Investigation Regarding the Correlation between Particulate Matter 2.5 Air Pollution and Mortality Rates due to Chronic Obstructive Pulmonary Disease

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ABSTRACT: In 2015, 3.2 million people died due to Chronic Obstructive Pulmonary Disease (COPD), worldwide. In fact, survival rates for those living with severe COPD are lower than for those with cancer. The one known contributor to this disease is air pollution, and with its rising levels every year, it is necessary to determine the exact correlation between air pollution and COPD. Data was gathered for a selection of 20 countries from the World Bank Database and Health Data Database. This data was graphed and analyzed using the Pearson correlation coefficient, which is a statistical test that measures the relationship between 2 variables. When calculated, the Pearson correlation coefficient was 0.756, determining that there is a significant relationship between air pollution and COPD. Through the investigation, it is concluded that there is a positive correlation between PM2.5 air pollution and mortality rate due to COPD. PM2.5 is a component of air pollution defined as the amount of atmospheric particulate matter with a diameter less than 2.5 micrometers. Due to its small physical nature, PM2.5 can easily infiltrate the lungs, causing infections in the respiratory organs. They can reach the bronchi and even the alveoli, causing inflammation which ultimately results in COPD and premature deaths. Therefore, this research will aim to investigate the relationship between PM2.5 air pollution and COPD, allowing for a better understanding of these variables.

KEYWORDS: Chronic Obstructive Pulmonary Disease (COPD), Particulate Matter (PM), Human Development Index (HDI)

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a chronic inflammatory disease which slowly progresses to cause inflammation of the lung airways [1]. This disease eventually causes an obstruction of airflow which makes daily activities more difficult [2]. COPD is currently the fourth leading cause of death worldwide [3] and is also the only chronic disease with continuously increasing mortality, meaning more and more individuals die as a result of this each year [4]. In addition, levels of air pollution are also increasing around the world, [5] which is an influential factor in this disease [6].

There are 2 types of COPD: chronic bronchitis and emphysema [1]. Chronic bronchitis is a constant inflammation of the lining of the bronchial tubes, while emphysema is a progressive lung disease that causes shortness of breath due to hyperinflation of the alveoli resulting in a loss of elasticity [7]. Many factors can result in these inflamed respiratory

organs; however, the primary etiology is the inhalation of polluted air [8]. Polluted air can come from many different sources such as forest fires, cigarette smoke and the combustion of fossil fuels [9]. The polluted air is inhaled into the body and infects the bronchi and alveoli in the lungs, causing inflammation [7]. Therefore, air pollution is a large factor in the development of COPD [10]. Particulate matter 2.5 (PM_{2.5}) is a significant component of air pollution, which is defined as the amount of atmospheric particulate matter with a diameter less than 2.5 micrometers [11]. They are abundant on Earth and tend to stay longer in the air because of their light weight, which also increases the probability of human inhalation [11]. Their miniscule size can also allow them to enter the body easily, without much interaction with the body's natural defence systems such as mucus and cilia [12]. As such, PM_{2.5} may be linked to COPD as particles less than 2.5 micrometres in diameter can penetrate deep into the lungs, potentially resulting in chronic inflammation and/

or emphysema.

METHODOLOGY

This investigation aims to assess the interaction between the level of PM_{2.5} air pollution and mortality rates due to COPD (measured in the number of deaths per 100,000 people) in countries with an HDI above 0.8.

If countries have high PM_{2.5} air pollution, then they should have reasonably high mortality rates due to COPD because particles less than 2.5 micrometres in diameter can penetrate deep into the lungs, leading to COPD which ultimately results in premature death [13]. The Null Hypothesis (H₀) for Pearson correlation coefficient statistical testing (with 5% confidence) is that PM_{2.5} air pollution has no impact on the mortality rate due to COPD. The Alternative Hypothesis (H₁) is that PM_{2.5} air pollution has a positive correlation on the mortality rate due to COPD.

