RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

DOI: 10.4274/atfm.galenos.2024.91259
Ankara Üniversitesi Tıp Fakültesi Mecmuası 2024;77(3):258-264

MEDICAL SCIENCES / DAHİLİ TIP BİLİMLERİ

A Correlation Study that Reveals the Relationship Between Countries' GDP, Frequency of Access to Clean Fuel, Level of PM2.5, and Death Rate Related to Air Pollution

Ülkelerin GSYİH'si, Temiz Yakıta Erişim Sıklığı, PM2.5 Düzeyi ve Hava Kirliliğine Bağlı Ölüm Hızı Arasındaki İlişkiyi Ortaya Çıkaran Bir Korelasyon Çalışması

Cemal Koçak

Ankara University Faculty of Medicine, Department of Public Health, Ankara, Türkiye

Abstract

Objectives: Air pollution is one of biggest environmental health problems and is responsible for 11.7% of deaths. It was aimed at examining the relationship between gross domestic product (GDP), the percentage of access to clean fuels, PM2.5 level, air pollution death rates.

Materials and Methods: This study is a correlational study. Data for 208 countries for 1990-2019 were accessed from "Our World in Data" web page in April-May 2023. Comparisons were made according to World Bank income groups.

Results: GDP per capita had a very strong positive correlation with percentage of access to clean/technological fuels (r=0.915), and a very strong negative correlation with indoor air pollution death rate (r=-0.914). There was a moderate negative correlation between GDP per capita and PM2.5 (r=-0.470). The average PM2.5 level had a moderate negative correlation with percentage of access to clean/technological fuel (r=-0.445), a moderate positive correlation with indoor air pollution death rate (r=0.433), and a strong positive correlation with outdoor air pollution death rate (r=0.602).

Conclusion: The percentage of access to clean/technological fuels has increased over the years, indoor air pollution death rate has decreased. It has been almost completely eradicated in high-income countries, but remains in low-income countries. By encouraging clean/technological heating and cooking methods, indoor air pollution death rate will no longer be a problem in any country. On the other hand, outdoor air pollution death rate is higher in countries with high PM2.5 levels. If policymakers reduce coal, oil consumption and prioritize clean energy, transportation, they can improve air quality by lowering PM2.5 levels.

Keywords: Indoor air pollution, outdoor air pollution, PM2.5, gross domestic product, clean fuel, World Bank country income groups

Öz

Amaç: Hava kirliliği en büyük çevre sağlığı sorunlarından biridir ve ölümlerin %11,7'sinden sorumludur. Gayri safi yurtiçi hasıla (GSYİH), temiz yakıtlara erişim yüzdesi, PM2.5 düzeyi ve hava kirliliğinden ölüm hızları arasındaki ilişkinin incelenmesi amaçlandı.

Gereç ve Yöntem: Bu çalışma korelasyonel bir çalışmadır. Nisan-Mayıs 2023'te "Our World in Data" web sayfasından 1990-2019 için 208 ülkeye ait veriye ulaşıldı. Karşılaştırmalar Dünya Bankası gelir gruplarına göre yapıldı.

Bulgular: Kişi başına düşen GSYİH, temiz/teknolojik yakıtlara erişim yüzdesi ile çok güçlü bir pozitif korelasyona (r=0,915) ve iç ortam hava kirliliği ölüm hızı ile çok güçlü bir negatif korelasyona (r=-0,914) sahipti. Kişi başına düşen GSYİH ile PM2,5 (r=-0,470) arasında orta düzeyde negatif korelasyon vardı. Ortalama PM2.5 düzeyi, temiz/teknolojik yakıtlara erişim yüzdesi ile orta derecede negatif korelasyona (r=-0,445), iç ortam hava kirliliği ölüm hızı ile orta derecede pozitif korelasyona (r=0,433) ve dış ortam hava kirliliği ölüm hızıyla güçlü pozitif korelasyona sahipti (r=0,602).

Sonuç: Yıllar geçtikçe temiz/teknolojik yakıtlara erişim yüzdesi arttı, iç ortam hava kirliliği ölüm hızı azaldı. Bu hız yüksek gelirli ülkelerde neredeyse tamamen ortadan kaldırıldı, ancak düşük gelirli ülkelerde varlığını sürdürüyor. Temiz/teknolojik ısıtma ve pişirme yöntemlerinin teşvik edilmesiyle,

Address for Correspondence/Yazışma Adresi: Cemal Koçak
Ankara University Faculty of Medicine, Department of Public Health, Ankara, Türkiye
Phone: +90 553 061 74 60 **E-mail:** ckocak@ankara.edu.tr **ORCID ID:** orcid.org/0000-0003-4799-5669
Received/Geliş Tarihi: 25.04.2024 **Accepted/Kabul Tarihi:** 06.08.2024

iç ortam hava kirliliğinden ölüm hızı artık hiçbir ülkede sorun olmayacak. Öte yandan PM2.5 seviyesinin yüksek olduğu ülkelerde dış ortam hava kirliliğinden ölüm hızı daha yüksektir. Politika yapıcılar kömür ve petrol tüketimini azaltır ve temiz enerji ile ulaşıma öncelik verirlerse PM2.5 seviyelerini düşürerek hava kalitesini artırabilirler.

