

Source gas and particulate matter emissions from a palm oil processing plant at Igwuruta, Port Harcourt, Nigeria

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ABSTRACT

The Portable Real-Time Monitoring Technique was used in ambient air monitoring around a Palm Oil processing plant in Igwuruta, Port Harcourt, Rivers State, Nigeria. Air samples were automatically analyzed for Nitrogen oxides (NO and NO₂), Oxides of carbon (CO and CO₂), Sulphur dioxide (SO₂), low explosive limit, LEL gases (Methane; CH₄), Volatile Organic Compounds (VOC), Ammonia (NH₃) and Particulate Matter (PM) content around the plant (Site 1) and 250 metres downwind (Site 2). Also noise levels and meteorological parameters were measured. The study discovered dangerous levels of noise pollution during palm oil processing operations and elevated levels of nitrogen dioxide, carbon monoxide and VOCs. Particulate matter also occurred in the study area at levels beyond every known regulation and these are levels that could endanger the health of people living or working within the vicinity of the plant. Pm 2.5 ranged between 51,867 and 1,679,106; Pm10 ranged between 2,205 and 2,546. Other unregulated parameters ranged between 0.03 – 0.6 for CO₂, 3.9 – 5.5 for NO, while CO ranged between 4.0 - 20.0 ppm which is within the USEPA daily range exposure but above maximum yearly exposure concentrations. NO₂ occurred far above the USEPA limits in the two sites while noise levels were also within acceptable limits in site 2 but above limits in the oil mill. VOCs had concentrations of 0.4 ppm in both sites which is close to concentration within the 10⁻⁶ cancer risk levels.

Key Words: Air Pollution; Air quality impacts; Air emissions monitoring; *Elaeis guineensis*, small-scale industries

INTRODUCTION

Palm oil is ubiquitous in the global marketplace. It is an ingredient in thousands of everyday products, from baked goods to shampoo; and also used to fry fast food and to fuel cars and trucks in many places around the world. Unfortunately current palm oil production methods often cause air pollution and contribute to global warming (Smith, 2014). Ohimain *et al.*, (2013) opines that air emissions during palm oil processing by smallholders are issues of public health concern demanding urgent intervention by

environmentalists. Their conclusions have also been affirmed by more recent studies (Bessou, 2016; Araújo *et al.*, 2017) to the effect that emissions from biomass were found to be significantly higher than that from fossil diesel, while noise was higher during digestion and directed the attentions of regulatory agencies to monitor the activities of smallholder oil palm processing to ensure the environmental sustainability of their operations.

Palm oil is pressed from the fleshy fruit of the oil palm tree (*Elaeis Guineen*) a species native to Africa that also thrives elsewhere in the humid tropics. The utilization of palm oil has risen dramatically in recent years, reflecting an increased demand for vegetable oil; today about a third of all vegetable oil used worldwide is palm oil (Singh *et al.*, 2013). Global production of palm oil was some 50 million metric tons per year in 2012, having more than doubled since 2000 (FAO 2013). This growth in palm oil production is likely to continue for the foreseeable future. Because of its high yield (about five to eight times more volume per hectare than the yields of its closest oil-crop competitors) (FAO 2013) and relatively low labour costs (sometimes due to forced or child labour), palm oil is the most inexpensive vegetable oil in the market today.

New research showing a link between the trans-fats in partially hydrogenated oils and health risks such as heart disease has also led to an increase in the use of palm oil, which is low in trans-fats, as replacement oil in many processed foods. In fact, Lael Goodman of the Tropical Forest and Climate Initiative stated in 2015 that the U.S. Food and Drug Administration (FDA) move to ban the use of partially hydrogenated oils, the main dietary source of artificial *trans* fats, after determining they are not safe to use in food, means an increased amount of palm oil (a *trans* fat-free vegetable oil) in the diet of Americans and an opportunity for companies to source only palm oil that is deforestation and peat-free. In addition, biodiesel fuel made from vegetable oil is currently a large market for palm oil and has the potential to expand greatly (US, 2014; Goodman, 2015; Brown, 2017).