The independent variable is Particulate Matter 2.5 Air Pollution measured in $\mu\text{m}/\text{m}^3$. The dependent variable is the mortality rates due to COPD measured per 100,000 population. The control variables are the HDI of countries and the years used in the investigation.

For this investigation, countries with HDI above 0.8, otherwise categorized as “very high”, were examined. The Human Development Index (HDI) measures a country's overall wealth through various socioeconomic dimensions [14]. A random selection of the top 20 countries in the world (in terms of HDI) was examined, where Hong Kong and Singapore were excluded due to insufficient data. From the 20 assessed countries, their levels of PM_{2.5} air pollution were analysed along with their mortality rates by COPD for the years 2014, 2015 and 2016. These 20 countries were randomly selected using an online randomizer and examined for this investigation. Only 20 countries were chosen due to time constraints. Using a third of all countries with an HDI of above 0.8 would ensure that the results of this investigation would be valid. These countries will be used because countries with similar HDI's signify similar education levels and similar technologies developed for treating respiratory disease [15]. Using countries with significantly different HDI's would be a confounding factor, as it is a variable that influences both the dependent variable and independent variable, causing a spurious association. Populations living in countries with low HDI are less likely to have the ability to make healthy life choices or have appropriate living/work environments due to their restrictive socioeconomic status [16]. These conditions

may result in a greater number of deaths by COPD; however, the COPD inflictions are more likely to be caused by the standard of living rather than PM_{2.5} air pollution. Individuals of low socioeconomic status may be exposed to more harmful particulate matter at their work (e.g. mines) or may live in areas more exposed to pollution.

Therefore, the HDI of the countries were kept similar to ensure that the standards of living would be relatively constant. The data was obtained from the years 2014, 2015 and 2016. The years were kept constant for each country because different global epidemics could have happened in different years, thereby skewing the data. For example, if we use data from 2016 for Canada, there would most likely be a greater level of PM_{2.5} air pollution because of the Fort McMurray fire whereas, if we used data from the 1990s there would likely be lower levels of PM_{2.5} air pollution because in the 1990s there were fewer pollutants releasing PM_{2.5} pollution [17]. Additionally, estimated deaths caused by COPD will be averaged for the 3 years to control and limit the errors.

The following databases were used for the present statistical analysis: World Bank Database of PM_{2.5} air pollution (2014, 2015 and 2016), Health Data Database for the number of deaths caused by COPD (2014, 2015, 2016), World Bank Database of Countries Populations (2014, 2015, 2016), and United Nations Human Development Reports for HDI. The World Bank is a global partnership organization and Health Data is by The Institute for Health Metrics and Evaluation (IHME), a health research center at the University of Washington.

For the exploration of this investigation (control study) 20 countries with “very high” HDIs were randomly selected with data from the years of 2014 to 2016. The countries were: Switzerland, Iceland, Finland, Japan, Austria, Luxembourg, France, Slovenia, Italy, Malta, Estonia, Cyprus, Andorra, Brunei D., Hungary, Croatia, Argentina, Bulgaria, Romania and Kazakhstan. Hong Kong and Singapore were excluded due to insufficient data. These countries were selected because they all have high living standards in terms of HDI, which is a variable that needed to be controlled. Since these countries have similar high HDI's, education and health care levels of the countries would be similar which would limit the impact of outside factors such as lifestyle habits or dietary preferences on the data. All the data was transferred to a Microsoft Excel program file where it was analysed.

