Urban Air Pollution – The challenge of the 21st century

A case study on citizens' level of awareness towards poor urban air quality and its consequences in The Ruhr-Valley

Abstract

Population growth and societal changes lead to constant pressure on the environment and shrinking green spaces resulting in urban air pollution. Seeking for alternatives, innovative and nature-based solutions became one of the main challenges of urban planners to mitigate air pollution and optimize the quality of life. 412 structured questionnaires with citizens of the Ruhr Valley and 3 semi-structured interviews with experts from the planning department were conducted to analyze the relationship between urban dwellers and their level of awareness towards air pollution and urban green infrastructure. The results show that most of the participants are aware of urban air pollution, however not about the long-term exposure and the resulting health effects. A similar conclusion can be drawn regarding Urban Green Infrastructure, whereas people do acknowledge its aesthetical value, but not its benefits for the environment and physical health. Therefore, a close cooperation between citizens and experts is inevitable to achieve sustainable and healthy cities.

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1. Introduction

1.1 Background:

The world has recorded an immense population growth during the past decades, in which the population increased from only 751 million people in 1950 to more than 4.2 billion people in 2018 (UN, 2018). As human beings are complex and dynamic, their lifestyle patterns have changed with the consequence of jobs and services accumulating in cities, resulting in large-scale urbanization (WHO, n.d.). The increased need for housing, facilities and infrastructure in cities lead to the sealing of green spaces and thus to the destruction of nature with tremendous consequences (EEA, 2016; Anguluri & Narayanan, 2017; Lennon, 2015; Rößler, 2015).

Accordingly, the World Health Organization (WHO) (2014) stresses that human activity remains the dominant cause of air pollution as a result of transportation, power generation and insufficient waste management, whereas transportation accounts for the largest contribution to air quality. Subsequently, 80% of urban dwellers are exposed to poor air quality (WHO, 2014; WHO, 2016; CDC, 2009). Furthermore, it is estimated that outdoor air pollution contributes to about 4.2 million deaths annually (WHO, n.d.). The main pollutants, namely carbon monoxide (CO), carbon dioxide (CO2), nitrogen dioxide (NO2) and particular matter (PM) lead to a decline in urban air quality, while increasing the risk for common cardiovascular diseases such as strokes, heart diseases and chronic and active respiratory diseases, including asthma and lung cancer (Demzuere et al., 2014).

These concerns lead to the emergence of Urban Green Infrastructure (UGI)– an approach that faces the threat of urbanization and greenhouse gas emission, while 'improving the quality of life' (Finley et al., 2015; Haq, 2011; WHO, n.d.). Thus, UGI plays an important role in achieving sustainable cities (UN, 2018). Not only is the development of an approach necessary to address the problems, but also to raise public awareness of an individual's contribution towards air pollution and its consequences. As stated by the United Nations (UN) (2018), green areas are inevitable in order to enable healthy living in cities, thus UGI must be integrated into public policy making, as well as into urban planning to reduce the exposure to pollution.

Furthermore, the pollutant concentration of Ozone[1], PM2.5 and NO2 exceeding the limits set by the WHO in urban background locations in German agglomerations (Umweltbundesamt, 2019). Additionally, Figure 1 (Umweltbundesamt, 2020) shows the amount of people, exposed to PM2.5 in Germany. Even though the amount is declining, 53.9 million inhabitants are still exposed to PM2.5 leading to premature deaths (Umweltbundesamt, 2017).

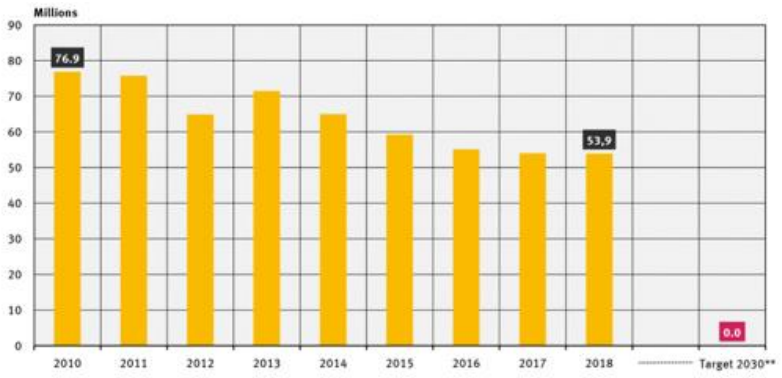

Figure 1: Population exposed to PM2.5 – concentrations exceeding the WHO annual mean guideline value

[1] Ozone – referring to a greenhouse gas, contributing to smog.

Considering the emission by sectors in Germany, 'commercial, institutional and households' are leading, followed by motor vehicles (EEA, 2019). Nevertheless, the German population does not seem to be aware of the consequences caused by Urban Air Pollution (UAP) (Umweltbundesamt, 2020). Therefore, this paper aims to research the level of awareness of the impacts of air pollution and UGI on air quality in Germany's largest urban area – the Ruhr Valley. This study provides new knowledge and insights, which can be used as a basis for the development of new policies and planning strategies in order to mitigate problems of UAP.

1.2 Research Question

As proposed by scientists and organizations, UGI can be a beneficial approach to tackle problems related to air quality. (WHO, 2016; Yu et al., 2017; Schäffer, 2016; TO2 federatie, 2016; Demuzere et al., 2014; Anguluri et al., 2017). Besides approaching the problem of poor urban air quality, the awareness of citizens' contribution towards pollution and the awareness of its impacts on health are important factors that need to be addressed. This poses the following main research question:

To what extent does public awareness towards Urban air pollution and Urban Green Infrastructure play a role in achieving sustainable and healthy cities in the Ruhr Valley, Germany?

A subsequent secondary aim is to explore the level of awareness and the perception of citizens, leading to the first sub-question:

"To what extent are people aware of the impacts of urban air pollution and the benefits of UGI?"

Besides citizens awareness, experts play an important role in terms of delivering information and finding solutions to address the problem of UAP, which leads to the following sub-question:

"To what extent are urban planners and policy makers able to influence and steer current developments? "

1.3 Structure of the Thesis:

This paper is structured as followed. The next chapter describes the key concepts and theories this study is based on. In the following, the conceptual framework as well as the hypotheses, are introduced. The third chapter includes a short description of the study area – the Ruhr Valley, followed by the methodology and the results. Finally, the conclusion and policy recommendations are stated, as well as the strength and weakness of the study. The reference list and appendices, including the interview-guide, questionnaire and statistical output, can be found at the end of the thesis.

2. Theoretical Framework

In the last decades, the concept of UGI has becoming more relevant. A cities' physical and natural environment is increasingly important, as it influences the well-being of its inhabitants. Regarding to the WHO (2019) and the UN (2018) further urbanization and an increased emission of PM and NO2 threatens the quality of urban air and consequently people's health.

2.1 Urban Green Infrastructure

UGI is a concept, designed to minimize the consequences of climate change with nature-based solutions (Lennon, 2015). Accordingly, it attempts to retain the natural quality of the environment (Anguluri & Narayanan, 2017), while facilitating urbanization and climate change adaptions and mitigations (EEA, 2016). UGI can be seen as an effective approach to improve ecosystem services, quality of life, urban air quality and health. In other words, UGI aims to produce a sufficient amount of green spaces, that are substantial for sustainable development of urban areas (Anguluri & Narayanan, 2017). Such as Anguluri & Narayanan (2017), most studies refer to green spaces as parks, garden, recreation places, green spaces surrounding historical sites, railways and roads. As UGI is an inter-linked network, some studies also take blue spaces, namely oceans, lakes, rivers and other bodies of water into account (Foley & Kistemann, 2015; Völker & Kistemann, 2013). Accordingly, green and blue spaces lead to long-term benefits (Gascon et al., 2015), which will be elaborated on in more detail during this study. UGI does not only include green parks, but also green roofs and walls as well as permeable surfaces - whereas in this study, the main focus is on urban green areas.

2.2 Natural Environmental Benefits of UGI – Air quality

As mentioned, most of the greenhouse gases are emitted in urban areas. Thus, the air quality in cities is significantly lower than in rural areas. Traffic digestion, deforestation, burning of fossil fuels and exhaust from factories and industries are the most significant contributors. According to studies reviewed by the CRC (2008), Price et al. (2015), Vuijviv et al. (2019) and Guevara-Escobar et al. (2007) UGI is an effective reducer of the following air pollutants: CO, NO2, phosphors, as well as other microscopic PM. Besides this, vegetation is a large storage of CO2 and most strikingly, Paullet et al. (n.d.) stress that one grown tree can store 3t of carbon, which is comparable with the emission of driving a car for about 18.000km. Therefore, urban vegetation cover plays an important role in regulating air quality and reducing greenhouse gases in the atmosphere. This is in line with Haq (2001), who refers to UGI as 'Urban lungs' because of the discharge of oxygen and provision of clean air. As this study does not only focus on the environmental benefits, the following section introduces how UGI promotes physical health through the availability of green spaces and improved air quality.

