environmental sciences proceedings

MDPI

Proceedings

Changes of Air Quality Health Index in a Coastal City of Southeastern Aegean Sea Between a Summer and Winter Period of 2022 †

Ioannis Logothetis [1,2,*], Christina Antonopoulou [1], Georgios Zisopoulos [1], Adamantios Mitsotakis [1] and Panagiotis Grammelis [1]

[1] Centre for Research and Technology Hellas, Chemical Process and Energy Resources Institute, Thermi, GR 57001 Thessaloniki, (I.L.) logothetis@certh.gr, (C.A) antonopoulou@certh.gr, (G.Z.) zisopou-los@certh.gr, (A.M.) adamis@certh.gr, (P.G.) grammelis@certh.gr

[2] Aristotle University of Thessaloniki, Laboratory of Atmospheric Physics, Department of Physics, Greece; ilogothe@physics.auth.gr

* Correspondence: logothetis@certh.gr, (I.L.)

† Presented at the title, place, and date.

Citation: Logothetis, I.; Antonopoulou, C.; Zisopoulos, G.; Mitsotakis, A.; Grammelis, P. Changes of Air Quality Health Index in a Coastal City of Southeastern Aegean Sea Between a Summer and Winter Period of 2022. **2023**, *5*, x. https://doi.org/10.3390/xxxxx

Academic Editor:

Received: date
Accepted: date
Published: date

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2023 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).

Abstract: The increased concentration of pollutants is a challenge for the population health. This work aims to investigate the health risk that is related to pollutants' level in the center of Rhodes city. Rhodes Island is a desirable tourist destination with important economic activity over the southeastern Aegean Sea. The analysis covers the (summer) July-August months and the (winter) December month of 2022. Hourly recordings of the concentrations of PM2.5, NO2 and O3 from a mobile Air Quality Monitoring System (AQMS) are analyzed. In order to investigate the effects of pollution level on people's health, the Air Quality Health Index (AQHI) is calculated. Results show that summer compared to winter period shows increased health danger possibly due to the increased traffic emissions, tourist density as well as the different meteorological conditions. In summer period, the AQHI is classified between middle and upper Medium health risk class. During winter month, AQHI is mainly classified in low Medium health risk class. The summer shows increased health risk although the AQHI diurnal variability is lower as compared to December. Additionally, the diurnal differences between two periods show increased health risk in summer period for the majority of the hours. Finally, the analysis shows that the traffic activities possible affect the health risk and also highlight that the authorities should adopt green policies to protect human's health and environment.

Keywords: Air quality health index (AQHI); air quality; pollution; Rhodes Island; southeastern Mediterranean; Aegean Sea; PM2.5; NO2; O3

1. Introduction

The World Health Organization (WHO) highlights that the increased pollution are related with various health issues such as respiratory disorders, cancers, cardiovascular disorders etc [1]. The air quality degradation is a health challenge for contemporary societies [2]. In this context, the scientific community is highly interested to further investigate the air quality and the related impact on human's health [3,4].

The Rhodes Island is located in the southeastern Aegean Sea over the southeastern Mediterranean. The Rhodes city is the capital of Dodecanese municipality and it is located in the north edge of the Island. The temperate climate conditions, the mild winter and hot (sunny) summer [5], in combination to the unique landscapes, gastronomy and cultural heritage are some of the factors that make this place a desirable destination for thousands

of tourists each year. The increased anthropogenic activities that includes human activities, traffic and vehicle emissions are some of the fundamental factors that affect the local air quality [5,6]. The high traffic emissions in the city center of Rhodes affects the pollution levels degrading the air quality in this region [5]. Additionally, the synergy between the poor air quality and discomfort conditions increases the health risk for local population [7]. Previous studies have already shown that the anthropogenic activities, meteorological conditions as well as the atmospheric circulations determine the level of pollution in the region of Aegean affecting the air quality in the city [5,6,8].

