Evaluation of Istanbul from the environmental components’ perspective: what has changed during the pandemic?

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Abstract This study aims to determine the 1-year change over the pandemic period in Istanbul, the megacity with the highest population in Turkey, based on environmental components. Among the environmental topics, water consumption habits, changes in air quality, changes due to noise elements, and most importantly, the changes in usage habits of disposable plastic materials that directly affect health have been revealed. The results obtained showed that, in Istanbul, $8.1 \times 10^8$ gloves should be considered waste, and considering the population living in districts along coastal areas, the number of waste masks that are likely to end up in the sea was 325,648 pieces/day. The results of the air quality and noise measurements during the pandemic showed that reductions in parallel with human activities were recorded with the lockdown effect. The average noise values of the districts along both sides of the Bosporus, where urbanization is concentrated, were between 50 and 59 dB. The precautions taken during the pandemic have had an effective role in reducing air pollution in Istanbul. In the measurements, the parameters with effective reductions were PM$_{10}$ (7–47%), PM$_{2.5}$ (13–48%), NO$_2$ (13–38%), and SO$_2$ (10–56%). As a result, Istanbul’s year of changes during the pandemic period, in terms of water, air, noise, and solid plastic wastes, which are the most important components of the environment, is presented.

Keywords Environmental components · Water consumption · Plastic solid waste · Air quality · Noise pollution · Istanbul

Introduction

With the emergence of pneumonia with an undiscovered cause in Wuhan, China, in late December 2019, a pandemic was announced by the World Health Organization (WHO) on March 11, 2020, after the new coronavirus disease COVID-19 was transmitted globally at an outbreak level (Zhu et al., 2020). The pandemic felt more effective, especially in megacities. This is because the pandemic effect is a more serious threat to large cities, and large cities are more open to dangers, unlike rural areas (Cheval et al., 2020). Istanbul, one of the few metropoles in the world, has been covered by the national and local press about this issue.
Also, with these outstanding features, Istanbul hosts approximately 1/4 of Turkey’s population. According to data from the Turkish Statistical Institute (TUIK, 2021), the population of Istanbul reached 15,462,452 people in 2020, which is higher than the population of 145 countries (for example, Cuba, Belgium, Greece, Czech Republic, Hungary, Sweden, Portugal, Austria, Israel, Switzerland, Finland, and Georgia).

The most significant negative effects of the pandemic on ecosystem health are primarily caused by water consumption and poor waste management in developing countries (Abu-Bakar et al., 2021; Almulhim & Aina, 2022; Kalbusch et al., 2020; Sarkodie & Owusu, 2021; Vanapalli et al., 2021). As a result of this important practice, significant changes are observed in the water consumption habits of the people, especially during epidemic and pandemic periods (Kalbusch et al., 2020). The increase in household water consumption can be associated with diurnal consumption increases since people stay home. During the lockdown, the daily water consumption has increased 35% in the UK and 11% in Brazil (Abu-Bakar et al., 2021; Kalbusch et al., 2020). Care should be taken in waste management because the greater rate of waste generation will trigger an unprecedented abundance of plastic waste around the world (Sarkodie & Owusu, 2021; Vanapalli et al., 2021). In addition, the extent of the danger arising from plastic pollution can be clearly understood when considering the intense but also mandatory use of health equipment (surgical masks, gloves, medical gowns, face shields, safety glasses, protective aprons, disinfectant containers, plastic shoes, etc.) (Benson et al., 2021; Haque et al., 2021). Moreover, because personal protective equipment (PPE) has a heterogeneous composition and contamination risk, an appropriate plan is required for disposal management in accordance with hazardous waste status, especially in areas where the risk of contamination increases (e.g., hospitals, medical centres, and public transport vehicles). In particular, microplastics (plastic fragments < 5 mm) managed to attract attention before the pandemic as common and persistent environmental pollutants (Aragaw, 2020; Fadare & Okoffo, 2020; Prata et al., 2021).

During the pandemic, the halt in human movements due to restrictions in the international transportation sector, the halt of industrial activities and curfews/restrictions have caused an unprecedented decrease in greenhouse gas emissions (Le Quéré et al., 2021; Travaglio et al., 2021). In addition, significant reductions were observed in urban areas around the world in the concentrations of gaseous pollutants such as nitrogen dioxide (NO₂), sulphur dioxide (SO₂), carbon monoxide (CO), and PM (particles < 10 μm in diameter are called PM₁₀, and particles < 2.5 μm in diameter are called PM₂.₅) (Briz-Redón et al., 2021; Donzelli et al., 2021; Liu et al., 2022; Silva et al., 2022; Srivastava, 2021; Venter et al., 2020). In metropolitan cities where cases were seen and lockdowns began, PM₂.₅ and NO₂ concentrations declined at rates of 36% and 51% in New York (Zangari et al., 2020), 49% and 60% in Delhi (Kumari & Toshniwal, 2020), and 26% and 36% in London, respectively (Higham et al., 2021). Recent studies show that SARS-CoV-2 can be carried by particles (Kayalar et al., 2021), and statistically significant relationships were found between mobility, temperature, humidity, and PM₂.₅ in COVID-19 transmission (Albrecht et al., 2021).

This study aimed to evaluate the positive and negative effects of a 1-year (March 2020–April 2021) change in environmental components in Istanbul during the pandemic period. With a sustainable and holistic perspective, potential pressures and impacts on the ecosystem were investigated in the following areas: (I) water consumption by district due to the change in water usage habits, (II) waste management, particularly of single-use plastics during the pandemic, (III) pandemic-related changes in air quality, and (IV) changes in noise pollution during the pandemic. In this context, the results of the present study were compared to the data of previous studies carried out in Istanbul, as well as to practices and sanctions. This study has the potential scientific contribution by evaluating integrated environmental management based on environmental components over a 1-year pandemic period in a megacity with the typical life cycle in Istanbul.
Materials and methods

In this study, the main topics that constitute the public health of Istanbul were selected from the environmental components’ perspective, and the data collection methods of these topics are given in Fig. 1. To determine the change in water consumption and habits, the amounts of water consumption before and during the pandemic period were described as a scenario and interpreted in accordance with the results of a survey study. In addition to the numerical analysis of water consumption data, water consumption was interpreted using projections based on the results of the survey study.

In waste management, the abundance of plastic products, which have attracted attention due to their increased usage, particularly during the pandemic period, and which contribute to permanent pollution, has been calculated, as have the possible effects on coastal areas. The amount of waste, especially disposable products, was calculated. In addition, the chemical compositions of plastic products were interpreted using the results obtained from FTIR (Fourier transform infrared spectroscopy) analyses to determine the possible microplastic threat to coastal areas and marine ecosystems based on polymer structures.

To determine the pandemic’s influence on air quality, data on air pollutant parameter collected at air quality measurement stations (AQMS) were analysed. Two-year AQMS, NO₂, PM₁₀, PM₂.₅, and SO₂ data were used at selected stations in the coastal areas of the city, covering the year before March 2020, when the first case was announced in Turkey.

