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Assessing Levels of Ambient Air Quality for Pulp and Paper Milling Industry in Kenya

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Abstract
Paper as a commodity is of great importance to human kind as it has continued to define human civilization. The significance of pulp and paper industry either historically or at present cannot be gainsaid. Pulp and paper industry has been characterized as a resource inefficient and heavy pollutant emitter. This industry uses about a fifth largest energy consumer processes; approximately 4% of total energy is used worldwide. There is paucity of empirical evidence to indicate air pollution levels that are pulp and paper specific in developing countries more so Africa. Webuye Pan Paper Mills –the case for this study, has been operating since its establishment in 1974 despite the several environmental concerns raised by the residents concerning plantation establishment, liquid effluents, air emissions, sludge and solid waste disposal. By sheer observation, the most obvious environmental effect of pulp and paper milling in Webuye and its environs manifests itself in malodorous gasses emitted in the air around the mill. This study therefore provides a basis of dealing with industrial pollution by estimating ambient air pollution levels. In order to estimate the levels of concentration of various air pollutants identical to pulp and paper milling such as particulate matter, Sulphur dioxide and Nitrogen oxide. Using correlational study design the study modelled relationship between emission and metrological data to determine concentration levels. Emission data obtained from secondary sources through meta-analysis was modelled against secondary quarterly metrological data (wind speed, direction, temperature and distance from emission site) for the periods February 2007 to January 2009. The study found that highest emissions of the pollutants under consideration were experienced in Webuye town a finding that can be attributed to the proximity to the pollution source. The study established that the Paper Mills emits toxic gases such as Sulphur dioxide (SO_2), Nitrogen Oxide (NO), and particulate matters (TP_{10}) in levels that sometimes were two times higher than the WHO global recommendation. The study concludes that there is no significant difference between emissions levels in Webuye town and the neighbouring locations of Chimoi, Lugulu and Matisi. Conversely, there was a significant difference in emission levels of Webuye environs compared to those of Kakamega town which was used as a control site. The study recommends that an industrial national pollution standard be established in industrial zones. Further, such standard should be monitored through a pollution monitoring centre as part of standards enforcement
Keywords: Ambient air quality; Pollution, Pulp and paper; Mean emissions.

1. Introduction

Paper as a commodity is of great importance to human kind as it has continued to define human civilization. The significance of pulp and paper industry either historically or at present cannot be gainsaid. The World Bank (2014) reported that pulp and paper products were the second most traded commodities based on quantity globally. This privileged position of the industry means that in addition to direct products of pulp and paper, the industry contributes enormously in terms of employment and improved livelihoods of household at a micro level (Panwar, 2006; Hubacek, 2009).

Pulp and paper industry has been characterised as a resource inefficient and heavy pollutant emitter. This industry according to Ince1, Cetecioglu and Ince (2012) uses about a fifth largest energy consumer processes; approximately 4% of total energy is used worldwide. In addition, large amounts of water are used to support the paper manufacturing processes. This position is aggravated by more than 100 million kilos of toxic pollutants that are released every year from this industry (Cheremisinoff & Rosenfeld, 2010).

Extensive research on the subject by EPA (2002) point out to the fact that gas emissions would normally occurs in the form of water vapours, particulates or particulate matter (PM) nitrogen oxides, volatile organic compounds (VOCs), sulphur oxides and total reduced sulphur compounds (TRS). EPA has also estimated that U.S. pulp and paper mills release approximately 245,000 metric tons of toxic air pollutants each year. Browne et al (2012) has estimated that globally, pulp and paper industry is responsible for at least 2% of carbon dioxide emissions.

