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Forecasting air quality index (AQI) and air quality health index (AQHI) by time series models in Ahvaz, Iran

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Abstract

Background: Air pollution indexes are used to indicate the level, quantity, and quality of air pollution. The air quality index (AQI) and air quality health index (AQHI) have been developed to report their association with human health.

Methods: Air quality variables ($PM_{2.5}$, O_3, and NO_x) per hour were obtained for March 2021 to March 2022 from three central pollution control centers in Ahvaz, the capital city of Khuzestan province, southwest of Iran. R3-3-4, Minitab-17, and SPSS-19 software were used to analyze the obtained data.

Results: In this study, AQHI and AQI were predicted with actual data, forecasting the air quality with two confidence interval percentages of 95 and 80 illustrated for future days. Also, the relationship between AQI and AQHI was determined; hence, this relationship is important for some cities for which the AQHI index is not measurable. AQHI can be determined for each place using AQI values and the obtained relationship.

Conclusion: The result indicated that we could also forecast the AQI and AQHI for future days and obtain a new equation for AQHI due to AQI values.

Keywords: Air pollution, Human, Cities, Iran

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Introduction

According to the air clean act (ACA), clean air is a principal requirement for human health (1). Nowadays, air pollution is one of the initial environmental stressors associated with urban areas, especially in industrial and developing countries, which has led to decreased levels of human health, and increased patient numbers and death rates (2). According to a study's results, in 2013 ambient air pollution was the main factor for 5.5 million people deaths worldwide (3). To indicate the air quality situation and associated health risks, index (4) was used. Different air pollution indexes (APIs) are used to give air quality management plants. To make an air quality index (AQI), two terms are needed. Firstly, determining the pollution's health effects on the community, secondly, simplifying large amounts of data, and making standardized data, which are used for the development of policy (5). The pollution standards index (PSI) was the first AQI that was established by the U.S. EPA in 1976. This index classifies air quality according to five major (criteria) air pollutants (PM_{10}, CO, SO_2, NO_2, and O_3) in terms of "good", "moderate", and "unhealthy" (6). In 1999, PSI was completed and amended by the U.S.EPA and renamed to the AQI; the new index (AQI) corrected some of the previous weaknesses (7). The new index defines six classes of pollution (good, moderate, unhealthy for sensitive groups, unhealthy, very unhealthy, and hazardous). Also, there are two new sub-indexes for this system for $PM_{2.5}$ and 8-hour average ozone (O_3) (6). Also, there are some limitations. One of these limitations is that this index does not describe the health effects associated with air pollution, and AQI results determined only a pollutant that has the highest contamination level (U.S. EPA 2006) (7). Due to the AQI defects, in 2001, Environment Canada and Health Canada carried out and developed a new AQI based on human health, named the air quality health index (AQHI). The results of this index are expressed on the combined impact of $PM_{2.5}$, O_3, and NO_2 (8). This index is classified into four bands that include 10 indexes. AQHI values can help better protect old men, children, and sensitive humans (9). Extensive research has not been conducted on the AQI and AQHI constraints and available gaps, but a few studies have been conducted on the prediction of AQI (10). Most studies have been designed to predict air pollutants and determine AQI. For example, Carbajal-Hernández et al in 2012 (11) developed a prediction of air quality using autoregressive models and fuzzy logic. Also, Yildirim and Bayramoglu in 2006 (12) predicted ambient pollutants for daily levels based on neuro-fuzzy. The results of other studies indicate that prediction models are suitable for the determination of air pollutants (6,13-15). According to the adjustment mode via the authors following studying local conditions, a time series is an ordered sequence of values mode at equally spaced time intervals. Time series predictions use past and present real data and predict their values for the next time (16). Time series have been used in various sciences (17-19). When time series methods are used, we have a large number of data (15). Nowadays, time series methods are used for environmental issues such as air pollution and air quality measurements (14,15,20). The methodology used to estimate environmental parameters is derived from descriptive statistics. According to a study by Schwartz and Marcus in 1990, a time series analysis may be an appropriate approach to fixing ambiguity and contributing to a comprehension of effect relationships in many environmental problems (21). To date, no predictive study has been done for AQI and AQHI by time series models. However, some of the time series studies have predicted criteria air pollution, air quality, and the relationship between AQHI with mortality and morbidity. For example, in a study, the AQHI and asthma morbidity were developed (9). And in some studies, the Neuro-fuzzy models were used to predict air pollution levels (11,12,22). However, only criteria air pollution or air quality were predicted by the aforementioned studies, but none of the studies have predicted the AQI and AQHI. That tends to minimize the impact of air pollution effect on human health, especially elders and children (23,24). In the present study, the time series methods were used to determine and predict AQI and AQHI in Ahvaz city, south-west of Iran. This study developed a novel prediction by the R program, which introduced the new package to AQI and AQHI determination and prediction in Ahvaz. This approach can be globally used, as an integrated tool for air quality predictions and air quality assessment. It also can help local authorities with air pollution management issues. In addition, the findings of the study help managers, policymakers, and engineers to use AQI results to obtain the AQHI results. The last goal will be important to some cities that do not have an integrated management for the determination of air quality system.