The noise measurement data, on the other hand, belong to the selected districts of the coastal areas of the city before and after the full lockdown period (April 2020). (The first measures were taken in public areas as of March 11, 2020, and the first curfew restrictions (weekday evenings and weekends) were enforced as of April 11, 2020. The latest curfew was on April 29, 2021, with a 17-day full lockdown.). The measurements taken simultaneously in all districts of Istanbul at 4 different times of day during the full lockdown period of April 2020 were used.

Water consumption

To evaluate the impact of measures taken to prevent the spread of the coronavirus (COVID-19) on daily urban water consumption, the answers to 2 questions in the social awareness study survey were considered. In the study, data were obtained using a survey specifically developed for a study conducted to determine the awareness level of the people regarding water consumption during the pandemic.

The survey aimed to determine the most accurate responses concerning the water consumption awareness level. The questionnaire questions were formatted as

Fig. 1 Positive and negative factors specific to ecosystem health from the environmental components’ perspective, and inputs and outputs of these factors during the pandemic period. (Study design, methods, and results flowchart)
“multiple-choice” responses with individual answers. In this survey, the 4 response options to the question “How would you describe the change in your hand washing habits during the pandemic period?” were “(a) I wash my hands 3–5 times, (b) I wash my hands 5–8 times, (c) I wash my hands 8–12 times, and (d) my hand washing habits have not changed”. Another question was “Which of your habits intensified during the pandemic period?”, with the response options being “(a) hand washing, (b) washing shopping materials, (c) doing the laundry, (d) all”. The study sample was divided into 3 age/education groups: 17–25, 26–44, and > 45. In addition, the gender of the participants was taken into consideration. Each option in the survey had an available ratio of 0.25 ratio. The formula below with a 0.90 significance level and a 0.05 error (Seker et al., 2010) was used to compute the lowest valid number \( n \) of participants (Eq. 1):

\[
\begin{align*}
    n & = (1.645)^2 \times (0.25 \times 0.75)/(0.05)^2 = 203 \\
\end{align*}
\]

The basic question in the projection part of the water consumption section was as follows: "If the pandemic that affected the whole world had not been present, what would be the expected amount of water consumption in Istanbul?" The results of this projection scenario question were compared with the official water consumption data of the pandemic period. For the scenario, the water consumption projections by year given by Sivri et al. (2017) and verified with the data from that year was used. Thus, in addition to comparing the amount of water consumption before and during the pandemic, the “if there was no pandemic scenario” and the amount of water consumption in Istanbul during the pandemic period (in the real situation) were compared. Both the results obtained from the scenario on the survey and the actual consumption values were interpreted together.

Waste management

Supply of products

Within the scope of the measures taken to prevent the transmission and spread of the virus, characterisation studies were carried out for the materials provided, considering the changing shopping behaviours of consumers and consumption materials. In this study, plastic-based products, which are frequently preferred by the public within the scope of pandemic prevention action plans, were purchased for the analysis of their chemical structures. These products were grouped as face masks (surgical (FCC) and respiratory masks (FCN)) (further details about face masks can be found as Supplementary Material), products preferred in food takeaway services (forks, spoons, knives, lunch boxes, plastic wrap, and packaging products) and transport items used during shopping (market bags, refrigerator bags, food containers, and gloves), and structural analyses were performed without personal use, taking into account the risk of contamination (Supplementary Fig. 1, 2 and 3).

Physico-chemical characterisation of products

Selected products of PPE (face masks) take away sets (forks, spoons, knives, lunch boxes, plastic wrap, packaging products) and transport elements used during shopping (market bags, transparent bags, food containers, and gloves) were reduced to 3 × 3 cm dimensions using stainless steel scissors. Care was taken to ensure that the products were not used beforehand so that they were not exposed to any contamination that may have changed the analysis. Subsequently, Fourier transform infrared spectroscopy (FTIR), which has an attenuated total reflection (ATR) accessory, was used to analyse polymer samples. ATR-FTIR transmittance spectra were measured in the 650–4000 \( \text{cm}^{-1} \) range using a Perkin Elmer Spectrum 100 FT-IR spectrometer.

Estimation of plastic wastes generation

In the calculation of the amount of waste generated after the use of the products that entered our lives with the pandemic, the studies carried out by Nzediegwu and Chang (2020) and Benson et al. (2021) were used to estimate the amount of waste from face masks, and the data published on the official website given by the T.R. Ministry of Environment and Urbanization, oral interviews with the relevant companies, and unofficial commercial records were used as the basis for plastic waste generated by other products.

The use of disposable face masks per day is computed as a function of a country’s total population, face mask consumption per day and per person, and a random percent face mask acceptance rate by the city population (Benson et al., 2021; Nzediegwu & Chang, 2020). The equations below were used in
the calculation of the total daily estimated face mask productions (Eqs. 2 and 3):

$$\text{Total daily face masks generated} = T_p \times U_p \times A_r \times A_c \times 10^{-3}$$  \hspace{1cm} (2)

$$\text{Estimated waste amount} = \text{total daily face masks generated} \times C_w$$  \hspace{1cm} (3)

where $T_p =$ population, $U_p =$ the percentage of city population, $A_r =$ the percent face mask acceptance rate, $A_c =$ the mean everyday face mask consumption per person, and $C_w =$ 20–40%.

When determining the population ($T_p$), 2 different approaches were used. In the first approach, as in Benson et al. (2021), the entire population of the city was considered. The second approach aimed to determine the shoreline effect of this city on the Asian and European continents (Fig. 2) (further details about data collection and basic assumptions regarding the study can be found as Supplementary Material).

Air pollution

Thirty-eight AQMSs were established and operated by the Ministry of Environment and Urbanization (MoEU) and Istanbul Metropolitan Municipality (IMM). At these stations, air quality measurements are performed with standard methods, and the results of basic air pollution parameters are published on the web pages of the relevant ministry and municipality (CSB, 2021; IMM, 2021). Within the scope of the study, 8 stations were selected, 4 on the European continent and 4 on the Asian continent, which are close to the main roads and settlements in the coastal area in Istanbul (Information about the selected stations is given in Supplementary Table 1).

The PM$_{10}$, PM$_{2.5}$, SO$_2$, and NO$_2$ data measured at these stations were examined for two distinct periods: pre-pandemic (March 2019–March 2020) and the period from the onset of the pandemic to the first year end (March 2020–February 2021). Accordingly, in Turkey, the first official lockdown (generally on Sundays) occurred between 11 April and 1 June 2020 (in March, schools and universities switched to distanced education, and online working was initiated in private companies as much as possible). The second lockdown took place between 17 November 2020 and 26 February 2021 (9 pm–5 am on weekdays and the whole weekend).

