Environmental Science and Pollution Research (2020) 27:30885–30892
https://doi.org/10.1007/s11356-020-09701-4

SHORT RESEARCH AND DISCUSSION ARTICLE

An exploratory evaluation of the potential pulmonary, neurological and other health effects of chronic exposure to emissions from municipal solid waste fires at a large dumpsite in Olusosun, Lagos, Nigeria

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Received: 22 August 2019 / Accepted: 11 June 2020 / Published online: 15 June 2020

Abstract

Open municipal solid waste (MSW) combustion is a major emission source of particulate air pollution, polycyclic aromatic hydrocarbons, and more exotic hazardous organic pollutants including polychlorinated biphenyls and brominated flame retardants. However, the adverse impact of MSW combustion emission on health among the general population is unknown. Therefore, a cross-sectional study was conducted to explore the associations between potential exposure to MSW combustion-related air pollution and symptoms of adverse health effects among residents of a community adjacent to a large open landfill in Lagos, Nigeria. Using ordinal logistic regression and controlling for age, sex, and smoking, it was observed that residence for ≥ 11 years had increased odds ($p < 0.05$) of daily occurrence of tingling/numbness/whiteness of fingers (2.614), headaches (2.725), memory problems (2.869), tremor/cramps (2.748), and confusion (3.033) among other symptoms. These results indicate adverse health impacts of chronic exposure to MSW combustion emission.

Keywords Municipal solid waste · Landfill · Dumpsite · Combustion · Air pollution · Health effects · Symptoms

Introduction

Uncontrolled open municipal solid waste (MSW) combustion is a major source of ambient air pollution with a contribution of 29% of anthropogenic release of fine particulate matter ($PM_{2.5}$: PM with aerodynamic diameter ≤ 2.5 μm) into ambient air (Wiedinmyer et al. 2014). Open burning of MSW is a global activity of public health concern. It occurs in high income countries (HICs) mostly in less densely populated rural areas, but on a more intense scale in low and middle-income countries (LMICs) (Kodros et al. 2016; Wiedinmyer et al. 2014). Open MSW combustion in many LMICs often occurs on large dumpsites that are located in highly populated urban metropolitan areas (Kodros et al. 2016). Consequently, there is potential for exposure of substantial populations to resultant emissions.

Although, evidence indicates that open MSW combustion smoke may negatively affect lung function and birth outcome (Amegah et al. 2012; Gumede and Savage 2017), the adverse health impacts have not been studied extensively. Nonetheless, its potential impact on human health can be inferred from its composition. As a major contributor to ambient air $PM_{2.5}$ which is the leading environmental risk factor for respiratory and cardiovascular morbidity and mortality (Cohen et al. 2017; Lim et al. 2012), the impact is likely to be substantial. In the recent estimate from the Global Burden of Disease study, smoke from open MSW combustion caused 270,000 premature adult deaths annually (Kodros et al. 2016).

Responsible Editor: Philippe Garrigues

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11356-020-09701-4) contains supplementary material, which is available to authorized users.

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This estimation is an extrapolation, and is not based on original data about the independent adverse health effects of air pollution from open MSW combustion.

Smoke and PM emitted from open MSW combustion can be more varied in their composition compared to emissions from the more traditional and well-studied ambient air pollution sources including traffic and combustion of biomass fuels (Das et al. 2018; Nagpure et al. 2015; Wiedinmyer et al. 2014). Some components of MSW, including garbage, recyclables, electronics, and other household/consumer products, contain hazardous materials (Oladapo et al. 2012). Consequently, the burning of MSW results in the generation of more typical combustion-related PM constituents such as metals, polycyclic aromatic hydrocarbons (PAHs) and dioxins, and more exotic organics including polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) that are used as flame retardants in household and electrical products (Fierens et al. 2007; Gullett et al. 2009; Hogarh et al. 2018; Wiedinmyer et al. 2014). Dioxins, PCBs, and PBDEs are persistent organic pollutants (POPs) with biological half-lives that are between few and 20 years (Ogura 2004), and can cause adverse effects beyond the respiratory and cardiovascular systems (Berghuis et al. 2015; Mocarelli et al. 2007; Vested et al. 2014). Some of these compounds are endocrine disrupting and may cause reproductive and developmental toxicity. Exposures to them have also been associated with diabetes (De Tata 2014; Lim et al. 2008; Longnecker and Michalek 2000; Silverstone et al. 2012).