Materials and Methods

Study area

Ahvaz is a plain city located in the southwest of Iran, and northwest of the Persian Gulf (31° 20ʹ N, 48° 40ʹ E) near Iraq, Kuwait, and Saudi Arabia (25). Ahvaz has an area of 220 km^2 where the most important cause of air pollution in this city is particulate matter (26). The most important cause of air pollution in this city is particulate matter (25,27). The map of the study area location of air pollution monitoring stations is presented in Figure 1. In this study, hourly criteria air pollution (O_3, NO_2, SO_2, CO, and PM) between March 2021 and March 2022 was obtained from two central pollution control; the Center

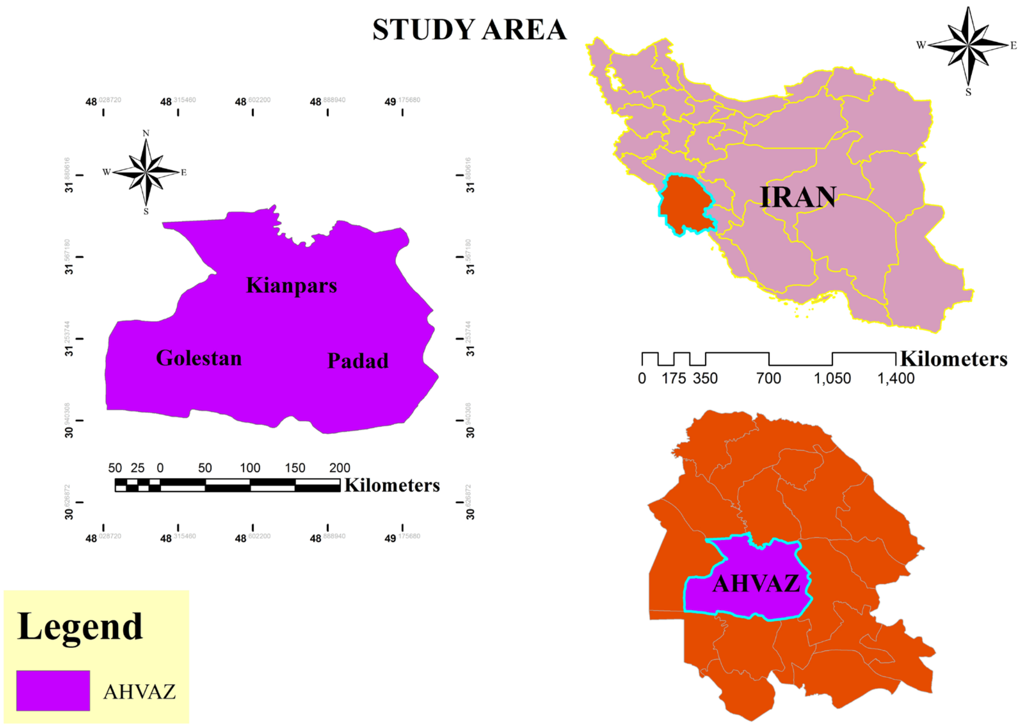

Figure 1. Map of study city

of Environmental Organization and Naderi Pollution Control Center. The map of these stations introduces the overview of air pollution in Ahvaz city. Available data indicate that particulate matter and dust storms are the most important ambient air pollution factors.

Canadian air quality health index

Canadian AQHI was developed to help the public with effects on short-term health. The ultimate goal of this index is to reduce the risk of air pollution in target groups. The AQHI is calculated based on a three-hour average concentration of fine particulate matter ($pm_{2.5}$), nitrogen dioxide (NO_2), and ground level-ozone (O_3). The AQHI has a scale ranging from 1 to 10+, and is classified into four classes; higher values indicate that the air quality is poor. It is typically classified as "low" (1-3), "moderate" (4-6), "high" (7-10), and "very high" (values > 10) human health risk (8). For more detailed information about AQHI, refer to Canadian AQHI (28). The AQHI value is calculated using the following equation 1 (8).

$$AQHI = \frac{10}{10.4} \langle 100 \times [(e^{(0.00087 \times NO2)} - 1) + \left|(e^{(0.000537 \times O3)} - 1) + \right|(e^{(0.000487 \times PM\,2.5)} - 1)] \rangle \quad (1)$$

As the quantities of exponential brackets in this equation are very small, therefore, to simplify the upper equation, the approximation exp(x) ~ 1 + X was used. The upper equation could be re-written as equation 2 (29).

$$\begin{aligned} &\text{AQHI} \sim 10/10.4 * 100 * \{(1+0.000871 * \text{NO2}) - 1 + \\ &(1+0.000537 * \text{O3}) - 1 + (1+0.000487 * \text{PM2.5}) - 1\} \\ &= 0.084 * \text{NO2} + 0.052 * \text{O3} + 0.047 * \text{PM2.5} \end{aligned} \quad (2)$$