The investigation of air quality and the related impact on human health are a dominant concern for the public and authorities over the southeastern Aegean [9]. This region is an important socioeconomic component regarding the sustainability of southeastern Aegean Sea. The Air Quality Health Index (AQHI) is a measure that provides a message (and suggestions) to public regarding the impact of pollution level on human health. AQHI is calculated using the concentration of PM2.5, NO2 and O3 in order to provide health suggestions for population [10].

This study is conducted in the context of the "ELEKTRON" project (https://elektron-project.gr/index.php) that aims to promote green technologies over the coastal regions of southeastern Aegean. In this work, a mobile Air Quality Monitoring System (AQMS) with sensors that measure the concentrations of PM2.5, NO2 and O3 are used during the summer and winter period of 2022. Generally, the AQMS do not show the desirable accuracy regarding the absolute values of the concentration of pollutants [11,12]. However, AQMS provide a solution for the investigation of the air quality in regions where the monitoring stations are missing [13]. In this context, this analysis aims to provide elements regarding the impact of pollutants on human health risk in the center of Rhodes city.

2. Materials and Methods

An AQMS (HazScanner™ model HIM-6000; [14,15]), equipped with calibrated sensor to measure concentration of pollutants, is located in the center of Rhodes city. The location of AQMS is selected because this area shows high vehicle density, increased commercial activities and it is also neighboring to the (high traffic) touristic area of medieval city (Fig. 1). The AQMS provides the ability for high-frequency recordings (sampling rate: 5 min) of pollutants' concentration. In particular, recordings of the concentration of PM2.5 (μm/m3), NO2 (ppb) and O3 (ppb) are used to calculate hourly and daily mean concentrations in order to investigate the effect of air quality on human's health risk. The analysis covers two summer (July – August; JA) and a winter (December) months of 2022. For the analysis the Air Quality Health Index (AQHI) is calculated following the analysis of Yao et al. [10] (Equation 1). Generally, AQHI provides to the population a health message that is related to the level of pollution. The classes of AQHI and the related health suggestion for the population is presented in Table 1.

$$AQHI = \frac{10}{10.4} * \left(100 * \left(e^{0.000871*NO_2} - 1 + e^{0.000537*O_3} - 1 + e^{0.000487*PM_{2.5}} - 1\right)\right) \quad (1)$$

(**a**) (**b**)

Figure 1. (**a**) The location of Air Quality Monitoring System (AQMS) in the city center of Rhodes and (**b**) the location of AQMS near medieval city in the center of Rhodes city.

In order to investigate the variation of air quality health conditions (in terms of the impact of the concentration of PM2.5, NO2 and O3 on human health) the daily mean values of AQHI is calculated for July-August (JA) and December period. Additionally, the diurnal variation of AQHI as well as the anomalies of JA diurnal variation of AQHI (with reference to December) are calculated to study the hours with the most degraded health conditions. The statistical significance of anomalies are calculated using the two-tailed t-test at significance level 95% [16]. Finally, the box-plot of daily mean AQHI is constructed in order to study the monthly variation of AQHI between a summer (high traffic activity) and winter (low traffic activity) period.

Table 1. The classes of Air Quality Health Index.

Health Risk	AQHI	Health Suggestions	
		Sensitive population	General Population
Low	**1 - 3**	Enjoy your usual outdoor activities.	Ideal air quality for outdoor activities.
Moderate	**4 - 6**	Consider reducing or rescheduling strenuous activities outdoors if you are experiencing symptoms.	No need to modify your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.
High	**7 - 10**	Reduce or reschedule strenuous activities outdoors. Children and the elderly should also take it easy.	Consider reducing or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation.
Very High	**>10**	Avoid strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion.	Reduce or reschedule strenuous activities outdoors, especially if you experience symptoms such as coughing and throat irritation.