First, a data table including the estimated deaths caused

by COPD, population and the amounts of PM_{2.5} air pollution of selected countries in the years 2014, 2015 and 2016 was created (Table 1). To calculate mortality rates, the death caused by COPD was divided by the population of that country. This death rate per person was then multiplied by 100,000 to find the more conventional death rate per 100,000 population (using Calculation #1 in Appendix A). Using this data, a data table of mortality rates due to COPD per 100,000 population was created (Table 2). Then, the average PM_{2.5} air pollution was calculated along with the average mortality rates for the 3 years (using Calculation #2 in Appendix A). The standard deviations were also calculated for both PM_{2.5} air pollution and the mortality rates to determine the error bars for the graphs (using Calculation #3 in Appendix A). Using this information, a data table for the average mortality rates per 100,000 population caused by COPD and average PM_{2.5} air pollution of selected countries in the years 2014, 2015 and 2016 was created (Table 3). All the data gathered was then graphed on a scatter plot to show the relationship between PM_{2.5} air pollution and mortality rates per 100,000 in the top 10 countries, in terms of HDI (Figure 1). Finally, the correlation between both variables was calculated, using the Pearson correlation coefficient (Sample Calculation #4 in Appendix A).

RESULTS

This scatter graph shows a linear correlation; therefore, the Pearson correlation coefficient test can be used for statistical testing. The error bars (from standard deviation) also indicate that these variables are statistically significant since most of them do not overlap and the few that do only have a small overlap [18]. Additionally, a majority of the data has smaller error bars, suggesting that the data is quite reliable. The error bar for Estonia appears to be the largest which could be easily explained as Northern parts of Estonia mine oil shales resulting in greater variances in levels of PM_{2.5} air pollution for that country [19]. However, the Pearson correlation coefficient test is necessary to determine if there is an actual correlation between the 2 variables.

Using the Pearson correlation coefficient, the 'r' value was calculated to be 0.756. This value means that there is a distinct correlation between the levels of PM_{2.5} air pollution and deaths caused by COPD. Moreover, through the Pearson correlation test, the null hypothesis is rejected. The critical value for 20 pairs of data with 19 degrees of freedom (found by the number of trials, 20, minus 1) and levels of confidence 0.05, is 0.433 [20]. The Pearson coefficient from this investigation is higher than this critical value, indicating

Table 1. Raw data showing the estimated deaths caused by COPD, population and the amounts of PM_{2.5} air pollution of selected countries in the years 2014, 2015 and 2016.

Countries	PM _{2.5} air pollution			Deaths caused by COPD			Populations		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
Switzerland	12.33	10.60	10.51	2,394.15	2,447.67	2,406.33	8,188,649	8,282,396	8,373,338
Iceland	7.71	7.33	7.30	89.57	92.38	95.46	327,386	330,815	335,439
Finland	7.12	6.28	6.23	1,313.25	1,312.32	1,355.30	5,461,512	5,479,531	5,495,303
Japan	12.88	13.15	13.16	32,662.46	32,953.24	33,966.76	127,276,000	127,141,000	126,994,511
Austria	16.47	15.03	14.97	2,995.79	3,083.61	3,063.21	8,546,356	8,642,699	8,736,668
Luxembourg	16.54	16.10	16.10	193.86	203.22	204.36	556,319	569,604	583,014
France	12.33	11.89	11.87	15,660.13	16,214.93	16,324.76	66,316,092	66,593,366	66,859,768
Slovenia	18.74	17.93	17.82	511.13	535.28	541.51	2,061,980	2,063,531	2,065,042
Italy	17.91	15.48	15.60	24,752.45	25,988.96	25,435.38	60,789,140	60,730,582	60,627,498
Malta	12.32	12.14	14.46	115.27	121.99	129.55	434,558	445,053	455,356
Estonia	8.72	5.93	6.04	254.24	244.97	241.80	1,314,545	1,315,407	1,315,790
Cyprus	17.23	17.87	17.90	340.60	358.67	370.07	1,152,309	1,160,985	1,170,125
Andorra	10.91	10.88	10.67	26.37	26.98	27.65	79,223	78,014	77,281
Brunei D.	5.66	6.43	6.37	62.70	65.08	67.98	411,704	417,542	423,196
Hungary	21.96	24.57	24.44	5,200.69	5,544.09	5,264.33	9,866,468	9,843,028	9,814,023
Croatia	19.84	19.82	20.10	1,786.37	1,896.33	1,799.59	4,238,389	4,203,604	4,174,349
Argentina	13.64	14.15	14.12	15,379.03	15,695.01	15,943.85	42,981,515	43,417,765	43,847,430
Bulgaria	27.56	25.65	25.68	3,244.68	3,174.95	3,131.87	7,223,938	7,177,991	7,127,822
Romania	19.00	19.06	19.42	6,413.21	6,527.59	6,546.70	19,908,979	19,815,481	19,702,332
Kazakhstan	19.17	19.66	19.62	4,803.24	4,744.25	4,749.60	17,288,285	17,542,806	17,794,055

