Air pollution and cardiometabolic risk among Ghanaian residents in Ghana and urbanized cities in Europe: the RODAM study

Tess de Lange

Tutor: Daniel Boateng
Daily Supervisor: George Downward
2nd Reviewer: Illonca Vaartjes, PhD

ABSTRACT:

Background—

Cardiometabolic disease (CMD) is a leading cause of death worldwide. While air pollution, CMD, and genetics are known to be related, it is unclear how these relationships differ by geography. In this study, we investigated how pollutants affect populations in low- and middle-income countries (LMIC) and their counterparts who migrated to a high-income setting. Specifically, the current study investigated the association between air pollution, CMD, hypertension, and diabetes among Ghanaians living in Europe and Ghana.

Methods and Results—

This study used data from a multi-center study that included 5898 Ghanaian adults residing in rural and urban Ghana and three European cities. Air pollution levels were regionally measured and assigned to residential addresses that corresponded to the study's participants. Figure 1 presents a graph of average pollutant values (Ambient $PM_{2.5}$, NO_2 , and PM_NODUST) per site. $PM_{2.5}$ levels in Europe were as follows: Amsterdam (13.4 µg/m3, SD 2.2), Berlin (15.6 µg/m3, SD 2.4), London (14.7 µg/m3, SD 1.4). The $PM_{2.5}$ levels in Ghana were as follows: urban Ghana (27.3 µg/m3, SD 3.7) and rural Ghana (32.7 µg/m3, SD 3.2). NO_2 averages were as follows: Amsterdam (14.5 µg/m3, SD 1.8), Berlin (18.4 µg/m3, SD 3), London (18.0 µg/m3, SD 3.8), urban Ghana (7.5 µg/m3, SD 1.4) and rural Ghana (3.4 µg/m3, SD 1.1). PM_NODUST averages were the following: Amsterdam (11.6 µg/m3, SD 1.9), Berlin (13.8 µg/m3, SD 2.1), London (12.4 µg/m3, SD (SD 1.3), urban Ghana (11.3 µg/m3, SD 1.9), and rural Ghana (13.1 µg/m3, SD 0.9).

Logistic regression was used to evaluate the association between CMD risk, diabetes, or hypertension and pollutant. The results of the study show the association between air pollutants and CMD, adjusted for site and other variables.
Participants living in Europe had higher percentages of CMD (between 7-10%) compared to Ghana (between 3-6%) and had higher percentages of hypertension.

Conclusions—

Ambient $PM_{2.5}$ and NO_2 levels were associated with increased CMD amongst Ghanaians living in Europe and Ghana. Based on key findings, recommendations of interventions for CMD risk factors in poorer quality pollution areas is important.

Layman's Summary:

Cardiometabolic disease (CMD), which includes a variety of cardiovascular conditions such as hypertension, heart failure, heart attack, diabetes, and stroke, is a leading cause of death worldwide. Air pollution and CMD have been suggested to be associated, however there is a lack of studies that fully investigate this association. For example, there is evidence that suggests that type 2 diabetes mellitus biomarkers are increased when exposure to air pollution increases. However, more studies are required to establish guidelines for air pollution measures that would reduce the prevalence of type 2 diabetes. There is a significant positive correlation between exposure to long-term pollutants and hypertension risk. In this study, the previously collected data from the RODAM (Research on Obesity and Diabetes in African Migrants) study was examined in combination with air pollution values from the five different RODAM study sites.

Air pollution is a global public health issue. Particulate matter (PM), a mixture of liquid and solid particles in the atmosphere, has become a concern for some countries' social and economic development. It has been reported that $PM_{2.5}$ (particulate matter with an aerodynamic diameter smaller than 2.5 μm) concentrations increase susceptibility to respiratory diseases, cardiovascular diseases, and gastrointestinal diseases.

The association between three different types of air pollutants, specifically $PM_{2.5}$, PM_NODUST ($PM_{2.5}$ with the dust/sea salt algorithmically removed), and NO_2 (nitrogen dioxide) with CMD was investigated in this study. For the purpose of this study, CMD was defined as having diabetes and hypertension. Participants' length of stay in their country of residence, age, and smoking status were all considered when evaluating the association to ensure the most accurate representation of CMD risk.

NO_2 is often used when describing pollution from automobiles and it has been previously linked to different adverse health outcomes. Measurements from $PM_{2.5}$ and NO_2 are derived from satellites and linked to the residential information of study participants. In Europe, there was precise residential information for all participants, but in Ghana there is only area level data, meaning we are less confident in those findings.

Findings of this study showed that $PM_{2.5}$ had much higher values in Ghana (27.3 µg/m^3 and 32.7 µg/m^3) compared to European (between 13.4 µg/m^3 and 15.6 µg/m^3). Additionally, NO_2 had much higher averages in Europe (between 14.5 µg/m^3 and 18.4 µg/m^3) compared to Ghana (7.5 µg/m^3 and 3.4 µg/m^3). The percentage of hypertensive study participants was between 31% and 56%. The percentage of diabetic study participants was between 5% and 12%. The percentage of study participants with both hypertension and diabetes was between 3% and 10%. The relationship between hypertension and $PM_{2.5}$ was slightly negative, the relationship between hypertension and NO_2 was slightly positive, and a slightly positive relationship between hypertension and PM_NODUST was observed. Overall, it is important that residence is considered when examining the correlation between effects of air pollution and an individual's cardiovascular health.

1. Background

Obesity and type 2 diabetes are major threats to the health of the African population (1). African migrants, for example, have a much higher prevalence of obesity and type 2 diabetes compared to populations who are from European descent (2). The Research on Obesity and Diabetes in African Migrants (RODAM) study (2017) was conducted to determine how much obesity and diabetes differed between rural/urban Africa and to compare that with African migrants who lived in 3 major European cities. The RODAM study also investigated environmental (lifestyle) factors, healthcare differences, and epigenetic factors of each study participant. The RODAM study compared obesity and type 2 diabetes between five different study populations (3). The RODAM study concluded that obesity and type 2 diabetes prevalence rates among African migrants are higher than the people from the European host population. In high-income countries, migrant populations are disproportionately affected by type 2 diabetes (2).