3. Results and Discussion

The daily mean values of AQHI during the JA and December months of 2022 is presented in Figure 2. The calculation of AQHI shows that the summer months (JA) presents degraded air quality health conditions compared to winter period (December). The mean pollutants' health conditions, which are related to the concentration of PM2.5, NO2 and O3, are classified mainly in middle and upper Moderate class (between 4 and 6 AQHI values). The reduced tourist activities, traffic emissions as well as vehicle density in the city center of Rhodes during the December is the main reason for the improved health risk as compared to JA of 2022. Robaina et al. [17], studying the air quality in five European countries, have found that the increased tourism is related with the degradation of air quality (in terms of particle matters). Our findings possibly shows that the improved AQHI during December (except 7th and 28th December that AQHI are classified in upper Moderate class) are related to the reduced anthropogenic activities such as vehicle traffic emissions and tourist density. Additionally, it is important to highlight that possible the differences in the height of boundary layer between summer and winter period affects the concentration of pollutants in low troposphere [18].

In order to investigate the hourly variation of air quality health risk, the diurnal variation of AQHI is calculated (Fig. 3a). This analysis shows that the hours between 7:00 to 18:00 shows improved AQHI for people during the mean summer (JA) months' day. Generally, December shows lower health risk, as compared to JA period, due to the decreased concentrations of PM2.5, NO2 and O3. The improved health conditions during daytime hours in the summer months possible are explained by the impact of the traffic emissions [19] and meteorological conditions such as wind speed and the diurnal development of the boundary layer [18]. Kim et al. [20] have shown that the wind speed shows a negative association to the pollution level near road arteries. Additionally, Murthy et al. [21] have shown that the height of mixing layer is negative correlated to NOx and PM2.5. The diurnal anomalies of JA AQHI show that both for July and August, the AQHI increases for the majority of day hours as compared to the December mean AQHI diurnal cycle (Fig. 3b,c).

An exception to this result is the difference of AQHI between August and December at 9:00 – 10:00 (Fig. 3c,d). To sum up, results show that summer months, as compared to December, present increased AQHI during the hours between middle day to early evening hours and between midnight to early morning (Fig. 3b,c).

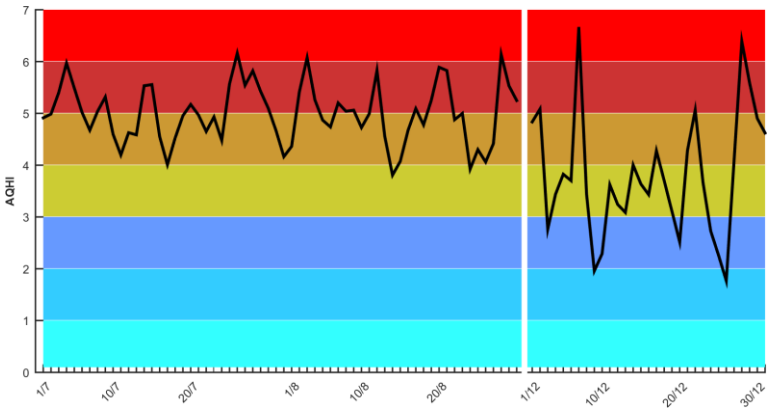


Figure 2. Daily mean evolution of AQHI during July-August (JA) and December months of 2022. Cold/ Warm colors indicate the Low/ Moderate to limited High AQHI classes.