There is paucity of empirical evidence according to WHO (2012) to indicate air pollution levels that are pulp and paper specific in developing countries more so Africa. While this is the case compared to developed countries where pollution abatement and regulation thrive, pollution levels in developing countries are bound to be greater. However, some scholars have provided seminal estimates of industrial air pollution levels with varied success. Milaku and Kariuki (2001) generated a basic spatial distribution map in respect of TSP using GIS techniques with the aim of giving city planners a much more effective visual perspective of the spatial variations in city air quality in Nairobi, Kenya. An assessment of ozone, nitrogen oxides, air particulate matter (PM10) and trace elements level in the ambient air of Nairobi city, (Odhiambo, et al cited in Maina (2004) revealed that the mean PM10 values were much higher than the recommended WHO guidelines; in some cases, up to over 150 % or even higher (WHO, 1992). Omanga, et al (2014) did not commit to measure air pollution levels in their study which assessed community awareness of rural industrial air pollution in Kenya.

None the less air pollution characteristics are not homogenous in the industry. For instance, Kraft milling which employs the Kraft chemical recovery process, is responsible for generation and release combustion compounds such as nitrogen oxides (NOx), sulphur dioxide (SO2), carbon dioxide (CO2), and particulates (Staudt (2010); Silva & Mendes (2008); Bordado & Gomes (2002); World Bank (1998); EPA (1993)). This is similar to the plant at Webuye hence the converging interest.

Webuye Pan Paper Mills –the case for this study, has been operating since its establishment in 1974 despite the several environmental concerns raised by the residents concerning plantation establishment, liquid effluents, air emissions, sludge and solid waste disposal. Experts have questioned the purification process of waste from this mill saying it is inadequate to mitigate against adverse effects of environmental pollution. Air sample taken from Webuye Pan Paper mills by Environmental Law Alliance Worldwide (ELAW) in September 2009 certified that the hydrogen sulphite level was more than 500 times the permissible limit in California and more than 140 times the WHO (ELAW, 2012)

By sheer observation, the most obvious environmental effect of pulp and paper milling in Webuye and its environs manifests itself in malodorous gasses emitted in the air around the mill. According to Kenya land alliance (2008) local people have reported that the smoke from the paper factory causes rusting on iron sheets within a year of building the house hence corroded roofs and discoloured vegetation. This study therefore provides a basis of dealing with industrial pollution by estimating ambient air pollution levels.

2. Literature Review

2.1 Assessing levels of ambient air quality

Whereas it is difficult to estimate the level of ambient air pollution (AAP) globally, different authorities have made an attempt to determine the extent to which the world is affected especially arising from manmade activities. WHO maintains a data base of ambient air pollution across the globe. In 2014, the data base included 93 countries out of the 191 UN recognised countries of the world. Accordingly, WHO (2014) reports that highest annual mean emissions per metre cubed (µg/m3) for particulate matter is 282 µg/m3 in Pakistan while the lowest is 9 µg/m3 as reported in Iceland. The large deviation is in data is an indicator of how turbulent ambient air pollution is.

AAP and attendant human exposure is prevalent in cities. According to UNEP (2014) and World Bank (2013) urban settlements are characterised by commercial and industrial areas some of which are pollution "hot spots" in addition to busy roads. In return residential areas found in these same cities match exposure. Whereas our study was set in an area that is characteristically different, pollution features and settlement experience were quite similar with these considered here.

Though there are several pollutants that contribute to AAP, studies and pollution abatement and mitigation methods have tended to concentrate on Particulate Matter (PM). PM is a widespread air pollutant, consisting of a mixture of solid and liquid particles suspended in the air. Commonly used indicators describing PM that are relevant to health refer to the mass concentration of particles with a diameter of less than 10 µm (PM10) and of particles with a diameter of less than 2.5 µm (PM2.5). PM2.5, often called fine PM, also comprises ultrafine particles having a diameter of less than 0.1 µm.

According to WHO (2013) in most locations in Europe, PM2.5 constitutes 50–70% of PM10. PM between 0.1 µm and 1 µm in diameter can remain in the atmosphere for days or weeks and thus be subject to long-range transboundary transport in the air.

PM is a mixture with physical and chemical characteristics varying by location. Common chemical constituents of PM include sulphates, nitrates, ammonium, other inorganic ions such as ions of sodium, potassium, calcium, magnesium and chloride, organic and elemental carbon, crustal material, particle-bound water, metals (including cadmium, copper, nickel, vanadium and zinc) and polycyclic aromatic hydrocarbons (PAH). In addition, biological components such as allergens and microbial compounds are found in PM (WHO, 2013) which makes PM exposure to cause negative effects to human health.