Anahtar Kelimeler: İç ortam hava kirliliği, dış ortam hava kirliliği, PM2.5, gayri safi yurtiçi hasıla, temiz yakıt, Dünya Bankası ülke gelir grupları

Introduction

Air pollution is the deterioration of the air content by pollutants such as heating, fuel, industrial activities, unplanned urbanization. Air pollution is one of the world's biggest environmental health problems. According to the Global Burden of Disease study of the Institute for Health Measurements and Evaluation, air pollution is responsible for 11.7% of deaths in the world (1). Air pollution; it is examined in two ways as outdoor and indoor air pollution.

Outdoor air pollution is caused by electricity generation, industrial emissions, vehicle exhaust, wind-blown dust and crop burning (2). According to the Global Burden of Disease study, 7.8% (4.5 million) of deaths are due to outdoor air pollution, and in some countries air pollution accounts for at least 10% of deaths. There are up to 10 times different death rates between countries. Rates increase as countries industrialize and move from low-income to middle-income, and are usually highest in middle-income countries (1). If air pollution death rates are to be reduced, both exposure should be reduced and health conditions should be improved (3).

There are two main outdoor air pollutants, ozone and particulate matter (PM). Mortality rates from PM pollution are higher than from ozone. What is meant here is "tropospheric ozone" found in the lower atmosphere near the surface. This should not be confused with the ozone layer in the stratosphere, which protects us from UV radiation (3). The main element of outdoor air pollution is PM, which is a mixture of solid and liquid, organic and inorganic particles. PM2.5 are fine particles that can be taken up by alveolar macrophages and endothelial cells in the lung and cause direct health effects (4). The World Health Organization (WHO) Global Air Quality Guidelines offer global guidance on thresholds and limits for key air pollutants that pose health risks, such as PM. So much so that WHO set out the annual average PM2.5 level up to 5 µg/m^3 as the clean air treshold in 2021 (5).

Indoor air pollution is caused by the burning of solid fossil sources such as wood, coal, manure for cooking and heating. Burning such fuels, especially in underdeveloped countries, causes pneumonia, lung cancer, heart disease, stroke (6). According to the Global Burden of Disease study, 4.1% (2.3 million) of global deaths are caused by indoor air pollution. On the other hand, WHO predicted more deaths, announcing that 3.2 million people died from indoor air pollution in 2020 (7). Only 60% of the world has access to clean fuel for cooking but this share is increasing (8).

Income is a strong determinant of energy access and fuel source choice. Low-income households mostly use traditional solid fuels such as wood and dung. As income increases, this energy mix shifts towards wood and coal. In higher-income countries, cleaner fuels such as natural gas and ethanol are often used instead of harmful fossil fuels. Electricity is mostly available at higher income levels. In countries with a per capita Gross Domestic Product (GDP) of less than 2,000 USD per year, access to clean energy in houses is less than 10% (8).

In this study, it is aimed at examining the relationship between the GDP of countries', the percentage of access to clean or technological fuels, outdoor PM2.5 levels, and air pollution death rates

Materials and Methods

This study is a correlational study. The data was obtained from the website https://ourworldindata.org/ in the period of April-May 2023, and data for 208 countries in total were obtained. Data between 1990-2017 for the variable "PM2.5", and data between 1990-2019 for the variables "GDP per capita", "indoor, outdoor and total air pollution death rates", "percentage of access to clean/technological fuel" are included in the analysis (9). Comparisons were made according to World Bank country income groups (high-income, upper-middle-income, lower-middle-income, low-income) available on the same website.

Statistical Analysis

Statistical analysis were evaluated using the R 3.5.1. program. Descriptive values are expressed as number, percentage, mean (standard deviation), median, minimum-maximum. Continuous variables were compared with the non-parametric Kruskal-Wallis test, as they did not conform to the normal distribution in the evaluation made with visual-analytical tests, and the relationships between them were evaluated using the Spearman correlation test. The correlation coefficient is weak if r=0.00-0.24, moderate if r=0.25-0.49, strong if r=0.50-0.74, very strong if r=0.75-1.00 (10). The significance level was taken as $p<0.05$. Since the study was produced from publicly available data, no application was made to the ethics committee.