2.3 Physical health benefits of UGI

Due to anthropogenic activity, the temperature in densely populated areas is significantly higher than in its surrounding areas. Consequently, these changed climate conditions have already led to an increased mortality rate during heatwaves (Lafortezza et al., 2009). Subsequently, the overall quality of life, including an individual's physical health is threatened (Anguluri & Narayanan, 2017; Wüstemann et al., 2017; Gascon et al. 2015). This is in line with the research conducted by Lafortezza et al. (2009), who state that extreme heatwaves can lead to heat exhaustion, nausea, insomnia, irregular breathing and heartbeats, whereas the elderly are more vulnerable. Besides this, Demuzere et al. (2014) acknowledges asthma and cardiorespiratory disorders as a result of reduced air quality and the existence of PM. The CDC (2009) confirms a positive relationship between increased particle matter in the air and respiratory and cardiovascular diseases. According to studies, decreasing the PM pollution from 70 to 20 yh/m, can reduce air pollution related deaths by 15% (WHO, 2016). Laumbach & Kipen (2012) raise the concern of confounders - other factors that may contribute to the development of health issues, such as smoking.

Additionally, Suppakittpaisarn et al. (2017) highlight the result of their study, that fewer people suffered from respiratory diseases such as asthma in rural areas. These findings are reflected by Abraham et al. (2010) who refer to UGI as 'keys to physical health'. Whereas many studies highlight the importance of physical activity as a means to improve one's health, other studies partly criticize this aspect. Weichenthal et al. (2014) and Li et al. (2014) argue that physical activity in an environment characterized by poor air quality has negative effects on health due to the increasing breathing rate and thus an increased intake of pollutants.

2.4 Public awareness

As discussed in the previous section, many scholars have been researching the relationship between UGI and the environment, as well as impacts of UAP on health effect. But according to Parmer et al. (2016), little has been done to spread the information to the public.

Additionally, Ramirez et al. (2019) researched the relationship between communication strategies and public awareness in San Joaquin Valley, California. As measures show, the air quality is on average worse than in other regions, leading to more premature deaths. Information is made available via websites, local newspaper, radio and television. Nevertheless, public sources do not provide enough information about the relationship between air quality and health. Studies show that real time data of pollutants can influence the behaviour to decrease its exposure. However, people must be aware of the consequences and sources of UAP, which is according to Cisneros et al. (2017) not necessarily the case. Besides this, not all information is equally accessible and more vulnerable populations are left behind (Ramirez et al., 2019). Chin et al. (2019) found a comparable pattern in Malaysia. Participants are aware of the polluted environment they are living in, but not of long-term health effects due to exposure. Especially people with pre-existing conditions, children and elderly are more vulnerable. Whereas some scholars argue that the level of awareness does not necessarily differ, others found contradictory results (Timothy et al., 2018; Reames & Bravo, 2019).

Taken UGI into account, people do acknowledge its value but not primarily its health benefits and ability to improve air quality (Derkzen et al., 2017).

2.5 Conceptual Model

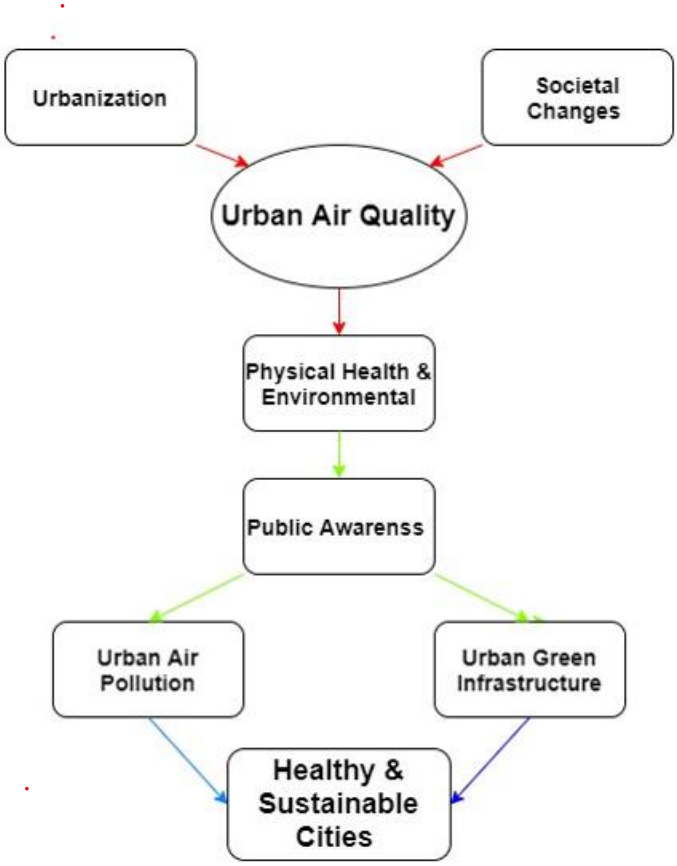

Figure 2: Conceptual Framework. Whereas the red arrows indicate causes and impacts, the green arrows demonstrate what is needed and the blue ones the desired outcome.

The conceptual framework (Figure 2) illustrates the research approach and intention of this study. Firstly, the main problem 'Urban Air Quality' as a consequence of Urbanization, accumulation in cities and emission of pollutants is highlighted. As discussed in the theoretical framework, studies show a link between the exposure of air pollution and physical health. Subsequently, approaches to tackle and reduce the effects in urban areas are needed. Firstly, as touched upon in the section above, UGI improves the air quality and the health of people. Secondly, a high level of knowledge about long-term health effects due to poor air quality is needed. Besides this, citizens must be aware of contributors towards air pollution, but also about the benefits of UGI. Therefore, this study aims to test public awareness towards UGI, air quality, health impacts and emission of pollutants. A subsequent aim of this research is to provide policy recommendations, based on the level of awareness of citizens about the impacts of poor air quality, as well as the benefits of UGI.

2.6Hypotheses

Based on previous studies, the following main hypothesis emerged: '*Urban dwellers are not fully aware of the consequences of UAP nor the benefits of UGI'.* Including the sub-hypotheses '*There are differences in the level of awareness based on gender, the availability of any kind of respiratory disease, and people who acknowledge UAP*'. As demonstrated in the conceptual model, public awareness towards UAP and UGI is fundamental in order to achieve healthy and sustainable cities.

3 Case Study Area: Ruhr Valley

The Ruhr Valley, Germany's largest and Europe's second-largest urban area, in which the three largest cities Dortmund, Essen and Duisburg consist of more than 500.000 inhabitants. A total of about 5 million people call the Ruhr Valley their home. The area is located in the western part of North-Rhine Westphalia as presented in Figure 3a. and widely known for its former coal and steel industry (RVR, 2020). Considering its population density and economic importance, a well-planned transport system is required, resulting in good highway connections, road networks and airports. As already mentioned, motor vehicle and transport are the main contributors to air pollution, making the Ruhr Valley a suitable study area (Figure 3b,c,d). Attention towards Green Infrastructure has been increased after the 'Green in Cities – for a liveable future' conference took place, where problems, future projections and the benefits of UGI were discussed (European Commission, 2015).

