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Residents' perception of the effects of soot pollution in Rivers State, Nigeria

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Air pollution is a growing cause of morbidity and mortality globally. Nigeria is confronted with rising air pollution concerns due to activities of extractives, industrialisation and high population growth rate. Many areas of Rivers State, which provide 60% of Nigeria's crude oil output, have recently been experiencing visible fallout of soot. To assess the perception of residents of Rivers State on the current soot pollution, a cross-sectional study was undertaken via an online survey among people residing in the state who were literate and had access to internet-enabled devices. Results indicated that most respondents (81.5%) were aware of the soot pollution and perceived the main causes of soot to be from artisanal refining of crude oil (87.8%) and burning of confiscated crude oil and its products (76.5%). Majority also perceived that the soot had caused them chronic cough (69.9%) and irritation to eyes, nose and throat (64.2%). Female respondents were significantly more likely (AOR=1.38 CI = 1.02, 1.86) to complain of a health effect from soot pollution. There is a critical need to investigate identified sources of soot and mitigate possible impact. Public health campaigns should be launched for adequate risk communication on the adverse effects of soot, with attention given to gender-sensitive messages. Relevant authorities should develop stringent policies to prevent soot pollution and improve access to appropriate services to address the health effects.

Key words: Air pollution, soot, health effects, chronic cough, artisanal refining.

INTRODUCTION

The onset of global industrialisation in the 18 and 19th centuries brought about peculiar socio-economic issues, many of which resulted in attendant environmental and health challenges (Kirby, 2013; Godish and Davis, 2015). Air pollution in particular has been a growing cause of morbidity and mortality, dating back to the Great London Smog of 1952 (Kirby, 2013). Air pollution occurs when air contains harmful substances different from its natural

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constituents, which are detrimental to human health and the environment (Natural Resources Defense Council, 2018). These substances can be in the form of gases, particulate matter (PM) or even energy such as heat or noise (Godish and Davis, 2015). Air pollution is arguably more prevalent in countries where natural resources mining, at the artisanal and regulated levels, are conducted devoid of best practice or acceptable standards (Efobi et al., 2019). In such countries, like Nigeria, human health is exposed to disproportionate and avoidable levels of air pollution which poses significant health risks to local populations.

Nigeria is battling with rising air pollution concerns. The vast oil exploration and production activities and high population growth rate are major contributors to this problem (Olowoporoku et al., 2012; Yakubu, 2018). As a result of more than 50 years of oil and gas exploration and production, Nigeria suffers extensive environmental degradation occasioned by gas flaring (Brandt, 2020) and oil spills (UNEP, 2011a; Zabbey et al., 2017). Despite Nigeria's commitment to climate action, the country is primarily dependent on fossil fuels, a major source of flared gas (Brandt, 2020). In the Niger Delta region, the hub of Nigeria's oil and gas production, air pollution has been attributed to use of biomass fuel like firewood, indiscriminate burning of vegetation and refuse, traffic and industrial emissions, and gas flaring (Adejoh et al., 2015; Fagbeja et al., 2008; Godson, 2011). Artisanal refining (small scale and unregulated burning of hydrocarbons to derive petrol, diesel and kerosene) of crude oil in Rivers State has also been shown to have detrimental effects on the atmosphere through the release of carbon dioxide, methane and other gases (UNEP, 2011b; Ogele and Egobueze, 2020).

The World Health Organisation (WHO) estimated that in 2016, 4.2 million deaths were attributed to diseases linked to ambient air pollution, with 91% occurring in low- and middle-income countries like Nigeria (WHO, 2016; WHO and International Programme on Chemical Safety, 1996). Particulate matter is the common proxy indicator for air quality and the WHO guideline values are 50 µg/m^3 24-h mean for particles with a diameter of 10 µ or less (≤ PM_{10}) and 25 µg/m^3 24-h mean for particles with a diameter of 2.5 µ or less (≤ $PM_{2.5}$) (WHO, 2016). Environmental monitoring data from the World Bank showed that by 2015, 94% of Nigerians were exposed to air pollution levels above the WHO guidelines (World Bank, 2015). By 2016, all Nigerians were exposed to high air pollutant levels exceeding WHO guidelines (World Bank Group, 2016). Rivers State, one of the nine states in the crude oil rich Niger Delta region of Nigeria (Figure 1), is the hub of oil and gas exploration in the region, and thus faces increasing air pollution problems. Studies have documented various effects of air pollution in Rivers State, notably acid rain and more recently, soot pollution (Chuks, 2015; Nduka and Orisakwe, 2010; Yakubu, 2018).