Results

Average values in the world between 1990-2019; GDP per capita was 13847.4 (1836.8) USD, indoor, outdoor, total air pollution death rates were 63.4 (22.1) (6.6% of deaths), 59.8 (1.1) (6.5% of deaths), 120.5 (22.2) (12.8% of deaths) per hundred thousand, respectively. Average PM2.5 level was 47.0 (2.1) μg/m³ between 1990-2017. Average values in Türkiye between 1990-2019; GDP per capita was 18730,9 (5201,8) USD, indoor, outdoor, total air pollution death rates were 5.4 (6.8) (0.7% of deaths), 66.2 (7.8) (9.6% of deaths), 70.8 (13.9) (10.1% of deaths) per hundred thousand, respectively. Average PM2.5 level was 42.8 (1.4) μg/m³ between 1990-2017. Average values in the world in 2019; GDP per capita was 16897,2 USD, indoor, outdoor, total air pollution death rates were 30.2 (4.1% of deaths), 57.4 (7.8% of deaths), 85.6 (11.7% of deaths) per hundred thousand, respectively. PM2.5 level was 45.5 μg/m³ in 2017. Average values in Türkiye in 2019; GDP per capita was 28197,3 USD, indoor, outdoor, total air pollution death rates were 0.3 (0.1% of deaths), 53.7 (9.5% of deaths), 53.3 (9.5% of deaths) per hundred thousand, respectively. PM2.5 level was 44.3 μg/m³ in 2017.

The average indoor air pollution death rates were 1.0 (0.8), 54.6 (31.9), 118.6 (35.5), 210.3 (36.3) per hundred thousand in high, upper-middle, lower-middle and low-income countries, respectively. As income decreased, indoor air pollution death rate increased (p<0.001). The average outdoor air pollution death rates were 25.1 (7.8), 79.9 (5.9), 76.6 (9.8), 33.2 (5.8) per hundred thousand in high, upper-middle, lower-middle, and low-income countries, respectively (p<0.001). While outdoor air pollution death rate was higher in upper-middle and lower-middle-income countries than high and low-income countries, it was higher in low-income countries than high-income countries. As income decreased, total air pollution death rates increased (p<0.001). The average PM2.5 level were 15.9 (0.8), 45.2 (3.8), 62.2 (2.1) and 41.7 (1.5) μg/m³ in high, upper-middle, lower-middle and low-income countries, respectively (p<0.001). In high-income countries, PM2.5 level was lower than other income groups. In addition, upper-middle income group and low-income group also had lower PM2.5 concentrations than lower-middle income group (Table 1).

Table 2 shows the correlation between GDP per capita and air pollution death rates, PM2.5 level and percentages of access to clean/technological fuel in the world between 1990-2017. GDP per capita had a very strong positive correlation with the percentage of access to clean/technological fuels (r=0.915), and a very strong negative correlation with indoor air pollution death rate (r=-0.914). There was a moderate negative correlation between GDP per capita and PM2.5 (r=-0.470). As GDP per capita increased, the percentage of access to clean/

Table 1: Comparison of GDP, air pollution death rates and PM2.5 levels among country income groups in the world in 2019-1990

World Bank income groups		GDP per capita (USD)	Indoor air pollution death rate*	Outdoor air pollution death rate*	Total air pollution death rate*	PM2.5 levels (μg/m³)#
High Income	Mean (SD)	41437,0 (5593,2)	1.0 (0.8)	25.7 (7.8)	25.9 (8.6)	15.9 (0.8)
	Median	42677,0	0.7	23.8	24.4	16.2
	Range	32193,1-50491,8	0.3-3.0	14.9-39.1	15.1-41.9	14.5-17.0
Upper-Middle Income	Mean (SD)	10097,5 (3867,2)	54.6 (31.9)	79.9 (5.9)	130.9 (34.2)	45.2 (3.8)
	Median	8936,5	51.3	81.9	132.3	44.7
	Range	5857,8-17393,4	13.8-114.7	66.2-85.4	78.8-187.9	39.0-50.9
Lower-Middle Income	Mean (SD)	4552,9 (1299,0)	118.6 (35.5)	76.6 (9.8)	189.8 (25.9)	62.2 (2.1)
	Median	4205,1	119.6	74.7	188.6	62.3
	Range	3162,2-7115,2	59.5-171.0	62.0-91.9	145.9-227.9	9.0-66.0
Low Income	Mean (SD)	1556,5 (258,5)	210.3 (36.3)	33.2 (5.8)	240.2 (30.8)	41.7 (1.5)
	Median	1480,5	213.2	30.8	241.0	41.8
	Range	1229,4-2022,0	148.5-263.7	27.2-43.7	188.6-287.4	39.4-44.3
p value		<0.001	<0.001	<0.001	<0.001	<0.001
Total	Mean (SD)	13847,4 (1836,8)	63.4 (22.1)	59.8 (1.1)	120.5 (22.2)	47.0 (2.1)
	Median	13767,5	63.0	60.0	120.5	46.6
	Range	11097,3-16897,8	30.2-100.1	56.8-6.0	85.6-156.1	44.3-50.8
Türkiye	Mean (SD)	18730,9 (5201,9)	5.4 (6.8)	66.2 (7.8)	70.8 (13.9)	42.8 (1.4)
	Median	17610,3	2.0	64.7	66.0	42.6
	Range	12507,3-28318,4	0.3-24.5	53.7-79.0	53.3-102.4	40.6-45.4

