



Evaluation of the air quality and CO₂-equivalent change of Kayseri during the COVID-19 outbreak

COVID-19 salgını sırasında Kayseri'nin hava kalitesi ve eşdeğer CO₂ değişiminin değerlendirilmesi

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Abstract

The focus of this paper is to evaluate the air quality change of Kayseri Province during the Covid-19 outbreak and examine the possible climate change impact. Air quality were evaluated using PM₁₀, SO₂, air temperature, and natural gas consumption data for 56-day quarantine period in Kayseri. Analysis of variance (ANOVA) applied to all data set and then the Tukey-Kramer procedure implemented. CO₂ equivalent calculated with EPA (United States Environmental Protection Agency) formulas. The PM₁₀ concentration of 2020 decreased by 40% and 9% in the city center and organized industrial zone (OIZ), respectively compared to 2019. As for SO₂, 34% and 30% decreased was seen for the city center and OIZ, respectively. CO₂ emission from transportation and natural gas decreased by 5.5 times and 16% than normal periods, respectively. Total reducing CO₂ emission during 56-day pandemic period was almost 1 million ton.

Keywords: Air quality, Climate change, COVID-19, CO₂-equivalent, Kayseri, Turkey,

1 Introduction

27 pneumonia cases whose ethiology is unknown and which showed itself in SARS-CoV and MERS-CoV strains before in 2003 and 2012 were detected in Wuhan city in China and the rapid increase in the number of cases in a very short period of time caused to worries in all over the world [1-3]. World Health Organization (WHO) declared this virus called as Covid-19 as global health emergency on January 30th, 2020 after its expansion to some countries with the foreign and domestic travels of the people [4, 5]. There are approximately 4,179,479-approved cases and a total of 287,525 deaths all over the world as of May 13th, 2020 and these numbers continue increasing day by day [5, 6].

The first emergence date of the virus in Turkey is March 11th, 2020 and there are 143114 approved cases and a total of 3952 deaths as of March 13th, 2020 according to the data of the Ministry of Health in the Republic of Turkey [7]. Turkey is one of the countries taking the earliest precautions regarding Covid-19, the precautions have been gathered under the headlines such as for the resource, for the infection way and for the healthy people and they continue to be taken [8]. Within this scope; social and communal precautions are taken in the struggle with the pandemia and the numbers of

Özet

Bu çalışma ile Covid-19 karantina önlemlerinin Türkiye genelinde başladığı 11 Mart 2020 tarihi kıstas alınarak Kayseri ili hava kalitesindeki değişimin belirlenmesi ve CO₂ eşdeğeri cinsinden iklim değişikliği üzerinde yarattığı pozitif katkının ortaya çıkarılması amaçlanmıştır. 11 Mart-5 Mayıs dönemlerine ait 56 günlük 2020 yılı ve geçmiş beş yıla ait PM₁₀ ve SO₂ konsantrasyonları, doğal gaz tüketim verileri, ortalama hava sıcaklığı ve araç trafiğine dair veriler temin edilip varyans (ANOVA) ve Tukey-Kramer çoklu karşılaştırma testi yapılmıştır. CO₂ eşdeğerlikleri EPA (U.S. Environmental Protection Agency) hesaplama kriterleri uyarlanarak hesaplanmıştır. Çalışma sonucunda kent merkezine ait PM₁₀ ve SO₂ konsantrasyonu 2020 yılında 2019'a göre sırasıyla %40 ve %34 azalırken, OSB bölgesi için bu değerler 2019'a kıyasla sırasıyla %9 ve %30 düşüş göstermiştir. Normal duruma göre CO₂ emisyonları araç trafiği için 5.5 kat ve doğal gaz tüketimi için ise %16 oranında düşüş göstermiştir. Atmosfere salınımı engellenen CO₂ emisyonu toplamda 1 milyon (1,003,455) ton olarak hesaplanmıştır.