The establishment of oil palm plantations in Sumatra, Kalimantan and East Malaysia has been cited as the major cause of the air pollution that affected many areas of

Southeast Asia in 1997 (Clay, 2004; Rosenberg, 1999; Sargeant, 2001). In the United States of America, The Clean Air Act requires EPA to set National Ambient Air Quality Standards for six common air pollutants. These commonly found air pollutants (also known as "criteria pollutants") are found all over the world. They are particle pollution (often referred to as particulate matter), ground-level ozone, carbon monoxide, sulphur oxides, nitrogen oxides, and lead. These pollutants affect human and general environmental health and also cause severe property damage.

Of the six pollutants, particle pollution and ground-level ozone are the most widespread health threats. EPA calls these pollutants "criteria" air pollutants because it regulates them by developing human health-based and/or environmentally-based criteria (science-based guidelines) for setting permissible levels. The set of limits based on human health is called primary standards. Another set of limits intended to prevent environmental and property damage is called secondary standards (USEPA, 2012). According to Lord and Clay (2011), in addition to medical effects, air pollution is also surmised to cause: loss of biodiversity, reduced forest carbon sinks, ground cover and organic matter, increased greenhouse gas emissions, and in the longer term, increased global warming and rising sea levels. Haze and air pollution also directly affect oil palm productivity with the total cost of lost crude palm oil in Sumatra in 1997 due to smoke haze and air pollution being estimated at US\$16.25 million (Sargeant, 2001).

Unlike large oil palm processing mills found in Indonesia and Malaysia, palm oil processing is carried out by smallholders' operations in Nigeria and is done manually and in batches, which depend on biomass fuel during boiling and diesel powered energy input during digestion. The

increasing levels of oil palm cultivation and commercial processing in Nigeria thus raises serious environmental concerns due to air emissions generated during local oil palm production (Ohimain *et al.*, 2013), and there are increasing global concern over the public health impacts attributed to environmental pollution, in particular, the environmental quality and human health risks associated with waste management. The World Health Organization estimated that about a quarter of the diseases facing mankind today occur due to prolonged exposure to environmental pollution (UNEP, 2013). Air pollution is a major threat to human life and most people inhale pollutants while at home or commuting to work irrespective of the mode of transportation. Depending on the dose and the exposure time, these pollutant gases have the potential to cause far reaching adverse health effects in man, but principally affect the respiratory and cardiovascular systems. The World Health Organization (WHO) estimates that about 2.4 million people worldwide (including about 93,700 Nigerians) die each year from causes directly attributable to air pollution (Ohiainain *et al.*, 2011).

Palm oil processing is a major business among small holders in the southern part of Nigeria and contributes significant air pollutants including gases and particulate matter into the environment. It is also a major source of disease burden to the nation through the exposure of nearby communities and plant operators to high dosage of pollutants emanating from the plants. This significant source of disease burden however has not been given adequate attention by governments and regulators by careful and thorough estimation of environmental impacts and subsequent policies and regulations.

An attempt to document air quality impacts from palm oil processing plants in Nigeria is the essence of this study and has as its primary aim, the evaluation of

gaseous and particulate matter emissions from smallholder oil processing plants in Port Harcourt, Nigeria.

MATERIALS AND METHODS

Study Area

The study area is the palm oil processing plant located along the Igwuruta-Igbo Etche Road near the Nigerian Army Shooting Range in Ikwerre Local Government Area of Rivers State. The study area which included 500 metre radius of the palm oil processing plant in the downwind direction is located within latitudes 4° 55' 40.73" and 4° 55' 40.73 and Longitudes 7° 02' 16.68 and 7° 02' 48.31".

The geology of the area is made up of weathered Coastal Plain Sands deposits and sandy clay soils which are prone to leaching and erosion when they occur in sloppy terrains. Rainfall is Equatorial subtropical characterized by heavy rainfall, high temperatures and high relative humidity all year round. Temperatures are usually above 30°, humidity above 50 and rainfall over 1800mm well spread all through the year, although with lesser frequency and intensity in the months of august and between December and march.

This study was carried out for one full day between 6 am to 6 pm and involved automatic measurements of gases, particulate matter, meteorological parameters of wind direction, wind speed, temperature, relative humidity and noise using the Portable Real-Time Monitoring Technique.

As stated earlier, increasing disease burden resulting from exposure to environmental pollution has been a serious matter of international concern. Therefore environmental monitoring has become *sine qua non* to the survival of man. Air quality monitoring is therefore of immediate public and environmental health relevance and the results of this study could assist in

shaping public policy and/or regulations in

a country where there seem to be none.