SD: Standard deviation, GDP: Gross domestic product, *per hundred thousand, #1990-2017

Table 2: Correlation between GDP, air pollution death rates, PM2.5 levels and percentages of access to domestic clean fuel/technology in the world in 1990-2017

		GDP per capita (USD)	Access to clean fuel (%)	Indoor air pollution death rate*	Outdoor air pollution death rate*	PM2.5 level (µg/m³)
GDP per capita (USD)	r	1,000				
	p	-				
Access to clean fuel %	r	**0.915**	1,000			
	p	**<0.001**	-			
Indoor air pollution death rate*	r	**-0.914**	**-0.929**	1,000		
	p	**<0.001**	**<0.001**	-		
Outdoor air pollution death rate*	r	-0.010	**0.055**	**0.081**	1,000	
	p	0.460	**<0.001**	**<0.001**	-	
Annual average PM2.5 level (µg/m³)	r	**-0.470**	**-0.445**	**0.433**	**0.602**	1,000
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	-

GDP: Gross domestic product, r: Correlation coefficient, p: Significance level, *per hundred thousand

technological fuel increased significantly, and as income and percentage of access to clean/technological fuels increased, indoor air pollution death rate and PM2.5 decreased. There was no significant correlation between GDP per capita and outdoor air pollution death rate. The average PM2.5 level had a moderate negative correlation with the percentage of access to clean/technological fuel (r=-0.445), a moderate positive correlation with indoor air pollution death rate (r=0.433), and a strong positive correlation with outdoor air pollution death rate (r=0.602). As PM2.5 level increased, indoor and outdoor air pollution death rates increased.

Figure 1 shows that as GDP per capita increases, the indoor air pollution death rate decreases.

Figure 2 shows that as the percentage of access to clean/technological fuel for cooking increases, the indoor air pollution death rate decreases.

According to Figure 3, as the PM2.5 increases, outdoor air pollution death rate also increases. The percentage of access to clean/technological fuels in the world has increased over the years, and indoor air pollution death rate has decreased. Despite the partial decrease in PM2.5 level, there is no significant decrease in outdoor air pollution date rate (Figure 4).

Discussion

The average indoor, outdoor and total air pollution death rates in the world were 63.4, 59.8 and 120.5 per hundred thousand in 1990-2019, respectively. Finally, the rates were 30.2, 57.4, 85.6 per hundred thousand in 2019, respectively. When the literature is examined; air pollution appears to be the second leading cause of death in Africa. There were 1.1 million deaths of which 697,000 indoor, 383,419 outdoor PM2.5 pollution, 11230 outdoor ozone pollution attributed to air pollution in Africa in

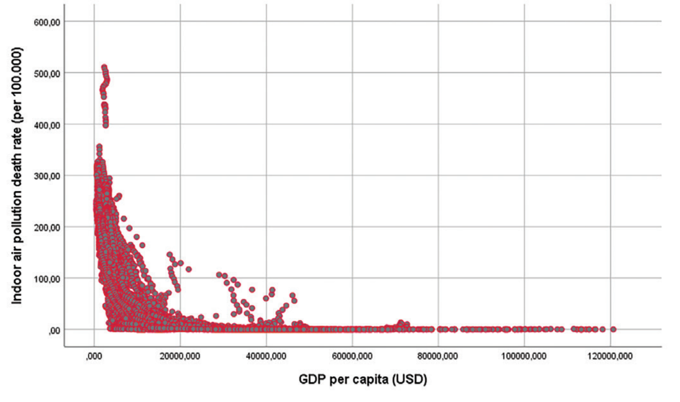

Figure 1: Relationship between GDP per capita and indoor air pollution death rate

