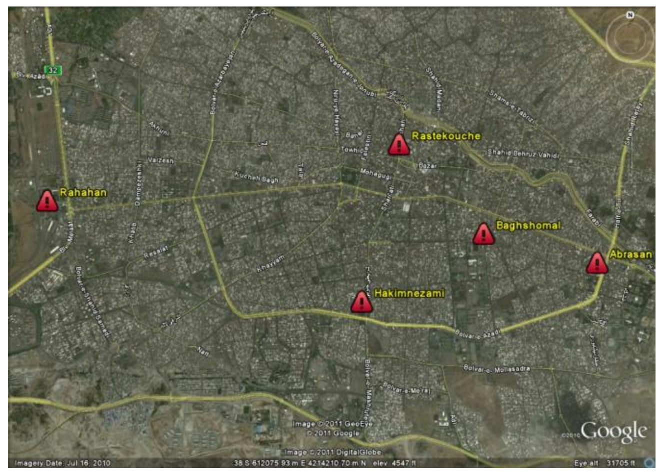

Figure 1. The pollutant stations of Tabriz city

The air quality index is a piecewise linear function of the pollutant concentration. At the boundary between AQI categories, there is a discontinuous jump of one AQI unit. To convert from concentration to AQI the equation I is used [1]:

$$AQI = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low} \quad (1)$$

I = the (Air Quality) index,
C = the pollutant concentration,
C_{low}= the concentration breakpoint that is ≤ C,
C_{high}= the concentration breakpoint that is ≥ C,
I_{low}= the index breakpoint corresponding to C_{low},
I_{high}= the index breakpoint corresponding to C_{high}.

For example, suppose a monitor records a 24-hour average fine particle concentration of PM10=85.3 micrograms per cubic meter. Based on Table III this value is in the 55-154 intervals, then:

$$C_{low} = 55,\ C_{high} = 154 \Rightarrow I_{low} = 51,\ I_{high} = 100$$

Now, we can calculate the AQI:

$$AQI = \frac{100-51}{154-55}(85.3-55)+51 = 66$$

Based on calculated value for AQI above, the emergency status is *moderate*. (Table III)

TABLE III. AQI INTERVALS CORRES PONDING TO AIR POLLUTANTS [1]

Emergency Status	AQI	Air Pollutant						
		NO_2 (ppm)	SO_2 (ppm)	CO (ppm)	PM2.5 (µg/m^3)	PM10 (µg/m^3)	O_3 (ppm) 1-Hour	O_3 (ppm) 8-Hour
Good	0-50	-	0-0.034	0-4.4	0-15.4	0-54	-	0-0.0059
Moderate	51-100	-	0.035-0.144	4.5-9.4	15.5-40.4	55-154	-	0.0060-0.0075
Unhealthy for Sensitive Groups	101-150	-	0.145-0.224	9.5-12.4	40.5-65.4	155-254	0.125-0.164	0.0076-0.0095
Unhealthy	151-200	-	0.225-0.304	12.5-15.4	65.5-150.4	255-354	0.165-0.204	0.0096-0.0115
Very unhealthy	201-300	0.65-1.24	0.305-0.604	15.5-30.4	150.5-250.4	355-424	0.205-0.404	0.0116-0.0374
Hazardous	301-400	1.25-1.64	0.605-0.804	30.5-40.4	250.5-350.4	425-504	0.405-0.504	-
Hazardous	401-500	1.65-2.04	0.805-1.004	40.5-50.4	350.5-500.4	505-604	0.505-0.604	-

TABLE IV. A CALCULATED AQI OF AIR POLLUTANTS FOR ONE OF POLLUTANT STATIONS AND MAXIMUM OF THEM

Date	PM_{10} AQI	SO_2 AQI	NO_2 AQI	CO AQI	O_3 AQI	Maximum AQI
2011/07/23	37	7	0	14	0	37
2011/07/23	147	9	0	15	0	147
2011/07/23	43	9	0	15	0	43
2011/07/23	75	7	0	8	0	75
2011/07/23	367	9	0	16	0	367

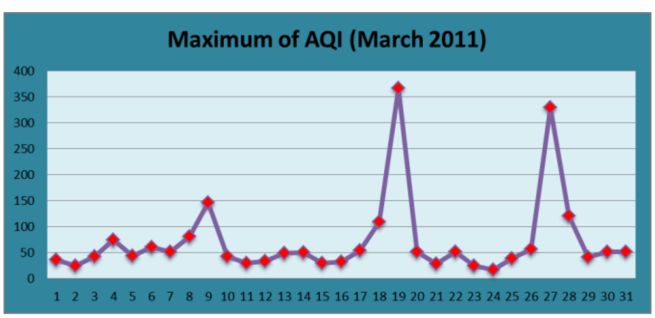

Figure 2. Maximum of AQI for Baghshomal monitoring station in March 2011.