Table 2. Processed Data: mortality rates due to COPD per 100,000 population

Countries	2014	2015	2016
Switzerland	29.2	29.6	28.7
Iceland	27.4	27.9	28.5
Finland	24.0	24.0	24.7
Japan	25.7	25.9	26.7
Austria	35.1	35.7	35.1
Luxembourg	34.8	35.7	35.1
France	23.6	24.4	24.4
Slovenia	24.8	25.9	26.2
Italy	40.7	42.8	42.0
Malta	26.5	27.4	28.5
Estonia	19.3	18.6	18.4
Cyprus	29.6	30.9	31.6
Andorra	33.3	34.6	35.8
Brunei D.	15.2	15.6	16.1
Hungary	52.7	56.3	53.6
Croatia	42.1	45.1	43.1
Argentina	35.8	36.1	36.4
Bulgaria	44.9	44.2	43.9
Romania	32.2	32.9	33.2
Kazakhstan	27.8	27.0	26.7

Table 3. Processed data: Average mortality rates per 100,000 population caused by COPD and average PM_{2.5} air pollution of selected countries in the years 2014, 2015 and 2016.

Countries	PM _{2.5} air pollution		Mortality rates per 100,000 population caused by COPD	
	Average	Standard Deviation	Average	Standard Deviation
Switzerland	11.15	1.03	29.2	0.45
Iceland	7.45	0.23	28.0	0.55
Finland	6.53	0.50	24.2	0.40
Japan	13.06	0.16	26.1	0.53
Austria	15.49	0.85	35.3	0.35
Luxembourg	16.25	0.25	35.2	0.46
France	12.03	0.26	24.1	0.46
Slovenia	18.16	0.50	25.6	0.74
Italy	16.33	1.37	41.8	1.06
Malta	12.97	1.29	27.5	1.00
Estonia	6.90	1.58	18.8	0.47
Cyprus	17.67	0.38	30.7	1.01
Andorra	10.82	0.13	34.6	1.25
Brunei D.	6.15	0.43	15.6	0.45
Hungary	23.66	1.47	54.2	1.87
Croatia	19.92	0.16	43.4	1.53
Argentina	13.97	0.29	36.1	0.30
Bulgaria	26.30	1.09	44.3	0.51
Romania	19.16	0.23	32.8	0.51
Kazakhstan	19.48	0.27	27.1	0.57

Figure 1. Relationship between PM2.5 air pollution and mortality rates per 100,000 in the 20 selected countries.

evidence against the null hypothesis. In addition, the p-value was calculated to be 0.000115. Since $p < 0.05$, the result is significant and also indicates evidence against the null hypothesis. Therefore the null hypothesis is rejected and the alternative hypothesis of “PM2.5 air pollution has a positive correlation on the mortality rate due to COPD” is not rejected.