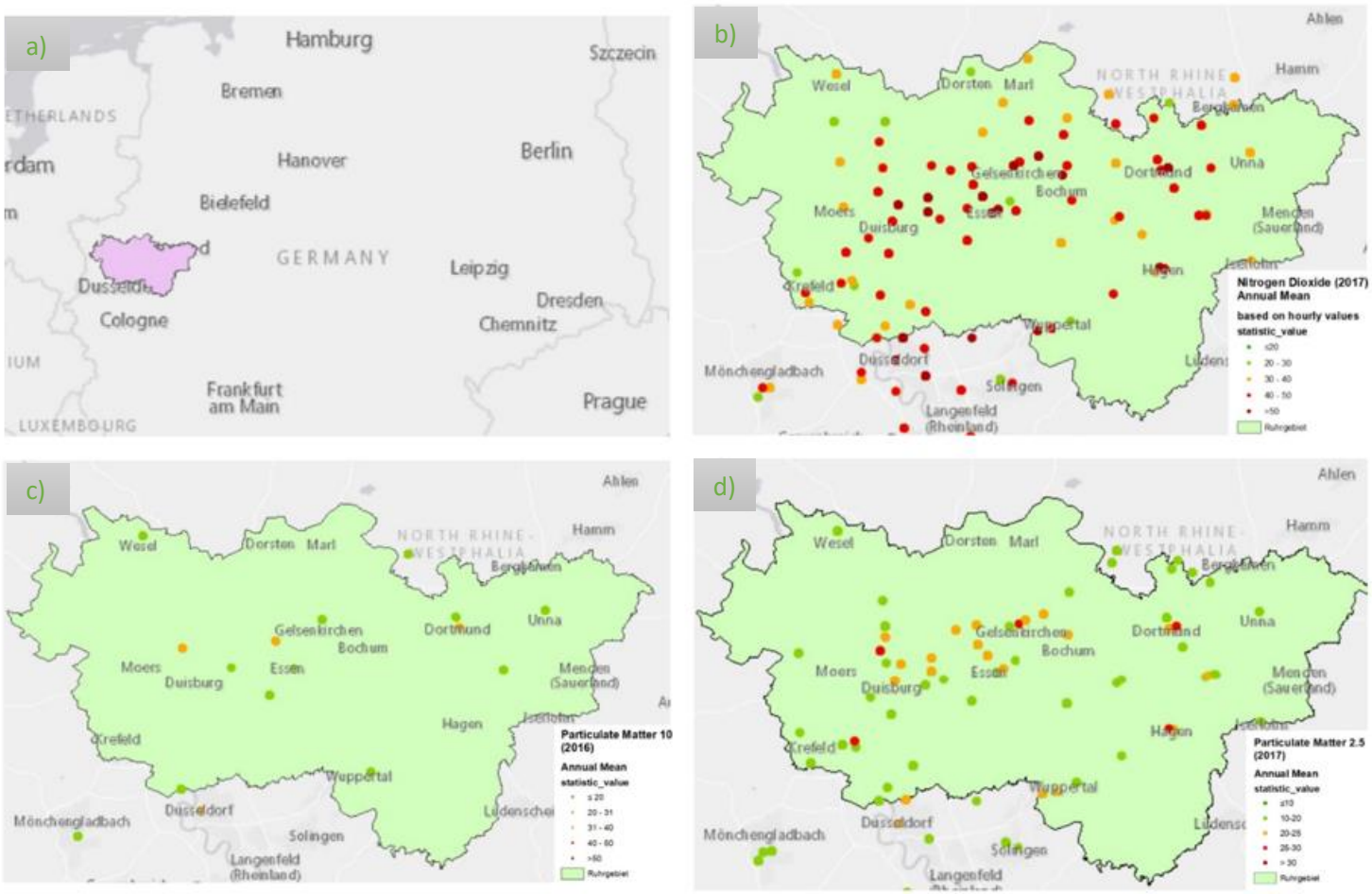

Figure 3: a) The location of the Ruhr Valley, Germany. b) Nitrogen Dioxide emission - Ruhr Valley, 2017. c) Particulate Matter 10 emission – Ruhr Valley, 2016. d) Particulate Matter 2.5 emission– Ruhr Valley, 2017. Source: EEA (2017). European air quality database. Retrieved on 5th May, 2020 from ArcGIS online.

4 Methodology

4.1 Research Method 1: Interviews

To further analyse the potential of UGI and the measurements related to air pollution, expert interviews were conducted. The interviewees give an insight into their capabilities and action taken to tackle problems of UAP and rise awareness. Combining public interests and knowledge about their level of awareness with the possibilities and insights of experts' new policy recommendations, as well as strategies can be introduced to achieve healthy and sustainable cities. Thus, the researcher asked questions about the current situation, as well as about approaches, such as the integration of UGI into urban planning. Besides this, the existence of future plans and strategies to tackle the problems were addressed (See Appendix A). Therefore, various regional planners from the Ruhr Valley were contacted through E-Mail/Phone, whereas 3 out of 12 agreed to give an interview (Table 1).

Interviewees	Job Description	Recruitment	Conducting	Duration
Participant 1 (P1)	Head of the department 'Urban development and planning – Gelsenkirchen'	Contacted by E-mail - Sent questions prior	Phone Interview	22 minutes
Participant 2 (P2)	Head of the department 'Urban development and planning – Hamm'	Contacted by E-mail - Sent questions prior	E-mail Interview	-
Participant 3 (P3)	Employee of Regional Authority - Ruhr Valley (RVR)	Contacted by E-mail - Sent questions prior	Phone Interview	19 minutes

Table 1: Characteristics of interviewees, including employment, recruitment process and type of interview.

4.1.1 Analysis:

Prior to the interview, a semi-structured interview guide was constructed. This method allows the interviewer to dig deeper into the phenomena, as well as to give the participants the chance to respond freely and openly (Longhurst, 2016). The interviews were conducted in German - the mother tongue of the interviewer and the interviewees and translated into English. With consent from the participants, all interviews were recorded and transcribed. Using the software AtlasTI, specific codes were created to compare and analyse the data (Figure 4). The analysis follows an inductive approach, where the new model is based on the three interviews and its most important findings (See section 5.1, Figure 7).

Figure 4: Analysis Scheme – Qualitative Data.

4.2 Research method 2: Questionnaires

In order to answer the quantitative sub-question, questionnaires were spread among the Ruhr Valley inhabitants via social platforms, and web-links during March and April 2020. Quantitative data is an effective approach to discover habits and patterns in the society, as well as characteristics, perceptions and behaviour (McLafferty, 2016). Furthermore, conducting online surveys is inexpensive, convenient for the respondents and are able to address immobile groups (McLafferty, 2016). Everyone with access to the internet has the same chance of being selected, and thus it follows the random sampling approach (Burt et al, 2009). Nevertheless, online surveys exclude the ones without internet access.

The survey design follows the guidelines and principles highlighted by McLafferty (2016), including simple, clearly defined terms and definitions, as well as short questions. Considering the usage of online surveys, a short explanation of the study and the research aim is included. As the sampling population only includes inhabitants of the Ruhr Valley in Germany, participants were asked to indicate their current place of residence to ensure reliability.

Prior to handing out the questionnaires, pilot studies were conducted to ensure the right interpretation of questions, accurate answer possibilities and a valid and reliable outcome. After the implementation of feedback, the questionnaires were distributed among the study population. A total of 425 answers were recorded after 4 weeks of online data collection in March/April, 2020.

The questionnaire is designed to get a deeper understanding of citizens and their perception and awareness of urban air quality and UGI. Thus, it aims to answer the sub-question: To what *extent are people aware of the impacts of urban air pollution and the benefits of UGI?".* It consists of standardized questions including pre-existing answer possibilities. Whereas categories are used to answer more general questions - the Likert Scale is used to gather more in-depth information. Furthermore, the survey is divided into five sections, namely; *'socio-demographic data'*, *'Awareness & Perception'*, '*Green Infrastructure'*, '*individuals' behaviour'* and *'information sources'* (See Appendix B).

The first category includes socio-demographic data to consider possible influences and differences between these categories. As the likelihood of respiratory diseases increases with air pollution, it is important to consider the current level of health, in relation to other socio-demographic information. The next category is constructed to address the second sub-questions, more specifically an individual's perception, awareness and knowledge about UAP and UGI. Followed by questions addressing people's attitude and action to test the relationship between the level of awareness and behaviour. Lastly, the focus is on the sufficiency of information sources. The main aim of the last two categories is to understand an individual's behaviour. Based on the outcomes, policy recommendations can be formed.

4.2.1 Analysis:

The gathered data is stored on the researcher's computer, secured by a password and only used for the purpose of this particular study. In order to analyse the data, the Statistical Package for Social Science (SPSS) was used. After the exclusion of unqualified cases, descriptive statistics followed to get an overview and insight into the study group and trends. Binary logistic regressions (BLG), Pearson's Correlation and Chi-square tests were performed to analyse the relationships, as demonstrated in Figure 5. Furthermore, the significance level is set to 0.05 (5%) for all statistical tests in this research.

Prior the data analysis using SPSS, categories were combined if the number of cases were below 30. Besides this, the Bayesian Information Criterion, and the Goodness of Fit were used as indicators to find the most appropriate model. This resulted in the combination of the categories: 'Strongly disagree & Agree' and subsequently to 'Strongly agree & Agree' to have the same amount of answers on the left and right-hand side of the Likert-Scale.