The fine particles in soot ($PM_{2.5}$) pose peculiar health challenges. When inhaled, the size of these fine particles enables them to penetrate deep into bronchiolar tissue causing oxidative stress and pulmonary inflammation, and possible deoxyribonucleic acid damage (Niranjan and Thakur, 2017; Valavanidis et al., 2013). Short-term effects of these are irritation of the eyes, nose and throat, cough, chest tightness, wheezing, dyspnea and acute exacerbation of asthma, while long-term effects include arrhythmias and lung cancer among others (EPA, 2017; Niranjan and Thakur, 2017). A study in England reported that residents of an air polluted town perceived that the pollution had worsened allergies, asthma, bronchitis and lung cancer (Howel et al., 2003). Similarly, common health complaints related to air pollution as reported in the Niger Delta region are difficulty in breathing, cough, exacerbation of asthma, and skin disorders (Godson, 2011; Obafemi and Eludoyin, 2012). These documented adverse health effects from exposure to soot establishes it as a major environmental risk to human health.

Even with the existence of environmental laws and regulations like the Constitution of the Federal Republic of Nigeria, the National Oil Spill Detection and Response Agency (NOSDRA) Act (2006), Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) and National Environment Standards and Regulation Enforcement Agency (NESREA) Act of 2007, poor monitoring and regulatory control of the oil industry have contributed to an increase in environmental pollution (Sam et al., 2017). Recently, concerns over air pollution have heightened in Rivers State by the visible fallout of soot over many areas of the state (Onukwugha, 2018; Giles, 2018; Todo and Ebiri, 2018). Previous concerns over environmental pollution in the Niger Delta have led to agitations and conflict between the community members and industrial companies or authorities, as typified in Ogoniland, Rivers State (Richard et al., 2001; Lindén and Pålsson, 2013). Hence, it is pertinent that the recent air pollution be addressed on all fronts, considering public perceptions, to prevent an escalation of the situation.

In response to the soot pollution, the Rivers State Government set up a technical team to generate preliminary air quality data in Port Harcourt (Rivers State Government, 2019). However, the study was limited to only one local government area and did not assess the perceptions of the local residents, as well as the effect the pollution had on the daily activities of residents. The study, nonetheless, reported the possible causes of the soot to include artisanal refining, emissions from asphalt factories, indiscriminate burning of mixed waste, burning of tyres and vehicular emissions (Rivers State Government, 2019). Although industrial sources were identified (e.g. emissions from asphalt factories), most of the other sources mentioned were due to activities of residents (e.g. artisanal refining, indiscriminate burning of mixed waste, burning of tyres and vehicular emissions).