In Table IV, for example, the calculated AQI and their maximum for concentrations related to Table II are presented. The Maximum of AQI for Baghshomal monitoring station in March 2011 is shown in Fig. 2. It is determined from Fig. 2 there are about 5 days in March that air pollution is very much and the emergency status is *Hazardous*.

V. IMPLEMENTATION

In this paper, a program has been developed in ARCObjects™ [2] that it first calculates AQI values for whole of pollutant data and selects the maximum of them then merges these values properly to attribute information of pollutant monitoring stations. Finally, based on these attribute information, the pollution status on the relevant maps or satellite images is represented as daily, monthly and yearly with various statistical tools. For example Fig. 4 and Fig. 6 represent the maximum AQI of pollutants in March and July 2011 with variable slice sizes and Fig. 5 and Fig. 7 represent the same maximum AQI with identical slice sizes. In these figures the sequence of days is based on Fig. 3.

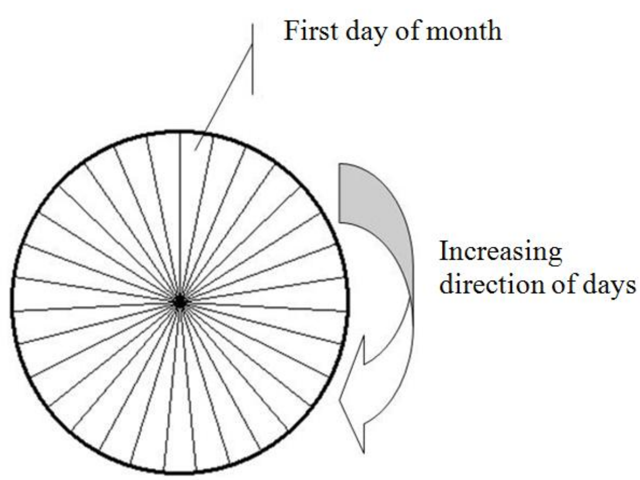

Figure 3. The sequence of days in one month

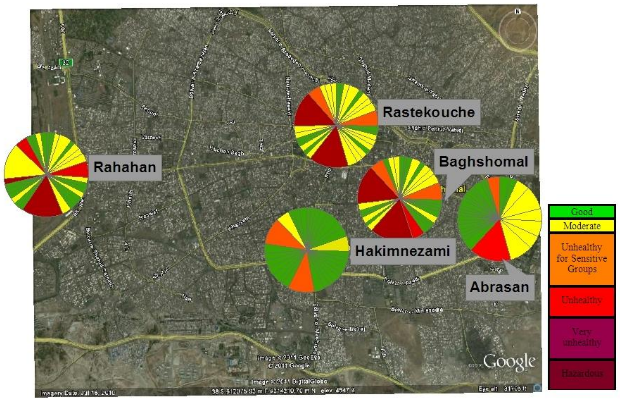

Figure 4. Maximum of AQI corresponding to pollutants of Tabriz in March 2011 with variable slices

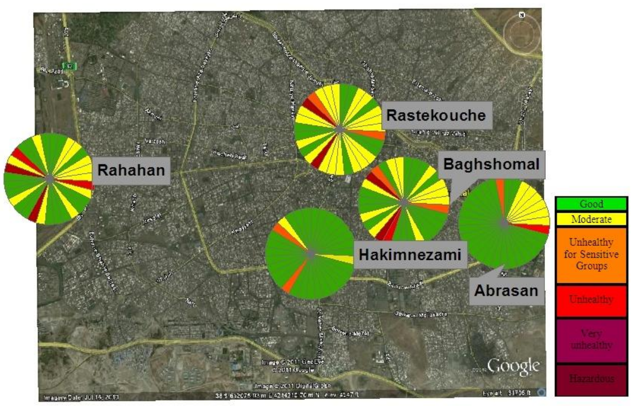

Figure 5. Maximum of AQI corresponding to pollutants of Tabriz in March 2011 with identical slices