DISCUSSION

A strong positive correlation was found between levels of PM2.5 in the air and mortality rates due to COPD. Therefore, the alternative hypothesis is supported by the data from this investigation. This suggests that increasing levels of PM2.5 air pollution also increases the probability of inhaling these particles, thereby leading to inflamed bronchi and alveoli and potentially resulting in COPD. It is estimated that COPD can reduce life expectancy by as much as 14 years [21]. Since PM2.5 particles are so small, they can stay longer in the air and can also easily bypass the nose and throat, even whilst interacting with the cilia and mucus, thereby infiltrating the lungs [22]. These particles then cause infections in the respiratory organs as they are able to reach the bronchi and even the alveoli, causing inflammation which ultimately results in COPD [21].

The graphical representations of data of the countries, Figure 1, shows a relatively linear relationship between the exposure of the PM2.5 air pollution and the death rates due to COPD. For Figure 1, the equation of the line of best fit was found to be $y = 1.2385x + 13.559$ with an R^2 value of 0.5712. The R^2 value is greater than 0.5 which generally suggests a moderate to strong relation [23]. There also appears to be a consistent positive trend; however, there appears to be

greater variance in the middle section of the graph. PM2.5 levels at the extreme (high and low) have a consistent mortality rate difference of around 10 however, the middle numbers of PM2.5 (from around 10 - 20 PM2.5) have almost double the difference, with the difference of mortality rates being around 20. Since there is a variation between the differences towards the middle of the graph, it can be concluded that there is a correlation between the levels of PM2.5 air pollution and COPD with some discrepancy.

Additionally, the conclusion from this investigation is supported by a study published in The Lancet by Cui Guo and colleagues [24]. Their study, with data from Taiwan, also showed a positive relationship between PM2.5 air pollution and COPD. It showed that an increase in ambient PM2.5 was associated with a decline in lung function and increased incidence of COPD [25]. The study controlled factors such as smoking and second-hand smoke which allowed the researchers to analyse the data in more depth and were able to come to a more precise conclusion. Overall, the data from their study and this investigation suggest the same thing; there is a positive linear relationship between the levels of PM2.5 air pollution and COPD.

Some future areas of research include determining the relationship between the level of PM2.5 air pollution and mortality rates due to COPD in people who have never smoked cigarettes. Smoking is also a way in which many people inhale contaminated air. This can, in theory, cause COPD as well. However, this factor of smoking was not controlled or discussed in this experiment. Therefore, for future work, smoking can also be controlled to determine if there is indeed, a correlation between PM2.5 air pollution and COPD. In addition, this same investigation can be redone using the mortality rates due to COPD in DALYs (Disability-Adjusted Life Years). With this research, the age of each person dying from COPD can be investigated, to see how long one needs to be in the presence of PM2.5 air pollution to develop fatal COPD. This would also allow for the trend to be analyzed over a time period which was not taken into account in this specific investigation.

There are some weaknesses in this investigation that could be improved on for future work. Firstly, random error may have occurred with the randomly selected population. The 20 countries selected for this investigation could have all supported the hypothesis, while the other 38 countries might not support the hypothesis. Therefore, a complete larger-

scale analysis of all the countries needs to be done to ensure that the data is accurate and precise. Secondly, the data is strictly national, meaning it does not represent regional differences in these specific countries which could have more pollution relative to more rural areas. For example, when a forest fire begins it does not spread all across the country, it is limited to a smaller area and that specific area would suffer from a greater level of air pollution [26]. Therefore, by using the data from whole countries, there is a systematic error resulting in a slight inaccuracy throughout all the data. To improve this, data from specific cities in a country should be used.