Anahtar kelimeler: Hava kalitesi, Covid-19, CO₂-eşdeğer, İklim değişikliği, Kayseri, Türkiye

cases, tests, deaths and intubated patients are daily published in the website of the ministry <https://covid19.saglik.gov.tr/>. After the observance of the first case in March 11th, 2020; chronologically, schools were dismissed in Turkey all over the country as of March 12th, comprehensive travel and transportation were limited on March 15th, all foreign flights were stopped as of March 28th, domestic plane-bus travels were subjected to permit and vehicle capacities were decreased by 50%. Curfew was declared for citizens below 20 and above 65 on April 4th, curfews were applied every weekend and in all official holidays following April 10th and continue to be applied [7]. The legislative background of the alternative methods such as flexible working, working on shift and home working were arranged in public and private sector. Legislative regulations were realized in the issue of proceeding to distance education and flexible academic calendar following the obligatory cessation of the education by the necessary ministries [7]. A new normalization process was entered as of May 11th depending on the decreasing number of cases, curfews were decreased from 31 cities to 15 cities and flexibility decisions were reached in social life areas [8].

WHO has demanded the people all over the world to obey to the social distance applications, avoid from mass

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transportation vehicles and isolate themselves from other people during the pandemic and suggested rapid and hard precautions to keep people at their home by closing the schools, industries, operations, travels, domestic and international borders for many countries [9]. This unaccustomed situation has brought the normal life to a halt all over the world as of February 2020 and a perceptual improvement has been observed in terms of environment [9]. Studies conducted on the positive or negative impacts of Covid-19 process all over the world in terms of the environment have rapidly started to take their places in the literature. While Scripps Oceanography Institute has foreseen that the fossil fuel usage will decrease by approximately 10% all over the world due to the expansion of Covid-19 [10], studies showing that waste amounts have decreased at the beaches due to the number of visitors and the package based inorganic waste types have increased in parallel to the increase in online food consumption have been published [11]. In their study, Calma et.al. [12] have specified that there has been an increase in the waste stemming from the personal protective equipment such as mask and glove in the countries and also in the report prepared by RIVM National Public Health and Environment Institute in Netherlands, they have expressed that first findings about Covid-19 have been found in the canalization systems. In the study conducted by Barcelo [13], it has been stated that Covid-19 virus has been detected in the samples of canalization waters coming from Australia. While air pollution stemming from human activities has been observed to have decreased during the quarantine period, the studies within this scope have been generally seen to have started to aggregate on the impacts of air pollution on the expansion of Covid-19 or on human health [14-16].

The main aim of this conducted study is to reveal what kind of a positive impact the 56-day (March 11th, 2020-May 5th, 2020) period taken to the scope of the study will cause to in terms of the climate change during the pandemic process. Within this direction; the change in the air quality of Kayseri has been assessed upon the parameters of PM₁₀ and SO₂ and CO₂ equivalents prevented to be released in this process have been calculated in terms of the natural gas consumption and the decrease in traffic. An assumption has been presented with reliable data that could be attained at short period without neglecting the requirement that many different parameters should be considered when it is thought within the city scale. The study has a more different qualification than the air pollution studies specified in the literature with this aspect it has, and it has the property of being the first representation in terms of Turkey. Results of the study are leading within the direction of submitting a foresight for the precautions necessary to be taken by the countries in the struggle against global climate change.

2 Material and methods

2.1 Study area

Kayseri is the third largest city of Central Anatolia after Ankara and Konya and is also an important industrial center. According to the data of TUIK; the city with the population of 1,407,409 as of December 2019 is settled in Central

Kızılırmak side and on the foot slopes of Erciyes Mountain [17]. Kayseri whose wind speed is 1.8 m/s, average air temperature is 10.6 °C and average precipitation amount is 389 mm according to the long-year average data of the Regional Directorate of Meteorology (RDM) is located relatively like a pot with its six neighbor cities and the high mountains surrounding it. Kayseri Organized Industrial Zone (OIZ) being a value assessment zone of ours and bearing 17 out of 500 greatest companies of Turkey and in which companies above 500 in almost all sectors conduct production is at a distance of 15 km to the city centrum and is established on an area of 11,500,000 square meter. With its status, OIZ continues its production and employment activities in a quality of giving acceleration to the developing economy of mainly Kayseri and Turkey [17]. The settlement location of the study region is shown in Figure 1.