Air quality index

The U.S. EPA (2006-2009) was developed to reflect possible health and environmental impacts associated with ambient air pollution. This is a forecasting tool to determine human health related to the major ambient pollution incl`uding O_3, PM, NO_2, SO_2, and CO. The AQI as a yardstick score from zero to 500 is classified into six categories: good, moderate, unhealthy, very unhealthy, and hazardous. The groups were separated based on the concentration breakpoints of pollution. The pollution with the highest concentration is named "responsible pollution". The protective recommendations for each responsible pollution are different. For more detailed information, the AQI value is referred to for each pollution, and the response pollution is calculated using the following equation 3 (7).

$$\text{IP} = \frac{\text{IHi} - \text{ILo}}{\text{BP}Hi - BPLp} \left(Cp - BPlo \right) + \text{Ilo} \quad (3)$$

Where *Ip* is the AQI for pollution P, *Cp* is the rounded concentration of pollution P, *BPHi* is the breakpoint that is greater than or equal to Cp, *BPlo* is the breakpoint that is less than or equal to Cp, *IHi* is the PSI value corresponding to BPhi, and *ILo* is the PSI value corresponding to *BPlo*.

Data analysis

Time series analysis

A time series model has been developed for modeling and forecasting of complex systems (30). The time series method records the different observations or facts that are the values recorded concerning different times. The time series methods used in other sciences, ranging from the physicochemical process (31), environmental epidemiological (32,33), and management science (34) to forecasting value estimates for missing causality links introduced with a confidence interval. These observe behavior during the past time and make a forecasting behavior. In the time series, we use the different models, autoregressive (AR), moving average (MA), autoregressive moving average (ARMA), autoregressive integrated moving average (ARIMA), spatial autoregressive moving average (SARMA), seasonal autoregressive integrated moving average (SARIMA), and bivariate models for different forecasting. Air pollution measurements are a good example of time series models for estimation of environmental parameters (15). In this study, univariate and multivariate models were used to forecast the AQI and AQHI, and also, to determine the relationship and correlation between them. AQI and AQHI quantity were measured by the univariate models. ARMA is a univariate forecasting model, which is obtained from the assimilated of AR and MA and calculated by equation 4 (35).

$$\text{Yt} = \emptyset 1Yt - 1 + \emptyset 2Yt - 2 + \ldots + \emptyset pYt - p + \varepsilon t + \theta 1\varepsilon t - 1 + \theta 2\varepsilon t - 2 + \theta q\varepsilon t - q \quad (4)$$

Yt is the observation at time T, *εt* is the random error, *Ø* is non-seasonal AR parameters, *Θ* is non-seasonal MA parameters.

Also, used from multivariate models for observation collected over time with dimension and they are considered as vector auto regressive VAR(p).

Validation of this study

Validation of this study can be addressed in four approaches. Firstly, the methodology used is useful for air quality and air pollution forecasting. This is especially important for older people and children to be protected from air pollution.

Secondly, the methodology can be presented as an R package. Therefore, the results can be referred to cities or regions with a similar status to this study. Especially for Middle Eastern countries, it is useful.

Thirdly, this study introduces a new method for cities where AQHI values cannot be set, so that policymakers can use the AQI results to determine the value of the AQHI.

Finally, the obtained results, which can become an R package, help policymakers to determine and forecast AQI and AQHI index based on criteria air pollutants. The

R 3-4-4 results are shown in the indexes.

Results

Trends of yearly AQI and AQHI levels, depending on real pollutant quantities, are illustrated in Figure 2. The AQI and AQHI results indicate that among the criteria studied pollutants concentration, the average of $PM_{2.5}$ is mostly upper compared to standard levels. Table 1 indicates the pollutant concentrations in Ahvaz ambient air. According to the results, particulate matter is the main factor in increasing the AQI. In addition, Table 1 shows that in Ahvaz city, the annual $PM_{2.5}$ average is higher than the National Ambient Air Quality Standard (NAAQS) and the annual AQI is at a moderate level of health concern. Figure 2 indicates that AQHI and AQI are in a more repeatedly dangerous state from September 2021 to January 2022.

Figure 3 illustrates the relationship of O_3, NO_2, and $PM_{2.5}$ with AQHI. As shown in the figure, a good correlation can be seen between $PM_{2.5}$ and AQHI, and $PM_{2.5}$ is introduced as a criteria pollutant in Ahvaz and other air pollutants are less effective on the AQI and AQHI modifications. To decrease the error rate for days where the AQI was above 500, it was considered to be 500, and AQHI that was above 10, it was considered to be 10, as shown in Figure 2. We also used the AR model to determine residual values and used the autocorrelation function (ACF) and partial autocorrelation function (PACF), as indicated in Figure 4. The autoregressive 1, with specified AR coefficient, constant factor, and standard errors, was used to fit the univariate model. The coefficient and constant quantity of AQHI and AQI for time (AQHIt and AQIt), are shown by equations 5 and 6; the equations were obtained based on the results presented in Figure 3.

$$AQHIt = 2.5153 + 0.512\,AQHIt - 1 + \varepsilon t \quad (5)$$

$$AQIt = 135.485 + 0.5734\,AQIt - 1 + \varepsilon t \quad (6)$$

In addition, AFC and PAFC figures illustrated in Figure 4 that select the model. According to Figure 5, the AQI and AQHI were determined in 2017 for day 1 to day 365 for Ahvaz City and forecasted by confidence intervals of 95% and 80% from day 365 to day 400. The forecasting of the AQI and AQHI for the future time, with two confidence intervals of 95% and 80% are illustrated in Figure 6.