CONCLUSION

Through this investigation, a strong positive correlation was found between levels of PM_{2.5} in the air and mortality rates due to COPD. The null hypothesis is rejected as the data supports a correlation between both variables. The data suggests that the increasing levels of PM_{2.5} air pollution also increases the chances of someone inhaling these particles which results in inflamed bronchi and alveoli, finally resulting in COPD.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

- Decramer, M., Janssens, W., & Miravittles, M. (2012) Chronic Obstructive Pulmonary Disease. *The Lancet*. doi: 10.1016/S0140-6736(11)60968-9
- Cologne, Germany: Institute for Quality and Efficiency in Health Care (IQWiG); 2006-. Chronic obstructive pulmonary disease (COPD): Overview. 2007 Mar 23 [Updated 2019 Mar 14].
- The leading causes of death in the world - can they be cured?: Proclinical Recruitment blogs. (n.d.). Retrieved from <https://www.proclinical.com/blogs/2017-5/the-leading-causes-of-death-in-the-world-can-they-be-cured>
- Murray, C. J., & Lopez, A. D. (1997). Alternative projections of mortality and disability by cause 1990–2020: Global Burden of Disease Study. *The Lancet*, 349(9064), 1498–1504. doi: 10.1016/s0140-6736(96)07492-2
- Petty, T. L. (2006). The history of COPD. *International Journal of COPD*, 1(1), 3–14. doi: 10.2147/copd.2006.1.1.3
- Hannah Ritchie and Max Roser (2020) - "Air Pollution". Published online at OurWorldInData.org. Retrieved from: <https://ourworldindata.org/air-pollution>
- Centers for Disease Control and Prevention (US); National Center for Chronic Disease Prevention and Health Promotion (US); Office on Smoking and Health (US). How Tobacco Smoke Causes Disease: The Biology and Behavioral Basis for Smoking-Attributable Disease: A Report of the Surgeon General. Atlanta (GA): Centers for Disease Control and Prevention (US); 2010. 7, Pulmonary Diseases.
- Jiang, Q., Mei, X., & Feng, D. (2016) Air pollution and chronic airway diseases: what should people know and do? *Journal of Thoracic Disease*. doi: 10.3978/j.issn.2072-1439.2015.11.50
- Essick, P. (2019, June 25). Air Pollution Causes, Effects, and Solutions. Retrieved from <https://www.nationalgeographic.com/environment/global-warming/pollution/>
- Schikowski, T., Mills, I.C., Anderson, H.R., Cohen, A., Hansell, A., Kauffmann, F., et al. (2013) Ambient air pollution: a cause of COPD? *PubMed*. doi: 10.1183/09031936.00100112
- Particulate Matter (PM) Basics. (2018, November 14). Retrieved from <https://www.epa.gov/pm-pollution/particulate-matter-pm-basics>
- Dezybe, R., (2019, April) Defense Mechanisms of the Respiratory System. Johns Hopkins University
- Marino, E., Caruso, M., Campagna, D., & Polosa, R. (2015). Impact of air quality on lung health: myth or reality? *Therapeutic Advances in Chronic Disease*, 6(5), 286–298. doi: 10.1177/2040622315587256
- The Economic Times. (n.d.). What is Human Development Index. Retrieved from <https://economictimes.indiatimes.com/definition/human-development-index>
- Bradley, R. H., & Putnick, D. L. (2012). Housing Quality and Access to Material and Learning Resources Within the Home Environment in Developing Countries. *Child Development*, 83(1), 76–91. doi: 10.1111/j.1467-8624.2011.01674.x
- Human Development Reports. (n.d.). Retrieved from <http://hdr.undp.org/en/content/human-development-index-hdi>
- Mueller, Z. (2018, August 28). Forest fires cause record poor air quality levels | Sherwood Park News. Retrieved from <https://www.sherwoodparknews.com/news/local-news/forest-fires-cause-record-poor-air-quality-levels>
- Biology for Life. (n.d.). Interpreting Error Bars. Retrieved from <https://www.biologyforlife.com/interpreting-error-bars.html>
- OECD. (2017, March 1). Estonia should reduce its oil shale reliance for greener growth. Retrieved from <https://www.oecd.org/newsroom/estonia-should-reduce-its-oil>