As air pollution from MSW combustion emission is unique and its adverse health effects in the general population remains largely uninvestigated (Kodros et al. 2016), it is therefore of value to elucidate the independent health effects of emissions from open MSW combustion. We conducted an exploratory study to investigate the potential respiratory, neurological, and cardiovascular effects of chronic exposure to MSW combustion-related air pollution. We conducted the study within the context of residence (living or working) in areas adjacent to a very large open dumpsite (103 acres large and 10 stories tall) that is located in Lagos, Nigeria. Specifically, we examined the relationships between the duration of residence and frequencies of various respiratory, neurological, and cardiovascular symptoms.

Methods

This was a cross-sectional study conducted in July 2015 at and around the Olusosun landfill located in the Ojota area of Lagos, Nigeria. The Olusosun landfill is one of the largest in the world and the largest in Africa (Ife-Adediran and Isabota 2018; Kalu 2018). It is located within the Lagos metropolis in close proximity to homes and business premises. The waste stream flowing into this landfill (more precisely a dumpsite or open landfill) includes garbage, recyclables, electronics, and household consumer products. Fires occur regularly at this landfill, either spontaneously, as a result of the natural outcome of combustion of trapped gases such as methane, or due to the incineration activities of scavengers (LASG n.d.; Ogunrinola and Adepegba 2012; Oladapo et al. 2012).

Study area

The study area consisted of two streets in residential areas that are in proximity (within 1000 m) of the landfill. We carefully selected these streets to ensure that they were away from industrial sources of emission by ensuring there were no factories within 5 km of the sampling locations.

To demonstrate potential high levels of exposure to pollutants at the landfill and the selected adjacent streets, we obtained multiple instantaneous measurements of ambient air concentrations of gaseous pollutants including carbon monoxide (CO), sulfur dioxide (SO_2) and nitrogen oxide (NO_2), ammonia (NH_3), and Hydrogen sulfide (H_2S) as well as volatile organic compounds (VOC) at eight locations within the dumpsite and two locations on each of the two selected residential streets adjacent to the dumpsite. ToxiRAE II single gas monitors (Honeywell, Charlotte, NC) were used to measure CO (measurement range, 0–500 ppm; resolution, 1 ppm), SO_2 (0–20 ppm; 0.1 ppm), NO_2 (0–20 ppm; 0.1 ppm), and NH_3 (0–50 ppm; 1 ppm). GasAlert Quattro multi gas monitor was used to measure H_2S (0–200 ppm; 1 ppm) and VOC (0–100 ppm; 1 ppm). The equipment takes multiple measurements over a 10-min duration and when saturated produces the mean concentrations of the pollutants measured. We also obtained noise levels measured by an Extech 407730 (Extech Instruments, Waltham, MA) digital sound level meter (± 2 dB accuracy; 0.1 dB resolution) that is equipped with a 12.7-mm electrets condenser at these locations. For comparison, we measured the level of these pollutants and noise levels at the University of Lagos Botanical gardens, which is a serene environment that is located 10 miles upwind from the dumpsite to serve as a control site.

Participant selection and questionnaire administration

We included consecutively consenting adolescents and adults aged 16 years and above who either lived or worked in buildings located along the two selected streets adjacent to the landfill. Using a structured questionnaire administered by trained field workers during a face-to-face interview, we obtained demographic information (age, sex), residential status (living or working), years of residence, smoking status (yes or no), the daily number of cigarette if currently smoking, and the frequencies of respiratory, neurological, dermatological, gastrointestinal, and musculoskeletal symptoms. The responses

for the frequencies of symptoms were "rarely," "less often than once a week," "at least once a week," and "daily." Informed consent was obtained from each of the subjects prior to participation in the study.