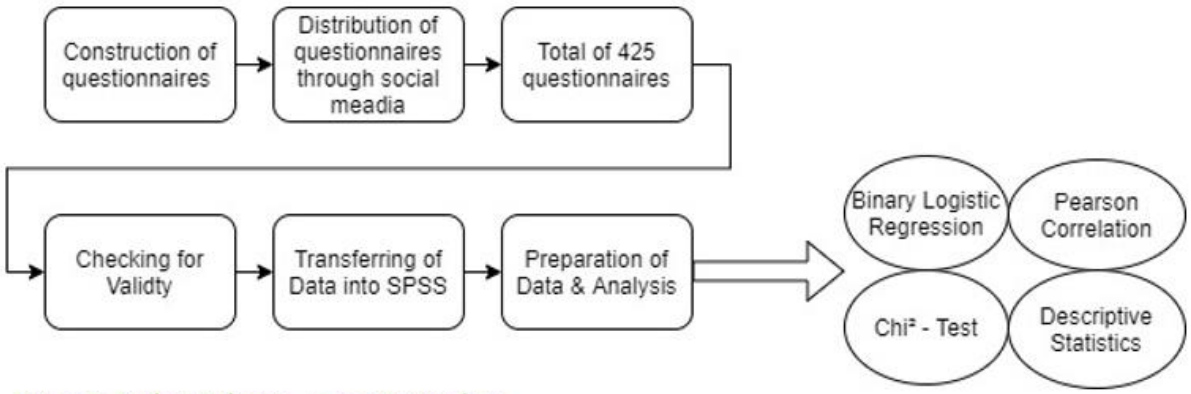

Figure 5: Analysis Scheme – Quantitative data.

4.3 Ethics for Primary Data Collection

An important factor applicable to all types of research, but especially during primary data collection, is to address ethical considerations. As mentioned by Hay (2016), the researcher must protect the rights of its participants, do good and avoid harm, show respect, and be as confidential as possible. Besides this, the 'Netherlands Code of Conduct for Research Integrity', was used as a guideline for the data collection (NWO, 2018).

- Honesty
- Scrupulousness
- Transparency
- Independence / Impartiality
- Responsibility

Thus, the participation is voluntary, with the right to withdraw at any stage. Furthermore, the participants remain anonymous and no confidential information that makes it possible to trace individuals back is published. An integral part of ethics in research is the informed consent, participants needed to sign prior. It informs about the study purpose, anonymity, and a participant's rights, securing honesty and transparency towards the participants. As being responsible to secure ethics, all participants were informed about the project and its purpose, as well as what is done with their personal data. People who did not sign the informed consent got completely excluded from the study and their data was deleted immediately. Besides this, all gathered data is only used for this specific purpose and not shared with others.

5 Results

5.1 Interviews

The Ruhr Valley and its main vision to transform the area from a former steal and coal industrial region towards a sustainable and liveable urban region is in line with the main 'Sustainable Development Goals' of the European Union (EU) (European Commission, 2020). As a response to the climate change and an overall decreased air quality, the EU set emission limits for PM and NO2. Various cities in the Ruhr Valley have been exceeding these limits caused by traffic congestions (P1, P3). Thus, the Ruhr Valley developed the so-called 'Air pollution control plan' including the 'green low-emission-zone' (Umweltzone), where high-emission vehicles are not permitted (Figure 6).

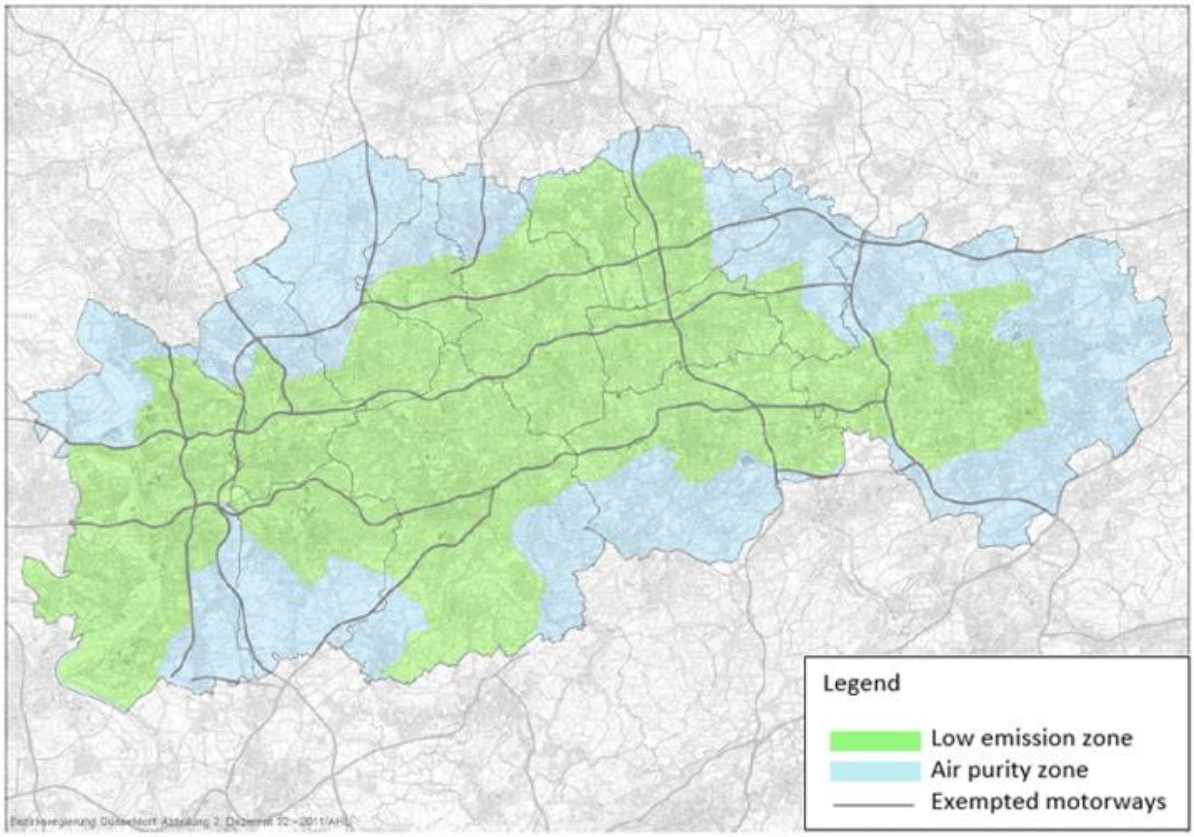

Figure 6: Ruhr Valley – Low Emission zone & Air Purity Zone

Source: Luftreinhalteplan Ruhrgebiet, 2011. Bezierksregierung Arnsberg.

In order to be able to monitor and analyse the air quality, measurement stations are located across the main roads and the most polluted areas (P1, P2, P3). The measured values are used to develop strategies, such as the prohibition of trucks in certain areas, the rerouting of traffic streams and car- unattractive cities through one-way roads. Besides this, P1 elaborated on the example of the Schellarevie Straße, which is the most polluted area through traffic congestions in Gelsenkirchen. Therefore, the number of lines got reduced from four to two to decrease traffic and thus the emission of NOx and PM, which is according to Demuzere et al. (2014) harmful to an individual's health. Proposed plans for the resulting free space include new cycle lanes and the expansion of the tramway, whereas the costs for these projects remain problematic.

Apart from that, UGI plays an important role in the planning and redevelopment process of cities. Due to the increased need and demand for housing, especially for newly constructed buildings the amount of sealed green areas has risen. Urban renewal, a process of the reconstruction of urban centres with predominantly sealed areas in the past has been criticised due to the loss of infiltration areas and greenery and thus cities started to reverse these phenomena and to increase the amount of vegetation cover (P1, P3). Rößler (2015) & Lennon (2015) also mentioned this as one of the main problems caused by urbanization and population growth.

Correspondingly P2 mentioned the advantages of fresh air isles, park and forest expansion as well as façade greenery in urban areas. Another approach mentioned by P1 is green roofs, which is partly implemented on buildings owned by the city of Gelsenkirchen and supported with a small funding program. Even though these approaches help to improve the urban air quality, the main purpose is to address climate change, as well as to secure biodiversity and citizens health (P1, P3). As studies have shown, UGI can positively influence the environment and physical health of people (Anguluri & Narayanan, 2017; Gascon et al., 2015).

'Influencing an individual's behaviour is the key to citizens health' (P2) highlights the importance of informing and including citizens. The city Hamm offers workshops and informs its inhabitants through the newspaper, the internet, and presentations (P2). Furthermore, citizens participation is included in the decision-making process for development plans and urban renewal projects and even put down into laws and regulations. Thus, all data including plans, projections, and information about the current state of air quality is publicly accessible, but still not used enough by the public (P2). However, this is also criticized by some scholar, as people do not seem to be aware the provided information (Parmer et al., 2006).