Correlation between AQHI and AQI

The relationship between AQI and AQHI is given in Table 2.

According to the table, the multivariate model was used to determine the correlation and the AQI impact on the AQHI value and vice versa the effect of AQHI on the AQHI value. Table 2 shows the coefficient and *P* value, based on the coefficient and constant for forecasting AQHIt shown by equation 7. To $P > |Z|$ in table (X), it was revealed that AQHI does not affect AQI.

$$AQHIt = 0.8836 + 0.2414\,AQHIt - 1 + 0.0969\,AQIt - 1 + \varepsilon t \quad (7)$$

We analyzed the monthly mean concentration for the ratio of $PM_{2.5}$ to PM_{10} in Ahvaz city. In often the month, the mean $PM_{2.5}/PM_{10}$ ratio was demonstrated about 0.25, the mean ratio of $PM_{2.5}/PM_{10}$ concentration, have the PM ratio in this study is lower than in other studies. That it can happen to the PM ratio in soil or PM ratio in desert dust. The results of $PM_{2.5}/PM_{10}$ are indicated in Figure 7.

Discussion

The AQHI based on the health effect estimates of multi-

Table 1. The statistical results for air pollutants and AQI

Parameter	Mean	Median	Mode	SD
O_3 (ppm)	0.03	0.026	0.02	0.02
$PM_{2.5}$ (µg/m³)	61.42	37.3	32.5	148.1
NO_2 (ppm)	0.046	0.032	0.02	0.04
AQI	114.4	104.7	93.75	65.6