Besides the RODAM study, another example of the effect of migration on health is from a large cross-sectional study including a large cohort of migrants who migrated from the Philippines to Rome. The study found a high prevalence of undiagnosed type 2 diabetes and hypertension in migrants, where 52.5% of study participants were recorded to have had abdominal obesity (4). The years spent in Rome/Italy directly correlated with food intake and weight gain, which suggests lifestyle directly impacted these migrants (4). Lifestyle factors of migrants can directly correlate with food insecurity and inadequate nutrient and food intake. Migrant health relies heavily on employment, income, their education level and housing situation (5). In the RODAM study, Ghanaians who migrated to Europe had both a higher rate of hypertension and diabetes (6).

CMD is a leading cause of death worldwide (7). Several lines of research have reported associations between ambient air pollution and CMD. However, this research was primarily performed on residents of high-income countries (HICs), meaning that this association is much less clear for lower- and middle- income countries (LMICs). Additionally, little is known about how migrants from these LMICs are affected by pollutants (8). The studies that are available were performed in higher income countries where resources such as medical equipment and access to healthcare were readily available. These HICs tended to have air pollution that was lower than LMICs (9). Due to the limited number of studies done in LMICs, it is difficult to translate findings from HICs to LMICs. Since there has been a substantial increase in the prevalence of cardiovascular diseases (CVDs) and its risk factors worldwide, it is important to study the association between air pollution and CVD risk in multiple settings (10).

Socioeconomic status (SES) has also been reported to influence exposure to air pollution. Wang et al.(2017) explained that an increase in the urbanization rate (speed of development in the area) is associated with an increased disposable income (urban disposable income per capita), which then in turn significantly reduced the level of $PM_{2.5}$ pollution (11). Results from their study showed that people with lower SES showed a stronger association between $PM_{2.5}$ and mortality (11). However, further studies need to be done to further evaluate these implications. Speculations could be that there is maybe less access to healthcare or adequate housing or food options.

Particulate material (PM) with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$) is a mix of different chemical species (12). It is composed of a combination of solids/aerosols consisting of a variety of shapes, sizes, and chemical compositions. According to Brook et al. (2018), "$PM_{2.5}$ is the principal air pollutant posing the greatest threat to global public health" (13). People with pre-diabetes have a higher susceptibility to the cardiometabolic effect of air pollution when compared to healthy people (1). In a study by Han et al. (2019), people with diabetes were more susceptible to adverse health effects from the pollutant PM, including death and CVD (14).

Brook et al. (2018) explains that there is evidence that there is an association between long-term $PM_{2.5}$ exposure and cardiovascular events. In their study, they found that living in an area with a high level of $PM_{2.5}$ leads to a 10.6% increase (per 10 $\mu g/m^3$) in cardiovascular mortality compared to low $PM_{2.5}$ levels. Therefore, Brook et al.(2018) hypothesized that multiple exposures to $PM_{2.5}$ may lead to chronic diseases such as diabetes and hypertension as well as related mortalities (13). However, the long-term effect of the pollution level with CMD still has not been evaluated, as most studies in this area have been cross-sectional (14).

Previous studies have hinted that long-term exposure to different pollutants, including NO_2, may be a risk factor for CMD (15). A Korean study looked at this association and reported a potential correlation between NO_2 and CMD in Korean adults (15). According to Kim et al. (2019), who followed participants who were exposed to NO_2 for one year, a larger exposure to regional air pollutants is associated with higher lipid levels. These associations were better seen in obese study participants, which suggests that there may be an association between obesity and the effect of NO2 exposure on lipid levels (16).

The recently conducted PURE study concluded that long-term $PM_{2.5}$ concentrations had an increased risk of CVD in adults aged 35-70 years. It was found to be necessary to reduce air pollution concentrations (especially in LMICs where the air pollution levels are the highest), because it is a vital risk factor for cardiovascular disease (17).

Among pre-diabetic subjects in the RODAM study, 6 of the 20 biomarkers that were assessed significantly affected cardiometabolic changes (and therefore also CMD) in the prediabetic subjects versus the non-prediabetic subjects. The biggest increases were in blood pressure (systolic and diastolic), heart rate, and glucose (14). Pre-diabetes in sub-Saharan Africa is said to be 25% (95% CI 22.8 to 28.3) (18). Since pre-diabetes is so common, it is important to evaluate the effect of $PM_{2.5}$ on CMD.

In prior studies, estimating ambient air pollution in LMICs has been a challenge, due to the absence of large-scaled monitoring campaigns or detailed land-use regression (LUR) models, which are used often to analyze air pollution in these areas (19). Furthermore, in the past, it has been difficult to study the air pollution levels in LMICs due to monitoring systems being unavailable or not fully accurate (19). However, global land-use regression models that incorporate satellite imaging and ground-based data have been developed. These models give insight into potential ambient air pollution in locations that were previously difficult to access (19). These types of models are currently being used and tested in a study on ambient air pollution in Asia (20). Additionally, in this study, we were able to employ LUR models to get a better understanding about rural areas.

1.2 Purpose and objective of this study

The objectives of this study are 1) quantify the exposure to $PM_{2.5}$ and NO_2 of Ghanaians residing in Amsterdam, Berlin, London, urban Ghana, and rural Ghana; and 2) investigate the association between pollutants $PM_{2.5}$ and NO_2 and the three different outcomes: diabetes, hypertension, and CMD among Ghanaians living in the five different RODAM study sites.

Using the RODAM study data allows for the ability to examine the association between ambient concentrations of $PM_{2.5}$, NO_2, and CMD disease risk (factors) (such as sex, age, smoking, and education level) in different settings.

2. Methods

2.1 Study Design and Population

The RODAM study was a multi-center cross-sectional study comparing groups of people living in different European countries and urban and rural Ghana. The study included 5898 Ghanaians who either resided in Ghana or had migrated to one of three European cities (Amsterdam, Berlin, and London). The study was conducted from 2012-2015 and recruited Ghanaians of the ages 40-70 living in Amsterdam, Berlin, London, urban Ghana, and rural Ghana (2). The Ghanaian migrants were either born in Ghana and have one or both parents born in Ghana (migrants being 1st generation) or if the participant was not born in Ghana, then participants have both parents born in Ghana (so in this case the migrants being 2nd generation) (3).

2.2 Recruitment and Sampling

In Amsterdam (n=1633), Ghanaians were randomly selected from the Amsterdam Municipal Health register, which shows not only an individual's birthplace, but also that of their parents, thus being able to look at ethnic origin. In Berlin (n=578), the federal state of Berlin's registration office provided a list of Ghanaians living in Berlin. However, this sampling frame had to be modified as there was a "low" response rate. Therefore, the sampling frame in Berlin for RODAM participation was changed to Ghanaian churches and organizations. In London (n=1120), they had no migrant registry. Therefore, different Ghanaian organizations became the sampling frame for the RODAM participants in London. UK-based data was collected from London boroughs, the Ghanaian Embassy, and the Association of Ghanaian Churches in the UK (2).