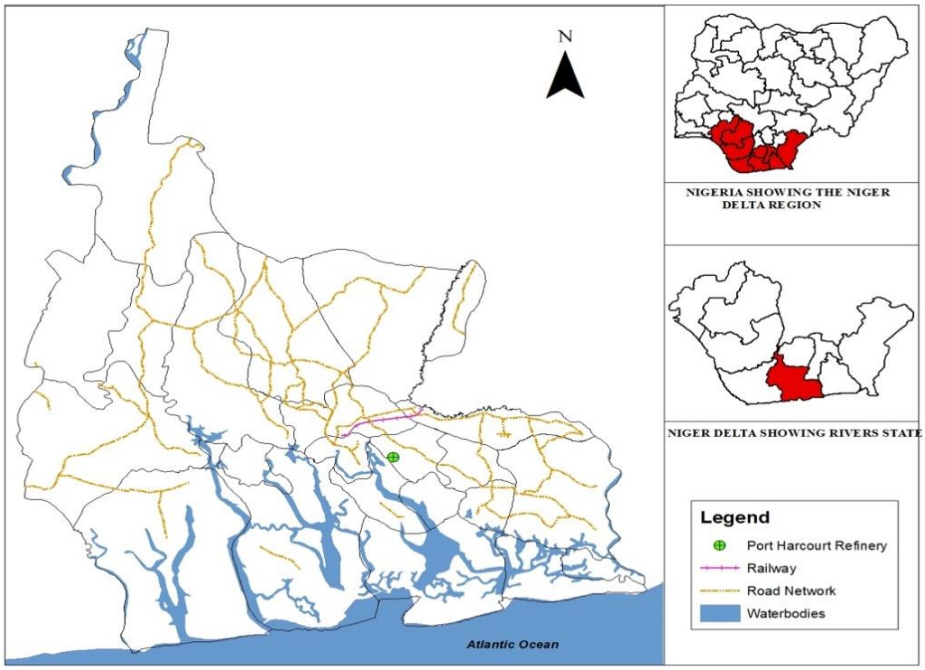

Figure 1. Map of Rivers State, and its location in the Niger Delta region of Nigeria.

A classic example is the stockpiling of expired tyres at the Abali park area of Port Harcourt which was set ablaze by unknown residents in 2017 resulting in the emission of pollutants, including soot, contributing to air pollution. Nevertheless, not much has been done since the report was published in terms of mitigating these causes, or creating awareness through public sensitization and behaviour change communication. Residents of Rivers State continue to inhale visible black particles (soot) in Rivers State with limited information on the socio-economic, environmental and public health effects it can cause to them. This study assessed the perception of residents of Rivers State on the current soot pollution, and its effect on their health and daily activities. The findings of this research will aid in informing relevant stakeholders (public and policy makers) as they undertake appropriate measures for minimising exposure to, and communicating risk associated with soot, while taking into consideration the perceptions of the residents.

METHODOLOGY

Study area

The survey was conducted in Rivers State, located in the Niger Delta region of Nigeria (Figure 1) with an estimated total population of 7,745,000 as at 2018 (Rivers State Government, 2016). It comprises 23 local government areas (LGAs) with diverse ethnic groups, and functions as the hub of oil and gas production in the Niger Delta region. The state is well known for its large crude oil and natural gas reserves, contributing more than 60% of Nigeria's crude oil output (Rivers State Government, 2016). The thriving oil and gas sector has contributed to its growing population especially in the Port Harcourt metropolis (Port Harcourt and Obio/Akpor LGAs). It has a high literacy rate with 84% of women and 95% of men having completed at least secondary level of education and can read (NPC and ICF International, 2019).

Study population

Respondents were people living in Rivers State who were literate and had access to internet enabled devices, like smartphones and tablets. A compulsory first question was designed to exclude all respondents who did not live in Rivers State from participating in the study.

Sample size and sampling method

A minimum sample size of 597 was calculated using Taro Yamane's formula for known populations (Yamane, 1973), at a confidence level of 95%, a precision of 5%, and a response rate of 67% based on a similar study (Elliott et al., 1999). A 17-question survey was designed on the Survey Monkey website (www.surveymonkey.com) and divided into four parts: sociodemographic information, awareness of soot and its possible causes, perceived health impacts of soot and behavioural changes made due to soot pollution. The questionnaire was structured based on available literature from similar studies (Elliott et al., 1999; Howel et al., 2003). The questions ranged from single to multiple choice and some open-ended questions.

Data collection methods

A brief message with a link to the survey was posted selectively on social media group pages which had the majority of their members

residing in Rivers State. It was circulated via social media, and the link was active for two weeks before the survey closed in January 2018.

Ethical consideration

Ethical approval to carry out the study was obtained from the Rivers State Health Research Ethics Committee. Respondents were informed that their participation in the survey was voluntary and confidential and they signified consent by proceeding to fill the questionnaire. No personal identifiers, including Media Access Control addresses, were collected during the study. The dataset was downloaded from the site as an Excel spreadsheet and then exported to Stata version 15 (StataCorp, College Station, Texas, USA) for analysis. It will be stored for a period of three years on a password protected device accessible only to the authors.

RESULTS

Socio-demographic characteristics of respondents

A total of 1,001 responses were obtained while the survey was open, of which 98% were eligible as residents of Rivers State. Responses were obtained from people living in 22 out of 23 LGAs in the state, with most of them residing in Obio/Akpor LGA (50.8%). The mean age of respondents was 39.3 ± 10.3 years and majority of the respondents were male (58.5%). Half of the respondents had completed postgraduate level of education (50%), while a greater proportion were employed in the public or private sector (64%) and lived in urban LGAs (86.7%) (Table 1).