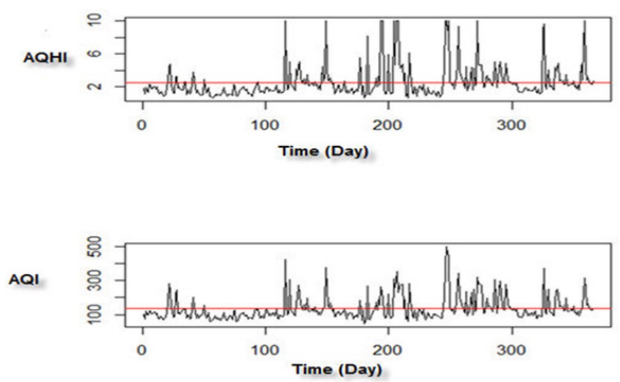

Figure 2. The annual trend of AQHI and AQI

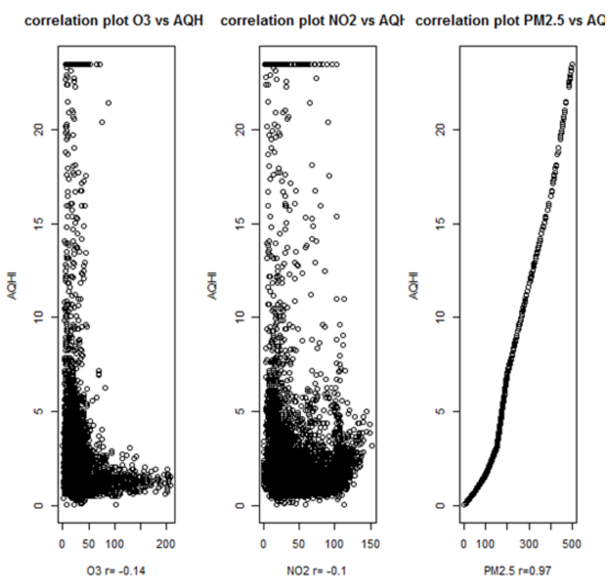

Figure 3. Correlation plot for O_3, NO_2, and $PM_{2.5}$ with AQHI

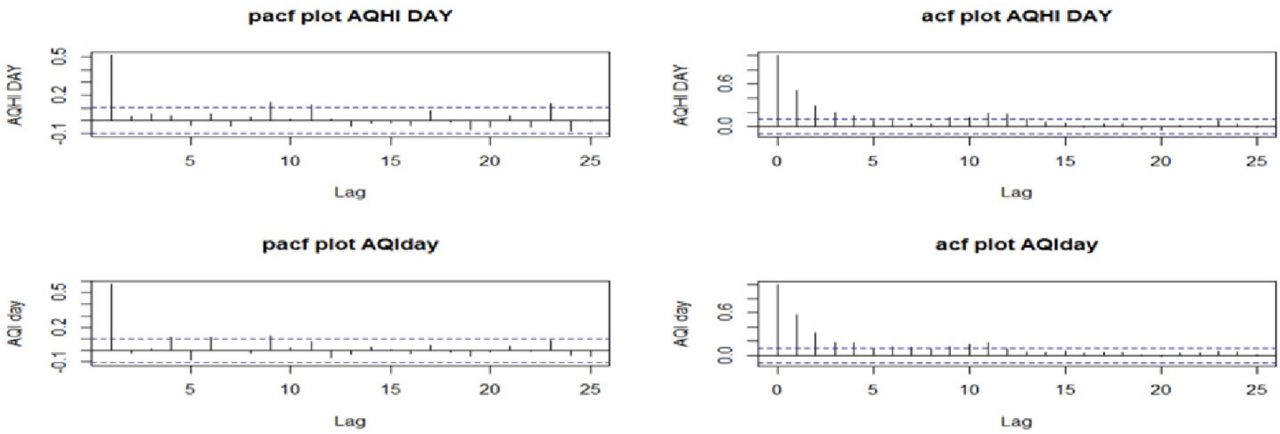

Figure 4. The ACF and PACF plots for the AR model

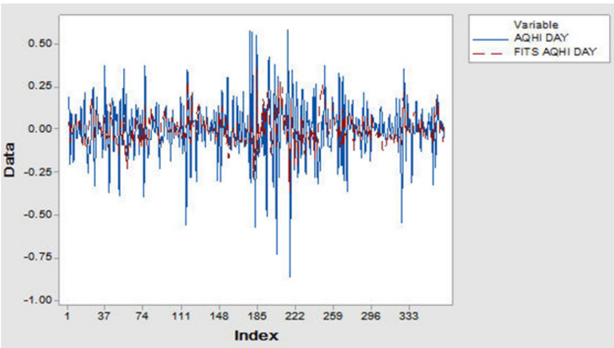

Figure 5. Time series plot for daily AQHI

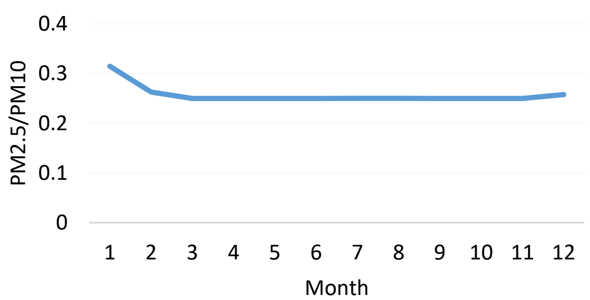

Figure 7. The ratio of $PM_{2.5}/PM_{10}$ in different months

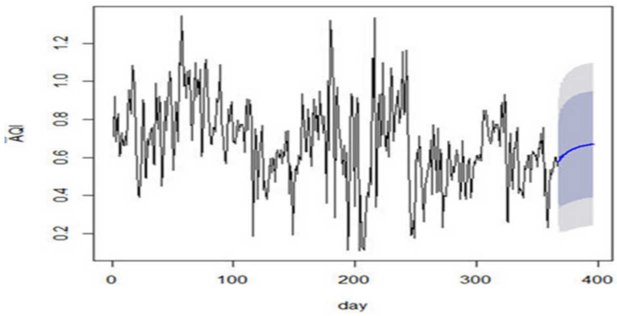

Figure 6. Forecasting AQI for days 365 to 400

Table 2. Coefficient and constants for AQHI and AQI

Coefficients	Index	
	AQHI	AQI
A.R coefficient	0.5734	0.5734
	0.0447	0.0426
Constant	2.5153	135.485
	0.1798	7.02

pollutants, including $PM_{2.5}$, O_3, and NO_2 have been developed (36). In the present study, the AQHI was evaluated based on three pollutants. However, in some cities, the index is based on different pollutants. For example, in Hong Kong, the AQHI is based on pollutants SO_2, NO_2, and O_3. This difference in using different pollutants for determining AQHI was due to the use of local air pollution situations and health statistics (3). In Ahvaz City, PM_{10} and $PM_{2.5}$ are the main cause of air pollution in comparison with other air pollution criteria (37). The western parts of Iran, from Ahvaz to Tabriz, have suffered from the Middle East Dust (MED) storms (38,39). Fine dust and particulate matter are the main issue air pollutants in all of Iran and is currently considered as a serious health problem. Particles suspended in air are a matter of concern in environmental health as they can enter the respiratory system and cause breathing and cardiovascular problems. Various studies show that the adverse health effects of suspended particles with $PM_{2.5}$ micrometers in diameter are more than other particle matters. The study by Zahedi et al in Ahvaz showed that the carcinogenic risks of children exposed to the $PM_{2.5}$-bound carcinogenic metalloids industrial area are higher than other sites (37). In the present study, $PM_{2.5}$ had a seasonal pattern and an increasing trend in the cold seasons. Some studies conducted in Ahvaz and Abadan, Iran, also showed that ambient air particle matter had an increasing trend over the cold seasons (40,41). This has happened due to prevailing winds from dust centers towards urban and residential areas (42). PM_{10} and $PM_{2.5}$ reach their maximum concentration in Ahvaz from November to December. The study by Liu et al in Taiwan demonstrated that PM_{10} has a seasonal pattern and the maximum values are seen in spring (43). The results indicated the application of EPA, AQI, and Canadian AQHI for Ahvaz City and some cities such as Mongolia, Sydney, Haifa, Mali, and Saudi Arabia where the dust storm phenomenon occurs. Dust storm sources and high levels of PM in those regions are Sahara Bodele, Taoudenni, Eyre, Sistan, Etosha, Tarim, Uyuni, and the Great Salt Lake (27); particulate matters have the greatest impact on AQHI and AQI.