As a concluding remark, P2 mentioned the necessity of a world-wide cooperation as inevitable since air pollution is not restricted to specific areas. The most important findings of the interviews are illustrated in Figure 7.

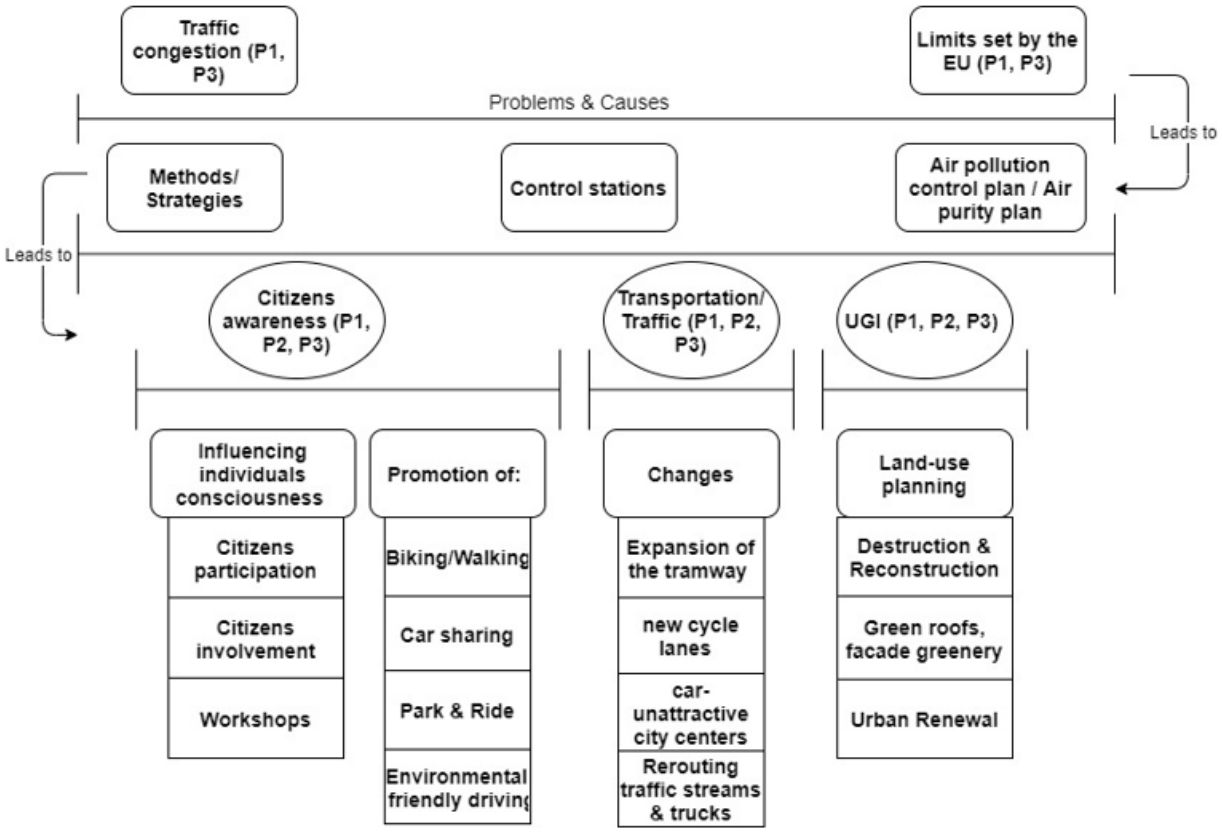

Figure 7: The most important findings based on the expert interviews.

Nowadays, citizens involvement and participation play an important role in urban and regional planning, including making information accessible for everyone. However, not everyone seems to be aware of these possibilities. Urban & Regional planner are only able to influence and steer current development to a certain extent. Not only the lack of citizens awareness towards UAP, but also complicated bureaucracy and insufficient funding is problematic. The next section gives an insight into the results of the surveys, where the citizens' perspective is linked with the experts' perspective.

5.2 Questionnaires

5.2.1 Descriptive statistics

A total of 425 responses were recorded, whereas 12 cases are categorized as invalid. The dataset consists of about 70% females and 30% males. However, in this study, gender is not crucial for the outcome. Considering the large number of cases (413), variety in age (17-75) and place of residency, the sample can be seen as representative. Beyond this, 74 of the respondents had a respiratory disease (See Appendix C).

Urban Air Pollution

Table 2 shows that only 35.8% inform themselves about air pollution, whereas the majority (72.4%) indicate that 'Air pollution can harm my health'.

I inform myself about air quality.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	265	64,2	64,2	64,2
	Yes	148	35,8	35,8	100,0
	Total	413	100,0	100,0	

Air pollution can harm my health

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	114	27,6	27,6	27,6
	Yes	299	72,4	72,4	100,0
	Total	413	100,0	100,0	

Table 2: Descriptive Statistics of the variables 'I inform myself about air pollution' & 'Air pollution can harm my health'.

Only 22.1% of those surveyed think that the air they breathe is clean, leaving 37.7% thinking that they do not breathe clean air and another 40.3% with a neutral attitude (Figure 8) - a similar pattern of results was obtained by Pu et al. (2019).

Nonetheless, the trend is towards 'breathing polluted air', only 1/3 think that the air they breathe can be harmful to their health. Even though cities and communities provide information about air pollution and its consequences, including information about NOx, PM 10/2.5 values (P2), it does not seem to be of interest by the citizens. This is consistent with similar studies conducted by Timothy (2018) in a different location, who doubts the effectiveness and awareness of air quality reports. Nevertheless, people do seem to be aware of the general consequences of UAP, as the majority agrees with the last two statements (Figure 8).

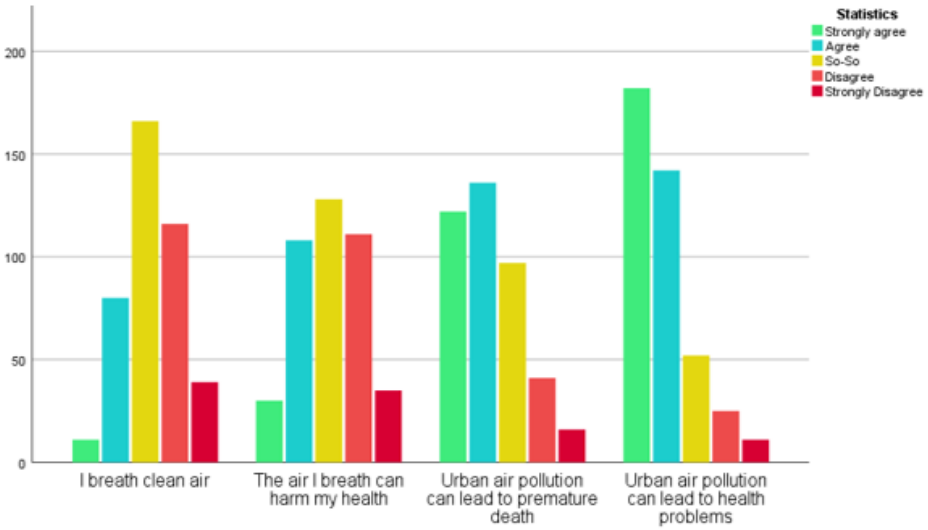

Figure 8: Descriptive Statistics of the second category of the questionnaire. X-axis: Independent variable; Y-Axis: count

Urban Green Infrastructure

The second category aims to analyse citizens' awareness towards the benefits of UGI, as presented in Figure 9. The overall response was surprisingly positive as only a few participants disagree with the statements. The Ruhr Valley organises campaigns and promotes a more sustainable way of living, including Urban Green Infrastructure, which may have influenced the overall positivity. Overall, people seem to acknowledge that UGI has certain benefits, but mostly relating to aesthetical and economic benefits rather than purification through UGI (Derkzen et al., 2017; Tsantopoulos et al., 2018). Contrary to previous studies and these findings, research conducted in Romania shows that citizens are not aware of the concept of UGI and its environmental benefits (Gavrilidis, 2020).