Awareness of soot pollution

Almost all respondents (96%) indicated they had observed the presence of soot in the state. Majority said they had first noticed it between October 2016 and March 2017 (Figure 2).

Perceived causes of soot pollution

The three major causes of the soot were perceived to be illegal or artisanal refining of crude oil ("kpofire") (87.8%), burning of confiscated crude oil and its by-products (76.5%) and industrial sources such as factories (53.9%) (Figure 3).

Perceptions on the health effects of soot pollution

Majority of the respondents thought that the soot had affected their health or the health of a member of their household. Cough (69.8%), irritation to the eyes, nose or throat (64.2%), and skin irritation (32.6%) were the most common health effects mentioned in relation to soot pollution (Table 2).

Controlling for age, female respondents were significantly more likely to complain of a health effect (AOR = 1.38, CI = 1.02, 1.86) associated with soot pollution than males. Other factors showed no evidence of significant association with perceived health effects of soot pollution (Table 3).

Effect of the soot pollution on the daily life of residents

When asked to report how the soot pollution had affected their daily routine, majority of respondents reported that they were cleaning surfaces and floors more often (89.5%). Other reported effects were washing their hands and feet more often, worrying about their children's health, doing less outdoor activities such as recreation, exercise, farming, and fishing, and even planning to relocate to a less polluted area (Figure 4).

DISCUSSION

Sampled residents in Rivers State were aware of the soot pollution and first noticed the soot visibly between the last and first quarter of 2016 and 2017, respectively, with the highest level of awareness in January, which coincides with the peak of the dry season in Nigeria. Previous studies in some African cities, including Rivers State, have shown seasonal variations in particulate matter levels, with the highest values recorded in the dry season (Ugbebor et al., 2016; Ogele and Egobueze, 2020).

Artisanal or illegal refining of crude oil, in addition to burning of confiscated crude oil and its by-products, and emissions from industrial sources such as factories were perceived to be major causes of soot in Rivers State. This is consistent with findings from other studies carried out in Rivers State where the majority of participants agreed that illegal refining of crude oil was a major cause of air pollution (Kalu, 2018; Rivers State Government, 2016).

Majority of the respondents thought that the soot had affected their health or the health of a member of their household. Omanga et al. (2014) reported similar findings in a study conducted in rural Kenya where over 80% of study participants perceived that air pollution posed a serious risk to their health (Omanga et al., 2014). Another study carried out in Delta State, located in the Niger Delta region as our study site, also described that most respondents had strongly agreed that air pollution from gas flaring had negative, harmful effects on health (Edino et al., 2010).

Multivariate logistic regression analysis in this study showed that being female was significantly associated with a perception that the soot had affected their health. A study conducted in the United States on the

Table 1. Socio-demographic characteristics of respondents.

Demographic variables	Frequency	Percentage
Age (years)		
Mean ±SD	39.3 ± 10.3	-
Place of residence	**n=980**	
Rural	130	13.3
Urban	850	86.7
Sex	**n=820**	
Male	480	58.5
Female	340	41.5
Education	**n=833**	
None	4	0.4
Primary	3	0.4
Secondary	20	2.4
Tertiary	390	46.8
Postgraduate	416	50.0
Occupation	**n=833**	
Student	26	3.1
Unemployed	71	8.5
Self-employed/Business owner	203	24.4
Employed (public/private sector)	533	64.0