GDP: Gross domestic product

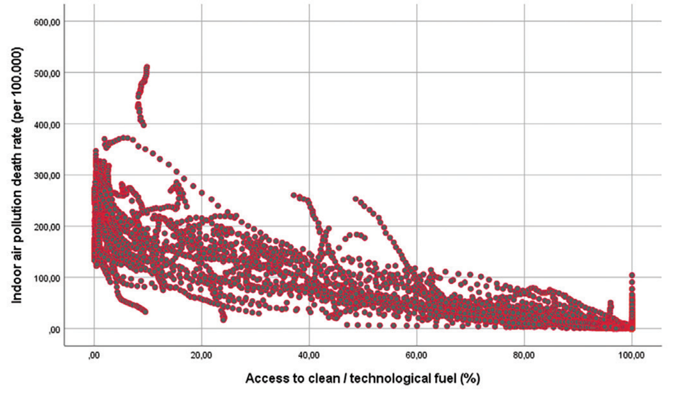

Figure 2: Relationship between percentage of access to clean/technological fuel for cooking and indoor air pollution death rate

2019. This was 16.3% of all deaths. Although indoor air pollution death rate have decreased, outdoor air pollution death rate have increased from 26 per 100,000 in 1990 to 29 per 100,000 in 2019, according to one study (2). The frequency in this study is lower than ours. In our study, while the outdoor air pollution death rate in Africa was 31.5 per hundred thousand in 1990, it was 46.1 in 2019. This difference may be due to the different countries in the sample. In our study, average indoor, outdoor and total air pollution death rates were 5.4 (0.7% of deaths), 66.2 (9.6% of deaths), 70.8 (10.1% of deaths) per hundred thousand in Türkiye between 1990-2019, respectively. Finally, the rates were 0.3 per hundred thousand (0.1% of deaths), 53.7 (9.5% of deaths), 53.3 (9.5% of deaths) in 2019, respectively. In studies conducted in different regions of Türkiye, the share of air pollution in deaths was found to be, 16.8% (4), 33.5% (4) and 29.2% (11). In our study, this percentage for Türkiye is 9.5% in 2019, and lower than the values in the studies above.

In the world, average PM2.5 level was 47.0 µg/m³ between 1990-2017, and 45.5 µg/m³ in 2017. In Türkiye, average PM2.5 level was 42.8 µg/m³ between 1990-2017, and 44.3 µg/m³ in 2017. In the literature, exposure to PM2.5 was high in many low and middle-income countries in Africa and Asia in 2017.

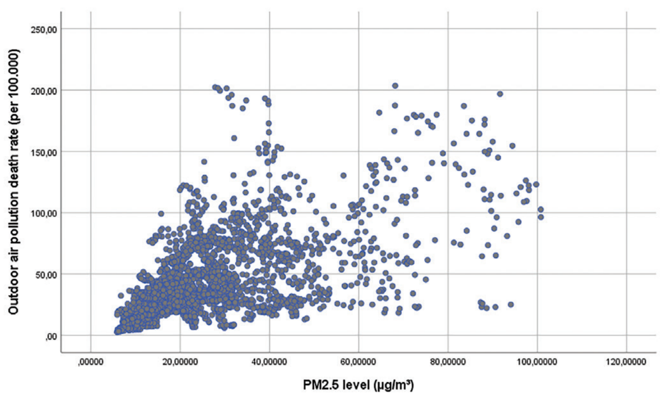

Figure 3: Relationship between annual average PM2.5 concentration and outdoor air pollution death rate

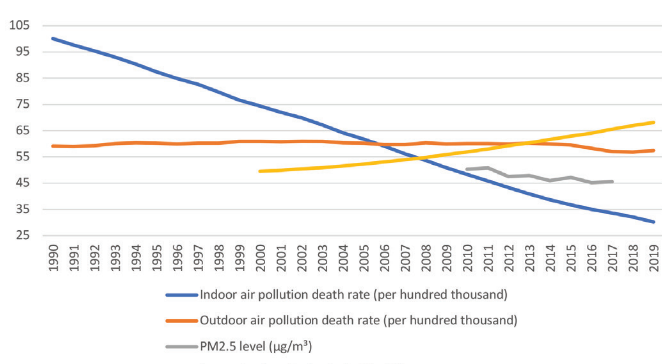

Figure 4: Changes in air pollution death rates, PM2.5 levels and percentages of access to clean/technological fuel over the years in the world

In particular, it was very high in North Africa, up to 200 µg/m³, due to dry conditions with more sources of sand and dust. Whereas in Sweden it was 40 times lower at 5 µg/m³ (4). Annual PM2.5 level in Sub-Saharan Africa was 45 µg/m³ in 2019 (2). Many African countries had PM2.5 concentrations that exceed the WHO guideline (12). The average annual PM2.5 level in China was 52.7 µg/m³ in 2017, 9% lower than in 1990. In 2017, all Chinese population lived in areas that exceeded the WHO guideline of 10 µg/m³, and 81.1% of them lived above the interim target of 35 µg/m³ (13). The average PM2.5 level in houses was 51 µg/m³. This was 10 times higher than the WHO recommended value. (14). According to the Global Study of Disease, Injury and Risk Factors, PM air pollution was the 4th risk factor for death and disability-adjusted life years in China (15). The Chinese Government has implemented a number of measures to reduce PM2.5 levels (16). As a result, PM2.5 levels have decreased in heavily polluted areas such as Beijing (17). Türkiye's 2017 PM2.5 level was high, although slightly below China's. For this reason, it is necessary to implement practices similar to those in China in our country.