![Fig. 2 Istanbul coastal area districts selected as the study area](image-url)
Data were taken as hourly averages, and all statistical analyses were performed using Excel (MS, 2021) and the R programming language (R Core Team, 2020) with the open-air package (Carslaw & Ropkins, 2012).

Noise pollution

Noise pollution caused by different factors, such as traffic, industrial and construction activities, and social occasions, increases at a gradual and alarming rate in urban parts of megacities. Therefore, this part of the study aimed to investigate the noise pollution levels of Istanbul, a megacity, during the pandemic closure in April 2020 in various parts of districts classified as industrial, commercial, and institutional. As a result of reviewing similar studies in the literature, measurement methods were ascertained. A literature review showed that past studies have used similar measurement techniques as well as measurement time periods. To reveal the most precise account of noise pollution in the region, 23 points were selected. The principal measurement areas were chosen considering these criteria:

- Taking at least 3 separate measurements from different points of each district.
- Taking the measurements simultaneously and with the same application in 4 different time zones.
- Including regions with traffic density in the measurements,
- Presence of popular shopping malls and public markets for locals.

In the districts of Istanbul, noise was measured. The districts had people measure the sound by applying the same procedure between 9:30 and 10:00 am, 1:00 and 1:30 pm, 5:00 and 5:30 pm, and 9:00 and 9:30 pm. To ensure that the measurement was accurate, each location was measured for at least 15 min. During the lockdown week, each location was measured solely on 2 days on weekdays and 2 days on weekends. Three different measurements, morning, noon, and evening, were performed each day.

Measurements were taken using a smartphone application because this study required regular measurements to be taken in order to increase monitoring and regulation of environmental noise levels. This necessitates the availability of a readily available, inexpensive, and easy-to-use noise measuring device. In the literature, numerous studies have been discovered that test the sensitivity and validity of mobile “smart” phones. Studies on smartphone usage and performance evaluations in sound level measurements have been conducted studied (Ibekwe et al., 2016; Kardous & Shaw, 2014; Ventura et al., 2017). In studies on the accuracy of the Decibel-X mobile phone application, the effectiveness of several iPhone phone applications (apps) for accurately measuring noise exposure was assessed. Apps that were free to download and had at least one rating were included. Apps were evaluated using a calibrated pure tone sound field and a soundproof testing booth. A 3-frequency audiogram (1000 Hz, 2000 Hz, and 4000 Hz) was employed at 25 dB, 40 dB, 55 dB, 70 dB, and 85 dB. As a result, a total of nine apps were tested, with four of them achieving a goodness-of-fit coefficient ($R^2$ value) greater than 0.9. One of them had a Decibel-X score of $R^2$ of 0.62.

Within the scope of this study, Decibel-X, one of the most popular and free applications in this category, was preferred for use with iPhone (Apple Inc., 2013–2020) smartphones for noise measurements (Decibel-X 2020). The iPhone measurements taken with the application had the lowest standard deviation in the range of 40–70 dB at reference sound levels in an isolated environment and provide the highest level of accuracy and sensitivity (Crossley et al., 2021). As a final decision, this application was selected for periodic measurements.

The Decibel-X mobile phone application instantly identified the lowest and highest values among the measurements and excluded extreme results. The noise levels (dB) in the districts were recorded and compared with the accepted limits given by the CPCB (The Central Pollution Control Board) guidelines.

Results and discussion

During the 1-year pandemic period experienced in the megacity of Istanbul, which has a usual life cycle, the evaluations of 4 different elements are presented under the main title of environment. Regarding this concept, the results were evaluated the positive and negative effects based on environmental components 1-year change over the pandemic period in Istanbul.
The effect of the pandemic on the amounts and habits of water consumption

In this study, data in the report, which includes the work of local governments to determine water consumption (Fig. 3), show an increase of 12.3% in the amount of water consumption before the pandemic (138 L day$^{-1}$ person) and during the pandemic period (154 L day$^{-1}$ person) (IMM, 2021; ISKI, 2021; NWP, 2022). In a study conducted in Germany, “According to the results, daily household water consumption increased by 14.3% (3968 m$^3$), and there was a

![Figure 3](image)

**Fig. 3** Water consumption amounts of individuals residing on the European and Asian sides of Istanbul in 2019–2020 (L day$^{-1}$) (IMM, 2021; ISKI, 2021; NWP, 2022)
rise in the demand peaks in the morning and evening throughout the day” (Lüdtke et al., 2021). In addition to the increase in usage-related water consumption in households during full lockdown periods, there was a decrease in general water consumption due to the closure of some workplaces with intense water consumption (Birişçi & Öz, 2021; Elmaslar Özbaş et al., 2021). Considering the results announced every day by the IMM (IMM, 2021; ISKI, 2021; Yılmaz et al., 2022), the average 3 million m³ water supplied to the city reached 3.2 million m³ in July 2020. A study by Kalbusch et al. (2020) in Brazil found that before and after the 26-day lockdown, there was an 11% increase in residential water consumption as well as a decrease in industrial, commercial, and public water consumption. In some areas in the UK, a 35% increase was recorded in the highest daily consumption during the lockdown (Abu-Bakar et al., 2021). Although these results vary depending on the usage habits of individuals in countries and cities, as a general result, there was an increase of 10–40% in water consumption (Abu-Bakar et al., 2021; Balamurugan et al., 2021; Dzimińska et al., 2021; Kalbusch et al., 2020; Lüdtke et al., 2021).

In this regard, instead of relying on data from other studies, a survey study was conducted regarding both culturally acquired habits and changes in handwashing habits throughout the pandemic. The government does not impose any sanctions on individuals based on the content of the questions in the survey. Therefore, the survey questions are not designated to compel respondents to answer in the manner advised by the government. In the survey, it is noteworthy that the majority responses to the question “How would you describe the change in your hand-washing habits during the pandemic period?” chose the option “I wash my hands 5–8 times”, in line with the frequent handwashing warning recommended in Turkey. Considering that the correct handwashing time recommended by the WHO is 22 s, raising awareness to prevent wasted water in this process with an average of 5 times/person handwashing calculation for only the population of Istanbul will save 16.000 m³ days⁻¹ (in this calculation, the water to be used by leaving a faucet flowing at an average speed open for 22 s is accepted as 1 L. The result represents an average value, as habits may vary over time as individuals learn to be more mindful or act less cautiously). Efforts to inculcate saving habits were accelerated and supported by documentaries, TV programmes on water consumption, and short public ads.

During the pandemic, not only the frequency of hand washing but also the washing of all materials purchased after shopping and the frequency of washing clothes increased 2.7 times compared to the normal period. The idea that women are responsible for hygiene and sanitation at home due to cultural habits in Istanbul is in parallel with the result of the survey that women (56%) consume more water.