In Ghana (urban Ghana n=1449; rural Ghana n=1109), there were two purposely chosen cities and 15 villages in the Ashanti region used for urban and rural Ghana recruitment sites. Based on a 2010 census, people were randomly chosen to be a part of the study (2). The percentage of people who were asked to be in the study and agreed for each city were as follows: Amsterdam (53%), Berlin (68%), London (75%), urban Ghana (74%), and rural Ghana (76%). Almost all (99%) of the Ghanaians residing in Europe were first generation migrants and the average length of stay was equivalent across the three sites (2). For this study, 5889 participants were included. Cases of participants who had incorrect enrollment dates were excluded from the study (n=2).

2.3 Measurements

The outcome variables examined were hypertension, diabetes, and CMD. Covariates assessed were education, smoking, age, and site, which were predetermined.

Information on demographics, educational level, and migration histories were all collected through a questionnaire given to all participants. Education levels were separated into four different categories: 1) never been to school/elementary school only, 2) lower vocational schooling/lower secondary schooling, 3) intermediate vocational schooling/intermediate secondary schooling/higher secondary schooling, and 4) higher vocational schooling/university. Smoking was split up into current smokers, past smokers, and people who never smoked, and sex, and age is self-explanatory.

Hypertension is a binary measure that can be defined in three separate ways: 1) self-report of hypertension, 2) uses antihypertensives or 3) has a mean systolic blood pressure(SBP)>=140 mmHg or a mean diastolic blood pressure (DBP)>=90 mmHg. Diabetes was determined based on known or newly detected diabetic cases. Using the WHO criteria for diagnosis, a participant has type 2 diabetes mellitus if they had a fasting glucose, ≥7.0 mmol/L, or if one has a current use of medication prescribed to treat diabetes mellitus or self-reported diabetes mellitus (2).

To have the most accurate results, the data collection methods were standardized. Practitioners who conducted physical examinations were trained to follow guidelines for data collection. For instance, how this study defined diabetes, hypertension, and obesity was all made clear before the study began(2). Blood pressure was measured three separate times in a sitting position with at least 5 minutes of rest between each measurement to get the most accurate blood pressure measurement. It was measured using a semi-automated device called The Microlife WatchBP (2). Blood samples were collected by trained research assistants in all five sites. All research assistants were trained to follow a standardized data collection method. Blood glucose concentration was measured with a hexokinase, which is an enzymatic method. Cholesterol concentrations were examined with colorimetric test kits. Anthropometrics, blood pressure, and blood and urine samples (HbA1c, and glucose tests) were some of the tests performed during the RODAM study (2). Additionally, in this study, obesity was defined as body mass index (BMI) >= 30 kg/m^2, and central obesity as a waist circumference >102 cm in men or >88 cm in women (21).

2.4 Cardiometabolic Disease (CMD)

CMD was defined in many instances including diabetes and hypertension. For instance, in an article by Zhang et al (2019), cardiometabolic multimorbidity was defined as having two of three of the following: hypertension, diabetes, and CVD (22). Another example explaining how CMD is the combination of hypertension and type 2 diabetes comes from a Warwick Medical School CMD presentation. The presenters explained that CMD is a term that can be described as a clustering of disorders that includes hypertension, type 2 diabetes, and CVD (23). Due to previous work defining CMD this way, we define CMD in this study as having both diabetes and hypertension.

2.5 Assessment of air pollution

Through collaboration with the Institute for Risk Assessment Sciences (IRAS) from Utrecht University, residential information on RODAM study participants was linked to annual average air pollutant concentrations ($PM_{2.5}$, NO_2, PM_NODUST) using LUR models for all five sites. The residential information for each RODAM participant was coded as GPS coordinates (provided by RODAM or converted to GPS coordinates with an automated software) and it was overlaid with a global map generated from the LUR model and spatially joined using GIS software (ArcGIS). This was performed with all sites, so that comparability of findings between research centers could be ensured.

Outdoor air pollution levels were assigned to residential addresses that corresponded to the RODAM participants. $PM_{2.5}$ measurements were derived from satellite and generated through LUR models (24). Many different satellites were used to acquire this information (including Moderate Resolution Imaging Spectroradiometer, Multi-angle Imaging SpectroRadiometer, and Sea-Viewing Wide Field-of-View Sensor) (24). NO_2 values were produced using estimations of the GOME-2 and SCIAMACHY satellites and from the outputs of global GEOS-Chem Model (24). These different satellites when combined provided different PM concentrations using the GEOS-Chem model and ground-based sun photometer (AERONET) observations. When the satellites were incorporated, it provided a steady surface of concentrations (in $\mu g/m^3$) of $PM_{2.5}$ and NO_2. Predictions of $PM_{2.5}$ were further adjusted by algorithmically removing dust and sea salt, referred to as PM_NODUST in this study.

2.6 Data Analysis

In this study, there were 5889 participants comprising five subgroups of between 578 and 1633 participants. These subgroups included five different locations, which make up the RODAM study sites. They include three bigger European cities (Amsterdam, Berlin, and London) and two Ghanaian sites (urban Ghana and rural Ghana). To quantify the burden of CMD on Ghanaians from migration, age-adjusted CMD rates were calculated overall and stratified by site among Ghanaians living in Ghana and Europe. Analysis was restricted to men and women who lived in either urban and rural Ghana, the Netherlands, Germany, or the United Kingdom for >25 years. Standardized data on the main outcomes, and non-genetic factors, such as smoking habits and education, were collected in this study.

The association between hypertension, diabetes mellitus (DM), and CMD with air pollution was evaluated through logistic regression. For each pollutant, three levels of confounder/covariate adjustment were done: no adjustment (model 1), adjustment for site (model 2), and adjustment for common confounders: site, age, smoking, education, and sex (model 3). Model 3 was considered the "final" model with the other models being kept for comparison. All statistical tests used a $P<0.05$ significance level and data were analyzed using R.

3. Results

3.1 Characteristics of the study population

In Table 1, general characteristics based on study populations were included. Each outcome (CMD, hypertension, and diabetes) was compared with pollutant values ($PM_{2.5}$, PM_NODUST, and NO_2).