Figure 1. Location of Kayseri city center and OIZ region (Source: Google Maps)

2.2 Collection of data sets

56-day supplied data belonging to the previous five years within the period of March 11th-May 5th within the scope of the study and their properties are summarized in Table 1. Consumptions of fossil fuel known to be efficient on the air quality, but to which we could not find the opportunity of reaching to “reliable” data sets in this process except for natural gas used for heating purposes in the city centrum have not unfortunately been evaluated within the scope of the study. Turkish statistical Institute (TUIK) and Highway Commission vehicle data have been proportioned again and calculated for Kayseri using EPA factors for revealing the impact caused by traffic jam.

2.3 Statistical analyses

Statistical evaluation of the difference among the data sets has been conducted with variance (ANOVA) analysis. Besides, ANOVA and afterwards, Tukey-Kramer procedure have been applied on the data belonging to previous years. All the analyses have been conducted on Excel with the reliability range acceptance of 95%.

Table 1. Data sets and sources

Parameter	Region	Data Source	Period
Average Air Temperature	City Center	Regional Directorate of Meteorology [18]	
Average Wind Velocity	City Center		
Natural Gas Consumption	City Center	KayseriGaz Incorporated Company [19]	2016-2017-2018-2019 and 2020 data for the period of March 11-May 5.
Natural Gas Consumption	Organized Industrial Zone		
PM ₁₀ Concentration	City Center and Organized Industrial Zone	Ministry of Environment and Urbanization/ National Air Quality Monitoring Network [20]	
SO ₂ Concentration	City Center and Organized Industrial Zone		
Number of road motor vehicles registered to the traffic	Kayseri Province	Turkish Statistical Institute-TÜİK [21]	Data for the end of March 2020
Distribution of registered vehicles by fuel types	Kayseri Province		
Average distance traveled by vehicles annually	Kayseri Province	Highway Transportation Statistical Report [22]	Year 2018

2.3 Calculation of CO₂ equivalent

Consumption of natural gas being one of the types of fossil fuel considered to have an impact on the air pollution on provincial basis and in the periods specified in OIZ and the greenhouse gas emission equivalent of the emission amounts stemming from traffic depending on the decrease in the number of vehicles in the traffic have been calculated with conversion formulas in terms of CO₂ equivalents. All calculation coefficients and formulas have been taken from EPA (United States Environmental Protection Agency). The formula coefficients and resources used in the conversion are shown in Table 2. CO₂ equivalent calculation has been calculated according to the decrease occurring in the consumption of natural gas upon the consumption in m³ supplied from KayseriGAZ. Emission conversion coefficients given in Table 2 and taken from EPA have been used in the CO₂ equivalent calculation regarding the decrease in the emission stemming from traffic. Criteria conversions have been calculated by conversion from the highway traffic data given in Table 1 in the calculation of emission stemming from traffic.

Table 2. CO₂ emission coefficients originated from vehicles [23]

Vehicle Type	The amount of emissions	CO ₂	Source
Car	0.368 kg CO ₂ /mile		(EPA 2019) [23, 25]
Minibus	0.501 kg CO ₂ /mile		
Van	0.501 kg CO ₂ /mile		
Motorcycle	0.197 kg CO ₂ /mile		
Bus	1.256 kg CO ₂ /mile		
Truck	1.456 kg CO ₂ /mile		
Fuel Type	The amount of emissions	CO ₂	Source
Natural Gas	1.858×10 ⁻³ CO ₂ /m ³	Metric ton	(EPA 2019) [24]
Gasoline	8.887×10 ⁻³ CO ₂ /Gallon	Metric ton	
Diesel	10.180×10 ⁻³ CO ₂ /Gallon	Metric ton	Federal Register (2010) [25]
LPG	5.680×10 ⁻³ CO ₂ /Gallon	Metric ton	