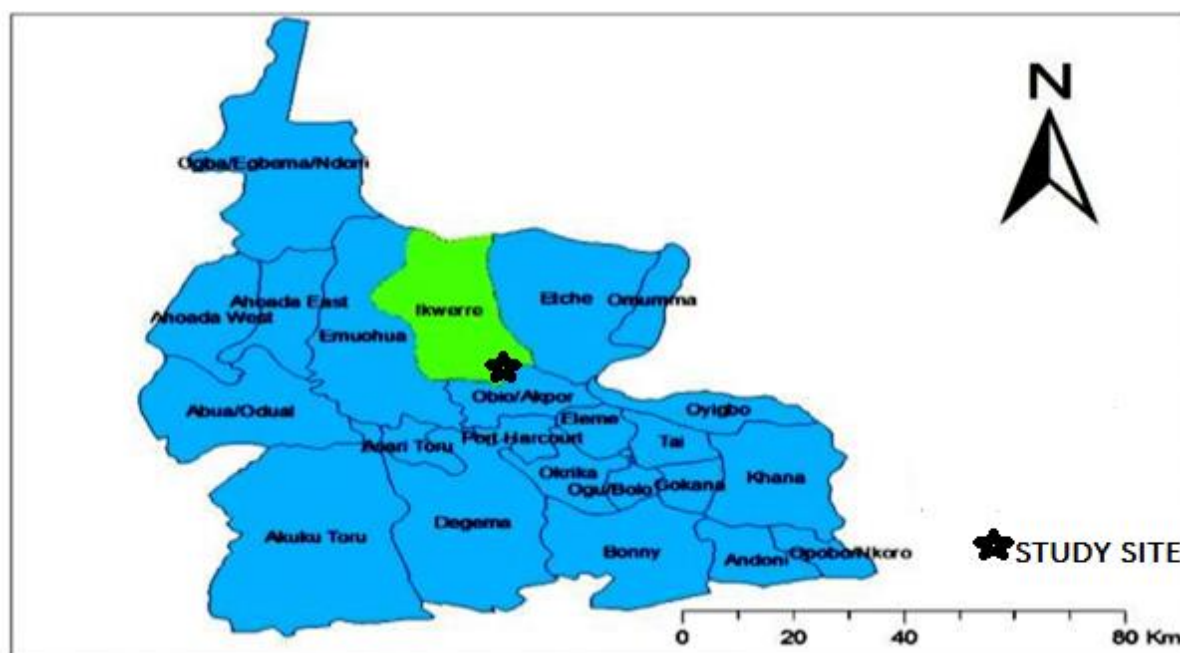


Figure 1: Location of study area within the Ikwuruta-Eneka area of Port Harcourt (Adapted from Google Maps, 2017).

Study Design

This study used real-time ambient air monitoring techniques by measuring air quality measurements at point of impacts (POI) and 250 metres downwind from the oil palm processing plant (ATSDR, 2001). Particulate matter was measured using the Met One GT-321 One Channel Particle Counter, which has a high functionality allowing for the rapid analysis of particulates in the range of 0.3, 0.5, 1.0, 2.0 and 5.0 microns. The met-one particle counter provides fast and accurate measurement of particulate contamination in particles per cubic foot. The particle counter has a NIST traceable calibration in accordance with JIS B 9921 and ASTM F328 and ASTM F649. The sampler takes a total of 10 samples after which it averages them to represent the result per location. A conversion factor from the Air Quality Sensor Network for Philadelphia-Data Validation- was used to estimate the $Pm_{2.2}$ and Pm_{10} levels in $\mu g/m^3$. The mass of a particle in the PM10 channel is $1.21E-4 \mu g$ while that of $Pm_{2.5}$

is $5.89E - 7 \mu g$ (Arling *et al.*, 2010). A zero test was carried out using a zero test filter (Met One Part Number G3111) to the GT-321 inlet nozzle. The zero filters remove 99.99% of all particles larger than 0.3 micron.

Noise levels were measured using the Extech 407730 Digital Sound Level Meter, while humidity, temperature, air velocity and light were measured using the Extech 45170 Hygro-Thermo-Anemometer-Light Meter. VOCs, methane, ammonia, SO_2 , NO_2 , CO_2 , CO and NO were measured using the MX6 iBrid™ (Industrial Scientific) Gas Monitor. Measurements were taken around 6 am, 12 noon and 6pm and results presented as ranges representing a 24 hour analysis. The geographical location of each sampling point, were recorded using handheld GPS equipment (Garmin 76).