The socio-demographic characteristics of study participants are shown in Table 1. 38% of the total participants were male. The proportion of male participants across the different sites are as follows: Amsterdam (39%), Berlin (54%), London (38%), urban Ghana (29%) and rural Ghana (39%). The mean age of study participants was between 45-48 years, with some variation between sites. The lowest mean age was Berlin (45) and the highest was rural Ghana (48).

The total percentage of diabetic participants in the study was 14%. When split by site, the proportion of diabetic participants among the different sites was Amsterdam (14%), Berlin (15%), and London (13%), urban Ghana (11%) and rural Ghana (5%). The total percentage of hypertensive participants in the study was 46%. Across the various sites, the proportion of hypertensive participants among the different sites was Amsterdam (55%), Berlin (56%), London (54%), urban Ghana (37%) and rural Ghana (31%). The percentage of study participants with CMD was 9% in total. When split by site, the percentage of study participants with CMD was Amsterdam (12%), Berlin (12%), London (10%), urban Ghana (7%), and rural Ghana (3%).

3.2 Pollutant levels

Figure 1 presents a graph of the average pollutant values ($PM_{2.5}$, NO_2, and PM_NODUST) per site. The average levels of $PM_{2.5}$ was 21.2 μg/m^3 (SD 8.4), where Europe had averages of 13.4 μg/m^3 (SD 2.2) in Amsterdam, 15.6 μg/m^3 (SD 2.4) in Berlin, and 14.7 μg/m^3 (SD 1.4) in London. These numbers were quite different from the average levels in Ghana, which was 27.3 μg/m^3 (SD 3.7) in urban Ghana, and 32.7 μg/m^3 (SD 3.2) in rural Ghana. For NO_2, average level was 10.8 μg/m^3 (SD 6.3). Europe had averages of 14.5 μg/m^3 (SD 1.8), 18.4 μg/m^3 (SD 3), 18.0 μg/m^3 (SD 3.8) in Amsterdam, Berlin, and London, respectively. Average levels in Ghana were 7.5 μg/m^3 (SD 1.4) in urban and 3.4 μg/m^3 (SD of 1.1) in rural Ghana. The average level of PM_NODUST was 12.2 μg/m^3 (SD 1.9). Across the European sites, average PM_NODUST was 11.6 μg/m^3 (SD 1.9), 13.8 μg/m^3 (SD 2.1), 12.4 μg/m^3 (SD 1.3) in Amsterdam, Berlin, and London, respectively. The Ghanaian numbers were similar being 11.3 μg/m^3 (SD 1.9) and 13.1 μg/m^3 (SD 0.9).

3.3 Logistic Regression Findings:

Table 2 presents results of the association between air pollutants and hypertension, diabetes, and CMD.

Hypertension models:

A negative association was observed between $PM_{2.5}$ and hypertension [OR 0.95 (95% CI 0.95, 0.96), P <0.01]. The effect remained when site was adjusted. In the fully adjusted model, 1 μg/m^3 increase in $PM_{2.5}$ was associated with an OR of 0.97 (95% CI 0.95, 0.98), P<0.01 for hypertension. In fully adjusted models examining NO_2 and hypertension, a positive relationship was observed. A 1 μg/m^3 increase in NO_2 was associated with an OR of 1.03 (95% CI 1.01, 1.06), P<0.01. There was no association between PM_NODUST and hypertension [OR of 1.01 (95% CI 0.98, 1.05, P=0.45)].

Diabetes models:

A negative association was observed between $PM_{2.5}$ and diabetes [OR 0.97 (95% CI 0.96, 0.98), P<0.01]. The effect remained when site was adjusted (P=0.03). In the fully adjusted model, 1 $\mu g/m^3$ increase in $PM_{2.5}$ was associated with an OR of 0.97 (95% CI 0.94, 1.01), P=0.10, for diabetes. There was no association between NO_2 and diabetes [OR of 0.96 (95% CI 0.90, 1.01), P=0.09]. There was no association between PM_NODUST and diabetes [OR of 0.96 (95% CI 0.91, 1.01), P=0.12].

Cardiometabolic Disease models:

There was a positive association between $PM_{2.5}$ and CMD [OR 1.04 (95% CI 1.03, 1.05), P<0.01]. There was no association between $PM_{2.5}$ and CMD when site was added [OR of 0.996 (95% CI 0.98, 1.02), P=0.70] or in the full model [OR of 0.99 (95% CI 0.97, 1.01), P=0.50]. There was a negative association between NO_2 and CMD [OR 0.95 (95% CI 0.94, 0.96), P<0.01]. There was no association between PM_NODUST and CMD [OR of 0.99 (95% CI 0.96, 1.02), P=0.60].

4. Discussion Section

4.1 Problem/Project

The relationship between ambient air pollution concentrations of $PM_{2.5}$, NO_2 and PM_NODUST and CMD in different LMIC and HIC settings has not been heavily researched in the past. This study quantified the exposure to $PM_{2.5}$, NO_2, and PM_NODUST of Ghanaians residing in the various RODAM study sites and investigated association between cardiometabolic risk factors and pollutants across the five different RODAM study sites.

4.2 Key Findings

One key finding found was that European countries had a significantly higher percentage of people who had hypertension. Another finding found was the percentage of diabetic participants were more similar between the European countries and the Ghanaian sites, where the European countries had percentages ranging from 54-56% and Ghanaian sites had percentages ranging from 31-37%.

Thirdly, the percentage of Ghanaian study participants with CMD was 12% in Amsterdam, 12% in Berlin, 10% in London, 7% in urban Ghana, and 3% in rural Ghana.

4.3 Discussion of Key Findings

Our findings from this multi-center study showed higher proportion of CMD in the Ghanaian migrants in Europe compared to the Ghanaian population residing in urban and rural Ghana for all pollutants. Therefore, migration to Europe could have increased risk of CMD, or in any case, it influences the risk. According to the World Population Review, the percentage of the population with diabetes and the percentage of the population with undiagnosed diabetes per country from the RODAM study includes: Netherlands (5%, 5%); Germany (7%,7%); England (6%,6%); and Ghana (3%,3%) (25). Therefore, lifestyle in Europe could be a factor of higher diabetes and thus higher CMD for Ghanaian migrants. According to the World Health Rankings, death per 100,000 people from hypertension in each RODAM study site includes: Netherlands (1.62), Germany (8.36), United Kingdom (2.97), and Ghana (17.73) (26).