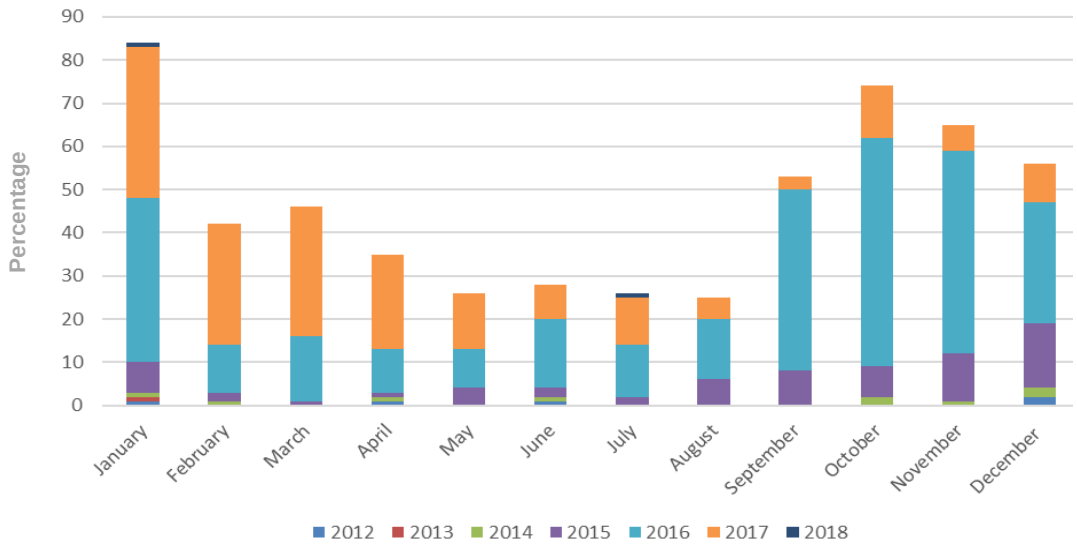

Figure 2. Awareness of soot pollution by respondents.

association between $PM_{2.5}$ and all-cause and specific-cause mortality showed suggestive evidence of increased susceptibility of women to the effects of $PM_{2.5}$ compared to men (Franklin et al., 2007). Similarly, Ezzati and Kammen (2001) showed that women were more likely to be near various sources of pollution for a longer duration leading to higher levels of exposure than men (Ezzati and Kammen, 2001).

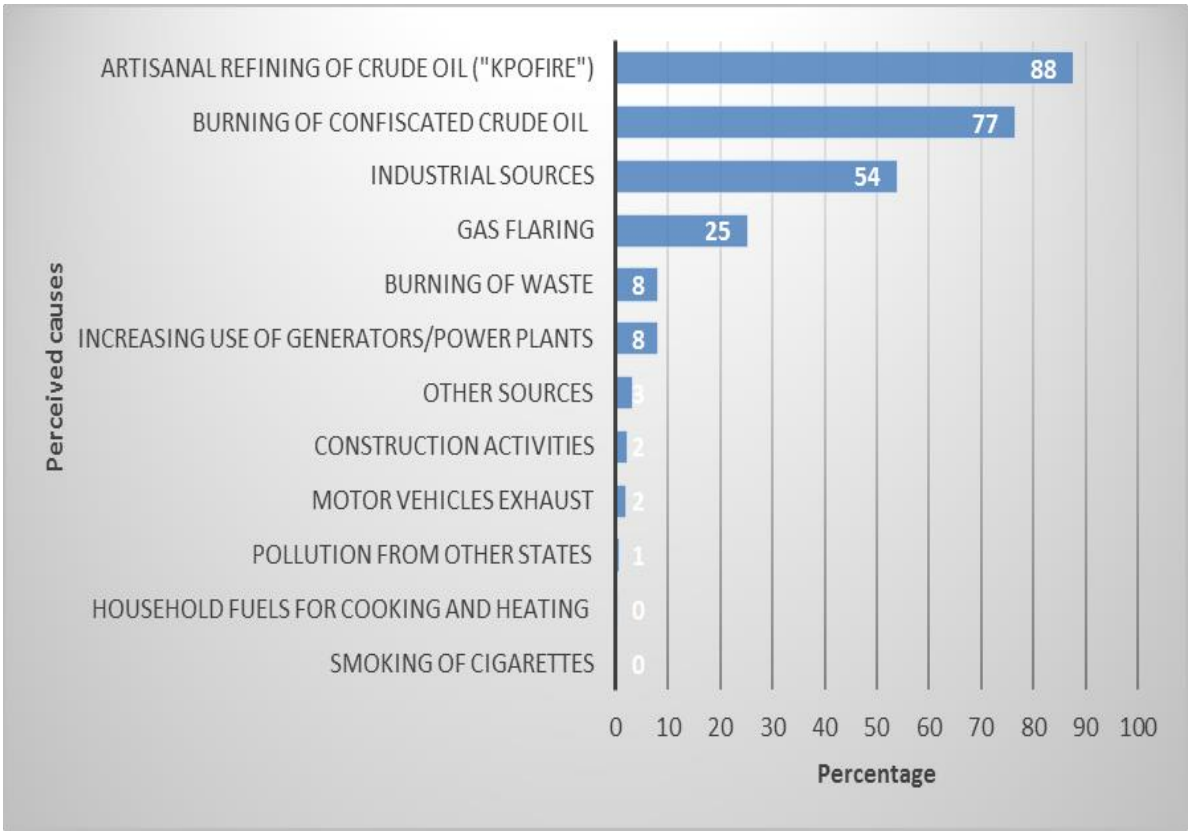

Figure 3. Perceived causes of air pollution among residents.