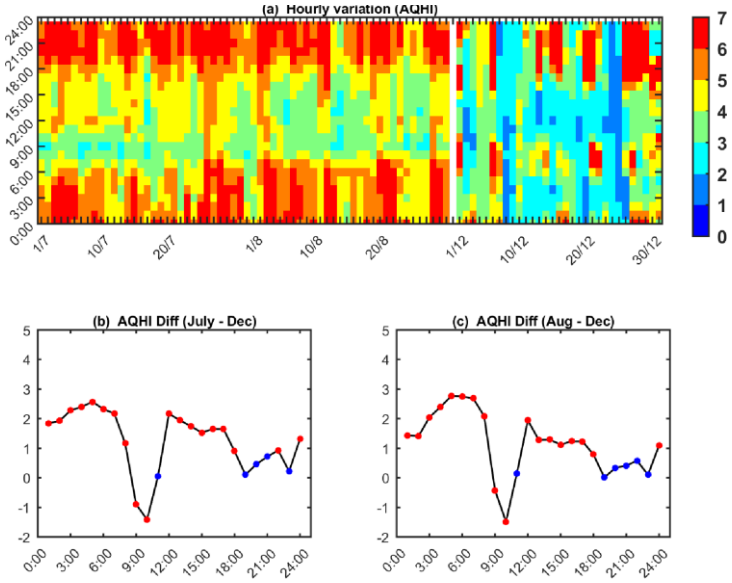
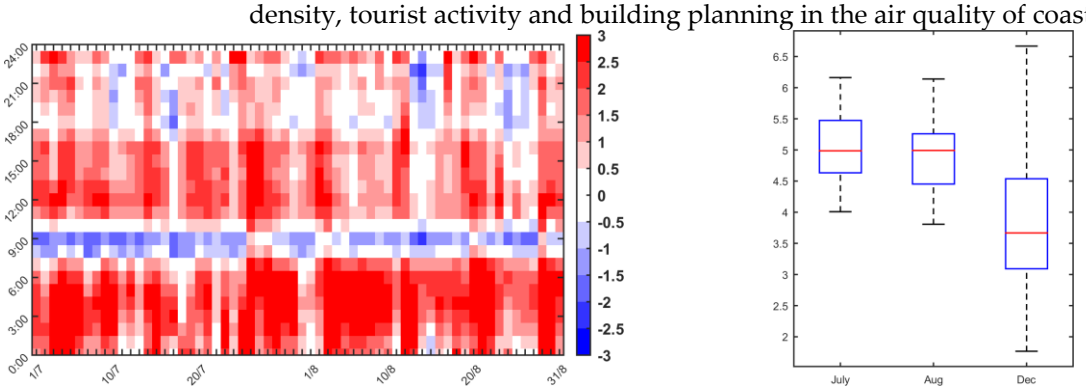


Figure 3. (a) Hourly variation of AQHI for July-August (JA) and December months, 2022; **(b)** Hourly differences of AQHI between July and December and **(c)** hourly differences of AQHI between August and December. The red/ blue points denotes the statistical significant/ insignificant differences at 95%.

To further investigate the diurnal changes of AQHI between the summer (July-August; JA) and winter (December) period, the diurnal anomalies of JA AQHI, with reference to the diurnal variation of December AQHI, is calculated (Fig. 4a). The analysis indicates that the maximum AQHI changes (stat. sign. at 95%) are mainly presented during the midnight to early morning hours (Fig. 4a & Fig 3b,c). Song et al. [19] have shown that diurnal traffic emissions, which are related to vehicle traffic, increase the level of pollution during these hours affecting people's health risk. These elements provide an evidence for the impact of vehicle traffic and anthropogenic activities in human health risk.

The median of daily mean AQHI distribution of JA is classified in Moderate class (medium Moderate AQHI; Fig 4b). December shows that the median of daily mean AQHI distribution is about 3.5. In comparison to December, July and August shows an increase of AQHI values about 1.2. This point shows that during December the air quality health

conditions is classified in lower limit of Moderate AQHI class (about 3.5) indicating reduced people's health risk compared to the summer period. Logothetis et al, [5] have shown that the meteorology and traffic activity affect the air quality of Rhodes city (summer 2021). The further investigation of the air quality and AQHI in different areas of Rhodes city over the seasons could improve our knowledge regarding the impact of traffic density, tourist activity and building planning in the air quality of coastal areas.