This study found that the highest risk for type 2 diabetes was among Ghanaians living in European countries, and lowest risk was in rural Ghana. According to the WHO, there are around 60 million diabetic people in Europe. Of all people >=25 years of age, 10.3% of men are diabetic and 9.6% of women are diabetic. The causes of diabetes in this age group are mostly attributed to lifestyle factors such as poor diet and physical inactivity (25).

Previous research has found that type 2 diabetes among African migrants are significantly higher than Africans who still live in Africa. Based on previous findings from the RODAM study, there is a considerable risk of type 2 diabetes and obesity for the African migrants living in Europe and in the urban African environment (2). This may have to do with dietary and sedentary lifestyles. According to Afrifa-Anane et al (2020), physical inactivity was higher in the migrants from the RODAM study (14.6% in Amsterdam, 24.1% in Berlin, and 36.6% in London) and people from urban Ghana (29%) compared to people from rural Ghana (11.2%) (27). It could be that in rural areas, land is spread apart more, and therefore activity is inevitably higher than in urban areas. Furthermore, according to Galbete et al (2017), the Ghanaians living in Europe consumed the most energy, followed by the Ghanaians living in rural Ghana and lastly the Ghanaians living in urban Ghana. The RODAM participants living in Europe had a higher BMI and waist circumference than the participants living in Ghana (28).

Air pollution, traffic noise, and noise annoyance are suggested to be factors that are associated with higher blood pressure levels and with hypertension, however, this evidence is inconsistent (29). There is evidence of a link between CVD, air pollution, and noise, where there is a strong association between 1) CVD and diabetes and between 2) CVD and sex. However interestingly enough, this was not consistent with what was found in this study (29).

Null findings were found between air pollution and CMD risk factors. Findings, however, did vary between the five different RODAM sites, as there were associations between hypertension and diabetes. According to the RODAM study, being older, being male, and having a higher waist circumference as a diabetic Ghanaian living in Europe associated with a higher odds of hypertension (3). This suggests that there are site-specific factors that should be accounted for, such as method of cooking and physical inactivity.

4.4 Strengths and limitations

The main strength of this study was that the data had standardized approaches for data collection across all their five study sites. Another strength is that a similar population (Ghanaians) was used in all sites. This could allow for the studying of potential migration effects for people living in Europe. Another strength is that there was a homogeneous data collection method/measurement used in the RODAM study.

Some limitations of this study include that the recruitment strategy had to be adapted because of the initial recruitment strategy not being sufficient in gathering enough people to participate in the study. Therefore, the recruitment process differed between study sites. This could have limited the diversity of the participants and therefore potentially also the generalizability. One major weakness for this project was that we had address level information for the European cities Amsterdam, London, and Berlin, but we had to average the geographic areas in Ghana, which results in a much higher risk for misclassification. Further, our models did not take biomass burning (for cooking/heating) into account, which may be occurring in rural Ghana. This thus poses another limitation of this study. Pollutant values needed to be approximated with a confidence interval due to Ghanaians not having official residential addresses available for the global map application that was used.

5. Conclusion:

Overall, we found lower rates of CMD, diabetes, and hypertension among Ghanaian residents in Ghana compared to Ghanaian residents in urbanized cities in Europe, when taking air pollution into account. Based on Figure 1, $PM2_{.5}$ levels in Ghana are significantly higher than in the European countries in the study. NO_2 levels are higher in Europe and PM_NODUST pollution levels are similar across all countries. Overall, this study gave an interesting perspective on the importance of the effect of different ambient pollutants on CMD and the health of a person. It will be important to study the different effects in more depth in the future, such as what role the site-specific factors have, and which extra site-specific factors would be important to investigate further.

References:

1. Chen R, Yin P, Meng X, Liu C, Wang L, Xu X, Ross JA, Tse LA, Zhao Z, Kan H, Zhou M. Fine Particulate Air Pollution and Daily Mortality. A Nationwide Analysis in 272 Chinese Cities. *Am J Respir Crit Care Med*. 2017 Jul 1;196(1):73-81. https://doi.org/1. 10.1164/rccm.201609-1862OC.

2. Agyemang C, Meeks K, Beune E, Owusu-Dabo E, Mockenhaupt FP, Addo J, de Graft Aikins A, Bahendeka S, Danquah I, Schulze MB, Spranger J, Burr T, Agyei-Baffour P, Amoah SK, Galbete C, Henneman P, Klipstein-Grobusch K, Nicolaou M, Adeyemo A, van Straalen J, Smeeth L, Stronks K. Obesity and type 2 diabetes in sub-Saharan Africans – Is the burden in today's Africa similar to African migrants in Europe? The RODAM study. *BMC Med*. 2016. 14**:**166. https://doi.org/10.1186/s12916-016-0709-0.

3. Boateng D, Agyemang C, Buene E, Meeks K, Smeeth L, Shulze M, Addo J, de-Graft Aikins A, Galbete C, Bahendeka S, Danquah I, Agyei-Baffour P, Owusu-Dabo E, Mockenhaupt FP, Spranger J, Kengne AP, Grobbee DE, Stronks K, Klipstein-Grobusch K. Migration and Cardiovascular Disease Risk Among Ghanaian Populations in Europe: The RODAM Study (Research on Obesity and Diabetes Among African Migrants). *Circulation: Cardiovascular Quality and Outcomes*. 2017. November; 10(11):e004013. https://doi.org/10.1161/CIRCOUTCOMES.117.004013.

4. Montesi L, Caletti MT, Marchesini G. Diabetes in migrants and ethnic minorities in a changing world. *World Journal of Diabetes*. 2016. February 10; 7(3): 34-44. https://doi.org/10.4239/wjd.v7.i3.34.

5. Refugee and Migrant Health. *World Health Organization*. 2022. May 2. https://www.who.int/news-room/fact-sheets/detail/refugee-and-migrant-health

6. Agyemang C, Addo J, Bhopal R, de Graft Aikins A, Stronks K. Cardiovascular disease, diabetes and established risk factors among populations of sub-Saharan African descent in Europe: a literature review. Globalization and Health. 2009. 5;7. https://doi.org/10.1186/1744-8603-5-7.

7. Cardiometabolic Disease. *Laboratory for Statistical & Translational Genomics*. https://transgen.med.upenn.edu/research/cardiometabolic-disease/.