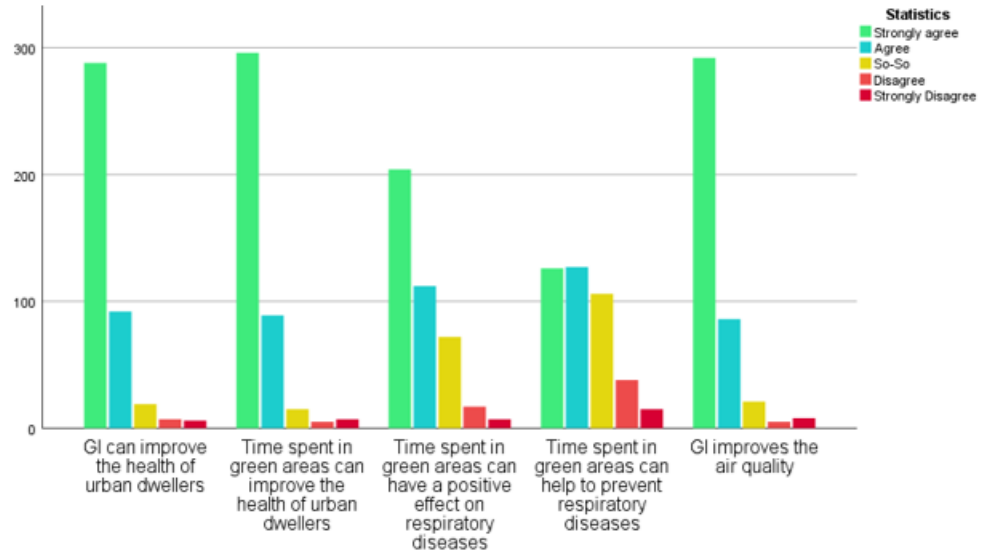

Figure 9: Descriptive Statistics of the third category of the questionnaire. X-axis: Independent variable; Y-Axis: count

Behaviour

When the subjects were asked about their own behaviour, the majority can be categorised as environmentally friendly, aware of their behaviour as well as willing to change their own lifestyle to improve the environment (Figure 10). The eagerness to change one's behaviour and the options given by the experts form a basis for sustainable development (P1, P2, P3). A similar conclusion was reached by Pu et al. (2019) in China, pointing out that people would reduce the use of private cars and other household appliances - as they are concerned about air pollution.

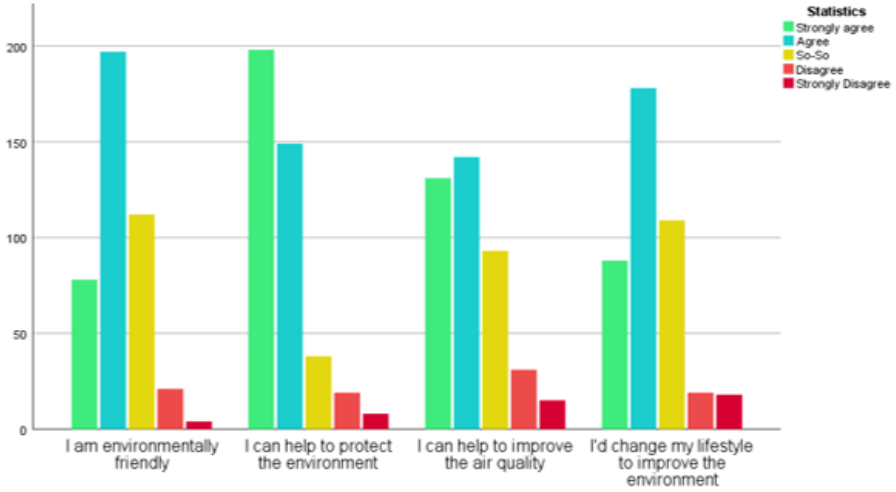

Figure 10: Descriptive Statistics of the fourth category of the questionnaire. X-axis: Independent variable; Y-Axis: count

Information sources

In response to the questions concerning information sources, almost half (49.8%) of those surveyed indicated that the government does not provide sufficient information sources, and subsequently 55.1% would like more information about UAP, and more than 2/3 (67.9%) think that air pollution should be discussed more in public (Figure 11). However, P2 highlighted that all information is accessible for everyone, as well as the inclusion of citizens during the decision-making process. Contradictory, Timothy et al. (2018) noted that not enough information reaches the people and health care providers should promote healthier living among patients.

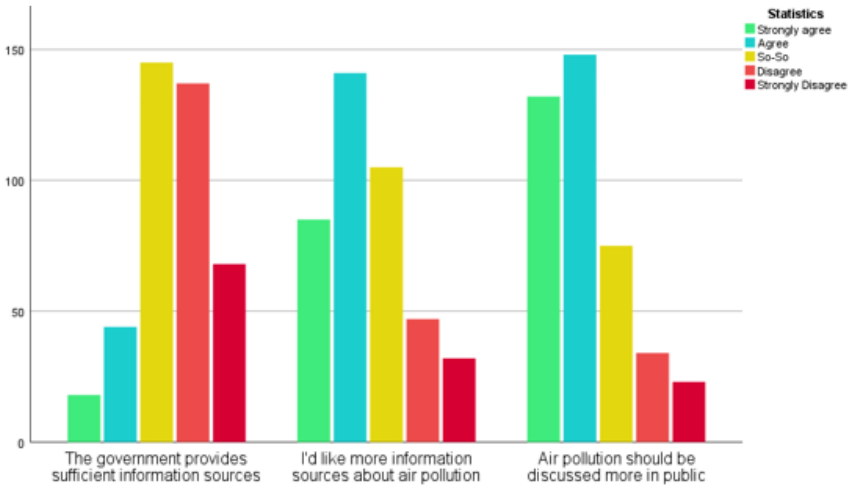

Figure 11: Descriptive Statistics of the fifth category of the questionnaire. X-axis: Independent variable; Y-Axis: count

5.2.1 SPSS – Analysis

Besides interviews and descriptive statistics, Binary Linear regression, Pearson's Correlation and Chi-Square tests were conducted to examine the relationship between the variables, including the Likert-scale like variables. As the descriptive analysis shows, the majority of people seem to be quite aware of the consequences of UAP and UGI's positive effects. However, this section aims to get a deeper understanding of the relationship and the influences of the participants characteristics. The analysis of the BLR contains all variables, that are included in the descriptive statistics.

Influence of Gender

Table 3 shows a section of the full model, demonstrating that there is hardly a relationship between Gender and the level of awareness. Even though previous studies indicate that females are more anxious about air pollution (Liu et al., 2014) and more concerned about health risks (Reames & Bravo, 2019). Contrary, Johnson (2012) noted a negative relation to being female, which is in line with this study, confirming that females seem to be less aware of the consequences of UAP ($p < 0.007$) - although more likely to change their lifestyle in order to protect the environment ($p < 0.28$).

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	I think I breath clean air			2,305	2	,316	
	I think I breath clean air(1)	-,522	,347	2,263	1	,133	,594
	I think I breath clean air(2)	-,085	,333	,065	1	,799	,919
	Urban Air Pollution can lead to premature deaths			7,730	2	,021	
	Urban Air Pollution can lead to premature deaths (1)	-1,073	,397	7,324	1	,007	,342
	Urban Air Pollution can lead to premature deaths (2)	-,760	,486	2,446	1	,118	,468
	I would change my lifestyle to improve the environment			6,342	2	,042	
	I would change my lifestyle to improve the environment(1)	,185	,318	,340	1	,560	1,204
	I would change my lifestyle to improve the environment(2)	-1,283	,583	4,851	1	,028	,277

Table 3: Section of the binary Logistic Regression model with the dependent variable 'Gender'. *p≤0.05.

Additional testing using the Pearson Correlation shows that there is a relationship between Gender and the 'I inform myself about air pollution, but not between Gender and 'the Urban Air I breath can harm my health' (See Appendix D).

Influence of Suffering from Respiratory Disease

Despite the sub-hypothesis, that there are differences based on the availability of any kind of respiratory disease, the BLR barely shows significant results. Even though Reames & Bravo (2019) state that having a respiratory disease increases the odds of perceiving worsening pollution and according to Johnson (2012), people are more willing to change their behaviour when unhealthy; other studies do not find a relationship between the availability of a respiratory disease and the level of awareness of air pollution, but towards air quality reports and information (Timothy et al., 2018).

Table 4 presents the influences of having respiratory diseases among the participants, showing that people with a respiratory disease are less likely to agree to the statement: 'Time spent in green areas can improve the health of urban dwellers. However, they are 2.715 times more likely to think that time spent in green areas can have a positive effect on respiratory diseases.