While PM emissions may arise from different sources, studies undertaken that emission levels from manmade activities such as manufacturing are significant in causing AAP. Thurston and Spengler (1985) assigned roughly 40 per cent of the fine mass to particles measured in the stacks of coal-fired power plants in Boston despite the fact that this elaborate study considered sources such as soil motor vehicle, oil and salt aerosols.

Schauer et al (1996) attributed 85% of PM emission in Los Angeles to industrial combustion, diesel engine exhaust, gasoline-powered vehicle exhaust, plus emissions from food cooking and wood smoke in that order. Another interesting finding in their study was that the levels of toxicity was directly related to PM source. A US wide study by Thurston et al (2011) categorised PM sources in order of intensity as Metals Industry; Crustal/Soil Particles; Motor Vehicle Traffic; Steel Industry; Coal Combustion; Oil Combustion; Salt Particles and Biomass Burning. This AAP was witnessed in highly industrialised cities and major port cities.

The significance of industrial sources as major PM emitters is further highlighted by Zhao et al (2010) 45% of PM emissions in certain regions of china was attributable to coal fired power plants. Viana (2006) also found industrial emitters to be predominant source of PM emission in Spain over and above road dust and traffic exhaust. This review so far indicates that industrial sources are important PM emitters like the case of Webuye paper mills which is the focus of this study.

2.2 Emission characteristics of pulp and paper industry

Pulp and paper industry is considered as one of the most polluter industry in the world (Thompson et al., 2001; Sumathi & Hung, 2006). The production process consists two main steps: pulping and bleaching. Pulping is the initial stage and the source of the most pollutant of this industry. In this process, wood chips as raw material are treated to remove lignin and improve fibres for papermaking. Bleaching is the last step of the process, which aims to whiten and brighten the pulp. Whole processes of this industry are very energy and water intensive in terms of the fresh water utilization (Pokhrel & Viraraghavan, 2004).

The major air emissions of the industry come from sulphite mills as recovery furnaces and burns, sulphur oxides (SOx), from Kraft operation as reduced sulphur gases and odour problems, from wood-chips digestion, spent liquor evaporation and bleaching as volatile organic carbons (VOCs), and from combustion process as nitrogen oxides (NOx) and SOx. VOCs also include ketone, alcohol and solvents such as carbon disulphide methanol, acetone and chloroform (Smook, 1992; Ince 2011).

2.3 Air quality guidelines

WHO's air quality guidelines were first published as Air Quality Guidelines for Europe in 1987 (WHO 1987). Since 1993 the Air Quality Guidelines for Europe has been revised and updated, incorporating a review of the literature published since 1987 (WHO 1999a). The WHO Air Quality Guidelines for Europe (WHO 1987) were based on evidence from the epidemiological and toxicological literature published in Europe and North America. They did not consider the effects of exposure to the different ambient air particle concentrations in developing countries, as well as the different conditions in these countries. However, these guidelines were used intensively throughout the world. In view of the different conditions in developing countries, the literal application of the WHO Air Quality Guidelines for Europe could be misleading. Factors such as high and low temperature, humidity, altitude, background concentrations and nutritional status could influence the health outcomes after the population has been exposed to air pollution.

Air quality measurements are typically reported in terms of daily or annual mean concentrations of PM10 particles per cubic meter of air volume (m3). Routine air quality measurements typically describe such PM concentrations in terms of micrograms per cubic meter (µg/m3). When sufficiently sensitive measurement tools are available, concentrations of fine particles (PM2.5 or smaller), are also reported.

Small particulate pollution have health impacts even at very low concentrations – indeed no threshold has been identified below which no damage to health is observed. Therefore, the WHO 2005 guideline limits aimed to achieve the lowest concentrations of PM possible.

In addition to guideline values, the Air Quality Guidelines provide interim targets for concentrations of PM10 and PM2.5 aimed at promoting a gradual shift from high to lower concentrations.