8. Hystad P, Larkin A, Rangarajan S, AlHabib KF, Avezum Á, Calik KBT, Chifamba J, Dans A, Diaz R, du Plessis JL, Gupta R, Iqbal R, Khatib R, Kelishadi R, Lanas F, Liu Z, Lopez-Jaramillo P, Nair S, Poirier P, Rahman O, Rosengren A, Swidan H, Tse LA, Wei L, Wielgosz A, Yeates K, Yusoff K, Zatoński T, Burnett R, Yusuf S, Brauer M. Associations of outdoor fine particulate air pollution and cardiovascular disease in 157 436 individuals from 21 high-income, middle-income, and low-income countries (PURE): a prospective cohort study. *Lancet Planet Health*. 2020 Jun; 4(6):e235-e245. doi: 10.1016/S2542-5196(20)30103-0. PMID: 32559440; PMCID: PMC7457447.

9. Burroughs Peña, MS, Rollins A. Environmental Exposures and Cardiovascular Disease: A Challenge for Health and Development in Low- and Middle-Income Countries. *Cardiology clinics. 2017*; *35*(1): 71–86. https://doi.org/10.1016/j.ccl.2016.09.001.

10. Baeradeh, N, Ghoddusi Johari, M, Moftakhar, L, Rezaeianzadeh R, Hosseini SV, Rezaianzadeh A. The prevalence and predictors of cardiovascular diseases in Kherameh cohort study: a population-based study on 10,663 people in southern Iran. *BMC Cardiovasc Disord*. 2022; 22(244). https://doi.org/10.1186/s12872-022-02683-w.

11. Wang Y, Shi L, Lee M, Liu P, Di, Q, Zanobetti A, Schwartz, JD. Long-term Exposure to PM2.5 and Mortality Among Older Adults in the Southeastern US. *Epidemiology*. 2017. March; *28*(2): 207–214. https://doi.org/10.1097/EDE.0000000000000614.

12. Inhalable Particulate Matter and Health (PM2.5 and PM10). 2021. *California Air Resources Board*. https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health.

13. Brook RD, Newby DE, Rajagopalan S. Air Pollution and Cardiometabolic Disease: An Update and Call for Clinical Trials. *American Journal of Hypertension*. 2018. January; 31(1):1-10. https://doi.org/10.1093/ajh/hpx109.

14. Han Y, Wang Y, Li W, Chen X, Xue T, Chen W, Fan Y, Qiu X, Zhu T. Susceptibility of prediabetes to the health effect of air pollution: a community-based panel study with a nested case-control design. *Environ Health*. 2019. 18: 65. https://doi.org/10.1186/s12940-019-0502-6.

15. J. Shin, J. Choi, K.J. Kim. Association between long-term exposure of ambient air pollutants and cardiometabolic diseases: A 2012 Korean Community Health Survey. *Nutrition, Metabolism and Cardiovascular Diseases*. 2019. February; 29:2: 144-151, ISSN 0939-4753. https://doi.org/10.1016/j.numecd.2018.09.008.

16. Kim JS, Chen Z, Alderete TL, Toledo-Corral C, Lurmann F, Berhane K, Gilliland FD. Associations of air pollution, obesity and cardiometabolic health in young adults: The Meta-AIR study. *Environment International*. 2019. December; 133(A): 105180. https://doi.org/10.1016/j.envint.2019.105180.

17. Hystad P, Larkin A, Rangarajan S, AlHabib KF, Avezum Á, Calik KBT, Chifamba J, Dans A, Diaz R, du Plessis JL, Gupta R, Iqbal R, Khatib R, Kelishadi R, Lanas F, Liu Z, Lopez-Jaramillo P, Nair S, Poirier P, Rahman O, Rosengren A, Swidan H, Tse LA, Wei L, Wielgosz A, Yeates K, Yusoff K, Zatoński T, Burnett R, Yusuf S, Brauer M. Associations of outdoor fine particulate air pollution and cardiovascular disease in 157 436 individuals from 21 high-income, middle-income, and low-income countries (PURE): a prospective cohort study. *Lancet Planet Health*. 2020. Jun; 4(6):e235-e245. https://doi.org/10.1016/S2542-5196(20)30103-0.

18. Hodel N, Hamad A, Reither K, Mwangoka G, Kasella I, Praehauser C, Abdulla S, Hatz C, Mayr M. Assessment of diabetes and prediabetes prevalence and predictors by HbA1c in a population from sub-Saharan Africa with a high proportion of anemia: A prospective cross-sectional study. *BMJ Open Diabetes Research & Care*. 2020; 8(1):e000939. https://doi.org/10.1136/bmjdrc-2019-000939.

19. Larkin A, Geddes JA, Martin RV, Xiao Q, Liu Y, Marshall JD, Brauer M, Hystad P. Global land use regression model for nitrogen dioxide air pollution. *Environ Sci Technol*. 2017. 51(12):6957-6964. https://doi.org/10.1021/acs.est.7b01148.

20. Kusuma WL, Chih-Da W, Yu-Ting Z, Hapsari HH, Muhamed JL. PM2.5 Pollutant in Asia—A Comparison of Metropolis Cities in Indonesia and Taiwan. *International Journal of Environmental Research and Public Health*. 2019. December; 16:24: 4924. https://doi.org/10.3390/ijerph16244924.

21. Agyemang C, Beune E, Meeks K, Owusu-Dabo E, Agyei-Baffour P, Aikins ADG, Dodoo F, Smeeth L, Addo J, Mockenhaupt FP, Amoah SK, Schulze MB, Danquah I, Spranger J, Nicolaou M, Kipsetein-Grobusch K, Burr T, Henneman P, Mannens MM, van Strallen JP, Bahendeka S, Zwinderman AH, Kunst AE, Stronks K. Rationale and cross-sectional study design of the Research on Obesity and type 2 Diabetes among African Migrants: the RODAM study. *BMJ Open*. 2015. https://doi.org/10.1136/bmjopen-2014-004877corr1.

22. Zhang D, Tang X, Shen P, Si Yaqin, Liu X, Xu Z, Wu J, Zhang J, Lu P, Lin H, Gai P. Multimorbidity of cardiometabolic diseases: prevalence and risk for mortality from one million Chinese adults in a longitudinal cohort study. *BMJ Open*. 2019;9:e024476. https://doi.org/10.1136/bmjopen-2018-024476.

23. Cardiometabolic disease: the new challenge? *John Wiley & Sons, Ltd. Pract Diab Int*. 2006. April; Pract Diab Int 23(3). https://onlinelibrary.wiley.com/doi/pdf/10.1002/pdi.909.