shale-reliance-for-greener-growth.htm

20. Statistics Solutions. (n.d.). Table of Critical Values: Pearson Correlation. Retrieved from <https://www.statisticssolutions.com/table-of-critical-values-pearson-correlation/>
21. Shavelle, R.M., Paculdo, D.R., Kush, S.J., Mannino, D.M., and Strauss, D.J. (2009) Life expectancy and years of life lost in chronic obstructive pulmonary disease: Findings from the NHANES III Follow-up Study. DovePress. doi: 10.2147/copd.s5237
22. How Tobacco Smoke Causes Disease: The Biology and Behavioral Basis for Smoking-Attributable Disease: A Report of the Surgeon General. (2010). PsycEXTRA Dataset. doi: 10.1037/e590462011-001
23. Zikmund, W.G. (2000) Business Research Methods. 6th Edition. Retrieved from [http://www.scirp.org/\(S\(czeh2tfqyw2orz553k1w0r45\)\)/reference/ReferencesPapers.aspx?ReferenceID=1200594](http://www.scirp.org/(S(czeh2tfqyw2orz553k1w0r45))/reference/ReferencesPapers.aspx?ReferenceID=1200594)
24. Guo, C., Zhang, Z., Lau, A.K.H., Lin, C.Q., Chuang, Y.C., Chan, J., et al. (2018, March) Effect of long-term exposure to fine particulate matter on lung function decline and risk of chronic obstructive pulmonary disease in Taiwan: a longitudinal, cohort study - The Lancet. doi: 10.1016/S2542-5196(18)30028-7
25. Gao, W. & Wen, CP. (2018, March 1). PM2.5: an important cause for chronic obstructive ... - The Lancet. doi: 10.1016/S2542-5196(18)30025-1
26. Forest Fires and Climate Change. (n.d.). Retrieved from <https://climateatlas.ca/forest-fires-and-climate-change>
27. Hoffman, M. (2017, August 21). 3.2 Million COPD Deaths Worldwide in 2015. Retrieved from <https://www.mdmag.com/medical-news/32-million-copd-deaths-worldwide-in-2015>
28. Laennec RT, Ramadge FH, Laennec M, Andral G. A Treatise on Mediate Auscultation, and on Diseases of the Lungs and Heart. H. Bailliere...; Paris: JB Bailliere; 1846.

APPENDIX

Calculations

Sample Calculation #1: Mortality rate per 100,000

$$\text{death rate per person} = \frac{\text{estimated death count}}{\text{total population}} \times 100,000$$

Example: Norway's death rate due to COPD per person in 2014

$$\begin{aligned} &= \frac{2373.6}{5,137,232.0} \times 100,000 \\ &= 46.2 \end{aligned}$$

Note: the final results are all rounded to 1 decimal place to ensure consistency and easier data processing

Sample Calculation #2: Mean (average) air pollution and mortality rates

$$\text{mean} = \frac{\text{sum of all numbers}}{\text{number of items}}$$

Example: Average PM2.5 air pollution in Norway

$$\begin{aligned} &= \frac{8.87 + 7.91 + 7.87}{3} \\ &= 8.21666 \dots \approx 8.22 \end{aligned}$$

Sample Calculation #3: Standard deviation for air pollution and mortality rates

$$\sigma = \sqrt{\frac{\sum(x - \mu)^2}{n - 1}}$$

Example: Standard Deviation of air pollution in Norway

$$\begin{aligned} &= \sqrt{\frac{(8.87 - 8.22)^2 + (7.91 - 8.22)^2 + (7.87 - 8.22)^2}{3 - 1}} \\ &= 0.56615 \dots \approx 0.57 \end{aligned}$$

Sample Calculation #4: Pearson correlation coefficient

$$\begin{aligned} r &= \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{(n\sum x^2 - (\sum x)^2)(n\sum y^2 - (\sum y)^2)}} \\ r &= \frac{20(110061.121) - (634.6)(293.45)}{\sqrt{(20(21761.88) - (634.6)^2)(20(4911.191) - (293.45)^2)}} \\ r &\approx 0.756 \end{aligned}$$