During the lockdown, individuals changed their ordinary consumption habits at a dramatic level in a significant number of categories globally. As a result, a dramatic rise was observed in spending, particularly on essentials and food (Baker et al., 2020). Studies reveal how COVID-19 affected water use impacted mass demand and overall demand peaks. For example, in Germany, the mass demand peak was 07:10 during the pre-lockdown and became 09:40 during the lockdown (Aquatech, 2020).

The second stage of the water consumption heading of the survey was presented as a scenario: “If the pandemic that affected the whole world had not been present, what would be the expected amount of water consumption in Istanbul?” to compare the amount of water consumption during the pandemic period, the projection by Sivri et al. (2017) was used as the basis. Increases of 18.29% in expected water consumption for Istanbul in 2019 and 29.79% in expected water consumption for Istanbul in 2020 were calculated (Fig. 4). However, the pandemic period confirmed the hypothesis of the study, and the real situation for 2020 was higher than expected compared to 2019.

Effect of the pandemic on macro-/meso-/microplastic formation

Disposable face mask use

The calculated disposable face mask use according to two different approaches is given in Table 1. In the first approach, where all districts of Istanbul are considered, the total number of used waste masks is 9.289.841 day⁻¹. Assuming that 20% of the total amount of waste masks in this megacity can reach marine areas (Marmara and Black Sea), the projected possible number of waste masks in the seas will be 1.857.968 day⁻¹. Considering the total population of Istanbul, this value corresponds to 1/8 of the population.
In the second approach, where only the population living in the coastal areas of the megacity is taken into account, the total number of waste masks is 814,121 day\(^{-1}\). Assuming that 40% of the waste belonging to the people living in the coastal region will end up in the seas (Marmara Sea and Black Sea), the possible number of waste masks in the seas was found to be 325,648 day\(^{-1}\). Considering the population living in the coastal area of Istanbul, this value corresponds to 1/4 of the population.

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\text{End up as waste in sea (piece)} = \frac{1}{4} \times 325,648 \text{ day}^{-1}
\]

Table 1 Single-use face mask consumption

| District  | Population | The percentage of urban population of the country | The percent face mask acceptance rate | Face mask/capita | Estimated daily face mask disposed (piece) | The percentage of end up as waste in sea | End up as waste in sea (piece) |
|-----------|------------|--------------------------------------------------|---------------------------------------|------------------|--------------------------------------------|----------------------------------------|-------------------------------|
| **All area** |            |                                                  |                                       |                  |                                            |                                        |                               |
| Asia      | 5,436,921  | 75.1                                            | 80                                    | 1                | 3,266,502                                  | 20                                     | 653,300                       |
| Europe    | 10,025,531 | 75.1                                            | 80                                    | 1                | 6,023,339                                  | 20                                     | 1,204,668                     |
| İstanbul  | 15,462,452 | 75.1                                            | 80                                    | 1                | 9,289,841                                  | 20                                     | 1,857,968                     |
| **Shoreline effect** |            |                                                  |                                       |                  |                                            |                                        |                               |
| Asia      | 577,542    | 75.1                                            | 80                                    | 1                | 346,987                                    | 40                                     | 138,795                       |
| Europe    | 777,520    | 75.1                                            | 80                                    | 1                | 467,134                                    | 40                                     | 186,854                       |
| İstanbul  | 1,355,062  | 75.1                                            | 80                                    | 1                | 814,121                                    | 40                                     | 325,648                       |

**Takeaway sets and plastic transport objects people used while shopping**

From the amount of single-use plastic waste generated in Turkey in 2020, the amount of waste generated in Istanbul in 2020 was calculated based on the ratio of the population of Istanbul to the population of Turkey (Table 2). In addition to these data, it is predicted that this amount will increase by approximately 10–15% (per piece) for 2021 and that more...
than 50 million boxes of gloves will be sold, with disposable gloves becoming necessary in vaccination procedures (NTV, 2021). Although the Ministry of Environment and Urbanization published in a circular numbered 84,334 on April 7, 2020 (CSB, 2021), the measures to be taken regarding the management of personal hygiene material wastes, such as disposable masks and gloves, during the pandemic, the problem of contamination of nature that emerges because these products are lightweight (~3–7 g) should not be ignored (Ak, 2020).

In addition, the number of bags used in Turkey in 2019 (35 × 10⁹ bags) decreased by 77% under the government’s “Zero Waste Approach” and Zero Waste Regulation. However, the effects of the pandemic led to an increase of 40–50% in the number of waste bags in 2020 (Bostanoglu, 2021). During the COVID-19 period, the consumption of disposable plastics such as forks, spoons, knives, and cups has increased by 25% (PAGEV, 2021a). On e-commerce sites, packages of disposable plastic products such as 10 plastic plates, forks, spoons, knives, and cups are sold at differing prices between 1 and 2 Turkish Liras. The calculations were made with the data obtained, and the average price of 10 packs is accepted as 1.5 Turkish Liras.

According to a report on the e-commerce industry in the USA (Stackline), disposable gloves ranked first as the category with the fastest-growing internet shopping in the country between March 2020 and March 2021, with an increase of 670% (Stackline, 2021). Jedruchniewicz et al. (2021) reported that there was a 30% increase in the manufacturing of gloves in Poland in March 2020 during the pandemic period compared to the same period in 2019. In Italy, whose population is 60.4 million, lockdown monthly consumption of PPE is predicted to be 1 billion face masks and 0.5 billion gloves (Prata et al., 2020).

In this study, plastic waste (especially disposable protective equipment and shopping materials) related to the COVID-19 pandemic can be observed in public spaces in Istanbul, including parks, open markets, coastal recreation areas, parking lots, and walking paths, due to both carelessness and climatic conditions (Supplementary Fig. 4). Since the specific gravity of plastics such as PP, LDPE, HDPE, and PS is smaller than that of water (0.85–0.97 g cm⁻³), they can be easily transported from waste collection centres by wind and precipitation. Whether plastic wastes reach coastal areas still whole or degraded due to different factors in the areas where they are found, they continue to degrade in the coastal areas and can easily cause meso-, micro-, and nano-sized particles to accumulate and pose a threat in these areas.

The physicochemical properties of microplastics (e.g., specific density, load, and chemical composition), hydrodynamic factors, and environmental characteristics (e.g., current, temperature, and wind) can affect their distribution and accumulation in marine areas (Çullu et al., 2021; Guzzetti et al., 2018; Rocha-Santos & Duarte, 2015). Many researchers have revealed a positive correlation between the increase in populations in residential areas and both the abundance of microplastics and the increase in plastic debris accumulation in the marine environment (Guzzetti et al., 2018). In Istanbul, in a study conducted before the pandemic in the southwestern part of the study area, the abundance of microplastics was found to be 33 MPₜ L⁻¹ on average. In a recent study from the same area, the microplastic abundance was found to be 56 MPₜ L⁻¹ on average (Sönmez & Cumbul Altay, 2022). While the effects of the increase in microplastics caused by the increased use of plastics during the pandemic period have not yet begun to be observed,
the future damage to be inflicted by the increase of the potential effect in MPs L⁻¹, which has almost doubled, can be foreseen.