Data analysis

Descriptive statistics (Wald Chi-square tests) were used to determine differences in the distribution of the participants across the categories of the potential confounders (age, sex, and smoking status) and frequencies of symptoms by the residential status or years of residence. Ordinal logistic regression models were used to examine the cross-sectional associations of residential status and years of residence (exposures) with self-reported frequency of symptoms (outcome). Odds ratios were estimated for exposures and the associated outcome: comparing reported "daily" symptoms to the "less frequent" symptoms referent group. Models were adjusted for age, sex, and smoking status. All analyses were performed using SAS version 9.4 software (SAS Institute Inc., Cary, NC, USA). Statistical significance was defined as a two-sided $p < 0.05$ for all analyses.

Results

Study subjects

The demographic information about the study participants according to their residential status (whether living or working in the exposed community adjacent to the dumpsite) or duration of residence is presented in Table 1. More of the participants (52%) worked vs. lived in the exposed community, while the majority (42%) were residents for 0–5 years. Sixty percent of the study participants were male. Expectedly, age was associated with the duration of residence with the oldest participants being the likeliest to have been residents for more than 10 years. Sixty-two percent of the male participants had been residents for more than 5 years. Ever smokers were more likely to have been residents of the community for 0–5 years.

Ambient air pollutant concentrations

All instantaneous instrument readings were non-detects for the concentrations of the criteria gaseous pollutant (CO, SO_2, NO_2), other inorganic gases (NH_3, H_2S), and VOCs for the control site, 10 miles away from the dumpsite. Detectable amounts of these pollutants were measured at the dumpsite and the exposed community surrounding it. As indicated by the maximum values in the range of measurements that are presented in Table 2, elevated concentrations relative to the United States National Ambient Air Quality Standards (NAAQS) and/or the Nigerian NAAQS were measured on occasions at the dumpsite and in the exposed community for some of the pollutants: once for CO (9.2 ppm), NO_2 (150 ppb) and SO_2 (100 ppb) NH_3 (0.5 ppm) and NO_2 (150 ppb); twice for H_2S (0.4, 1 ppm); and four times for SO_2 (200, 500, 1500, 2100 ppb) (FEPA 1991; USEPA 2018).

Frequency of symptoms

The distribution of the participants across residential duration and status with regard to the frequencies of symptoms and the unadjusted chi-square statistic is provided in Supplementary Table 1. There was no apparent difference in self-reported frequencies of symptoms based on residential status. However, self-reported frequencies of memory problems, tremors or cramps, and joint problems were significantly associated with the duration of residence ($p = 0.015$, 0.029, 0.014, respectively) Supplementary Table 1). In addition, there was noticeable significant ($p < 0.05$) linear trend (increased frequency with increased duration of residence) for most of the symptoms (Supplementary Table 2).

After adjusting for age, sex, and smoking status, persons living compared to working in the exposed community tended to report more frequent (daily) symptoms (odds ratio [OR] was between 1.074 and 1.811), with statistical significance only being observed for extreme fatigue with an OR of 1.811(95% confidence interval: 1.014–3.234) (Table 3). Duration of residence was associated with frequency of symptoms, with higher odds of self-reported daily symptoms for persons who had been residents (living or working) in the exposed community for 6–10 or ≥ 11 years for most (11 of 16) or all the symptoms respectively compared with residents for 0–5 years (Table 4). The odds ratio of daily symptoms was always highest for those who had been residents for ≥ 11 years. Significantly ($p = 0.05$) increased odds of more frequent headaches (OR: 2.725), tingling/numbness/whiteness of fingers (2.614), confusion (3.033), memory problems (2.869), extreme fatigue (2.748), insomnia (3.386), tremor/cramps (2.882), problems with joints (3.741), and backaches (3.110) was observed in association with residence ≥ 11 years. Marginal significantly increased odds ($p > 0.05$ and < 0.1) of chest tightness (2.383) and ear/nose/throat irritation (2.317) was also observed among this group of participants.