Table 2. Perceived health effects of soot pollution on respondents.

Perceived health effects	Frequency (n=534)	Percentage
Cough	373	69.8
Irritation to eyes/nose/throat	343	64.2
Skin irritation	174	32.6
Worsens already existing allergies	170	31.8
Breathlessness	156	29.2
Poor or blurry vision	126	23.6
Worsens symptoms of already existing asthma	121	22.7
Worsens already existing bronchitis	73	13.7
Worsens already existing lung cancer	15	2.8

Implications of the study

In general, the research identified the need for regulatory authorities to design preventive measures, and mechanisms for addressing the impacted population. It also provided evidence for relevant agencies to develop appropriate risk management approaches and enact relevant laws and policy that would prevent soot production in the region. Subsequently, the intricate implications of the research are outlined.

Socio-cultural impacts of soot

The presence of soot largely affects cultural activities and lifestyle of residents as people spend more time indoors making community members communicate and interact less with themselves. This is buttressed by the results that showed that residents tend to spend most of their time indoors rather than outdoors, with parents restricting their children from outdoor activities out of fear of the impact of soot on children's health. A proportion of

Table 3. Sociodemographic factors associated with perceived health effects of soot pollution on respondents.

Variable	Has experienced health effect of soot		Adjusted odds ratio (95% CI)	p-value
	Yes [n (%)]	No [n (%)]		
Sex				
Female	227 (44.8)	113 (36.1)	1.38 (1.02 - 1.86)*	0.027*
Male	280 (55.2)	200 (63.9)		
Level of education				
Post-graduate	269 (52.7)	147 (45.5)	4.86 (0.50 - 47.76)	0.130
Tertiary	233 (45.7)	157 (48.6)	3.98 (0.41 - 39.01)	0.188
Secondary	6 (1.2)	14 (4.3)	1.48 (0.13 - 17.52)	0.810
Primary	1 (0.2)	2 (0.6)	1.49 (0.05 - 40.91)	0.868
None	1 (0.2)	3 (0.9)		
Place of residence				
Urban	465 (90.5)	389 (82.4)	1.42(0.91 - 2.21)	0.125
Rural	49 (9.5)	83 (17.6)		
Occupation				
Employed (Public/Private)	343 (67.5)	190 (58.5)	1.14 (0.66 - 1.97)	0.420
Self-employed	114 (22.4)	89 (27.4)	0.82 (0.46 - 1.47)	0.603
Student	11 (2.2)	15 (4.6)	0.52 (0.19 - 1.39)	0.086
Unemployed	40 (7.9)	31 (9.5)		

*Factor is significant at α = 0.05, C.I. ≠ 0.