According to the 2020 World Air Quality report of the Sweden-based IQAir group, PM2.5 was above the upper limit in 26 of 106 countries. The countries with the most polluted air were Bangladesh, Pakistan and India. Average PM2.5 was 77.1 in Bangladesh, 59.0 in Pakistan, 51.9 µg/m³ in India. In the Virgin Islands, New Caledonia and Puerto Rico, where the air quality was highest, PM2.5 levels averaged 3.7 µg/m³. Türkiye was the 46th most polluted country with an average PM2.5 level of 18.7 µg/m³ (18). Within the scope of a joint project, 31,476 deaths in Türkiye in 2019 were associated with air pollution and it was calculated that these deaths could have been prevented if PM2.5 levels was at the standards set by WHO (19). According to the 2021 European PM2.5 air quality ranking, Türkiye ranked 7th with 20 µg/m³. Finland was the only country to reach the 5 µg/m³ limit set by WHO (20). The average PM2.5 level in 2019 determined for Türkiye in these two studies is half of the average value of the last 30 years in our study. Although PM2.5 levels have decreased in the last 30 years for our country, it is regrettable that our country is still at the top of the world rankings.

Indoor air pollution death rates increased significantly as income decreased. While the outdoor air pollution death rate was significantly higher in upper/lower-middle-income countries than in high/low-income countries, it was significantly higher in low-income countries than in high-income ones. As income decreased, the total air pollution death rate increased significantly. The literature on inequalities between countries in air pollution is limited (21,22). Most of the literature documents inequalities for a given city. Less literature documents nationwide inequalities in the US, and indicates that those from low socioeconomic status are more exposed to pollution than those from higher socioeconomic status (23-25). Evidence for European countries is limited and a mixed relationship is considered (26,27). Information is also limited for China and other low- and middle-income countries, where 91% (26%) of outdoor air pollution premature deaths occur (22,28). In 2016, increased PM levels were associated with 8.4% mortality in undeveloped and developing countries and 4.2% in developed countries (29). As a result, in our study, as the income situation worsens, indoor and total air pollution and deaths increase in parallel with the literature.

In this study, PM2.5 levels were found to be lower in high-income countries than in other groups. In addition, the upper-middle and low-income group also have lower PM2.5 concentrations than the lower-middle income group. As income increased, the annual average PM2.5 level decreased significantly. In China, a positive relationship was found between socioeconomic status and outdoor air pollution. PM2.5 concentrations in China were higher in high socioeconomic status than lower socioeconomic status, and in long-term urban residents than come rural to urban people (13). In Europe, it is estimated that approximately 60% of the population of high-income countries and 80% of the population of middle and low-income countries are exposed to PM2.5 levels above the WHO limit (29). Similar to our study in Europe, there is an inverse correlation between PM2.5 levels and income, while the opposite is true in China. The fact that the majority of China's population lives in industrial and economically developed big cities may cause more air pollution in high-income regions.

In this study as a result of the correlation analysis; as income increased, the percentage of access to clean/technological fuel increased, and the indoor air pollution death rate decreased. In addition, as the percentage of access to clean/technological fuel increased, the indoor air pollution death rate decreased. Indoor air pollution is the common form of air pollution in Africa. The highest rates in Africa were seen in countries with the lowest social development indices, similar to our study. Indoor air pollution accounted for more than 80% of disease damage in Ethiopia and Rwanda, but only half in more economically developed Ghana (2). As countries get richer, they begin to take measures to reduce air pollution and related deaths. Countries with a GDP per capita of 5-15 thousand USD (such as India) are in the first phase. Countries that have become richer and more competent (such as China, Türkiye) enter the second phase. At this stage, air pollution-related deaths are reduced by increasing environmental investments. Türkiye's air pollution deaths, which were 60-70 per hundred thousand in the 1990s, decreased to 40-50 in the 2010s (Türkiye's 2020 GDP per capita was 30,000 USD). The decline is more striking in Singapore, which is much richer than Türkiye, with air pollution deaths falling from 43 per 100,000 in 1990 to 20 in 2017 (Singapore's 2020 GDP per capita was 102,000 USD) (30). In these studies, similar to ours, it was observed that the death rate of air pollution decreased as the income level of the country increased.