PM Ratio

In many studies, a close relationship was reported between PM_{10} and $PM_{2.5}$ (44). A study in Australia demonstrated a range of 0.4-0.6 for $PM_{2.5}/PM_{10}$, also another study in Canada shows a 0.5 ratio for $PM_{2.5}/PM_{10}$, these ratios follow the seasonal variation. In another study conducted in Taiwan, this ratio was between 0.25 and 0.9 for monthly mean concentration during 1999-2000 (6). In the other study by Shahsavani et al in Ahvaz, the annual mean value of 0.23 was obtained for the $PM_{2.5}/PM_{10}$ ratio (25).

The time series plot for AQI and AQHI shows that for Ahvaz, AQI and AQHI quantities are higher than the health value. In addition, on most days in Ahvaz City, air quality is not suitable. Therefore, the annual average AQI for $PM_{2.5}$ as a responsible pollutant is 61.42, which indicates an unhealthy annual air quality for sensitive groups. According to Figure 2, the highest levels of AQI and AQHI were observed from September to March, while the lowest levels were observed from March to July. It was revealed that dust storms occur most frequently from July to March, which is inconsistent with the results of the study by Najafi et al (45). This might be due to local storms that occur often in the cold season.

Conclusion

The AQI is a suitable index for air quality evaluation. According to the results of this study, AQI is not able to obtain the accumulative results for criteria air pollution. Also, the results cannot properly assess the effects of air pollutants on health to AQI is not able to indicate the short-term effects of air pollution on the population. Because of many different climatology parameters affecting air quality and air pollution, therefore, a sensitive tool is needed to involve different climatology parameters and the accumulative effects of air on health. According to the results, AQHI is a comprehensive tool for the classification of health risks for the general population and at-risk populations. In addition, it can indicate the short-term effects on the population. This study shows for countries and regions that the AQHI setup system has not been launched can use the AQI results for determination and forecasting of AQHI per region and countries. The results of this research indicate a good prediction for AQI and AQHI; the code of prediction for each part of this study is written by the R-3-4 program, and the codes are in the index section of this study.

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Authors' contributions

Conceptualization: Amir Zahedi, Neamatollah Jaafarzadeh.
Formal analysis: Yaser Tahmasebi.
Investigation: Amir Zahedi, Neamatollah Jaafarzadeh.
Methodology: Amir Zahedi, Neamatollah Jaafarzadeh, Yaser Tahmasebi.
Project administration: Neamatollah Jaafarzadeh.
Resources: Amir Zahedi, Neamatollah Jaafarzadeh.
Software: Iman Mirr.
Supervision: Neamatollah Jaafarzadeh.
Validation: Iman Mirr.
Visualization: Yaser Tahmasebi.
Writing–original draft: Amir Zahedi.

Competing interests

None.

Ethical issues

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References

1. Kuklinska K, Wolska L, Namiesnik J. Air quality policy in the US and the EU–a review. Atmos Pollut Res. 2015;6(1):129-37. doi: 10.5094/apr.2015.015.
2. Fiore AM, Levy H, Jaffe DA. North American isoprene influence on intercontinental ozone pollution. Atmos Chem Phys. 2011;11(4):1697-710. doi: 10.5194/acp-11-1697-2011.
3. Li X, Xiao J, Lin H, Liu T, Qian Z, Zeng W, et al. The construction and validity analysis of AQHI based on mortality risk: a case study in Guangzhou, China. Environ Pollut. 2017;220(Pt A):487-94. doi: 10.1016/j.envpol.2016.09.091.
4. Olstrup H, Johansson C, Forsberg B, Tornevi A, Ekebom A, Meister K. A multi-pollutant air quality health index (AQHI) based on short-term respiratory effects in Stockholm, Sweden. Int J Environ Res Public Health. 2019;16(1):105. doi: 10.3390/ijerph16010105.
5. van den Elshout S, Léger K, Heich H. CAQI common air quality index--update with PM2.5 and sensitivity analysis. Sci Total Environ. 2014;488-489:461-8. doi: 10.1016/j.