Discussion

Although, open MSW combustion is pervasive and is a substantial source of ambient air pollution, knowledge about the independent health effects of its emissions is limited. Nonetheless, the constituents of the smoke that is emitted include particulate matter, PAHs, inorganic gases, and metals, which are major hazards and potentially cause pulmonary and neurological adverse effects (Kodros et al. 2016; Wiedinmyer

Table 1 Study participants characteristics

Subject characteristics	Residence status			Years of residence			
	Living in study area $n = 81$	Working in study area $n = 89$	p value	0–5 years $n = 72$	6–10 years $n = 65$	11+ years $n = 33$	p value
Age							
16–25 years	20 (24.7)	28 (31.5)	0.586	30 (41.6)	18 (27.7)	0 (0.0)	< 0.001
26–35 years	30 (37.0)	27 (33.3)		27 (37.5)	21 (32.3)	9 (27.3)	
36–45 years	16 (19.8)	21 (23.6)		11 (15.3)	17 (26.2)	9 (27.3)	
> 46 years	15 (18.5)	13 (14.6)		4 (5.6)	9 (13.8)	15 (45.4)	
Sex							
Female	28 (34.6)	40 (44.9)	0.169	34 (47.2)	25 (38.5)	9 (27.3)	0.145
Male	53 (65.4)	49 (55.1)		38 (52.8)	40 (61.5)	24 (72.7)	
Ever smoked							
No	33 (40.7%)	44 (49.4%)	0.255	40 (55.6%)	29 (44.6%)	8 (24.2%)	0.011
Yes	48 (59.3%)	45 (50.6%)		32 (44.4%)	36 (55.4%)	25 (75.8%)	
Currently smokes							
No	49 (60.5%)	60 (67.4%)	0.347	46 (63.9%)	41 (63.1%)	22 (66.7%)	0.939
Yes	32 (39.5%)	29 (32.6%)		26 (36.1%)	24 (36.9%)	11 (33.3%)	
Daily number of cigarettes							
1–10 cigarettes	26 (32.1%)	25 (28.1%)	0.561	22 (30.6%)	19 (29.2%)	10 (30.3%)	0.925
10+ cigarettes	6 (7.4%)	4 (4.5%)		4 (5.6%)	5 (7.7%)	1 (3.0%)	
None	49 (60.5%)	60 (67.4%)		46 (63.9%)	41 (63.1%)	22 (66.7%)	

et al. 2014); Babadjouni et al. 2017; Cohen et al. 2017; Kioumourtzoglou et al. 2015; Laumbach and Kipen 2012). We postulated that potentially increased exposure to such emissions would be associated with higher frequencies of pulmonary and neurological effects, and our findings appear to align with this hypothesis.

Specifically, increase in residence time in areas adjacent to Olusosun dumpsite is associated with self-reported increase in the frequencies of respiratory (chest tightness, difficulty in breathing, and era/nose/throat irritation), neurological (headache, tingling/numbness/whiteness of fingers, memory problems, extreme fatigue, tremor/cramps, and insomnia), and musculoskeletal (backaches and problems with joints) symptoms. The odds of reporting daily vs. less frequent occurrence of these symptoms increased with longer residence time after adjusting for age, sex, residence status (living vs. working in the area), and smoking status. The odds for persons who had lived/worked in the area for ≥ 11 years compared to those who had done so for ≤ 5 years was at least double. Although, not significant, the odds ratios of increase in self-reported frequencies of 12 out of the 16 symptoms were higher than 1.0 for persons who had lived/worked in the area for 5–10 years compared with the referent group. Odds ratios for this group relative to the referent were below but close to 1.0 and not significant for the other four symptoms including three that are respiratory and one that is gastrointestinal. While we cannot definitively provide explanations, cross-sectional collection of information and small sample size could have accounted for why odds were lower for the 5–10-year group for these four symptoms. Nevertheless, the odds ratios were higher for most of the respiratory and neurological symptoms in persons in both groups that had lived/worked longer in the area. There is further evidence that longer residence time and, by extension, exposure to emissions from combustion of waste at the dumpsite are detrimental to respiratory and neurological health within the data. Persons who lived in the area, and presumably spent more time in the area adjacent to the dumpsite, tended to have higher odds of reporting more frequent symptoms, although none of the odd ratios were significant except for extreme fatigue.