(**a**) (**b**)

Figure 4. (a) Hourly anomalies of AQHI between JA and diurnal mean AQHI of December, 2022; **(b)** Box-plot of daily mean AQHI for July, August and December. Red line indicates the median of AQHI distribution. The blue box shows the limits of 25th and 75th percentile. The whiskers shows the maximum and minimum values.

4. Conclusion

This study investigates the impact of air pollution on the people's health risk in the city center of Rhodes using recordings from an Air Quality Monitoring System (AQMS). In order to investigate the impact of pollution levels' on health risk of population, the Air Quality Health Index (AQHI) is calculated. The analysis is focused in a summer (JA) - high traffic period and, a winter (December) - low traffic period of 2022. The daily variation of AQHI show that JA categorized mainly in Moderate health risk class. During December the health risk seems to be improved compared to summer period. The analysis of diurnal variation shows that summer period shows increased AQHI during the hours between midnight to early morning and midday hours possible due to the impact of high traffic emissions and anthropogenic activities. Additionally, the hourly AQHI variation during summer months is about 3 to 6 and it is increased, as compared to December, about 1.2. Results emphasize the importance to be adopted sustainable green measures from authorities. Finally, findings can provide the basis for the development of a real time message system that inform people regarding people's health risk in Rhodes city as well as other coastal areas over southeastern Aegean Sea.

Contributions: Conceptualization, I.L., A.M. and P.G.; methodology, I.L.; software, I.L.; validation, I.L.; formal analysis, I.L.; investigation, I.L.; resources, I.L.; data curation, I.L. and G.Z.; writing—original draft preparation, I.L.; writing—review and editing, I.L. and C.A.; visualization, I.L.; supervision, A.M. and P.G.; project administration, A.M. and P.G.; funding acquisition, P.G. All authors have read and agreed to the published version of the manuscript.

Funding: Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014– 2020) and co-financed by Greece and the European Union (European Regional Development Fund).

Institutional Review Board Statement: Not applicable

Informed Consent Statement: Not applicable

Data Availability Statement: Not applicable.

Acknowledgments: We acknowledge the support of this work by the project "ELEKTRON" (MIS: 5047136), which is implemented under the Action "Reinforcement of the Research and Innovation