Since the chemical decomposition products of the plastic types analysed in this study can be very different, this study is based on the accumulation of meso-, micro-, and nano-sized particles in ecosystems, which are caused by physical breaking into smaller pieces, not the details of polymer degradation.

**Experimental validation by structure analysis and polymer characterisation**

Disposable surgical face masks rank first among the plastic-based materials whose production and consumption have increased the most in the world, like our country, during the pandemic period. Different polymers, such as polyester, polypropylene, polyethylene, polycarbonate, polyurethane, polystyrene, and polyacrylonitrile, are used in the production of surgical face masks (Aragaw, 2020; Benson et al., 2021). In the masks produced as three layers, soft fibres are preferred in the inner layer, melt-blown fibres are preferred in the middle layer, and nonwoven fibres are preferred in the outermost layer. Production techniques and fibres used may differ from brand to brand (Fadare & Okoffo, 2020).

Polymeric materials have been used every day in many fields. An increase was observed in the use and kinds of polymeric materials during the COVID-19 pandemic. In this study, various polymer-based materials, such as face masks, food packaging, and examination gloves, could lead to microplastic pollution in the ecosystem due to the failure to manage solid wastes correctly. ATR-FTIR spectroscopy is a non-destructive analysis that allows a simple and efficient method for identifying and distinguishing polymer structures. Table 3 provides the structural units, FTIR spectra, and characteristic peaks of the samples (further details about the polymer characterisation can be found as Supplementary Material).

The impact of the pandemic on air pollution

The monthly averages of PM₁₀, PM₂.₅, NO₂, and SO₂ concentrations measured between March 2019 and February 2021 at 8 stations on the European and Anatolian sides of Istanbul are shown in Fig. 5. The European Union (EU) limit values for PM₁₀, PM₂.₅, NO₂, and SO₂ concentrations are 50 µg m⁻³, 25 µg m⁻³, 40 µg m⁻³, and 125 µg m⁻³, respectively. The same values have been accepted for the national limit values, with the exception that a limit value has not been defined PM₂.₅.

The main source of NO₂ in cities is traffic, and a decrease is observed with reduced mobility (Teixidó et al., 2021). Figure 5a shows that there has been a decrease in NO₂ concentrations compared to the previous year since the time when the first cases were announced. This decrease is noticeable on the European side, where traffic and population are denser. The highest monthly average during the sampling period was 61 µg m⁻³ in March 2019 and 48.8 µg m⁻³ in March 2020. The lowest monthly average occurred in July 2020 (27.2 µg m⁻³), when a general decrease was observed during the summer months. A study conducted in Istanbul examining the decrease in NO₂ concentrations on the European side, where traffic is more intense, reported similar results to those of this study (Şahin, 2020). In another study conducted in England, the reduction rate of NO₂ concentration in urban traffic areas (47.9%) during lockdown was found to be higher than the decrease in other urban areas (Jephcote et al., 2021).

Figure 5b and c show monthly average PM₁₀ and PM₂.₅ concentrations, respectively. While the monthly average highest PM₁₀ concentration was in November 2019 (45.9 µg m⁻³), this value decreased to 24.2 µg m⁻³ in November 2020, when weekday lockdowns between 21:00 and 05:00 and weekend lockdowns were implemented for the second time. PM₂.₅ concentrations were parallel to PM₁₀ values. The highest value was 28.7 µg m⁻³ in November 2019, and the lowest value was detected in August 2020 (12.9 µg m⁻³). However, a detail that needs to be examined is dust transport, which is closely related to PM concentrations. The effect of dust transport can be observed throughout Turkey during the spring and autumn seasons (Aslanoğlu et al., 2022; Baltaci et al., 2020; Çapraz & Deniz, 2021; Flores et al., 2017). Warnings were published in the national press in 2020 due to dust transport in these seasons (Daily Hurriyet Daily News, 2022; Sabah, 2020). In October 2020, monthly concentrations of PM₁₀ increased up to 30% compared to the previous year. Dust transport patterns affecting the western part of Turkey on selected days in October 2020 are shown in Supplementary Fig. 5.
Table 3  Structural unit, FTIR spectrum and characteristic peaks of single use plastic materials

| Sample                                                                 | Polymer matrix | Structural unit | FTIR spectrum | Characteristic peaks                                                                 |
|------------------------------------------------------------------------|----------------|-----------------|---------------|---------------------------------------------------------------------------------------|
| Disposable plastic (plastic flatware knife, fork and spoon) individual bag |                |                 |               | 2915 and 2850 cm\(^{-1}\) asymmetric and symmetric stretching of \(\text{CH}_2\), 1472, 730 and 717 cm\(^{-1}\) bending and rocking vibrations of \(\text{CH}_2\) |
| Clear crystal disposable fork                                           | PS             |                 |               | 2920 and 2840 cm\(^{-1}\) asymmetric and symmetric stretching of \(\text{CH}_2\), 2238 cm\(^{-1}\) \(\text{C}=\text{N}\) stretching, 869 cm\(^{-1}\) \(\text{C}=\text{II}\) stretching vibrations of butadiene double bond |
| Grocery roll market bag                                                | LDPE or LLDPE  |                 |               | 2915 and 2850 cm\(^{-1}\) asymmetric and symmetric stretching of \(\text{CH}_2\), 1472, 730 and 717 cm\(^{-1}\) bending and rocking vibrations of \(\text{CH}_2\), 1377 cm\(^{-1}\) \(\text{CH}_2\) bending deformation |
| Disposable plastic matrix                                             | PP             |                 |               | 2952 cm\(^{-1}\) and 1376 cm\(^{-1}\) asymmetric and symmetric \(\text{CH}_2\) stretching, 2918 cm\(^{-1}\) and 2838 cm\(^{-1}\) asymmetric and symmetric stretching of \(\text{CH}_2\), 998, 973 and 901 cm\(^{-1}\) asymmetric rocking vibrations of \(\text{CH}_2\), 844 and 810 cm\(^{-1}\) \(\text{CH}_2\) rocking vibrations |
| The outermost layer of disposable face mask                           |                |                 |               | Nonwoven PP fabric, additional peaks 3450, 1740 and 1230 cm\(^{-1}\) are due to the sterilization by radiation |
| The middle layer of mask is also made of non-woven polypropylene      |                |                 |               |                                                                                       |
| Transparent storage box                                               | PET            |                 |               | 2965 cm\(^{-1}\) asymmetric \(\text{CH}_2\) stretching, 1713 cm\(^{-1}\) \(\text{C}=\text{O}\) stretching, 1578 and 1505 cm\(^{-1}\) \(\text{C}=\text{C}\) stretching, 1453-1408-1340 cm\(^{-1}\) \(\text{C}=\text{O}\) stretching vibration and OH bending, 1238, 1016, 872 and 723 cm\(^{-1}\) aromatic group of PET |
| Plastic wrap                                                          | PVC            |                 |               | 2972 cm\(^{-1}\) and 2910 cm\(^{-1}\) \(\text{CH}_2\) asymmetric stretching vibration, 1725 cm\(^{-1}\) \(\text{C}=\text{O}\) stretching vibration of carboxylic acid, 1460 and 1250 cm\(^{-1}\) \(\text{C}=\text{H}\) bending, 610 cm\(^{-1}\) \(\text{C}=\text{I}\) gauche bond. |
Throughout Istanbul, SO$_2$ concentrations are considerably below the limits set due to the widespread use of natural gas as fuel for domestic heating and limitations on industrial use (5 (d)). At the same time, between March and December 2020, the number of ships passing through the Bosporus decreased by 8.36%, and the total gross tonnage decreased by 4.9% compared to the same interval of 2019 (UAB, 2021). Considering that ship-borne emissions are higher in the Sea of Marmara than in the Black Sea and British territorial waters Deniz and Durmuşoğlu (2008), and high SO$_2$ concentrations are emitted from large marine diesel engines using low-quality fuel (Yang et al., 2018), the decrease in ship traffic during the lockdown period may have been effective in decreasing monthly SO$_2$ concentrations.