As previously noted, and as the air pollutant measurement data demonstrate, combustion of MSW at Olusosun landfill results in emission of PM and other hazardous air pollutants to which neighboring residents could be exposed putting them at greater risk of adverse effects. Previous studies have also associated exposure to combustion-derived indoor and outdoor air pollution with respiratory and neurological symptoms such as was observed in this present study (Bernstein et al. 2008; Dales et al. 2009; Kampa and Castanas 2008; Lai et al. 2010; Patel et al. 2010; Schikowski et al. 2010; Xu et al. 2016). We also observed an unexpected association between duration of living/working in the community adjacent to the site and musculoskeletal symptoms, specifically backaches and joint problems. This observation is likely due to factors different from

Table 2 Air pollutant concentrations across study site

Pollutant concentrations								
Location	NH_3 (ppm)	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	$PM_{2.5}$ (number)	SO_2 (ppm)	VOC (ppm)	Noise levels (dB)
Olusosun Landfill Site	ND-0.5	ND-2.7	ND-1	ND-0.15	$3.30*10^7/m^3$–$9.10*10^7/m^3$	ND-2.1	ND-0.81	54.0 dB–86.0 dB
Neighboring Streets	ND-0.1	0.9–9.2	ND-0.1	ND-0.15	$5.36*10^7/m^3$–$7.76*10^7/m^3$	ND-0.2	ND-0.02	62.3 dB–89.9 dB
Unilag botanical/zoological garden (control)	ND	ND	ND	ND	$5.84*10^7/m^3$–$8.42*10^7/m^3$	ND	ND	60.1 dB–83.3 dB

ppm parts per million

dB decibels

ND non detect

combustion emissions from the dumpsite as associations between air pollution and musculoskeletal symptoms have not been reported in the literature. While work at the dumpsite is a plausible reason, higher odds of self-reported increase in the frequency of musculoskeletal symptoms was reported by persons living vs. those working in the community. However, we did not collect information about the occupation of the study participants. Nonetheless, a higher probability of engagement in strenuous work by persons who had lived/worked longest within the community remains a plausible explanation as such persons are more likely to be of the lower socio-economic class, who are also more likely to be engaged in physically demanding occupations which is the major extrinsic risk factor for backaches and joint problems (Leino-Arjas et al. 1998; Roffey et al. 2010; Wai et al. 2010; Yucesoy et al. 2015).

There is very limited data reporting on the health of persons potentially exposed to pollution from dumpsites or open landfills. Previous data is mostly from occupational exposure by workers at such facilities. In an Indian study, workers at an open landfill were at higher risks of reporting respiratory (sinusitis, running or stuffy nose, common cold, frequent sneezing, dry cough, wheezing, and chest discomfort) and neurological (headaches, tingling/numbness, transient loss of memory, blurred vision, burning sensation in extremity, and depression) symptoms compared with non-landfill worker controls (Ray et al. 2005). Similar results were observed in a study of landfill workers across Virginia (Kitsantas et al. 2000), and among waste collection and waste disposal workers in Greece and Italy (Athanasiou et al. 2010; Vimercati et al. 2016). Furthermore, reduced spirometry measures (forced vital

Table 3 Odds of reporting daily vs. less frequent symptoms based on residential status (living vs. working in the study area) after adjusting for age, sex, cigarette smoking, and residential duration