3 Results and discussion

3.1 Changes of PM₁₀ and SO₂ concentration

The changes of PM₁₀ and SO₂ concentrations have been assessed for the periods of March 11th being the date pandemia started and May 5th being the end of the assessment interval of the study. 56-day (March 11th-May 5th period interval) average change graphs between the years 2016-2020 are shown in Figure 2. PM₁₀ concentration belonging to 2020 has shown a decrease by 40% when compared to 2019 by decreasing from 49 µg/m³ to 29 µg/m³. The decrease in OIZ of PM₁₀ concentration has been 9% for the same period by decreasing from 40 µg/m³ to 37 µg/m³. SO₂ concentration belonging to 2020 has been calculated for the city centrum and OIZ respectively as 34% by decreasing from 6 µg/m³ to 3 µg/m³ and as 30% by decreasing from 6.50 µg/m³ to 4.55 µg/m³. p value confidence range has been 5.56 x 10⁻¹⁸ being too lower than 0.05 as a result of the regression (one-way ANOVA) test within the confidence range of 95% for the purpose of evaluating the statistical significance of the city centrum concentration of PM₁₀ among years. Average PM₁₀ concentration on March 11th-May 5th period bears statistically significant difference among years. Similar statistical difference has also been significant for the city centrum concentration of SO₂ value.

PM₁₀ and SO₂ concentrations within OIZ have shown statistically significant difference in terms of the values of the last five years especially in the quarantine process covering 56 days. However, Tukey-Kramer multiple comparison test has been applied to the data sets following ANOVA test for the purpose of being able to statistically assess the difference of each year with another year. Table 3 summarizes the results of all conducted statistical analyses. When the analysis results in Table 3 are carefully examined, average PM₁₀ and SO₂ values measured in 2020 pandemia

period for the city centrum are statistically and significantly different when compared to the average results of 2019. For OIZ; it has been concluded that there is a significant difference only for SO₂.

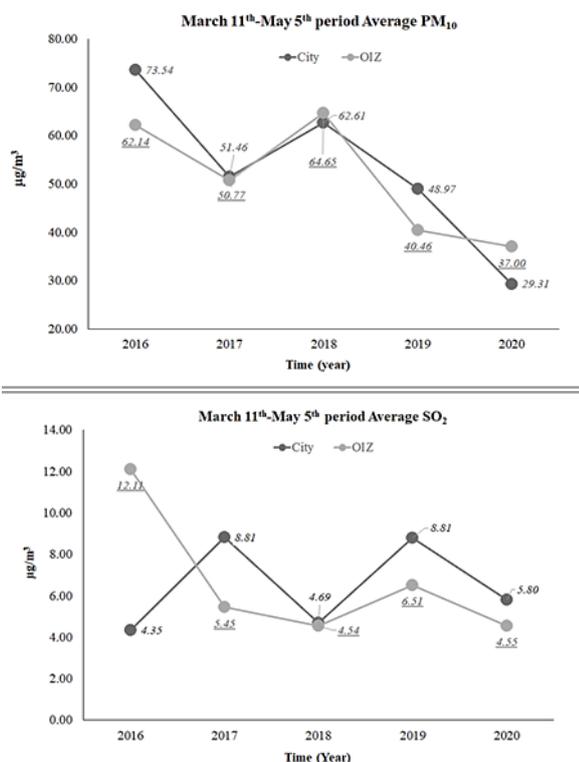


Figure 2. Periodical Change of Concentrations of PM₁₀ and SO₂

3.2 Natural gas consumption changes

The relation of natural gas consumption has been evaluated for March 11th being the commencement of the pandemia and May 5th being the end of the evaluation range. The average change graphs attained for 56 days between the years 2016-2020 are shown in Figure 3. While natural gas consumption has shown a decrease by 13.5% in 2020 when compared to 2019 for city centrum, this value has been 28% in OIZ. The increase in the consumption of natural gas observed in the transition from 2018 to 2019 has occurred as a result of the increase in the investments by the natural gas supplier company on the city adjacent area (Figure 3-c).