Figure 6 shows the reduction in air pollutants in two different lockdown periods in Istanbul compared to the same period of the previous year. When the average values are compared, significant reductions in pollutants are observed in the first and second lockdown periods. With these reduction ranges, the effective parameters were calculated as PM$_{10}$ (7–47%), PM$_{2.5}$ (13–48%), NO$_2$ (13–38%), and SO$_2$ (10–56%). In addition, the reduction rate increased with the prolongation of the lockdown periods covering weekdays and weekends in the second lockdown period and with the additional measures taken. The decrease in monthly SO$_2$ concentrations in the second lockdown period is more noticeable than that of the other parameters. In a similar study evaluating the air quality of 20 major cities around the world, the percentage reductions in air pollutant concentrations were found to be PM$_{10}$ (22.4%), PM$_{2.5}$ (22.6%), and NO$_2$ (40%) in Paris; PM$_{10}$ (28.7%), PM$_{2.5}$ (30.1%), and NO$_2$ (21.9%) in Frankfurt; and PM$_{10}$ (35.7%), PM$_{2.5}$ (36.6%), and NO$_2$ (39%) in London (Sannigrahi et al., 2021). In cities, restricting travel intensity and increasing control measures lead to significant reductions in air pollutant concentrations (Bontempi et al., 2022; Sahraei et al., 2021; Wang et al., 2021). In particular, PM$_{2.5}$ and NO$_2$ mobility trends show a significant relationship (Li & Tartarini, 2020). These results show that the measures taken, and the changes made to control the spread of the virus are also effective in reducing air pollution in Istanbul.
Figure 7 shows the average daily change in pollutant concentrations during the first and second lockdown periods. During the weekends (Saturday–Sunday), the average daily concentrations of all pollutants decreased significantly. The most significant decrease occurred on Sundays during the second lockdown period because the second lockdown period also included Saturdays. In general, in pre-pandemic Istanbul, since the traffic density is high every day of the week, there is no significant decrease in traffic-related pollutant parameters on the weekends (Şahin, 2020). The pandemic has been effective in changing pollutant concentrations measured on weekends.

The second lockdown period covered the night hours on weekdays (21:00–05:00), which caused the average concentrations to decrease on Friday. In addition, due to the decrease in hourly peak values during the lockdown period, the sizes of the variance boxes showing intraday concentration differences also decreased. The April–May 2020 weekend values of the distribution reveal a noticeable uniform and homogeneous distribution, which is most clearly observed in the SO2 data, especially on Sundays.

Impact of the pandemic on noise pollution

When the noise pollution values of 15 districts in the coastal area of the European side and 8 districts along the coastal area of the Asian side are compared, the pre-pandemic measurements of the districts decreased by 7–12% over the average values compared to the lockdown period. Data from Bakirköy, one of the districts of Istanbul with the highest noise values, confirm this hypothesis. Previous study results show that the average noise level was 71.44 dB on weekdays and 70.13 dB on weekends (Sivri et al., 2016). Noise sources originating from air transportation, especially due to its location close to the main roads and the airport, are the highest measured values (near the airport 81.88 dB).

In this study, Fig. 8 shows the coloured map created with the averages of all values in the districts along the coastal areas. During the morning (average value 47.80 dB) and noon (54.75 dB) measurements on the European side, where the airport is not active and other noise sources are relatively fewer, only natural life sounds were detected as noise sources. These significant decreases in noise
due to the absence of road and air transport during the lockdown periods have been supported by many researchers. Noise pollution is a widely experienced issue in protected places all over the country, and road traffic and airplanes are considered the largest sources of noise pollution (Terry et al., 2021; Xing & Brimblecombe, 2020). In particular, the main public transportation modes, such as rail, subways, and buses, have been used less often during the pandemic in many countries. Differences also occurred in urban areas because of fewer people and vehicles. In addition, noise levels for 24 noise monitoring stations decreased in Madrid by between 4 and 6 dB (Asensio et al., 2020). Basu et al. (2020) investigated the pre- and post-lockdown noise levels per hour obtained from 12 noise monitoring stations in Dublin. At station 11, there was a decline in noise levels during the lockdown of between 2.8 and 6.3 dB. The urban noise monitoring data collected in Stockholm, Sweden, presented a similar result (Lee & Jeong, 2021). According to this study, people were annoyed outdoors at a dramatically lower rate during the lockdown. The results obtained in the present study and that study are in parallel with each other.
Figure 9 shows that the general average noise values of the districts along both sides of the strait, where urbanization is concentrated, remained within the normal (50–59 dB) range, despite the lockdown period. The average values of the Büyükçekmece, Şile, and Silivri districts, where tourist activity is intense, but urbanization and industrialization are limited, were measured as 39.3, 43.38, and 44.73 dB, respectively.

Noise pollution affects human health physically, physiologically, psychologically, and in terms of performance. Problems including fast heartbeat, sleeping (physiological effects), neurotic problems, concentration impairment, and depressed mood (psychological effects) are caused by acute and chronic effects (Europe WHO, 2020; Halperin, 2014). People living in large cities might become more intolerant to noise in time. One might think that noise pollution primarily affects human health; however, noise pollution negatively affects all living things. Studies of terrestrial ecosystems showed that living things affected by noise pollution leave their environment forever. Birds migrate from ecosystems that can be easily affected. A metamorphosis effect might also be seen in the sounds of birds (Rheindt, 2003). However, during the lockdown period due to the pandemic, there was a change that positively affected human health and the existence of living things in ecosystems. With the results obtained, the existence of some districts that are almost at the whisper (30–40 dB) level is shown in yellow on the map. There are values in the range of 50–60 dB even in a quiet office environment, so it is understandable how significant the average values of the districts are. The lowest value measured during the study belongs to the Büyükçekmece district, with 33.1 dB. Except for some districts, values not found in megacities were measured in districts of the coastal area of Istanbul. In the measurements performed, especially in the morning hours of the districts, the average values of 8 districts belonging to the European side and 4 districts belonging to the Asian side were measured at 30–40 dB, which is at the whisper level. The noise levels (dB) in certain districts were significantly lower than acceptable limits set out by the CPCB guidelines. Zeytinburnu, which is one of the areas that continued its construction activities with special permits despite the full lockdown period, yielded the highest measurement value on the European side at 71.3 dB (measurement at 1:00 pm), while the Beykoz district yielded the highest measurement value on the Asian side at 88.7 dB (measurement at 5 pm). Figure 9 shows a map with the values of the
measurements performed at different intervals. This comparative study is beneficial in recognising what causes noise pollution in some Istanbul districts at different times.