scitotenv.2013.10.060.
6. Cheng WL, Chen YS, Zhang J, Lyons TJ, Pai JL, Chang SH. Comparison of the revised air quality index with the PSI and AQI indices. Sci Total Environ. 2007;382(2-3):191-8. doi: 10.1016/j.scitotenv.2007.04.036.
7. Sowlat MH, Gharibi H, Yunesian M, Tayefeh Mahmoudi M, Lotfi S. A novel, fuzzy-based air quality index (FAQI) for air quality assessment. Atmos Environ. 2011;45(12):2050-9. doi: 10.1016/j.atmosenv.2011.01.060.
8. Chen L, Villeneuve PJ, Rowe BH, Liu L, Stieb DM. The air quality health index as a predictor of emergency department visits for ischemic stroke in Edmonton, Canada. J Expo Sci Environ Epidemiol. 2014;24(4):358-64. doi: 10.1038/jes.2013.82.
9. To T, Shen S, Atenafu EG, Guan J, McLimont S, Stocks B, et al. The air quality health index and asthma morbidity: a population-based study. Environ Health Perspect. 2013;121(1):46-52. doi: 10.1289/ehp.1104816.
10. Kumar A, Goyal P. Forecasting of daily air quality index in Delhi. Sci Total Environ. 2011;409(24):5517-23. doi: 10.1016/j.scitotenv.2011.08.069.
11. Carbajal-Hernández JJ, Sánchez-Fernández LP, Carrasco-Ochoa JA, Martínez-Trinidad JF. Assessment and prediction of air quality using fuzzy logic and autoregressive models. Atmos Environ. 2012;60:37-50. doi: 10.1016/j.atmosenv.2012.06.004.
12. Yildirim Y, Bayramoglu M. Adaptive neuro-fuzzy based modelling for prediction of air pollution daily levels in city of Zonguldak. Chemosphere. 2006;63(9):1575-82. doi: 10.1016/j.chemosphere.2005.08.070.
13. Koçak K, Şaylan L, Şen O. Nonlinear time series prediction of O3 concentration in Istanbul. Atmos Environ. 2000;34(8):1267-71. doi: 10.1016/s1352-2310(99)00323-4.
14. Gocheva-Ilieva SG, Ivanov AV, Voynikova DS, Boyadzhiev DT. Time series analysis and forecasting for air pollution in small urban area: an SARIMA and factor analysis approach. Stoch Environ Res Risk Assess. 2014;28(4):1045-60. doi: 10.1007/s00477-013-0800-4.
15. Salcedo RLR, Alvim Ferraz MC, Alves CA, Martins FG. Time-series analysis of air pollution data. Atmos Environ. 1999;33(15):2361-72. doi: 10.1016/s1352-2310(99)80001-6.
16. Kayacan E, Ulutas B, Kaynak O. Grey system theory-based models in time series prediction. Expert Syst Appl. 2010;37(2):1784-9. doi: 10.1016/j.eswa.2009.07.064.
17. Scott SL, Varian HR. Bayesian variable selection for nowcasting economic time series. In: Goldfarb A, Greenstein SM, Tucker CE, eds. Economic Analysis of the Digital Economy. Chicago: University of Chicago Press; 2015. p. 119-36. doi: 10.7208/9780226206981-007.
18. Clements MP, Hendry DF. Forecasting Non-Stationary Economic Time Series. MIT Press; 2001.
19. Dekimpe MG, Hanssens DM. Time-series models in marketing: past, present and future. Int J Res Mark. 2000;17(2-3):183-93. doi: 10.1016/S0167-8116(00)00014-8.
20. Chen R, Wang X, Meng X, Hua J, Zhou Z, Chen B, et al. Communicating air pollution-related health risks to the public: an application of the air quality health index in Shanghai, China. Environ Int. 2013;51:168-73. doi: 10.1016/j.envint.2012.11.008.
21. Schwartz J, Marcus A. Mortality and air pollution J London: a time series analysis. Am J Epidemiol. 1990;131(1):185-94. doi: 10.1093/oxfordjournals.aje.a115473.
22. Hajek P, Olej V. Air quality indices and their modelling by hierarchical fuzzy inference systems. WSEAS Trans Environ Dev. 2009;10(5):661-72.
23. Radisic S, Newbold KB, Eyles J, Williams A. Factors influencing health behaviours in response to the air quality health index: a cross-sectional study in Hamilton, Canada. Environ Health Rev. 2016;59(1):17-29. doi: 10.5864/d2016-002.
24. Plaia A, Ruggieri M. Air quality indices: a review. Rev Environ Sci Biotechnol. 2011;10(2):165-79. doi: 10.1007/s11157-010-9227-2.
25. Shahsavani A, Naddafi K, Jafarzade Haghighifard N, Mesdaghinia A, Yunesian M, Nabizadeh R, et al. The evaluation of PM10, PM2.5, and PM1 concentrations during the Middle Eastern Dust (MED) events in Ahvaz, Iran, from April through September 2010. J Arid Environ. 2012;77:72-83. doi: 10.1016/j.jaridenv.2011.09.007.
26. Hashemimanesh M, Matinfar H. Evaluation of desert management and rehabilitation by petroleum mulch base on temporal spectral analysis and field study (case study: Ahvaz, Iran). Ecol Eng. 2012;46:68-74. doi: 10.1016/j.ecoleng.2012.04.038.
27. Goudie AS. Desert dust and human health disorders. Environ Int. 2014;63:101-13. doi: 10.1016/j.envint.2013.10.011.
28. Chen H, Copes R. Review of Air Quality Index and Air Quality Health Index. Environmental and Occupation Health. Toronto, ON: Public Health Ontario; 2013.
29. Robichaud A, Ménard R, Zaïtseva Y, Anselmo D. Multi-pollutant surface objective analyses and mapping of air quality health index over North America. Air Qual Atmos Health. 2016;9(7):743-59. doi: 10.1007/s11869-015-0385-9.
30. Taylor JW. A comparison of univariate time series methods for forecasting intraday arrivals at a call center. Manage Sci. 2008;54(2):253-65. doi: 10.1287/mnsc.1070.0786.
31. Lindahl O, Belgrano A, Davidsson L, Hernroth B. Primary production, climatic oscillations, and physico-chemical processes: the Gullmar Fjord time-series data set (1985-1996). ICES J Mar Sci. 1998;55(4):723-9. doi: 10.1006/jmsc.1998.0379.
32. Lu Y, Zeger SL. On the equivalence of case-crossover and time series methods in environmental epidemiology. Biostatistics. 2007;8(2):337-44. doi: 10.1093/biostatistics/kxl013.
33. Helfenstein U. The use of transfer function models, intervention analysis and related time series methods in epidemiology. Int J Epidemiol. 1991;20(3):808-15. doi: 10.1093/ije/20.3.808.
34. Froukh ML. Decision-support system for domestic water demand forecasting and management. Water Resour Manag. 2001;15(6):363-82. doi: 10.1023/a:1015527117823.
35. Dalimunthe DY, Sulistiana I, Saputra D, Aldila H, Pririzki SJ. Projection of the inflation rate in Pangkalpinang city using the autoregressive moving average (ARMA). Barekeng. 2023;17(3):1513-20. dOI: 10.30598/barekengvol17iss3pp1513-1520.
36. Cao R, Liu W, Huang J, Pan X, Zeng Q, Evangelopoulos D, et al. The establishment of air quality health index in China: a comparative analysis of methodological approaches. Environ Res. 2022;215(Pt 2):114264. doi: 10.1016/j.envres.2022.114264.
37. Zahedi A, Hassanvand MS, Jaafarzadeh N, Ghadiri A, Shamsipour M, Ghasemi Dehcheshmeh M. Increased allergic and asthmatic risks in children residing in industrial areas by surveying the pre-inflammatory (IgE, IL-4 and IL-