As seen in the results of the statistical analysis given in Table 3; the air temperature and natural gas consumption values belonging to the city centrum in 2020 have not shown any statistically significant difference when compared to 2019. However, in contrast, the decrease by 13.5% is thought to stem from the schools, dormitories, university, and public institutions finalizing their activities.

The relation of the natural gas consumption used in the city centrum during the pandemia to the air temperature is clearly seen from Figure 3-b and Figure 3-c. Natural gas consumption values in terms of OIZ have relatively shown a different course. According to the results of Tukey-Kramer multiple comparison test (Table 3); the consumption of 2020 is statistically and significantly different when compared to 2019. This result not observed in city centrum has been interpreted within the direction that there is a decrease in the natural gas consumption stemming from the process related to the work slow-down and curfews during the quarantine period in OIZ. How the average air temperature in Kayseri and OIZ natural gas consumption have changed is seen in Figure 3-d.

3.3 CO₂ equivalences

3.3.1 Conversion of natural gas consumption

Natural gas consumption is 1 million 766 thousand standard m³ in Kayseri city centrum in 2019 during March 11th-May 5th period. It has decreased to 1 million 512 thousand standard m³ on average during the pandemia process in 2020. The values have been measured as respectively 329 thousand and 237 thousand standard m³ within the same period among the years for OIZ. A total of 345 thousand standard m³ natural gas consumption has been saved in 2020 during the pandemia period when compared to 2019 for the city centrum and OIZ. Approximate CO₂ equivalent of this value is 640 metric tons (581 tons) according to EPA calculation factors given in Table 2. Equivalent CO₂ release of 581 tons has not been given to the atmosphere during the quarantine period due to the decrease depending on the natural gas usage. As a result of the comparison conducted according to the normal period; CO₂ release has decreased by 16% for the city of Kayseri during 56-day pandemia process because of the comparison conducted when compared to the normal period.

Table 3. Tukey-Kramer multiple comparison test results (Num df=5, Den df=219)

Years	City Center		Organized Industrial Zone		City Center		OIZ		City Center
	PM ₁₀ P<0.5	SO ₂ P<0.5	PM ₁₀ P<0.5	SO ₂ P<0.5	Natural Gas Consumption P<0.5	Natural Gas Consumption P<0.5	Natural Gas Consumption P<0.5	Natural Gas Consumption P<0.5	Air Temperature P<0.5
2016-2020	*	*	*	*	*	-	-	*	*
2017-2020	*	*	-	-	*	*	*	*	-
2018-2020	*	-	*	-	*	*	*	*	*
2019-2020	*	*	-	*	-	*	*	*	-

* The Tukey-Kramer multiple comparison test shows that the value between two years has a statistically "significant difference". (Abs diff > critical range)
 - The Tukey-Kramer multiple comparison test shows that the value between two years is statistically "no significant difference". (Abs diff < critical range)