In Africa, 60% of air pollution deaths are caused by indoor air pollution, and polluting fuels such as coal and kerosene are widely used. With the intervention of the government, non-governmental organizations and United Nations agencies, morbidity and mortality from air pollution in the home is decreasing, albeit slowly and sporadically. With exceptions like Nigeria, African countries haven't yet any precautions against the use of fossil fuels. Therefore, they have the opportunity to get rid of their dependence on oil and natural gas by investing in renewable energy and non-polluting technologies. Reducing dependence on fossil fuels, switching to non-polluting renewable energy sources such as solar, wind and hydroelectric, and improving public transportation are the main pollution prevention strategies (2). The proportion of households cooking with solid fuel in China decreased from 84.4% in 1990 to 61% in 2005 and 32.2% in 2017. The use of coal for cooking and heating has been banned in the areas around Beijing, and clean energy such as natural gas has been promoted in the country. The age-standardized death rate attributed to air pollution decreased by 60.6% in China between 1990 and 2017. The decrease for outdoor PM pollution is 12.0% and for indoor air pollution is 85.4%. In China, the age-standardized death rate attributed to PM decreased by 8.9% between 2013 and 2017. In addition, average PM2.5 concentrations decreased by 33.3% between 2013 and 2017 (31). As can be seen, both PM levels and air pollution death rates decrease as access to clean fuel increases.

Study Limitations

There are some limitations in this study. Only the relationships between income level/access to clean/technological fuel/PM2.5 levels and deaths due to air pollution was examined. As we know, there are many variables that have an effect on deaths, and the fact that these variables are not included in the analysis may lead to bias in the results.

Conclusion

In conclusion, there was a positive correlation between income and percentage of access to clean/technological fuels; there was a negative correlation between income and PM2.5, death rate from indoor and total air pollution. As the percentage of access to clean/technological fuels increased, PM2.5 and indoor air pollution death rates decreased. There was a negative correlation between percentage access to clean/technological fuels and PM2.5 level; there was a positive correlation between PM2.5 level, indoor and outdoor air pollution death rates.

The percentage of access to clean/technological fuels in the world has increased over the years, and indoor air pollution death rate has decreased. Indoor air pollution death rate has a clear economic distinction. It has been almost completely eradicated in high-income countries, but remains an environmental and health problem in low-income countries. By encouraging clean/technological heating and cooking methods at houses, the indoor air pollution death rate will no longer be a problem in low-income countries. On the other hand, outdoor air pollution death rate is higher in countries with high PM2.5 levels. If policymakers reduce coal and oil consumption and prioritize clean air, energy and transportation, it will benefit air quality improvement.

Ethics

Ethics Committee Approval: Since the study was produced from publicly available data, no application was made to the ethics committee.

Informed Consent: This study is a correlational study.

Financial Disclosure: This study received no financial support.