Symptoms	AOR	95% CI	*p* value
Headache	1.522	0.838–2.764	0.168
Chest tightness	1.339	0.760–2.362	0.313
Difficulty breathing	1.320	0.742–2.349	0.345
Tingling numbness or whiteness of fingers	1.309	0.743–2.307	0.352
Confusion/difficulty breathing	1.405	0.797–2.477	0.239
Memory problems	1.074	0.599–1.928	0.810
Ear nose or throat irritations	1.249	0.712–2.192	0.439
Flulike symptoms	1.117	0.635–1.966	0.700
Skin problems/irritation	1.517	0.867–2.651	0.144
Extreme fatigue	1.811	1.014–3.234	0.045
Stomach discomfort	1.176	0.668–2.068	0.575
Insomnia	1.119	0.629–1.989	0.703
Eye irritation/tear	1.121	0.637–1.975	0.692
Tremors or cramps	1.461	0.832–2.565	0.187
Problems with Joint	1.356	0.765–2.404	0.296
Backaches	1.159	0.634–2.120	0.632

AOR adjusted odds ratio

95% CI 95% confidence interval

Table 4 Odds of reporting daily vs. less frequent symptoms based on duration of residence after adjusting for age, sex, cigarette smoking, and residential status; the referent duration group is 0–5 years

Symptoms	AOR	95% CI	p value
Headache			
6–10 years	1.355	0.701–2.621	0.367
11+ years	2.725	1.017–7.302	0.046
Chest tightness			
6–10 years	1.663	0.877–3.153	0.120
11+ years	2.383	0.978–5.806	0.056
Difficulty breathing			
6–10 years	1.601	0.834–3.071	0.157
11+ years	1.952	0.790–4.825	0.147
Tingling, numbness, or whiteness of fingers			
6–10 years	1.407	0.742–2.666	0.296
11+ years	2.614	1.072–6.378	0.035
Confusion/difficulty breathing			
6–10 years	1.242	0.655–2.355	0.508
11+ years	3.033	1.247–7.378	0.014
Memory problems			
6–10 years	1.159	0.595–2.258	0.665
11+ years	2.869	1.162–7.086	0.022
Ear, nose, or throat irritation			
6–10 years	0.997	0.530–1.876	0.992
11+ years	2.317	0.943–5.691	0.067
Flulike symptoms			
6–10 years	1.668	0.878–3.166	0.118
11+ years	2.102	0.863–5.122	0.102
Skin irritation			
6–10 years	0.867	0.463–1.622	0.654
11+ years	1.920	0.794–4.639	0.147
Extreme fatigue			
6–10 years	1.638	0.859–3.123	0.134
11+ years	2.748	1.080–6.991	0.034
Stomach discomfort			
6–10 years	0.914	0.483–1.730	0.782
11+ years	1.687	0.694–4.103	0.249
Insomnia			
6–10 years	1.603	0.831–3.091	0.159
11+ years	3.386	1.375–8.338	0.008
Eye irritation, tears			
6–10 years	0.821	0.434–1.552	0.543
11+ years	1.403	0.573–3.438	0.459
Tremors or cramps			
6–10 years	1.598	0.849–3.007	0.146
11+ years	2.882	1.173–7.076	0.021
Problems with joints			
6–10 years	1.607	0.848–3.043	0.146
11+ years	3.741	1.467–9.541	0.006
Backaches			
6–10 years	1.188	0.610–2.316	0.612
11+ years	3.110	1.141–8.478	0.027

AOR adjusted odds ratio

95% CI 95% confidence interval

capacity or forced expiratory volume in 1 s) have been reported among waste collection and waste disposal workers relative to controls (Kitsantas et al. 2000; Vimercati et al. 2016).