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	I think I breath clean air			,144	2	,931	
	I think I breath clean air(1)	,170	,453	,140	1	,708	1,185
	I think I breath clean air(2)	,018	,354	,003	1	,959	1,018
	Green Infrastructure can improve the health of urban dwellers			6,802	2	,033	
	Green Infrastructure can improve the health of urban dwellers(1)	2,943	1,241	5,622	1	,018	18,980
	Green Infrastructure can improve the health of urban dwellers(2)	-,666	1,645	,164	1	,686	,514
	Time spent in green areas can improve the health of urban dwellers			5,332	2	,070	
	Time spent in green areas can improve the health of urban dwellers (1)	-2,098	,951	4,866	1	,027	,123
	Time spent in green areas can improve the health of urban dwellers (2)	,362	1,431	,064	1	,800	1,437

Table 4: Section of the binary Logistic Regression model with the dependent variable 'I suffer from (a) respiratory disease(s). *p≤0.05.

Regardless the expectations, neither the BLR nor the Chi-square test indicate that there is a relationship between the availability of a respiratory disease and being aware of air pollution or the provision of information sources (see Appendix E). Considering the interviews, all citizens are equally able to access information sources about air pollution and the actions taken by the governments/cities related to UGI (P2). This may explain the phenomena of not establishing any differences.

Influence of people who indicate that the urban air they breathe can harm their health

Another promising finding is that people who are aware of the harmfulness of urban air, are 21.825 times more likely to disagree with the statement 'I think I breath clean air', than people who are not aware of the consequences of UAP. Even though they are not significantly more likely to indicate that UAP can lead to premature deaths, they are 4.854 times more likely to agree that UAP can lead to health problems, as well as 5.752 times more likely to think that air pollution should be discussed more in public. The other indicators do not show a significant result, leading to the assumption that there is no major difference in perception and knowledge concerning the consequences of air pollution and the benefits of UGI (Table 5). Considering the above, the sub-hypothesis referring to the availability of differences based on whether people acknowledge or do not acknowledge air pollution can partly be confirmed.

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	I think I breath clean air			42,651	2	,000	
	I think I breath clean air(1)	-,652	,355	3,380	1	,066	,521
	I think I breath clean air(2)	3,083	,555	30,812	1	,000	21,825
	Urban Air Pollution can lead to premature deaths			3,000	2	,223	
	Urban Air Pollution can lead to premature deaths (1)	,595	,438	1,848	1	,174	1,813
	Urban Air Pollution can lead to premature deaths (2)	,828	,562	2,174	1	,140	2,289
	Urban air pollution can lead to health problems			11,627	2	,003	
	Urban air pollution can lead to health problems (1)	1,580	,523	9,107	1	,003	4,854
	Urban air pollution can lead to health problems (2)	-,185	,657	,079	1	,778	,831
	Air pollution should be discussed more in public			19,815	2	,000	
	Air pollution should be discussed more in public (1)	1,750	,446	15,374	1	,000	5,752
	Air pollution should be discussed more in public (2)	-,718	,614	1,368	1	,242	,488

Table 5: Section of the binary Logistic Regression model with the dependent variable 'Urban Air can harm my health'. *p≤0.05.

All new models predict the data significantly better than the role model. However, the hypotheses can only be accepted to an extent. The main expectation, that people who experience any kind of respiratory diseases are more aware of UAP, cannot be confirmed. Thus, no obvious trend was found in the analysis.

6 Conclusion

6.1 Experts & Citizens perspectives combined

As this research not only aims to offer an insight into the perspective of citizens, but also of experts it is important to combine both point of views. The regional & urban planners included in this study think that enough information is provided. However, the analysis of the questionnaires shows that many are not aware of the consequences of UAP and the benefits of UGI. Additionally, the majority would like to get more information. Therefore, it is of importance to raise attention towards the availability of freely accessible information sources. Previous developments show an increased inclusion of urban green, as well as the promotion of more environmentally friendly options in order to mitigate the climate change. Nonetheless, without influencing the behaviour of citizens, either passively through the construction of car unattractive cities and rerouting traffic streams, or actively by promoting public transportation and bikes, these projects seem ineffective. As this study shows most people are willing to adjust their lifestyle to protect the environment, it is important to have informed citizens.

6.2 Answering the Research Question

This study investigates, if, and to what extent public awareness towards UAP and UGI plays a role in achieving sustainable and healthy cities in the Ruhr Valley, Germany. The Research question was formulated in response to an increased problem of UAP and the standards and limits set by the EU to improve the overall air quality. The Urban environment - the hotspot of human life, is increasingly threatened by air pollution caused by anthropogenic activity creating a challenge for urban planners (Lafortezza et al., 2009). This paper demonstrates the importance of closer cooperation between experts and citizens as a mean to achieve sustainable and healthy cities. Even though all information related to air pollution and UGI is freely accessible, citizens do not seem to be fully aware of the sources nor the consequences, respectively benefits (Chin et al., 2019, P1, Figure 8 & 9). However, this study shows that the majority of the participants want more information and more public debates, indicating a willingness to be open for change (Figure 10). Despite the expectations to find differences in the level of awareness and perception among groups no obvious trend was found. Even people who are most detrimentally affected by UAP do not seem to be any more aware of its health risks (Table 4). The findings partly correspond with former research conducted in different countries (Ramirez et al, 2019; Chin et al., 2019). It can be argued, that UGI and more informed citizens are crucial, as UGI serves as ‘urban lungs’ and anthropogenic activity is the main cause of air pollution. Based on these findings, the updated conceptual model was created (Figure 12).

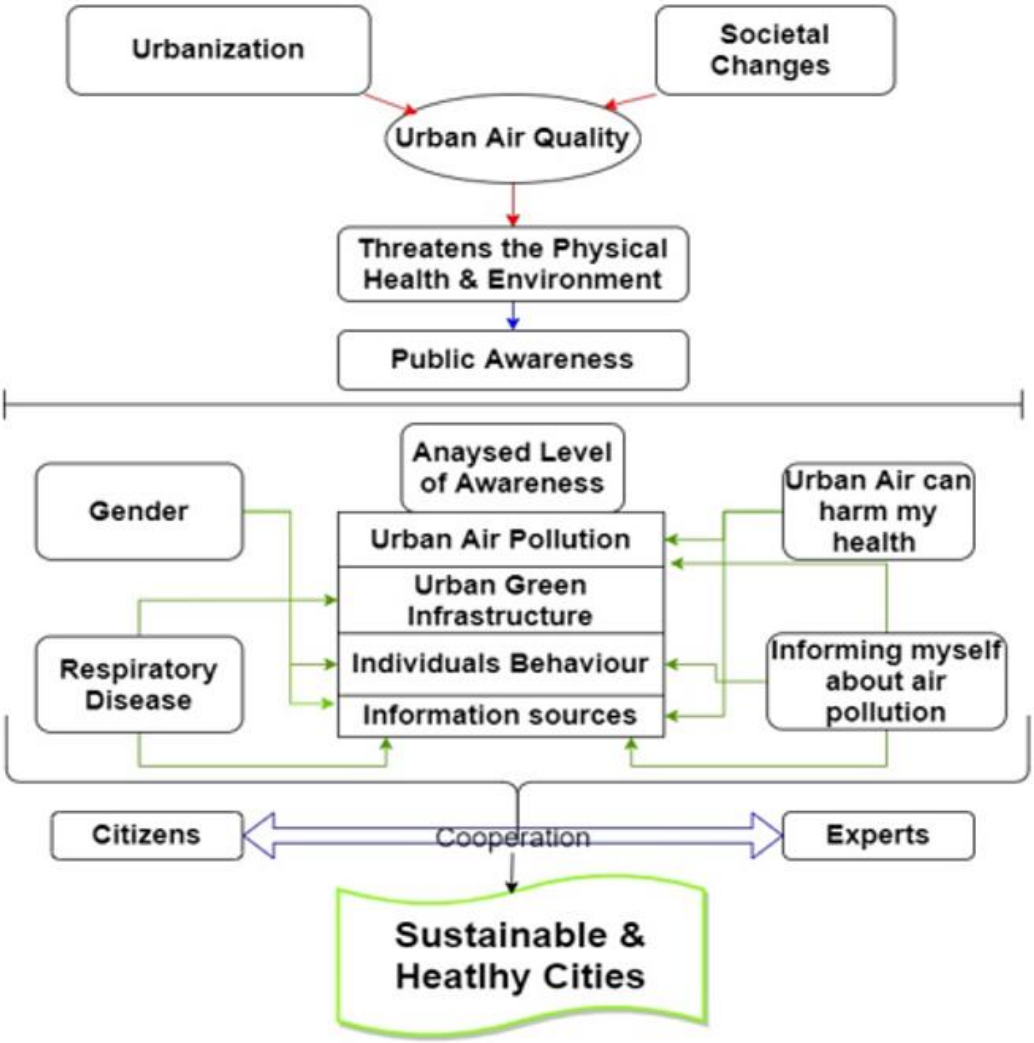

Figure 12: New conceptual model based on the study outcome including the results of the binary logistic regression and descriptive statistics. Whereas the light red arrows indicate the causes and impacts of Urban air pollution, the dark red arrows the consequences, and the blue ones what is needed to achieve Sustainable & Healthy cities. According to the results, no obvious trend was found in terms of different characteristics and the analysed level of awareness. However, the analyses show a few relationships, as indicated by the green arrows.