24. van Donkelaar A, Martin RV, Brauer M, HSU NC, Kahn RA, Levy RC, Lyapustin A, Sayer AM, Winker DM. Global estimates of fine particulate matter using a combined geophysical-statistical method with information from satellites, models, and monitors. *Environ Sci Technol*. 2016; 50(7):3762-3772. https://doi.org/10.1021/acs.est.5b05833.

25. Diabetes Mellitus Death Rate by Country. Death Rate Per 100,000. *World Life Expectancy.* https://www.worldlifeexpectancy.com/cause-of-death/diabetes-mellitus/by-country/.

26. Hypertension Death Rate Per 100,000. *World Life Expectancy*. https://www.worldlifeexpectancy.com/cause-of-death/hypertension/by-country/.

27. Afrifa-Anane E, DE-Graft Aikins A, A C Meeks K, Beune E, Addo J, Smeeth L, Bahendeka S, Stronks K, Agyemang C. Physical Inactivity among Ghanaians in Ghana

and Ghanaian Migrants in Europe. *Med Sci Sports Exerc*. 2020. October; 52:10:2152-2161. http://doi.org/10.1249/MSS.0000000000002357.

28. Galbete C, Nicolaou M, A C Meeks K, DE-Graft Aikins A, Addo J, Amoah SK, Smeeth L, Owusu-Dabo E, Klipstein-Grobusch K, Bahendeka S, Agyemang C, Mockenhaupt FP, Beune EJ, Stronks K, Schulze MB, Danquah I. Food consumption, nutrient intake, and dietary patterns in Ghanaian migrants in Europe and their compatriots in Ghana. *Food Nutr Res*. 2017. July; 61:1:1341809. http://doi.org/10.1080/16546628.2017.1341809.

29. Pitchika A, Hampel R, Wolf K, Kraus U, Cyrys J, Babisch W, Peters A, Schneider A. Long-term associations of modeled and self-reported measures of exposure to air pollution and noise at residence on prevalent hypertension and blood pressure. Science of The Total Environment. 2017. 593–594: 337-346. ISSN 0048-9697. https://doi.org/10.1016/j.scitotenv.2017.03.156.

Table 1: General Characteristics of the RODAM study participants:

	Total (n=5889)	Amsterdam (n=1633)	Berlin (n=1131)	London (n=1120)	Urban Ghana (n=1449)	Rural Ghana (n=1109)
Men, N (%)	2227(38)	639(39)	310(54)	428(38)	417(29)	433(39)
Age, y (SD)	46.1(12)	45.3(11)	44.4(12)	47.0(11)	45.3(12)	48.4(14)
Cardiometabolic Disease (%)	638(11)	148(9)	113(10)	136(7)	178(6)	63(3)
Type 2 diabetes mellitus, N (%) ‡	846(14)	171(10)	139(12)	169(9)	264(9)	103(5)
Hypertension, N (%)	2713(46)	898(55)	326(56)	609(55)	533(37)	347(31)
Smoking N (%)						
Current N (%)	162(3)	65(4)	53(9)	6(1)	14(1)	24(2)
Past N (%)	395(7)	131(8)	61(11)	47(4)	82(6)	74(7)
Never N (%)	4890(83)	1275(78)	459(79)	916(82)	1302(90)	938(85)
Education						
None/Elementary	1879(31)	518(32)	49(7)	85(7)	615(42)	612(55)
Lower Education	2002(33)	545(33)	288(43)	304(25)	549(38)	316(28)
Intermediate Education	1000(16)	356(22)	158(24)	239(19)	173(12)	74(7)
Higher Education	594(10)	91(6)	76(11)	324(26)	66(5)	37(3)
$PM_{2.5}$ *	21.2(8.4)	13.4(2.2)	15.6(2.4)	14.7(1.4)	27.3(3.7)	32.7(3.2)
NO_2 +	10.8(6.3)	14.5(1.8)	18.4(3.0)	18.0(3.8)	7.5(1.4)	3.4(1.1)
PM_NODUST†	12.2(1.9)	11.6(1.9)	13.8(2.1)	12.4(1.3)	11.3(1.9)	13.1(0.9)

* $PM_{2.5}$: particulate matter with an aerodynamic diameter smaller than 2.5 Mm
+ NO_2: Nitrogen dioxide
† PM_NODUST: PM2.5 with the dust/sea salt algorithmically removed
‡ Type 2 diabetes mellitus only had N=5227

Table 2: Association between outcomes and $PM_{2.5}$, NO_2, and PM_NODUST stratified by pollutant, study site, and other factors

Table 2A: Association between hypertension and $PM_{2.5}$, NO_2 and PM_NODUST stratified by pollutant, study site, and other factors

	Model 1 (M1)		Model 2 (M2)		Model 3 (M3)	
	OR	95% CI	OR	95% CI	OR	95% CI
$PM_{2.5}$	0.95	0.95-0.96	0.97	0.95-0.98	0.97	0.95-0.98
Site						
Berlin			1.09	0.89-1.33	1.24	0.99-1.56
London			1.01	0.85-1.20	0.97	0.78-1.21
Urban Ghana			0.47	0.35-0.64	0.42	0.29-0.59
Rural Ghana			0.36	0.24-0.54	0.22	0.14-0.35
Sex					0.97	0.84-1.11
Age					1.08	1.07-1.09
Smoking						
Current					0.72	0.30-1.70
Past					0.74	0.34-1.61
Education						
None/Elementary					1.20	0.63-2.29
Lower Education					1.20	0.63-2.29
Intermediate Education					1.35	0.70-2.61
Higher Education					1.05	0.54-2.07
NO_2	1.08	1.06-1.09	1.02	0.99-1.06	1.03	1.01-1.06
Site						
Berlin			1.08	0.81-1.44	1.40	1.01-1.94
London			0.86	0.68-1.09	0.97	0.73-1.28
Urban Ghana			0.59	0.45-0.79	0.41	0.29-0.57
Rural Ghana			0.44	0.30-0.65	0.18	0.12-0.29
Sex					1.06	0.89-1.26
Age					1.08	1.07-1.08
Smoking						
Current					0.70	0.21-2.03
Past					1.00	0.34-2.83
Education						
None/Elementary					1.40	0.57-3.50
Lower Education					1.34	0.54-3.34
Intermediate Education					1.45	0.58-3.64
Higher Education					1.14	0.45-2.90
PM_NODUST	1.00	0.97-1.03	1.00	0.97-1.03	1.01	0.98-1.05
Site						
Berlin			1.09	0.89-1.34	1.21	0.96-1.54
London			1.01	0.85-1.20	0.97	0.78-1.20
Urban Ghana			0.48	0.41-0.55	0.45	0.37-0.53
Rural Ghana			0.39	0.31-0.43	0.23	0.19-0.29
Sex					1.01	0.88-1.15
Age			1.06	1.04-1.07	1.08	1.07-1.09
Smoking						
Current					0.72	0.30-1.68
Past					0.99	0.44-2.22
Education						
None/Elementary					1.35	0.70-2.59
Lower Education					1.26	0.66-2.41
Intermediate Education					1.39	0.72-2.68
Higher Education					0.99	0.50-1.94