References

1. GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 2020;396:1223-1249.
2. Fisher S, Bellinger DC, Cropper ML, et al. Air pollution and development in Africa: impacts on health, the economy, and human capital. Lancet Planet Health. 2021;5:681-688.
3. Outdoor Air Pollution; Death rates from outdoor air pollution have fallen in around half of countries [online]. Available at: https://ourworldindata.org/outdoor-air-pollution Accessed June 11, 2023.
4. Altunok A, Eskiocak M. Trakya'da partiküler madde kirliliği ve mortalite ilişkisinin değerlendirilmesi. Turk J Public Health. 2020;18:124-132.
5. WHO, Ambient (outdoor) air pollution, Air quality guidelines. https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health?gclid=Cj0KCQiAm4WsBhCiARIsAEJIEzXBDZ2EhI31RxZyO3PxtargIyRjfYNAEwyOrqT_nMe3-nbAG-jAFaEaAniyEALw_wcB Accessed December 19, 2023.
6. World Health Organization. WHO guidelines for indoor air quality: household fuel combustion. World Health Organization, 2014 [online]. Available at: https://www.who.int/publications/i/item/9789241548885 Accessed June 11, 2023.
7. WHO- Fact sheet- Household air pollution. Updated November 2022 [online]. Available at: https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health Accessed June 11, 2023.
8. Our World in Data; Indoor Air Pollution; Access to clean fuels for cooking [online]. Available at: https://ourworldindata.org/indoor-air-pollution Accessed June 11, 2023.
9. Our World in Data; Air Pollution. 2023 [online]. Available at: https://ourworldindata.org/air-pollution Accessed June 11, 2023.
10. Aksakoğlu G. Sağlıkta Araştırma Teknikleri ve Analiz Yöntemleri. Dokuz Eylül Üniversitesi Yayın Komisyonu Yayını, ISBN 957-93363-0-08. D.E.Ü. Rektörlük Matbaası, İzmir, 2001.
11. Mayda AS, Karkaç D. Düzce'de hava kirliliğinin mortalite üzerine etkisi. Sakarya Tıp Dergisi 2021;11(4):829-835.
12. Global Health Observatory. Ambient air pollution [online]. Available at: https://www.who.int/data/gho/data/themes/air-pollution/ambient-air-pollution Erişim tarihi: 11 Haziran 2023.
13. Ministry of Environmental Protection of China. National ambient air quality standard of China. 2012 [online]. Available at: http://www.mee.gov.cn/ywgz/fgbz/bz/bzwb/dqhjbh/dqhjzlbz/201203/W020120410330232398521.pdf Accessed June 11, 2023.
14. Wang Y, Wang Y, Xu H, et al. Ambient Air Pollution and Socioeconomic Status in China. Environ Health Perspect. 2022;130:67001.
15. Zhou M, Wang H, Zeng X, et al. Mortality, morbidity, and risk factors in China and its provinces, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2019;394:1145-8.
16. Government of China. On the publication of National Action Plan for Air Pollution Control [online]. Available at: http://www.gov.cn/zwgk/2013-09/12/content_2486773.htm Accessed June 11, 2023.
17. Huang J, Pan X, Guo X, et al. Health impact of China's air pollution prevention and control action plan: An analysis of national air quality monitoring and mortality data. Lancet Planet Health. 2018;2:313-23.
18. Euronews Web Sitesi. Dünyanın hava kirliliği haritası: Türkiye'den 3 il 'Avrupa'nın havası en kirli 15 şehri' listesinde [online]. Available at: https://tr.euronews.com/2021/03/16/dunyan-n-hava-kirliligi-haritas-turkiye-den-3-il-avrupa-n-n-havas-en-kirli-15-sehri-listes Accessed June 11, 2023.
19. ÇİSİP (Çevre İklim ve Sağlık İçin İş Birliği Projesi). Hava kirliliğinin sağlık etkileri. 2022 [online]. Available at: https://www.env-health.org/wp-content/uploads/2022/03/Hava_Kirliligi_Bilgi_Notu.pdf Accessed June 11, 2023.
20. Euronews Web Sitesi. Dünya Hava kirliliği raporu: Türkiye 46. sırada, Iğdır ve Düzce Avrupa'nın en kirli kentleri, 2022 [online]. Available at: https://tr.euronews.com/2022/03/22/2021-de-dunyada-hicbir-ulke-dso-nun-hava-kalitesi-standard-n-tutturamad Accessed June 11, 2023.
21. Brauer M, Freedman G, Frostad J, et al. Ambient air pollution exposure estimation for the Global Burden of Disease 2013. Environ Sci Technol. 2016;50:79-88,
22. Cohen AJ, Brauer M, Burnett R, et al. Estimate sand 25-year trends of the global burden of disease attributable to ambient air pollution: ananalysis of data from the Global Burden of Diseases Study 2015. Lancet. 2017;389:1907-18.
23. Bell ML, Ebisu K. Environmental inequality in exposures to air borne particulate matter components in the United States. Environ Health Perspect. 2012;120:1699-704.
24. Clark LP, Millet DB, Marshall JD. Changes in transportation-related air pollution exposures by race-ethnicity and socioeconomic status: outdoor nitrogen dioxide in the United States in 2000 and 2010. Environ Health Perspect. 2017;125:097012.
25. Liu J, Clark LP, Bechle M, et al. Disparities in air pollution exposure in the United States by race/ethnicity and income, 1990-2010. Environ Health Perspect. 2021;129:127005.
26. Hajat A, Hsia C, O'Neill MS. Socioeconomic disparities and air pollution exposure: a global review. Curr Environ Health Rep. 2015;2:440-450.
27. Temam S, Burte E, Adam M, et al. Socioeconomic position and outdoor nitrogen dioxide (NO2) exposure in Western Europe: amulti-city analysis. Environ Int. 2017;101:117-124.
28. WHO- Fact sheet- Ambient (outdoor) air pollution. Updated Dec 2022 [online]. Available at: https://www.who.int/en/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health Accessed June 11, 2023.
29. WHO. Over half a million premature deaths annually in the European Region attributable to household and ambient air pollution. 2 May 2018 [online]. Available at: https://www.who.int/europe/news/item/02-05-2018-over-half-a-million-premature-deaths-annually-in-the-european-region-attributable-to-household-and-ambient-air-pollution Accessed June 11, 2023.
30. "The World in Numbers", The Economist The World in 2021, December 2020 [online]. Available at: https://macua.blogs.com/files/the-world-in-2021-the-economist.pdf Accessed June 17, 2023.
31. Yue H, He C, Huang Q, et al. Stronger policy required to substantially reduce deaths from PM2·5 pollution in China. Nat Commun. 2020;11:1462