Infrastructure", funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014–2020) and co-financed by Greece and the European Union (European Regional Development Fund). Finally, the authors would like to thank Ourania Hassiltzoglou for English Language editing.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. World Health Organization. (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. https://apps.who.int/iris/handle/10665/345329.
2. McCarron, A., Semple, S., Braban, C.F. et al. Public engagement with air quality data: using health behaviour change theory to support exposure-minimising behaviours. J Expo Sci Environ Epidemiol (***2022***). https://doi.org/10.1038/s41370-022-00449-2
3. Nastos P.T., Weather, Ambient Air Pollution and Bronchial Asthma in Athens, Greece. In: Thomson, M.C., GarciaHerrera, R., Beniston, M. (eds) Seasonal Forecasts, Climatic Change and Human Health. Advances in Global Change Research, ***2008***, vol 30. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-6877-5_11
4. Monforte P., Ragusa M.A., Evaluation of the air pollution in a Mediterranean region by the air quality index. Environ Monit Assess ***2018***,190, 625, https://doi.org/10.1007/s10661-018-7006-7
5. Logothetis, I.; Antonopoulou, C.; Zisopoulos, G.; Mitsotakis, A.; Grammelis, P. The Impact of Climate Conditions and Traffic Emissions on the Pms Variations in Rhodes City during the Summer of 2021. In Proceedings of the 7th World Congress on Civil, Structural, and Environmental Engineering, Virtual, 10–12 April 2022
6. Fameli K.M., Kotrikla A.M., Psanis C., Biskos G., Polydoropoulou A., Estimation of the emissions by transport in two port cities of the northeastern Mediterranean, Greece, Environmental Pollution, ***2020***, Volume 257, https://doi.org/10.1016/j.envpol.2019.113598.
7. Poupkou, A.; Nastos, P.; Melas, D.; Zerefos, C. Climatology of Discomfort Index and Air Quality Index in a Large Urban Mediterranean Agglomeration. Water Air Soil Pollut. ***2011***, 222, 163–183
8. Rizos K., Logothetis I., Koukouli M.E., Meleti C., Melas D. The influence of the summer tropospheric circulation on the observed 221 ozone mixing ratios at a coastal site in the Eastern Mediterranean, Atmospheric Pollution Research, 2022, Volume 13, Issue 4, 222 https://doi.org/10.1016/j.apr.2022.101381
9. OECD Environmental Performance Reviews, Greece HIGHLIGHTS 2020, https://ypen.gov.gr/wp-content/uploads/2020/11/OECD-EPR-Greece-2020-Highlights-English.pdf (*assessed on 31 March 2023*)
10. Yao, J., Stieb, D.M., Taylor, E. et al. Assessment of the Air Quality Health Index (AQHI) and four alternate AQHI-Plus amendments for wildfire seasons in British Columbia. Can J Public Health 111, 96–106 (2020). https://doi.org/10.17269/s41997-019-00237-w
11. Liang, L.: Calibrating low-cost sensors for ambient air monitoring: Techniques, trends, and challenges, Environ. Res. , ***2021***, 197, 111163, https://doi.org/10.1016/j.envres.2021.111163
12. Liu H.Y., Schneider P., Haugen R., Vogt M. Performance assessment of a low-cost PM2.5 sensor for a near four-month period in Oslo, Norway Atmosphere, 2019, 10 (2) p. 41, 10.3390/atmos10020041
13. deSouza P., Kahn R., Stockman T., Obermann W., Crawford B., Wang A., Crooks J., Li J., and Kinney, Calibrating networks of low-cost air quality sensors, Atmospheric Measurement Techniques, 2022, Volume 15, issue 21, https://doi.org/10.5194/amt-15-6309-2022
14. Achieng' G. O., Andala D. M., Determination of Ambient air quality status through Assessment of particulate matter and selected gases, International Conference on Air Quality in Africa (ICAQ'Africa2022)11-14 October, 2022 (Online)
15. EDC Environmental Device Corporation, https://environmentaldevices.com (accessed on 28 March 2023)
16. Wilks, D.S. Forecast Verification. Statistical Methods in the Atmospheric Sciences; Academic Press: New York, NY, USA, 1995.
17. Robaina M., Madaleno M., Silva S., Eusébio C., Carneiro M.J., Gama C., Oliveira K., Russo M.A., Monteiro A., The relationship between tourism and air quality in five European countries, Economic Analysis and Policy, 2020, Volume 67, Pages 261-272, https://doi.org/10.1016/j.eap.2020.07.012.
18. Kim K.H.; Lee S.-B.; Woo S.H.; Bae G.-N. NOx profile around a signalized intersection of busy roadway Atmos. Environ., 2014, 637 97, pp. 144-154
19. Song, J.; Wang, Z.H.; Wang, C. Biospheric and anthropogenic contributors to atmospheric CO2 variability in a residential neighborhood of Phoenix, Arizona. J. Geophys. Res. Atmos. 2017, 122, 3317–3329.
20. Kim K. H., Lee S.-B., Woo D., Bae G.-N., Influence of wind direction and speed on the transport of particle-bound PAHs in a roadway environment, Atmospheric Pollution Research, Volume 6, Issue 6, 2015, Pages 1024-1034, ISSN 1309-1042, https://doi.org/10.1016/j.apr.2015.05.007
21. Murthy B.S., Latha R., Tiwari A., Rathod A., Singh S., Beig G., Impact of mixing layer height on air quality in winter, Journal of Atmospheric and Solar-Terrestrial Physics, 2020, Volume 197, https://doi.org/10.1016/j.jastp.2019.105157.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.