M1: Pollutant/Outcome M2: Adjusted for Site; M3: Adjusted for Site, Sex, Age, Smoking, and Education, Ams=ref

Table 2B: Association between diabetes and $PM_{2.5}$, NO_2 and PM_NODUST stratified by pollutant, study site, and other factors

	Model 1 (M1)		Model 2 (M2)		Model 3 (M3)	
	OR	95%CI	OR	95%CI	OR	95%CI
$PM_{2.5}$	0.97	0.96-0.98	0.96	0.93-0.996	0.97	0.94-1.01
Site						
Berlin			1.30	0.95-1.76	1.25	0.89-1.74
London			0.86	0.64-1.16	0.77	0.54-1.08
Urban Ghana			1.43	0.85-2.39	1.21	0.69-2.09
Rural Ghana			0.87	0.42-1.79	0.50	0.23-1.08
Sex					0.8	0.64-1.00
Age					1.06	1.05-1.07
Smoking						
Current					0.62	0.15-3.05
Past					1.45	0.40-6.50
Education						
None/Elementary					0.95	0.36-2.93
Lower Education					1.08	0.41-3.32
Intermediate Education					0.97	0.37-3.00
Higher Education					1.05	0.39-3.34
NO_2	1.05	1.03-1.06	0.98	0.94-1.03	0.96	0.90-1.01
Site						
Berlin			1.40	0.92-2.11	1.49	0.94-2.33
London			0.79	0.53-1.15	0.77	0.48-1.20
Urban Ghana			0.69	0.43-1.10	0.60	0.35-1.01
Rural Ghana			0.30	0.16-0.56	0.18	0.09-0.38
Sex					0.80	0.61-1.05
Age					1.05	1.04-1.07
Smoking						
Current					0.67	0.11-5.78
Past					1.152	0.23-9.18
Education						
None/Elementary					0.66	0.19-2.87
Lower Education					0.98	0.29-4.24
Intermediate Education					0.85	0.25-3.72
Higher Education					0.98	0.28-4.34
PM_NODUST	0.93	0.90-0.98	0.94	0.89-0.99	0.96	0.91-1.01
Site						
Berlin			1.37	0.99-1.88	1.28	0.91-1.80
London			0.86	0.64-1.15	0.78	0.55-1.09
Urban Ghana			0.84	0.66-1.06	0.78	0.60-1.03
Rural Ghana			0.47	0.33-0.65	0.30	0.20-0.43
Sex					0.80	0.64-1.00
Age					1.06	1.05-1.07
Smoking						
Current					0.62	0.15-3.05
Past					1.45	0.39-6.51
Education						
None/Elementary					1.17	0.49-2.87
Lower Education					1.32	0.57-3.23
Intermediate Education					1.19	0.50-2.94
Higher Education					1.31	0.53-3.35

M1: Pollutant/Outcome M2: Adjusted for Site; M3: Adjusted for Site, Sex, Age, Smoking, and Education, Ams=ref

Table 2C: Association between CMD and $PM_{2.5}$, NO_2 and PM_NODUST stratified by pollutant, study site, and other factors						
	Model 1 (M1)		Model 2 (M2)		Model 3 (M3)	
	OR	95% CI	OR	95% CI	OR	95% CI
$PM_{2.5}$	1.04	1.03-1.05	0.996	0.98-1.02	0.99	0.97-1.01
Site						
Berlin			0.94	0.77-1.15	0.85	0.68-1.06
London			0.93	0.79-1.11	0.96	0.78-1.18
Urban Ghana			1.97	1.44-2.71	2.12	1.51-3.00
Rural Ghana			2.40	1.57-3.66	3.41	2.15-5.42
Sex					0.94	0.82-1.08
Age					0.94	0.94-0.95
Smoking						
Current					1.49	0.65-3.47
Past					1.33	0.61-2.96
Education						
None/Elementary					0.63	0.33-1.19
Lower Education					0.68	0.36-1.28
Intermediate Education					0.62	0.32-1.16
Higher Education					0.80	0.41-1.54
NO_2	0.95	0.94-0.96	0.99	0.96-1.02	1.04	1.01-1.08
Site						
Berlin			0.91	0.69-1.21	0.71	0.51-0.97
London			1.00	0.79-1.27	0.85	0.63-1.13
Urban Ghana			1.62	1.21-2.17	2.41	1.72-3.38
Rural Ghana			2.09	1.41-3.08	4.82	3.06-7.63
Sex					0.92	0.77-1.09
Age					0.95	0.94-0.95
Smoking						
Current					1.10	0.37-3.27
Past					0.90	0.33-2.51
Education						
None/Elementary					0.49	0.20-1.18
Lower Education					0.56	0.23-1.35
Intermediate Education					0.52	0.21-1.25
Higher Education					0.72	0.29-1.76
PM_NODUST	0.99	0.96-1.02	0.99	0.96-1.03	0.98	0.95-1.02
Site						
Berlin			0.95	0.77-1.16	0.87	0.69-1.09
London			0.93	0.79-1.11	0.96	0.78-1.19
Urban Ghana			1.86	1.61-2.16	1.90	1.60-2.26
Rural Ghana			2.24	1.89-2.67	3.02	2.45-3.72
Sex					0.94	0.82-1.08
Age					0.94	0.94-0.95
Smoking						
Current					1.49	0.65-3.47
Past					1.33	0.61-2.95
Education						
None/Elementary					0.63	0.33-1.19
Lower Education					0.68	0.36-1.28
Intermediate Education					0.62	0.32-1.16
Higher Education					0.80	0.41-1.54

M1: Pollutant/Outcome M2: Adjusted for Site; M3: Adjusted for Site, Sex, Age, Smoking, and Education, Ams=ref

Figure 1: Average Pollutant ($PM_{2.5}$, NO_2, PM_NODUST) Values based on study site in the RODAM study