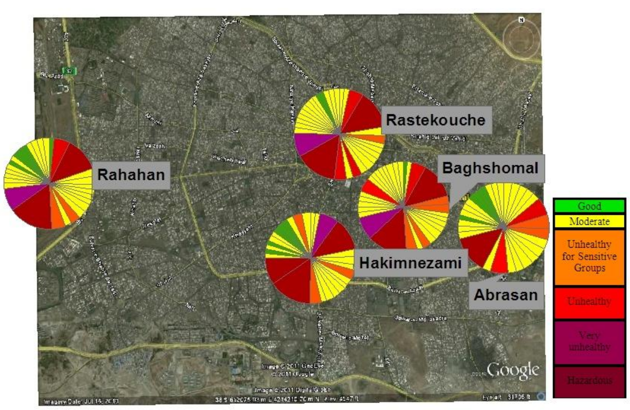

Figure 6. Maximum of AQI corresponding to pollutants of Tabriz in July 2011 with variable slices

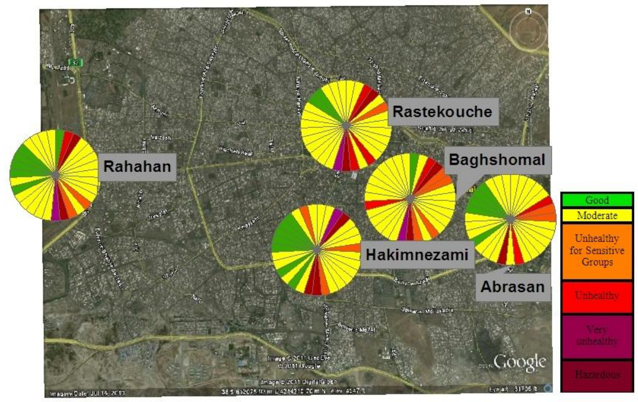

Figure 7. Maximum of AQI corresponding to pollutants of Tabriz in July 2011 with identical slices

Also, the maximum value of AQI corresponding to the pollutant data during the selected 6 months, March to August, of 2011 was calculated (Fig. 9) In these figures, the sequence of months is based on Fig. 8.

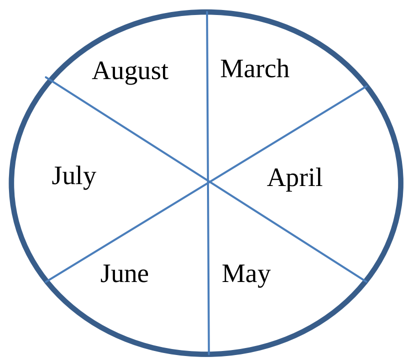

Figure 8. The sequence of the selected 6 months of 2011

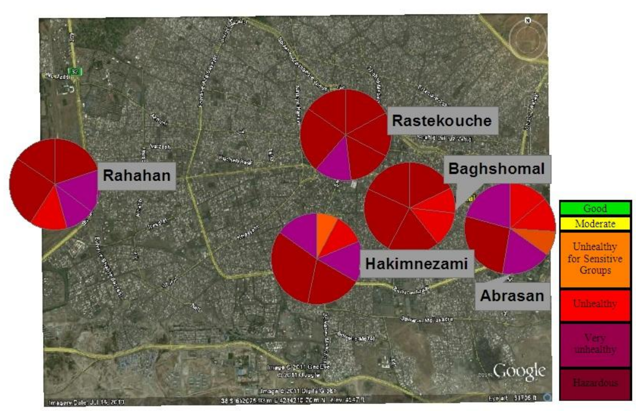

Figure 9. Maximum of AQI corresponding to pollutants of Tabriz in six months of 2011

It is seen from Fig. 9 that Tabriz city has air pollution in majority months of the year.

By more developing of the written program and customizing it, some radio buttons and check boxes can develop for best interface and GUI that every user can select daily, monthly or yearly and so select other options to best visualization and interpretation of results. This program can run on the Web for online visualization the results.

VI. CONCLUSION

By using GIS with various representations everyone can utilize visual, not only statistical, analyses based on different data especially pollution data. If the AQI is represented with identical slices, everyone can rapidly conclude that in which interval of month, 1st week or 2nd week and so on, the air pollution has maximum value and if the AQI is represented with variable slices, everyone rapidly conclude that what days have the maximum pollution.

Based on the data, it is obvious that PM_{10} is the major air pollutant in Tabriz city and other pollutants have a minor role in the pollution of its air.

If the number of pollutant monitoring stations in our city increase and the resulted data are available in the hands of analysts in every time and everywhere, they can represent the various results of these data in the different places of the cities for public, and also they can use GIS complex analyses such as Geostatistical Analysis for better analyzing the results and estimating the quantity of pollution in other places of city. It is expected that by this article and articles like it, such matters to be provided in the near future.

VII. ACKNOWLEDGMENTS

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