However, it is noteworthy that both the present study and previous studies did not measure personal exposures to air pollution, and direct physical contact to biohazards may contribute to symptoms among the landfill workers (Athanasiou et al. 2010; Kitsantas et al. 2000; Ray et al. 2005; Vimercati et al. 2016). Nonetheless, the outcomes that we have observed is similar to those among land fill workers as well as those associated with emissions from other combustion sources (e.g., traffic exhaust and smoke from residential combustion of biomass); making it plausible to infer that there may be a relationship with emission from combustion at the dumpsite (Bayer-Oglesby et al. 2006; Desalu et al. 2010; Diaz et al. 2007; Henderson and Johnston 2012; Ho et al. 2014; Langrish et al. 2012; Nachman and Parker 2012; Pope et al. 2014; Romieu et al. 2009; Schikowski et al. 2010; Xu et al. 2016). Additionally, restrictive lung function impairment has been reported in most (65%) children that lived within a 2-mi radius of a landfill in a recent study from South Africa (Gumede and Savage 2017).

Waste incinerator offers a much cleaner combustion process compared to open MSW burning, but it is also not free from adverse health outcomes and may not be the most appropriate alternative waste disposal option. Residence in a community adjacent to a waste incinerator was associated with increased risk of respiratory symptoms (wheeze and morning cough/phlegm) (Mohan et al. 2000). Results of other studies related to incinerators indicate that exposure to emissions from waste combustion could be risk factors for more debilitating health outcomes including cancers and adverse birth outcomes (preterm delivery) (Ancona et al. 2015; Candela et al. 2013; García-Pérez et al. 2013; Vinceti et al. 2008). Similarly, residential garbage burning by pregnant women has been associated with a 195% increase in risk of low birth weight of the offspring (Amegah et al. 2012).

We note that the results of this study are limited by the lack of specific exposure measures. Residence time of the participants in the community was used as a surrogate exposure measure, and their personal exposures to contaminants specific to garbage combustion were not monitored. However, elevated concentrations of combustion-related air pollutants including CO, NO_2, and SO_2 were detected in the community in area samples, whereas they were not detected in the control site. Although, we adjusted for age, sex, and smoking status in our analyses, some of the study findings might be explained by residual confounding. Nonetheless, all participants were residents of the same community, and potential confounding exposures that are pervasive such as traffic are not expected to vary by a large degree among the study participants within the same periods. It should be noted that exposure to emissions that are not combustion-related might also cause adverse respiratory and neurological outcomes (Heaney et al. 2011). For example, ammonia and H_2S were detected in area samples in the community adjacent to this landfill. While these air pollutants may be released by waste combustion (Rim-Rukeh 2014; Wiedinmyer et al. 2014), they may also be produced by decaying organic materials within the landfill (Behera et al. 2013; Heaney et al. 2011). Finally, due to small sample sizes,

we collapsed the categories of symptom frequencies and analyzed the odds of reporting symptoms "daily" or "at least once a week" vs. "rarely" or "less often than once a week." Although the estimates for some of the odds ratios became insignificant, the results remained consistent for the odds of reporting more frequent symptoms according to residential status (living > working in study area) and duration of residence (≥ 11 years > 6–10 years > 0–5 years).

Conclusion

In conclusion, we observed that potentially increased risk of exposure to combustion-related emissions from an open landfill based on residence adjacent to the landfill is associated with increased frequencies of respiratory, neurological, and musculoskeletal symptoms. Increased frequencies of the symptoms were self-reported among those who had lived/worked longest (≥ 11 years) relative to those who had done so for 0–5 years. Further research is needed to quantify the level of personal exposure to these emissions to corroborate or refute the association with adverse health outcomes.

Author contribution Conceptualization: Temilola Oluseyi; Methodology: Queen Uzoegwu, Temilola Oluseyi; Formal data analysis and investigation: James Odei, Obianuju Ozoh, Olorunfemi Adetona; Manuscript writing: Maria Lucas, Obianuju Ozoh, Olorunfemi Adetona; Manuscript review: James Odei, Maria Lucas, Obianuju Ozoh, Olorunfemi Adetona, Temilola Oluseyi

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