RESULTS

Table 1 is the result of air quality sampling and analysis from this study compared with relevant international standards while Table 2 shows the converted Particulate matter concentrations for study area. While SO₄ and NH₄ were below detectable limits (0.00) in all the sites, particulate matter exceeded all standards (Table 2). Pm 2.5 ranged between 51,867 and 1,679,106; Pm10 ranged between 2,205 and 2,546. Other unregulated parameters ranged

between 0.03 – 0.6 for CO₂, 3.9 – 5.5 for NO, while CO ranged between 4.0 –20.0 ppm which is within the USEPA daily range exposure but above maximum yearly exposure concentrations. NO₂ occurred far above the USEPA limits in the two sites. However, these concentrations are below the WHO standards (2006) of 40 – 200 (µg/m³). Noise levels were also within acceptable limits (USEPA, 2014) in site 2 but above limits in the mill. VOCs had concentrations of 0.4 ppm in both sites.

Table 1: Results of Sampling and Standards

Parameter	Oil Mill N °4 55'48.9" E °702' 435"	250m (Site2) N °4 55' 47.4" E °7 02' 39.9"	STANDARDS USEPA (2012) Ppm	WHO (2006) (µg/m ³)
SO ₂ ppm	0.00	0.00	0.075 – 0.5 (ppm)	20 (24-hour mean) 500 (10-minute mean)
NO ₂ ppm	0.30 (0.565 µg/m ³)	4.50 (7.904 µg/m ³)	0.053 – 0.1 (ppm)	40 (annual mean)
CO ₂ (% vol)	0.06	0.03		200 (1-hour mean)
NO ppm	5.50	3.90		
CO ppm	20.00	4.00	9 - 35 ppm	
VOCs ppm (PID)	0.40	0.40		
NH ₄ (% LEL)	0.00	0.00		
NH ₃ ppm	1.00	1.00		
Pm 0.3 µm (ppcf)	9,999,999	2,818,413	15 - 35 µg/m ³	PM2.5: 10 (annual mean) 25 (24-hour mean)
Pm 0.5 µm (ppcf)	7,510,275	407,790	15 - 35 µg/m ³	-
Pm 1 µm (ppcf)	2,096,451	32,112	15 - 35 µg/m ³	-
Pm 2 µm (ppcf)	2,973,519	63,297	15 - 35 µg/m ³	-
Pm 5 µm (ppcf)	12,573	612	150 µg/m ³	PM10: 20 (annual mean) 50 (24-hour mean)
Wind speed	0.4 - 2.1	1.1 – 2.4		
Wind direction	SE	SE		
R. humidity	41.50	53.20		
Temperature	42.50	34.60		
Noise	120	56.20		85 dB

*DPR (2002) Environmental Guidelines & Standards for the Petroleum Industry in Nigeria

Table 2: Converted Particulate matter concentrations for study area

Parameter	Palmoil plant	Site 2	USEPA (2012)	WHO (2005)
Pm2.5 µg/m ³	46,968.1	6,909.1	15 – 35	10 – 25
Pm10 µg/m ³	5,372.6	261.5	150	20 – 50

Table 3: USEPA Air Quality Standards (as of October 2011)

Pollutant [final rule cite]	Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide [76 FR 54294, Aug 31, 2011]	Primary	8-hour 1-hour	9 ppm 35 ppm	Not to be exceeded more than once per year
Nitrogen Dioxide [75 FR 6474, Feb 9, 2010]	primary	1-hour	100 ppb	98th percentile, averaged over 3 years
[61 FR 52852, Oct 8, 1996]	primary and secondary	Annual	53 ppb	Annual Mean
	primary	Annual	12 $\mu\text{g}/\text{m}^3$	annual mean, averaged over 3 years
	PM _{2.5} secondary	Annual	15 $\mu\text{g}/\text{m}^3$	annual mean, averaged over 3 years
Particle Pollution Dec 14, 2012	primary and secondary	24-hour	35 $\mu\text{g}/\text{m}^3$	98th percentile, averaged over 3 years
	PM ₁₀ primary and secondary	24-hour	150 $\mu\text{g}/\text{m}^3$	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide [75 FR 35520, Jun 22, 2010]	primary	1-hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
[38 FR 25678, Sept 14, 1973]	secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year