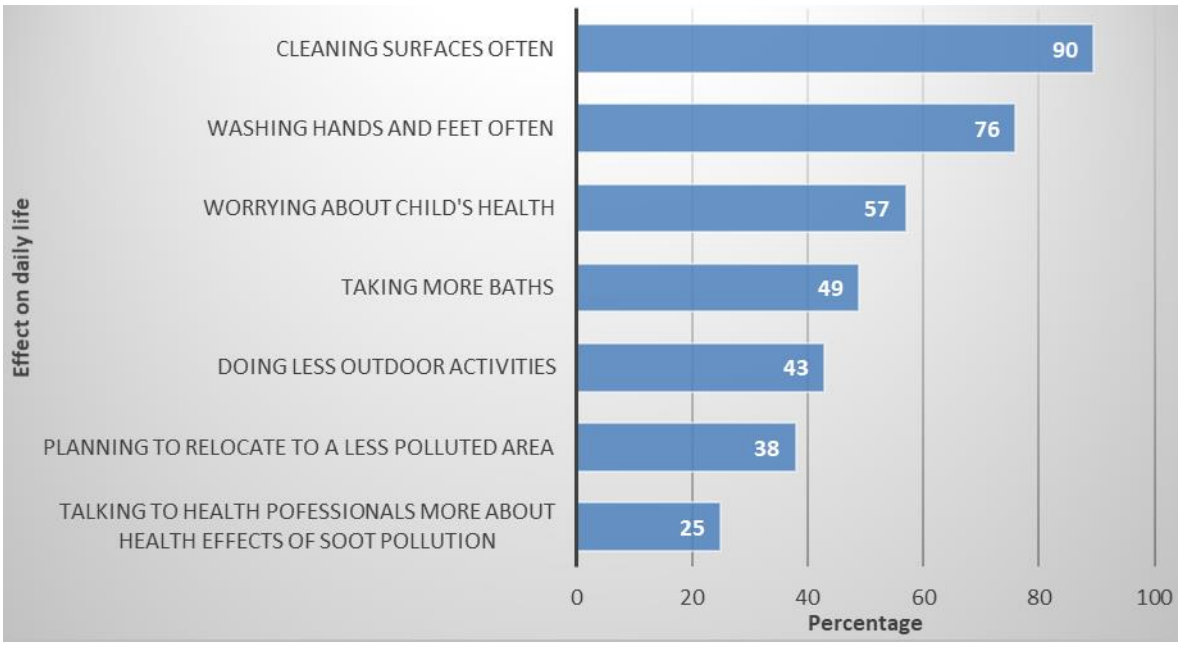

Figure 4. Effects of soot on daily life of residents.

respondents also indicated plans to relocate to other cities, thereby occasioning an economic imbalance on the communities if there is a depletion in human resources in polluted cities (Allen, 2017).

Policy changes and agency strengthening

With the outcome of this study, factual arguments should be proposed to ensure a significant change in policies and implementation of existing ones. Extant laws on environmental pollution and the development of stringent air quality thresholds for the regulation of air quality should be strengthened. Industries and firms responsible for emitting soot should be sanctioned or shut down where necessary. Surveillance of artisanal refining camps, education and sensitization of security personnel involved in crude oil seizures, increase in monitoring of firms involved in discharging soot especially particulate matter by environmental agencies should be implemented.

Public awareness and sensitization

This study can serve as an informative tool for the development of risk communication and health awareness for residents in Rivers State. Information, education and communication materials developed should be used for advocacy to engage policy makers and environmental regulators, as well as awareness creation for the local population to take steps at reducing soot and attendant air pollution in Rivers State. Gender-sensitive messages targeted at women who seem to be more vulnerable to the effects of soot should be prioritised in campaigns.

Establish alternate livelihood for artisanal refiners

Reports indicate that youth involvement in artisanal refining is as a result of unemployment and a mindset that it is lucrative, thereby negating the acute, chronic and remote health, social, economic and environmental effects (Zeeuw et al., 2018). A subsequent improvement in the livelihood means of the youths will result in a decline in their artisanal refining involvement with an end result of improved air quality in Rivers state and the region at large.

Behaviour change communication

This research identified burning of confiscated crude oil as one of the primary sources of soot in Rivers State. Behaviour change communication through trainings and seminars would be useful in initiating a change in attitude and mode of operations of the security agents involved in crude oil seizures would likely reduce the prevalence of soot in the state. More environmentally friendly options to dispose of confiscated crude oil and its by-products can be deployed such as appropriate storage in designated warehouses or tank farms. Standard operating procedures (SOP) and protocols could be developed in collaboration with the State's Ministry of Environment in this regard.

Conclusion

Soot pollution is a public health concern affecting the health and lives of residents of Rivers State, Nigeria. The perceived causes of the current soot problem should be investigated and mitigated by the relevant authorities. Public health campaigns should be launched for adequate risk communication on exposure limitation and access to health care. Relevant authorities should urgently develop stringent policies to prevent soot pollution, set baselines for air quality and further investigate the socio-economic impacts of soot on the local economy and residents. In addition, given the duration of exposure of residents in Rivers State to increasing levels of soot, there is need for an epidemiological study to underscore contextual health impacts and/or potential risks posed to the residents. Also, an extensive campaign and advocacy for behavioural changes, development of stringent air quality thresholds and strengthening of extant laws, regulatory agencies and development of alternate livelihood structures for artisanal refiners is recommended.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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