13) biomarkers. J Environ Health Sci Eng. 2022;20(2):609-15. doi: 10.1007/s40201-021-00646-5.
38. Bagherian Marzouni M, Alizadeh T, Rezaei Banafsheh M, Khorshiddoust AM, Ghanbari Ghozikali M, Akbaripoor S, et al. A comparison of health impacts assessment for PM10 during two successive years in the ambient air of Kermanshah, Iran. Atmos Pollut Res. 2016;7(5):768-74. doi: 10.1016/j.apr.2016.04.004.
39. Shahsavani A, Tobías A, Querol X, Stafoggia M, Abdolshahnejad M, Mayvaneh F, et al. Short-term effects of particulate matter during desert and non-desert dust days on mortality in Iran. Environ Int. 2020;134:105299. doi: 10.1016/j.envint.2019.105299.
40. Momtazan M, Geravandi S, Rastegarimehr B, Valipour A, Ranjbarzadeh A, Yari AR, et al. An investigation of particulate matter and relevant cardiovascular risks in Abadan and Khorramshahr in 2014-2016. Toxin Rev. 2019;38(4):290-7. doi: 10.1080/15569543.2018.1463266.
41. Zallaghi E, Goudarzi G, Sabzalipour S, Zarasvandi A, Echresh M, Arbian Garmsiri M. Concentration of PM2.5 and prediction of total death rates of people over 30 attributed to all causes of these matters in Ahvaz, Iran (2008-2017). Arch Hyg Sci. 2022;11(3):216-25.
42. Zahedi A, Hassanvand MS, Jaafarzadeh N, Ghadiri A, Shamsipour M, Ghasemi Dehcheshmeh M. Effect of ambient air PM2.5-bound heavy metals on blood metal(loid)s and children's asthma and allergy pro-inflammatory (IgE, IL-4 and IL-13) biomarkers. J Trace Elem Med Biol. 2021;68:126826. doi: 10.1016/j.jtemb.2021.126826.
43. Liu PW. Simulation of the daily average PM10 concentrations at Ta-Liao with Box-Jenkins time series models and multivariate analysis. Atmos Environ. 2009;43(13):2104-13. doi: 10.1016/j.atmosenv.2009.01.055.
44. Liu CM. Effect of PM2.5 on AQI in Taiwan. Environ Model Softw. 2002;17(1):29-37. doi: 10.1016/s1364-8152(01)00050-0.
45. Najafi MS, Khoshakhllagh F, Zamanzadeh SM, Shirazi MH, Samadi M, Hajikhani S. Characteristics of TSP loads during the Middle East springtime dust storm (MESDS) in Western Iran. Arab J Geosci. 2014;7(12):5367-81. doi: 10.1007/s12517-013-1086-z.