Using the formula developed by Arling *et al.*, (2010) in the supplement to the Air Quality Sensor Network for Philadelphia senior design project for particulate matter monitoring, particulate matter was categorized into Pm_{2.5} and Pm₁₀. Therefore Pm in the range 0.3 – 2 were added together and results converted to $\mu\text{g}/\text{m}^3$ using:

$$Pm (\mu\text{g}/\text{m}^3) = \text{number of particles (ppcf)} \times 3531.5 \times \text{particle mass.} \quad (1)$$

The product of using the formula above is presented as Table 2 below. Also some gases were converted from parts per million to microgram/cubic metre using the internet based Skc Inc converter (<http://www.skcinc.com/converter/converter.asp>).

Also, note that as at October, 2011, the USEPA (2012) set National Ambient Air Quality Standards for six principal pollutants (Table 3), which are called "criteria" pollutants. They have been listed

according to the various units of measurement as standards for comparing outdoor air quality. Units of measurement for the standards for the parameters are in parts per million (ppm) by volume, parts per billion (ppb) by volume, and micrograms per cubic meter by weight of air ($\mu\text{g}/\text{m}^3$). These criteria form the basis for constraining the results obtained from this study.

DISCUSSION

The USEPA (2012) through The Clean Air Act has set standards in USA for pollutants considered harmful to public health and the environment. The Clean Air Act identifies two types of national ambient air quality standards. *Primary standards* provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. *Secondary standards* provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings. A summary is provided in Table 3.

The USEPA (2012) further asserted that CO can cause harmful health effects by reducing oxygen delivery to the body's organs (like the heart and brain) and tissues. At extremely high levels, CO can cause death. Exposure to CO can reduce the oxygen-carrying capacity of the blood. People with several types of heart disease already have a reduced capacity for pumping oxygenated blood to the heart, which can cause them to experience myocardial ischemia (reduced oxygen to the heart), often accompanied by chest pain (angina), when exercising or under increased stress. For these people, short-term CO exposure further affects their body's already compromised ability to respond to the increased oxygen demands of exercise or exertion.

Nitrogen dioxide causes lung irritation and lowers the human body's resistance to respiratory infections such as influenza. The effects of short-term exposure are still unclear, but continued or frequent exposure to concentrations that are typically much higher than those normally found in the ambient air may cause increased incidence of acute respiratory illness in children. EPA's health-based national air quality standard for NO_2 is 0.053 ppm (measured as an annual arithmetic mean concentration). Nitrogen oxides contribute to ozone formation and can have adverse effects on both terrestrial and aquatic ecosystems. Nitrogen oxides in the air can significantly contribute to a number of environmental effects such as acid rain and eutrophication in coastal waters like the Niger Delta wetlands. Eutrophication occurs when a body of water suffers an increase in nutrients that leads to a reduction in the amount of oxygen in the water, producing an environment that is destructive to fish and other animal life (USEPA, 2012b).

Evidence from the EPA and State studies in the United States of America indicates that combusive and non-combustive gases including VOCs, methane and carbon dioxide has adverse effects on both public health and welfare. The first specific health and welfare effect of concern is ozone formation. Ground level ozone is created by sunlight acting on nitrogen oxides (NO_x) and NMOC in ambient air. Ozone may lead to health effects such as alteration of pulmonary function, aggravation of pre-existing respiratory disease, damage to lung structure, and adverse effects on blood enzymes, the central nervous system, and the endocrine system. Ozone also presents welfare effects such as reduced plant growth, reduced crop yield, necrosis of plant tissue, and deterioration of certain synthetic materials, such as rubber. A second concern is the cancer and non-cancer health effects of various NMOC. Many

NMOC are either known or suspected carcinogens, and have the potential to produce non-cancer health effects as well, such as adverse effects on the kidneys, liver, and central nervous system, since many of the NMOC are Hazardous Air Pollutants (HAP's).