If these interim targets were to be achieved, significant reductions in risks for acute and chronic health effects from air pollution can be expected. Progress towards the guideline values, however, should be the ultimate objective.

The effects of PM on health occur at levels of exposure currently being experienced by many people both in urban and rural areas and in developed and developing countries – although exposures in many fast-developing cities today are often far higher than in developed cities of comparable size.

"WHO Air Quality Guidelines" estimate that reducing annual average particulate matter (PM10) concentrations from levels of 70 µg/ m3, common in many developing cities, to the WHO guideline level of 20 µg/m3, could reduce air pollution-related deaths by around 15%. However, even in the European Union, where PM concentrations in many cities do comply with Guideline levels, it is estimated that average life expectancy is 8.6 months lower than it would otherwise be, due to PM exposures from human sources.

In developing countries, indoor exposure to pollutants from the household combustion of solid fuels on open fires or traditional stoves increases the risk of acute lower respiratory infections and associated mortality among young children; indoor air pollution from solid fuel use is also a major risk factor for cardiovascular disease, chronic obstructive pulmonary disease and lung cancer among adults.

There are serious risks to health not only from exposure to PM, but also from exposure to ozone (O3), nitrogen dioxide (NO2) and sulphur dioxide (SO2). As with PM, concentrations are often highest largely in the urban areas of low- and middle-income countries. Ozone is a major factor in asthma morbidity and mortality, while nitrogen dioxide and sulphur dioxide also can play a role in asthma, bronchial symptoms, lung inflammation and reduced lung function.

The recommended limit in the 2005 Air Quality Guidelines was reduced from the previous level of 120 µg/ m3 in previous editions of the "WHO Air Quality Guidelines" based on recent conclusive associations between daily mortality and lower ozone concentrations.

3. Methodology

In order to estimate the levels of concentration of various air pollutants identical to pulp and paper milling such as particulate matter, sulphur dioxide and nitrogen oxide. The design employed was correlational study design because it involved modelling relationship between emission and metrological data to determine concentration levels similar to studies by Dockery (1993); Naes et al, (1999); Zeka et al, (2005) and Xu et al, (2011). Emission data obtained from secondary sources through meta-analysis was modelled against secondary quarterly metrological data (wind speed, direction, temperature and distance from emission site) for the periods February 2007 to January 2009. This process estimated emission concentrations of pollutants for the quarter in maximum micrograms per cubic meter (µg/ m3).

Further, in order to implement correlational design detailed above and assess the severity of emission concentrations given the proximity of the emission site, case control design as applied in Monn (2000); Nielsen (2001); Gittikunda et al, (2003); Bayer-Oglesby et al, (2008); Ivy et al, (2008) and Patel et al, (2011) was employed in which case kakamega town was selected as the control site. This made it possible to test the hypothesis that emission concentrations were similar in the sites proximate to Webuye paper mill and the control site.

Study site was Webuye town and its environs (human settlement within 10 kilometres radius of PPM) and control site (Kakamega town) which is 46 kilometres south east of PPM. This being a rural settlement most socio-economic activities such as farming, herding cattle and trading is conducted outdoors hence pollution exposure.

Kakamega town was used as a control site because of further distance from emission point. According to Puett et al, (2014) increase in distance between residence and emission reduces the effect of exposure. In addition, Kakamega forest which is between the two towns may act as a buffer to any pollution emanating from the paper mill. In which case these findings have been observed by Chameides et al, (1988), Taha, (1996); Nowak et al., (2000) and Nowak et al (2014) who have revealed that forests are a viable strategy to help reduce urban pollution levels.

Webuye study site was divided into 3 rural clusters comprising of Chimoi, Lugulu and Matisi. Webuye town was also selected to represent the urban cluster. These clusters were within the 10 kilometre distance as explained before in the sampling frame.

The Gaussian plume algorithm and was used to estimate the pollution concentration levels of different pollutants in the study sites as emitted from the stack at pan paper mills. The model was implemented using VPLUME 2.1 which is an EPA modelling concentration modelling tool. Data inputs require according to EPA (2001) are height of the stack in units of meters; Emission rate (the amount of gas coming out of the stack, in units of grams per second); Gas exit velocity (the speed of the gas as it comes out of the stack, in meters per second); Ambient temperature (the temperature of the surrounding air, in degrees Celsius) and the atmospheric stability condition of 1-6 measure of the meteorology of the surrounding air, from very unstable (1) to stable (6).