Changes in human and commercial activities during pandemic measures have resulted in noticeable reductions in noise values in most countries due to the declines in public and private transport and other commercial activities (Zambrano-Monserrate et al., 2020). Baldasano (2020) reported a 6 dB decline in sound pressure levels due to reduced road traffic in Barcelona. In the study by Čurović et al. (2021), on the other hand, the environmental noise effects of the pandemic on the port were investigated, and the number of cruises at night decreased by 35%, and the noise level decreased by 2.2 dB. Noise levels were found to be reduced by 60% in Dublin compared to the pre-lockdown period (Basu et al., 2020). Overall, a significant decline was observed in the level of noise pollution created due to large industrial activities, such as stone quarries, after the COVID-19 lockdown was initiated (Derryberry et al., 2020; Mandal & Pal, 2020).

**Conclusion**

The primary issue that should be addressed at the national level is an environmental health, which is critical for the well-being of people, animals, and the environment. Adding pandemic pressure to existing environmental problems is likely to result in synergistic/antagonistic interactions and increase the already existing pressure. Therefore, when the pandemic comes to an end, to determine the acute or chronic effects of the pandemic on the environment, the comparison of the data obtained with the pre-pandemic values and contributing to the research with simulations is the top priority. For this reason, this study aimed to interpret the impact of the pandemic on the environment in Istanbul on an environmental perspective with analyses and assumptions for 1 year.
The most illustrative example of the increase in environmental pressure and acute/chronic effects are the acute effects of shoreline pollution because of sanitary disposal and the chronic effects of the increase in the abundance of meso-/microplastics because of different processes. The increase in the amount of personal protective equipment in the process of people leaving their houses (going to work, shopping, etc.). The possible number of waste masks in the seas was found to be 325.648 day⁻¹, under the shoreline effect of this city on the Asian and European continents. Moreover, wastes used in the process of meeting household needs (8.1 × 10^8 gloves, 22.1 × 10^8 disposable bags, and 33.3 × 10^8 takeaway sets) during the pandemic period contribute to the abundance of microplastics, especially in the Marmara Sea.

Especially during lockdown periods, changes in water usage and food consumption behaviours draw attention. It showed an increase of 12.3% in the amount of water consumption before the pandemic and during the pandemic period. As the pandemic crisis spreads around the world, it is becoming increasingly clear that those with the least access to essential services such as water will feel the most dramatic effects. Governments must now take steps to expand access to water to contain the pandemic and to build more resilient communities by addressing the core issues of water insecurity.

During the pandemic period, the decrease in pollutant concentrations in the months when restrictions were applied was 7–47% (PM_{10}), 13–48% (PM_{2.5}), 13–38% (NO₂), and 10–56% (SO₂). Significant decreases were observed in NO₂ and PM concentrations. These pollutants are considered the main pollutants affecting air quality in urban areas. In Istanbul, restriction measures (closing schools, remote working, etc.) that reduce human mobility and vehicle density are thought to have had a significant impact on the reduction of NO₂ and PM concentrations. On weekends, pollutant concentrations are at their lowest levels. In addition, the decrease in ship traffic in the straits is another factor contributing to the decrease in pollutant concentration levels.

The pre-pandemic measurements decreased by 7–12% over the noise pollution average values compared to the lockdown period. Perhaps the most positive effect of the pandemic is the low values of noise measurements made in cities, allowing bird sounds to be heard at a perceptible level. In addition, this study showed that bird song was a negative factor contributing to noise. Therefore, even when there is a low level of noise from outside, positive and natural sources of sound (Coensel et al., 2011; Jeon et al., 2010) disturb and distract people. For this reason, it is necessary to develop new design approaches so that the soundscape is optimised for achieving sustainability in cities. For example, looking for more effective sound maskers to maintain noise at reasonable levels is a good step.

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References

Abu-Bakar, H., Williams, L., & Hallett, S. H. (2021). Quantifying the impact of the COVID-19 lockdown on household water consumption patterns in England. npj Clean Water, 4(1), 13. https://doi.org/10.1038/s41545-021-00103-8

Ak, O. (2020). Another Consequence of COVID-19: Plastic Epidemic. TUBITAK Science and Technical Journal. https://bilimteknik.tubitak.gov.tr/system/files/makale/ayiklanan_baslik_tekstili.pdf

Albrecht, L., Czarnecki, P., & Sakelaris, B. (2021). Investigating the relationship between air quality and COVID-19 transmission. Journal of Data Science, 485–497. https://doi.org/10.6339/21-JDS1010

Almulhim, A. I., & Aina, Y. A. (2022). Understanding household water-use behavior and consumption patterns during COVID-19 lockdown in Saudi Arabia. Water, 14(3), 314. https://doi.org/10.3390/w14030314

Aquatech. (2020). Case study: Data links COVID-19 lockdown to consumption change. https://www.aquatechtrade.com/news/utilities/covid-19-lockdownimpact-water-consumption

Aragaw, T. A. (2020). Surgical face masks as a potential source for microplastic pollution in the COVID-19 scenario.
Fadare, O. O. & Okoffo, E. D. (2020) Covid-19 face masks: A potential source of microplastic fibers in the environment. Science of The Total Environment 737, 140279. https://doi.org/10.1016/j.scitotenv.2020.140279

Flores, R. M., Kaya, N., Eşer, Ö., & Saltan, Ş. (2017). The effect of mineral dust transport on PM10 concentrations and physical properties in Istanbul during 2007–2014. Atmospheric Research, 197, 342–355. https://doi.org/10.1016/j.atmosres.2017.07.009

Guzzetti, E., Sureda, A., Tejada, S., & Faggio, C. (2018). Microplastic in marine organism: Environmental and toxicological effects. Environmental Toxicology and Pharmacology. Elsevier B.V. https://doi.org/10.1016/j.etap.2018.10.009

Halperin, D. (2014). Environmental noise and sleep disturbances: A threat to health? Sleep Science, 7(4), 209–212. https://doi.org/10.1016/j.jslsci.2014.11.003

Haque, M. S., Uddin, S., Sayem, S. M., & Mohib, K. M. (2021). Coronavirus disease 2019 (COVID-19) induced waste scenario: A short overview. Journal of Environmental Chemical Engineering, 9(1), 104660. https://doi.org/10.1016/j.jece.2020.104660

Higham, J. E., Ramírez, C. A., Green, M. A., & Morse, A. P. (2021). UK COVID lockdown: 100 days of air pollution reduction? Air Quality, Atmosphere & Health, 14(3), 325–332. https://doi.org/10.1080/s11869-020-00937-0

Hurriyet Daily News. (2022). Dust transport. https://www.hurriyetedinalynews.com/april-bringing-heat-and-desert-dust-172573. Accessed 1 March 2022.