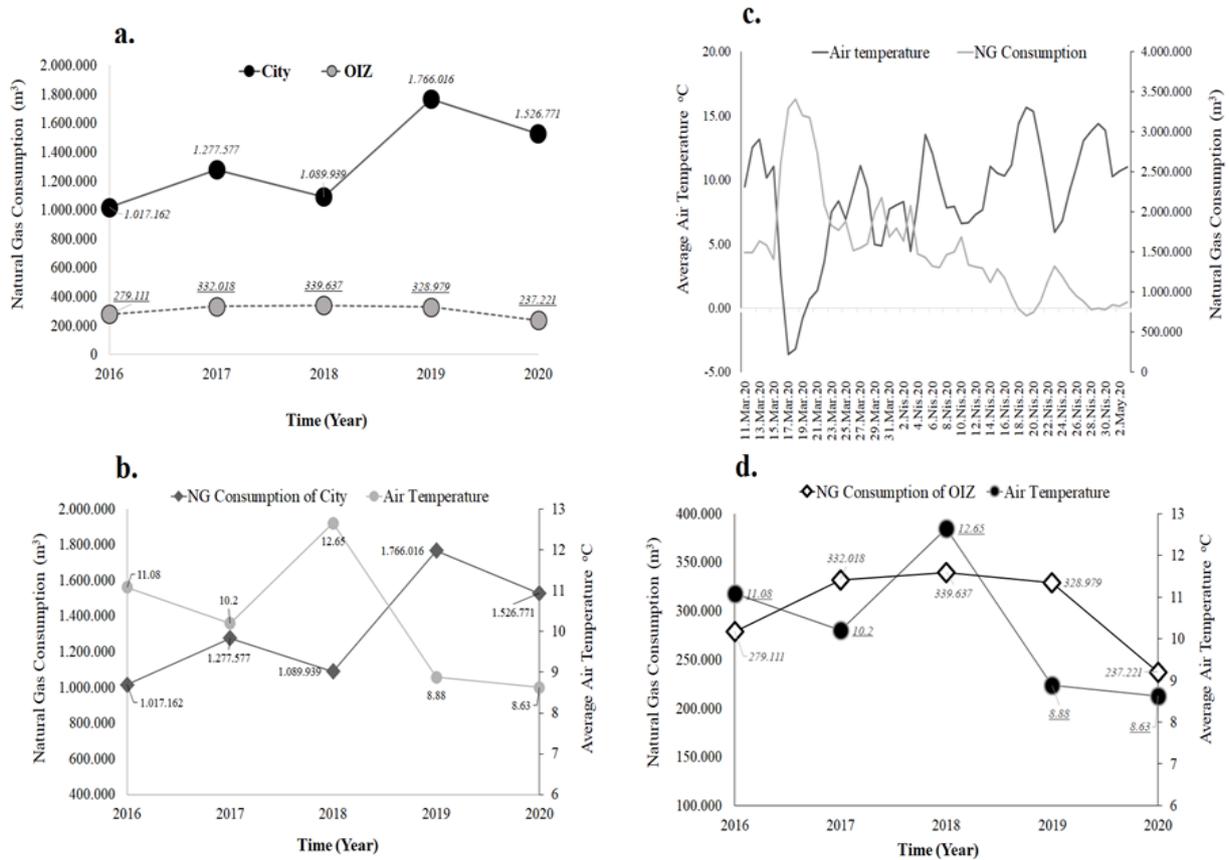


Figure 3. Natural gas consumption and air temperature comparison chart

3.3.2 CO₂ equivalent originated from traffic

According to TUIK data, the number of vehicles registered in traffic is around 341 thousand as of the end of March 2020 in Kayseri (private earth movers, tractors, and the vehicles whose registration is not known have been excluded). The distribution has been calculated according to the vehicle types for Kayseri from the report of “Vehicle number distribution” published by TUIK for Turkey in general. “Normal situation” and the assumption of “the decrease in vehicle usage by 80% in quarantine days” have been compared based on the distances of the vehicles covered daily on average. Results of the CO₂ equivalents calculated according to the EPA criteria given in Table 2 are specified in Table 4.

It has been calculated that approximately 1 million (1003455) tons of equivalent CO₂ have not been released to the atmosphere with the assumption of 80% decrease in vehicle usage in traffic for 56 days during the pandemic quarantine period being our periodical examination range. CO₂ not released to the atmosphere by the countries in the struggle with global warming and whose importance is the highest among greenhouse gases has the qualification of being the most efficient indicator. The calculating simulation values showing what kind of a positive impact the amount of CO₂ prevented to be released in general of the city of Kayseri

during the 56-day pandemic restriction has caused are shown in Figure 4.