4. Results and discussion

4.1 General metrological characteristic of Webuye and its environs

In order to estimate levels of ambient air pollution in Webuye and its environs, the study needed to collect metrological data required for measuring emission rates of various pollutants. According to EPA (2001) prevailing temperature data and wind speeds are required to determine an index referred to as atmospheric stability condition. Data on this two metrological characteristic over the period February 2007 to Janaury 2009 are given in figure 4.1(a) and 4.1(b) as obtained from Kenya Metrological Service.

Based on figure 4.1(a), the temperature range for the study period was between 24.40C to 21.90C. Hottest periods are observed early in the year while coldest periods are observed in the 3rd quarter or within the months of July and August. The observed temperature range is fairly small at 2.50C which means that during the period of the study, Webuye experienced almost an even temperature which serves to indicate that atmospheric conditions including those precipitated by pollution were not bound to vary greatly.

Wind data collected by the study is presented as a wind rose in figure 4.1 (b) above. The wind rose for Webuye shows how many hours per year the wind blows from the indicated direction. It can be observed that wind direction during the period of the study was fairly stable with Wind is blowing from South-West (SW) to North-East (NE) and West-South-West (WSW) to East-North-East (ENE) most of the hours during the year. The maximum speed wind observed is about 28km/hr.

Wind is responsible for dispersing pollutants from emission points to other points within the surrounding environment. Given the wind patterns observed, the study can deduce that residents living within the North-East (NE) and East-North-East (ENE) of Webuye town were most susceptible to pollution effects. However, since the study sites was mapped around a 10km radius of the emission site, the wind rose projects that the concentration again may be the same. Again, wind patterns indicate that wind rarely blows from the north to the south which is the direction of Kakamega from Webuye hence a justification of using Kakamega as a control site.

4.2 Pulp and paper mill emission concentration rates for pollutants

Pollutant concentration data is also a requirement in Gaussian plume modelling. Estimating concentration emission rates for pollutants under consideration required of meta-analysis of concentration data since primary data was not available.

This study did not have the advantage of emission measuring equipment or secondary data available from the same source courtesy of another study. To overcome this paucity, the researcher performed a meta-analysis for emission. Meta- analysis involved selecting studies which have been conducted in countries with high production of pulp and paper mill products.

To this end, the study identified seven studies conducted in fourteen sites from the years 1992- 2002. Studies included Pöyry (1992), conducted in the Nordic countries in pulp mills using Kraft technology. Girard and Jaegel (1994) conducted a case study of the Samoa Pulp mill. Laplante and Rilstone (1996), surveyed several Kraft mills operating in Canada especially in the Quebec area. Salo (1999) surveyed Kraft mills in Austria while Hekkert (2002) surveyed Western Europe state in Belgium, Netherlands and France. The study by Tarnawski (2004) was included though it was conducted outside the time frame because it was conducted on old Kraft mills and also because it allowed the consideration of Poland as one of the leading world producers of pulp and paper. Studies from other countries in the same league were not available. This study however notes that studies were only available in those countries which soon after regulated Kraft pulp and paper milling, meaning that the studies were actually precursor to the regulation process. The studies used, the country surveyed or the mill studied where applicable are tabulated in table 1 below.

In which case, it can be observed that monthly pollutant emission rates in maximum micrograms per cubic meter (μg/m3) for all the mills considered were relatively high for sulphur dioxide (SO2), Oxides of nitrogen (N2/NO2), and Particulate Matter (PM10) compared to limits prescribed by EPA. Means of the various pollutants are also presented in the table 1 and are observed to be higher than the limits by EPA and European Union(EU). In respect to PM10 the mean pollution rate was found to be more than twice the minimum limits by both EPA and EU.