According to the Wikipedia online dictionary, volatile organic compounds (VOCs) are organic chemicals that have a high vapour pressure at ordinary room temperature. Their high vapour pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublime from the liquid or solid form of the compound and enter the surrounding air. For example, formaldehyde, which evaporates from paint, has a boiling point of only -19°C (-2°F). VOCs are numerous, varied, and ubiquitous. They include both human-made and naturally occurring chemical compounds. Most scents or odours are of VOCs. VOCs play an important role in communication between plants, and messages from plants to animals. Some VOCs are dangerous to human health or cause harm to the environment. One VOC that is a known human carcinogen is benzene, which is a chemical found in environmental tobacco smoke, stored fuels, and exhaust from cars. Benzene also has natural sources such as volcanoes and forest fires. It is frequently used to make other chemicals in the production of plastics, resins, and synthetic fibres. Benzene evaporates into the air quickly and the vapour of benzene is heavier than air allowing the compound to sink into low-lying areas. Benzene has also been known to contaminate food and water and if digested can lead to vomiting, dizziness, sleepiness, rapid heartbeat, and at high levels, even death may occur (http://en.wikipedia.org/wiki/Volatile_organic_compound).

From the cancer risk analyses by Health Canada (1996), the United States

Environmental Protection Agency (US EPA 2000) and the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA 2001), the concentrations associated with a 1×10^{-6} (one in one million) risk of leukemia range from $0.06 \mu\text{g}/\text{m}^3$ (the most justifiable unit risk identified by OEHHA (2001)) to $0.45 \mu\text{g}/\text{m}^3$ (the upper bound of the range presented by US EPA (2000) Health Canada (2013)).

Also concentrations of particulate matter (Pm10) in the vicinity of the landfill were above the national average of $123.6 \mu\text{g}/\text{m}^3$ (Efe, 2008), and are far above any known standards for the protection of health.

The WHO (2006) concludes that the evidence on airborne particulate matter (PM) and its public health impact is consistent in showing adverse health effects at exposures that are currently experienced by urban populations in both developed and developing countries. The range of health effects is broad, but is predominantly to the respiratory and cardiovascular systems. All population is affected, but susceptibility to the pollution may vary with health or age. The risk for various outcomes has been shown to increase with exposure and there is little evidence to suggest a threshold below which no adverse health effects would be anticipated. In fact, the low end of the range of concentrations at which adverse health effects has been demonstrated is not greatly above the background concentration, which for particles smaller than $2.5 \mu\text{m}$ (PM2.5) has been estimated to be $3\text{--}5 \mu\text{g}/\text{m}^3$ in both the United States and western Europe. The epidemiological evidence shows adverse effects of PM following both short-term and long-term exposures.

CONCLUSIONS

The study discovered dangerous levels of noise pollution during palm oil processing operations and elevated levels of nitrogen dioxide, carbon monoxide and VOCs. Particulate matter also occurred in the study area at levels beyond every known regulation and these are levels that could endanger the health of people living or working within the vicinity of the plant. The range of health effects is broad, but is predominantly more critical to the respiratory and cardiovascular systems. All population is affected, but susceptibility to the pollution may vary with health or age.

Also the concentration of NO₂ within 250 metre radius of the plant was above the USEPA limits and these exposes the population to health risks. At high concentrations, nitrogen dioxide (NO₂) acts as an irritant of the airways and exposure can produce inflammation and bronchoconstriction (narrowing of the lungs) and can affect the immune cells in the lungs, increasing susceptibility to respiratory infections. Asthmatics are most susceptible, although high levels of NO₂ may also produce effects on the lung function of non-asthmatics (HPA, 2011).

Another indirect impact of high NO₂ levels is its action on ozone creation. The USEPA (1995) stated that ground level ozone is created by sunlight acting on nitrogen oxides (NO_x) and NMOC in ambient air. Ozone may lead to health effects such as alteration of pulmonary function, aggravation of pre-existing respiratory disease, damage to lung structure, and adverse effects on blood enzymes, the central nervous system, and the endocrine system. Ozone also presents welfare effects such as reduced plant growth, reduced crop yield, necrosis of plant tissue, and deterioration of certain synthetic materials, such as rubber.

RECOMMENDATIONS

It is hereby recommended that:

- Government should enact or enforce regulations that will help check air pollution from palm oil processing plants.
- Serious public health education is needed for both workers in mills and people who live in the ambience of these mills on the dangers they are exposed to, so they can take steps to reduce exposure levels.
- Mill workers should also be encouraged to wear personal protective equipment (PPE) during operations.

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