4 Conclusion

56-day restriction process within the scope of Covid-19 precautions has caused to decreases by 40% and 34% in PM₁₀ and SO₂ concentrations when compared to 2019 in the air quality of Kayseri city centrum. Same parameters have respectively shown a decrease by 9% and 30% for OIZ. PM₁₀ concentration in 2020 has been statistically and significantly different when compared to its values belonging to the last 5 years in city centrum. While natural gas consumption is 13.5% for the same period in city centrum, it has decreased by 28% in OIZ. A statistically significant difference has been observed to be existent for OIZ consumption values in 2020 in the assessment of the last five years. While the decrease occurring in city centrum by 13.5% has been considered to stem from schools, dormitories, university and public institutions stopping their activities, the decrease in OIZ has been interpreted within the direction of the decrease in natural gas consumption stemming from work slow-down and process during the quarantine period.

The decrease in total natural gas consumption and emission decrease originating from traffic have been calculated in CO₂ as an answer for the question “Has 56-day process had any positive impact on climate change in CO₂ equivalent?”

Table 4. Calculation of emission equivalent of CO₂ originated from traffic.

Type of Vehicle	¹ Number of vehicles registered to traffic in Kayseri	² The average annual distance travelled by vehicle (km)	The average daily distance travelled by vehicle (km)	³ CO ₂ equivalent under normal conditions within 56 days (10 ³ ton)	⁴ CO ₂ equivalent in assumption of 80% reduction for 56 days (10 ³ ton)
Automobile	203845	-	-	-	-
Powered by gasoline	49417	13117	36	234	47
Powered by diesel	78244	13117	36	370	74
LPG	76185	13117	36	361	72
Minibus	8064	26396	73	10	2
Bus	3473	44491	124	19	1.4
Van	62374	17845	50	54	11
Truck	13801	45735	127	89	6
Motorcycle	54582	3766	10	4	2
Total	346139	177584	492	1237	234
Avoiding CO ₂				1003x10 ³ ton CO ₂	

- ¹. By the end of March 2020, the number of vehicles registered in Kayseri in traffic distribution is calculated by dividing the number of cars in Turkey.
- ². The values published by the Turkish Statistical Institute (TUIK) for Turkey in 2016 was used in the same way for Kayseri.
- ³. On quarantine days, the calculation was made by estimating that the average distance traveled was normal. (Table 2).
- ⁴. Calculated on the quarantine days with the assumption that driving by 80% was reduced due to the distance traveled in traffic. (Table 2).

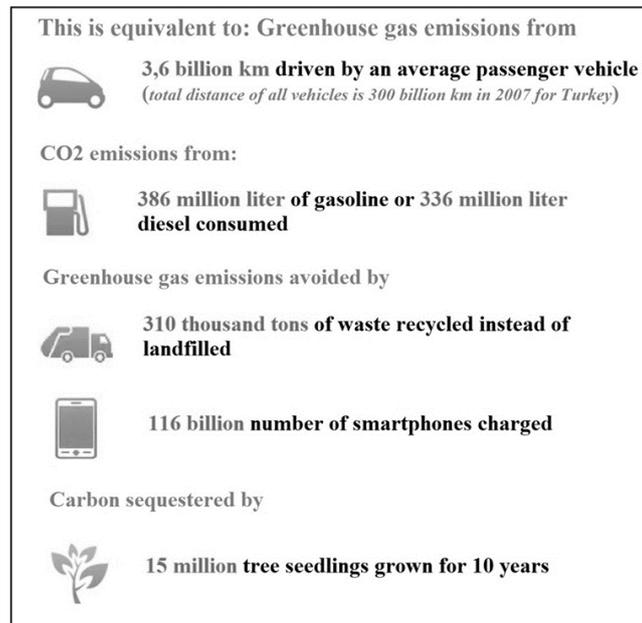


Figure 4. CO₂ equivalency results.

A total of 1003455 tons of CO₂ have not been released to atmosphere in the city of Kayseri during the restriction period. The positive impacts caused by this amount have been shown in Figure 4 in detail. As a result of this study, how the cities and even countries could make a contribution with their consumption limitations has been relatively revealed in the event that people may have to struggle with a more serious climate change phenomenon. We know very that that the decreases in CO₂ emissions in short term could be striking for the societies to review their consumption habits and to see the harmful effect they serve although it does not bring any sharp solution in the struggle with climate change.

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Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Similarity rate (iThenticate): 9%

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