These findings indicate that irrespective of the location of the mill, Kraft pulp and paper milling is a chronic pollutant emitting high levels of micrograms per cubic meter for pollutants under consideration. The means available from this analysis are considered credible for further modelling of ambient air quality in the study sites.

Questions concerning whether air pollution and health studies performed in industrialized countries are appropriate for use in developing countries have been raised (Bell et al., 2002). While a growing number of reports from several developing countries confirm that air pollutants such as PM and SO2 are associated with mortality and illness, with parallel health responses in other nations, there may be differences in the populations, healthcare systems, and nature of pollution. For example, the levels of pollution in the study site may be outside the range of concentrations examined in the original study, and the surviving populations in developed and developing countries may differ in important ways. Thus, locally conducted studies were given highest priority.

4.3 Mean study site emission rates for pollutants

Using Gausian Plume model applied, the study modelled the mean emission rate sulphur dioxide (SO2); Particulate Matter (PM10) and Oxides of Nitrogen (NO2) measured in micrograms per cubic metre (μg/m3) in the study site comprising of four locations- Chimoi, Lugulu, Matisi and Webuye Town. Data inputs used to for modelling was height of the stack in units of meters; Emission rate (the amount of gas coming out of the stack, in units of grams per second); Gas exit velocity (the speed of the gas as it comes out of the stack, in meters per second) which were obtained as secondary data from the paper milling factory. Ambient temperature (the temperature of the surrounding air, in degrees Celsius) and the atmospheric stability condition of 1-6 measure of the meteorology of the surrounding air.

The results are shown in table 2 below. The mean emission rates are shown and the respective standard deviation with the highest means being that of Webuye town at 47.9052µg/m3. The frequency is given as 8 signifying the 8 quarters from which the data was estimated.

These results indicate that the highest emissions of all the three pollutants ((SO_2; PM10 & NO_2) were experienced in Webuye town a finding that can be attributed to the proximity to the pollution source or the paper mill. Chimoi recorded the lowest mean emission rate which could be attributed to the wind direction in respect to the pollution source. The low standard deviation reported indicates that sulphur dioxide emission concentration is fairly evenly distributed within the four locations composing the study site.

4.4 Hypothesis testing difference between means for emissions in study sites

The study intended to determine whether emission characteristics in the locations making the study site were same or different in respect to the mean. In respect to this, the study tested the null hypothesis H0: $\bar{x}K=\bar{x}L=\bar{x}M=\bar{x}W$, (where $\bar{x}K$ is emission mean for Chimoi and so on) using one way ANOVA. The resultant *p* value was compared with $\alpha=0.05$ in which case, the null hypothesis would be accepted in if p value was greater than α and vice versa. The results are presented in table 3.

The p value of 0.1102, 0.201 and 0.112 were derived respectively. This indicates that the means difference in all cases are not significant at 5% level of significance. Hence the null hypothesis is accepted. Hence the study finds that emission characteristics of Sulphur dioxide (SO_2); Particulate Matter (PM10) and Oxides of Nitrogen (NO_2 are uniform across the various study sites within Webuye and its environs.

4.5 Hypothesis testing between the means of study site and control site

To determine whether the ambient air quality in Webuye and its environs was significantly different from the control site, the study performed a one tail student t test on the mean concentration for the pollutants of study sites(ss) and control site (cs). The hypothesis tested was stated as:

$$\mathbf{H0: : \bar{x}ss=\bar{x}cs; \quad H1: : \bar{x}ss>\bar{x}cs.}$$

The results of the test are given in table 4.

The mean concentration levels for the pollutants were much lower for the control site in comparison to the study sites. In some case such as particulate matter and oxides of nitrogen, the means for study sites are observed to be almost twice as much of those estimated in the control site.

When the pollution concentration levels are tested for the difference between study sites and control sites, the study find that for all the three pollutant, when tested at 5% significance level, the p values as indicated in table 4 above are below the significance level. This means that the null hypothesis is rejected. The study finds that there is a significance difference between the mean pollutant concentrations between control site and study sites. This could be attributed to three factors. Distance from the polluting mill, the wind direction and the buffer between the polluting industry and the control site offered by Kakamega forest.