Ibekwe, T. S., Folorunsho, D. O., Dahilo, E. A., Gbujie, I. O., Nwegbu, M. M., & Nwaorgu, O. G. (2016). Evaluation of dust-172573. Accessed 1 March 2022.

IMM, Istanbul Metropolitan Municipality (IMM). (2021). Department of Environmental Protection and Development, Istanbul Climate Change Action Plan 2021, https://data.ibb.gov.tr/en/organization/ceve-koruma-ve-kontrol-daire-baskanligi. Open Data Portal, Accessed: Jan 2022

ISKI. (2021). https://data.ibb.gov.tr/en/dataset?q=water+usage. Accessed: Jan 2022.

Jędruchniewicz, K., Ok, Y. S., & Oleszczuk, P. (2021). COVID-19 discarded disposable gloves as a source and a vector of pollutants in the environment. Journal of Hazardous Materials, 125938. https://doi.org/10.1016/j.jhazmat.2021.125938

Jeon, J. Y., Lee, P. J., You, J., & Kang, J. (2010). Perceptual assessment of quality of urban soundscapes with combined noise sources and water sounds. The Journal of the Acoustical Society of America, 127(3), 1357–1366. https://doi.org/10.1121/1.3298437

Jephcote, C., Hansell, A. L., Adams, K., & Gulliver, J. (2021). Changes in air quality during COVID-19 ‘lockdown’ in the United Kingdom. Environmental Pollution, 272, 116011. https://doi.org/10.1016/j.envpol.2020.116011

Kalbusch, A., Henning, E., Brikalski, M. P., de Luca, F. V., & Konrath, A. C. (2020). Impact of coronavirus (COVID-19) spread-prevention actions on urban water consumption. Resources, Conservation and Recycling, 163, 105098. https://doi.org/10.1016/j.resconrec.2020.105098

Kardous, C. A., & Shaw, P. B. (2014). Evaluation of smartphone sound measurement applications. The Journal of the Acoustical Society of America, 135(4), EL186-EL192.

Kayalar, Ö., Arı, A., Babuçu, G., Konyaliar, N., Doğan, Ö., Can, F., et al. (2021). Existence of SARS-CoV-2 RNA on ambient particulate matter samples: A nationwide study in Turkey. Science of the Total Environment, 789, 147976. https://doi.org/10.1016/j.scitotenv.2021.147976

Kumari, P., Toshniwal, D. (2020). Impact of lockdown measures during COVID-19 on air quality– A case study of India. International Journal of Environmental Health Research, 1–8. https://doi.org/10.1080/09603123.2020.1778646

Le Quéré, C., Peters, G. P., Friedlingstein, P., Andrew, R. M., Canadell, J. G., Davis, S. J., et al. (2021). Fossil CO2 emissions in the post-COVID-19 era. Nature Climate Change, 11(3), 197–199. https://doi.org/10.1038/s41558-021-01001-0

Lee, P. J., & Jeong, J. H. (2021). Attitudes towards outdoor and neighbour noise during the COVID-19 lockdown: A case study in London. Sustainable Cities and Society, 67, 102768. https://doi.org/10.1016/j.scs.soc.2021.102768

Li, J., & Tartarini, F. (2020). Changes in air quality during the COVID-19 lockdown in Singapore and associations with human mobility trends. Aerosol and Air Quality Research, 20(8), 1748–1758. https://doi.org/10.4209/aaqr.2020.06.0303

Liu, Z., Wang, H., & Zhang, S. (2022). Science of the total environment an enhanced risk assessment framework for microplastics occurring in the Westerscheldt estuary. Science of the Total Environment, 817, 153006. https://doi.org/10.1016/j.scitotenv.2022.153006

Lüdtke, D. U., Luetkemeier, R., Schneemann, M., & Liehr, S. (2021). Increase in daily household water demand during the first wave of the Covid-19 pandemic in Germany. Water, 13(3), 260. https://doi.org/10.3390/w13030260

Mandal, I., & Pal, S. (2020). COVID-19 pandemic persuaded lockdown effects on environment over stone quarrying and crushing areas. Science of the Total Environment, 732, 139281. https://doi.org/10.1016/j.scitotenv.2020.139281

MS. (2021). Microsoft Corporation, Microsoft Excel.

NTV. (2021). Disposable gloves. https://www.ntv.com.tr/ekonomi/turkiye-de-ilk-nitril-eldiven-fabrikasi-acildi-165-milyon-kutu-uretim,2or9JXZKpE63QbDL-G5hBw). Accessed: Jan 2022.

Nwediegwu, C., & Chang, S. X. (2020). Improper solid waste management increases potential for COVID-19 spread in developing countries. Resources, Conservation and Recycling, 161, 104947. https://doi.org/10.1016/j.resconrec.2020.104947

PAGEV. (2021a). PAGEV. https://pagev.org/covid-19-un-plastik-sektoru-ektisi-yuzde-3-5-daralma-olacak

PAGEV. (2021b). Disposable bag. https://pagev.org/koronavirus-tek-kullanim

Prata, J. C., Costa, J. P., Lopes, I., Andrade, A. L., Duarte, A. C., & Rocha-Santos, T. (2021). A One Health perspective of the impacts of microplastics on animal, human and environmental health. Science of the Total Environment, 777, 146094. https://doi.org/10.1016/j.scitotenv.2021.146094

Prata, J. C., Silva, A. L. P., Walker, T. R., Duarte, A. C., & Rocha-Santos, T. (2020). COVID-19 pandemic repercussions on the use and management of plastics. Environmental Science &
environment. *Science of the Total Environment, 728*, 138813. https://doi.org/10.1016/j.scitotenv.2020.138813

Zangari, S., Hill, D. T., Charette, A. T., & Mirowsky, J. E. (2020). Air quality changes in New York City during the COVID-19 pandemic. *Science of the Total Environment, 742*, 140496. https://doi.org/10.1016/j.scitotenv.2020.140496

Zhu, H., Wei, L., & Niu, P. (2020). The novel coronavirus outbreak in Wuhan. *China. Global Health Research and Policy, 5*(1), 6. https://doi.org/10.1186/s41256-020-00135-6

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