6.3 Policy Recommendations

Based on this research, the following policy recommendations emerged to promote a more sustainable and healthy life. As the study has shown, people acknowledge air pollution but are not fully aware of the consequences, thus the provision of information must be adapted. Even though all information is accessible to everyone, not all the participants know about it. Options to inform, but also to encourage citizens must be improved. Examples may include social media and workshops to inform and encourage the public. As people who suffer from respiratory diseases do not seem to be more aware of the consequences, even though they are more vulnerable, special attention should be paid towards this group. From a critical thinking perspective, it can be seen as a downfall of the WHO, who has the responsibility to protect its citizens- especially those in more evident danger. Thus, doctors should be obliged to inform their patients about the risks. With regard to mitigating air pollution and optimizing the quality of life, not only citizens must show a certain level of awareness, but also the government and the EU in terms of mobilising funds. As mentioned by the experts, important plans cannot be realized due to the lack of money. Furthermore, efforts from the government to put monetary rewards in place for the publics success in making efforts to reduce air pollution may stimulate more sustainable and healthy cities.

6.4 Strength & Weakness

A few strengths and weaknesses of this study should be acknowledged. Firstly, an overall response of 412 surveys was recorded, including various age groups. But despite the large sample size, there are barely any significant findings. These results may be influenced by possible co-founders such as age, education, employment, exact place of residence as well as having family members with pre-existing conditions. Besides this, for the statistical analysis the grouping of variables may have influenced the outcome. Furthermore, different variables could have been used and tested against each other, as well as the inclusion of different statistical tests such as ordinal linear regression to analyse the relationship between the Likert-scale-like variables.

By reflecting on the data collection process, an issue worth noting is the Covid-19 outbreak, resulting in online data collection rather than in-field and only a limited number of interviews. However, the study offers a mixed-method approach giving important insights into different perspectives.

6.5 Recommendations for further Research

Altogether, this research offers a new perspective on the level of awareness towards air pollution and UGI as not much research has been done yet. An idea for further research would be to consider number/location of pollutants around the area where the applicant lives. Because some may live quite a distance away from the pollutants e.g. factories, and their view on the level of pollution may be skewed. Additional testing in different areas may give another important insight into the analysed aspects and possible regional differences.

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8 Appendix

Appendix A: Expert Interview Guide

Introductory Question:

1. Can you tell me something about yourself?
    a. your position in the company
    b. your tasks
    c. your area of interest

Question related to air pollution:

2. How do you experience air pollution in (City)?
    a. Are there any differences? Now and 10 years ago?
    b. Measurement stations
3. What measurements have been done to tackle the problem of air pollution?
    a. Policies?
    b. More green areas?
    c. Speed limits on highways

Questions related to UGI:

4. Do you integrate Urban Green Infrastracture into urban planning and policy making?
    a. To what extent?
    b. Not only parks, but also green roofs/walls etc.
    c. Blue spaces

Future plans & Strategies:

5. Are there any future plans and strategies? Such as …
    a. Like 'Diesel Fahrverbot' in certain cities, etc.
    b. Promotion of more sustainable transport – bike, car sharing, public transport
    c. Car-unfriendly city centres? (One Example is Groningen)
    d. Who gets to decide this?
    e. Are citizens involved in the decision-making process?

Citizens awareness:

6. What about its citizens?
    a. Do you think they are aware of air pollution and its consequences of being exposed?
    b. Information sources for the public?
    c. Newspaper article, radio, campaign?
7. Do you think the problems of air pollution can be changed/reduced with a higher level of awareness? Or knowledge of benefits of Urban Green Infrastracture?
    a. More responsible behaviour (Eg: less car – more bike)
    b. Planting more trees
    c. Changed behaviour – less use of cars, more sustainable energy sources, etc.

Closing question:

8. Is there anything else you would like to share?

Appendix B: Questionnaire

Category 1: Socio-demographic data

1. How old are you? - ratio
    a. Scale
2. What is your gender? - nominal
    a. Male
    b. Female
    c. Prefer not to say / other
3. Where do you live? - nominal
    a. Urban
    b. Sub-urban
    c. 'rural'
4. Do you experience any respiratory diseases? - binary
    a. Yes
    b. No
5. Are you aware that polluted air can have impacts on your health? -> Binary
    a. Yes
    b. No

Category 2: Awareness & Perception – towards air pollution → Ordinal

1. The air I breath is clean. → Ordinal
    a. Scale
2. Breathing polluted air can do harm to my health. → Ordinal
    a. Scale
3. Long-term exposure to poor air quality leads to deaths →Ordinal
    a. Scale
4. Long-term exposure to poor air quality leads to health problems → Ordinal

Category 3: Awareness & Perception – towards benefits of UGI – parks → ordinal

1. Parks improve the overall air quality. → Ordinal
    a. Scale
2. UGI imp roves the overall well-being of urban dwellers. Ordinal
    a. Scale
3. Spending time in green areas can reduce the risk of chronic diseases. → Ordinal
    a. Scale

Category 4: Individuals Behaviour & willingness to adapt their lifestyle choices & Behaviour

1. I am environmentally friendly - ordinal
    a. Scale
2. Do you think you, as an individual can do something to improve the air quality? - ordinal
    a. Scale
3. I am happy to make changes in lifestyle to protect the air quality/environment - ordinal
    a. scale
4. I would support policies in favour for the environment, even if that means higher taxes, etc. - ordinal
    a. Scale
5. What is your main mode of transport? → nominal
    a. Car
    b. Public transport
    c. Scooter
    d. Bike
    e. Walking

Category 5: Sufficient Information sources – used for further policy recommendations

1. Are there information/news about the local air quality in the newspaper/radio/tv?
    a. Yes
    b. Yes, but not enough
    c. No
2. How do you get information about the environment/air pollution?
    a. Open question
3. Who should be responsible for controlling air quality? - nominal
    a. Individuals
    b. Cities
    c. Government
    d. organisations

Appendix C: Descriptive Statistics of the participants – Gender & Availability of Respiratory Disease

Frequency Table

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	123	29,9	30,0	30,0
	Female	287	69,7	70,0	100,0
	Total	410	99,5	100,0	
Missing	System	2	,5		
Total		412	100,0		

I suffer from respiratory diseases

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	338	82,0	82,0	82,0
	Yes	74	18,0	18,0	100,0
	Total	412	100,0	100,0	

Appendix D: Pearson Correlation model of the binary variables 'Gender' & 'I inform myself about air pollution' and 'Gender' & 'The urban air I breath can ham my health'.

Correlations

		Gender	I inform myself about air pollution
Gender	Pearson Correlation	1	-,110*
	Sig. (2-tailed)		,026
	N	410	410
I inform myself about air pollution	Pearson Correlation	-,110*	1
	Sig. (2-tailed)	,026	
	N	410	412

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		Gender	The urban air I breath can harm my health
Gender	Pearson Correlation	1	,096
	Sig. (2-tailed)		,051
	N	410	410
The urban air I breath can harm my health	Pearson Correlation	,096	1
	Sig. (2-tailed)	,051	
	N	410	412

Appendix E: Chi-Square output table of the variables a: 'Suffering from a respiratory disease' & 'Air pollution should be more discussed in public'; b: 'Suffering from a respiratory disease' & ' The government provides sufficient information sources'; c) 'Suffering from a respiratory disease' & 'Urban air can lead to premature deaths; d) 'Suffering from a respiratory disease' & Urban air can lead to health problems'.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1,531[a]	2	,465
Likelihood Ratio	1,648	2	,439
Linear-by-Linear Association	,766	1	,381
N of Valid Cases	412		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 10,24.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6,113[a]	2	,047
Likelihood Ratio	6,381	2	,041
Linear-by-Linear Association	,167	1	,683
N of Valid Cases	412		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 11,14.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4,744[a]	2	,093
Likelihood Ratio	5,264	2	,072
Linear-by-Linear Association	1,086	1	,297
N of Valid Cases	412		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 10,24.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2,345[a]	2	,310
Likelihood Ratio	2,533	2	,282
Linear-by-Linear Association	2,256	1	,133
N of Valid Cases	412		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 6,47.