The study found that the mean emission rate for sulphur dioxide for Webuye town as 47.9052 µg/m3. This is about ten times the allowed emission rates by EPA and BAT whose range given is 4.0-8.0 µg/m3 in both cases. This goes to show the severity of sulphur dioxide emissions in the study sites. Further, these findings report much higher concentrations than those reported by Routledge et al, (2006) who found mean exposure in London and Birmingham to be 31.4 µg/m3 for the period 2000-2006. Considering that these cities are industrial with multiple industrial emitters during the said period, then our study serves to show the severity of unabated pollution. The perilous nature of pulp and paper milling conditions even in developed economies has however been confirmed the range of studies by Rich et al, (2005) who found SO_2 emission rate to be 44.2 µg/m3 in Boston and Dockery (1993) who found SO_2 emission rates in some selected cities in the US to be 39.5 µg/m3. The findings however pale in comparison to emission rates of sulphur dioxide reported by Filleul et al (2005) in urban cities with high traffic in France such as Bordeaux between the periods 1971-1976 and in Shangai according to Chit-Ming (2008). This means that some urban populations around the world face as much pollution danger as residents of Webuye at the time of the study.

As regards to Particulate Matter (PM10), the mean emission rate for Webuye town was estimated at 102.171 µg/m3. This is about three times the allowed emission rates by EPA and BAT whose range given is 40.0 µg/m3 in both cases. This goes to show the severity of Particulate Matter pollution in the study sites. These findings further indicate that emission rates observed were in some instances twice or three times as much as those reported by Shah, et al (2013) based on median PM10 concentrations in the US. This levels are incomparable to findings by Miller et al, (2007) who found that in some metropolitan cities in the US overall median concentration of particle pollution were as low as 13.4 µg per cubic meter for the period 1994-1998. Similar observations have been made by Lippmann et al, (2000); Evans et al, (2013) and Forastiere et al, (2008) and Wellenius (2006). Conversely, similar or higher levels have been reported in Chinese cities of Wahun and Shanghai by Wong et al, (2008) yet the ascription of such levels to high atmospheric temperatures remains to be seen in Webuye whose temperatures as explained above are relatively mild.

With regard to mean emission rate for Oxides of Nitrogen (NO2) for Webuye town was found to be 66.1μg/m3. This is about two times the allowed emission rates by EPA and BAT lower limit given is 30 μg/m3 for both regulators. This goes to show the harshness of oxides of Nitrogen emissions in the study sites.Again, these results indicate that the highest emissions of oxides of Nitrogen was experienced in Webuye town a finding that can be attributed to the proximity to the pollution source or the paper mill. These findings are consistent with the findings of Shah et al, (2013) who found that nitrogen oxide was 77.1 μg/m3 as well as Hong et al. (1999) and Wong et al. (2001) but are 2 times as much Bakian et al (2015) study of salt lakecity county. The high levels observed in this study can be conjectured to have arisen from combustion in the kiln and digester which again is in tandem to findings by Samoli (2006) who attributed rising NO2 in European cities to increased use of diesel combusted motor vehicles.

5. Conclusions and recommendations

The study established that the Paper Mills emits toxic gases such as sulphur dioxide (SO2), Nitrogen Oxide (NO), and particulate matters (TP10). The study concludes that there is no significant difference between emissions levels in Webuye town and the neighbouring locations of Chimoi, Lugulu and Matisi. Further, the study concludes that there was a significant difference in emission levels of Webuye environs compared to those of Kakamega town which was used as a control site. The study conjectures that this is due to wind direction and the buffer provided by Kakamega forest.

From the study findings it is clear that either the Webuye Pan Paper mills emissions are in excess of the sustainable emissions. This implies that either the mitigation measures are not enough or the technology in use is outdated. Therefore, there is need to lay out emission standards and improve on monitoring of the same. The penalty for lack of adherence should be strictly implemented and should be based on the surrounding community's' total willingness to pay to avoid the effects of pollution.

The study notes that industrial pollution in Kenya is not limited to the study cite delved into by this study. The study therefore recommends that an industrial national pollution standard be established in industrial zones. Further, such standard should be monitored through a pollution monitoring centre as part of standards enforcement.

References

Bayer-Oglesby, L., Grize, L., Gassner, M., Takken-Sahli, K., Sennhauser, F. H., Neu, U., ... & Braun-Fahrländer, C. (2005). Decline of ambient air pollution levels and improved respiratory health in Swiss children. Environmental health perspectives, 113(11), 1632.

Bordado, J. C., & Gomes, J. F. (2003). Emission and odour control in Kraft pulp mills. Journal of Cleaner Production, 11(7), 797-801.

Brown, L. H., Buettner, P. G., Canyon, D. V., Mac Crawford, J., & Judd, J. (2012). Estimating the life cycle greenhouse gas emissions of Australian ambulance services. Journal of cleaner production, 37, 135-141.

Cetecioglu, Z., Ince, B., Orhon, D., & Ince, O. (2012). Acute inhibitory impact of antimicrobials on acetoclastic methanogenic activity. Bioresource technology, 114, 109-116.

Chameides, W. L., Lindsay, R. W., Richardson, J., & Kiang, C. S. (1988). The role of biogenic hydrocarbons in urban photochemical smog: Atlanta as a case study. Science(Washington), 241(4872), 1473-1475.

Cheremisinoff, N. P., & Rosenfeld, P. (2010). Handbook of Pollution Prevention and Cleaner Production Vol. 3: Best Practices in the Agrochemical Industry (Vol. 3). William Andrew.

Chen, H. W., Hsu, C. H., & Hong, G. B. (2012). The case study of energy flow analysis and strategy in pulp and paper industry. Energy Policy, 43, 448-455.

Dockery, D. W., Pope, C. A., Xu, X., Spengler, J. D., Ware, J. H., Fay, M. E., ... & Speizer, F. E. (1993). An association between air pollution and mortality in six US cities. New England journal of medicine, 329(24), 1753-1759.

Elaw impact (2007)Winning Clean Air for Kenya | ELAW https://elaw.org/winning-clean-air-for-kenya

EPA Office of Compliance Sector Notebook Project. Profile of the Pulp and Paper Industry. 2nd ed. Washington, November 2002.

Girard, K., & Jaegel, A. (1994). Closed-Cycle Totally Chlorine Free Bleached Kraft Pulp Production At Louisiana Pacific's Samoa Pulp Mill.

Guttikunda, S. K., & Gurjar, B. R. (2012). Role of meteorology in seasonality of air pollution in megacity Delhi, India. Environmental monitoring and assessment, 184(5), 3199-3211.

Hekkert, M. P., van den Reek, J., Worrell, E., & Turkenburg, W. C. (2002). The impact of material efficient end-use technologies on paper use and carbon emissions. Resources, conservation and recycling, 36(3), 241-266.

Hubacek, K., Guan, D., Barrett, J., & Wiedmann, T. (2009). Environmental implications of urbanization and lifestyle change in China: Ecological and water footprints. Journal of Cleaner Production, 17(14), 1241-1248.

Ince, B. K., Cetecioglu, Z., & Ince, O. (2011). Pollution prevention in the pulp and paper industries. In Environmental Management in Practice. InTech.

Ivy, D., Mulholland, J. A., & Russell, A. G. (2008). Development of ambient air quality population-weighted metrics for use in time-series health studies. Journal of the Air & Waste Management Association, 58(5), 711-720.

Laplante, B., & Rilstone, P. (1996). Environmental inspections and emissions of the pulp and paper industry in Quebec. Journal of Environmental Economics and Management, 31(1), 19-36.

Monn, C., Oglesby, L., Künzli, N., Schindler, C., Ackermann-Liebrich, U., Leuenberger, P., & SAPALDIA Team. (2000). Validity of annoyance scores for estimation of long term air pollution exposure in epidemiologic studies: the Swiss Study on Air Pollution and Lung Diseases in Adults (SAPALDIA). American Journal of Epidemiology, 152(1), 75-83.

Næss, Ø., Nafstad, P., Aamodt, G., Claussen, B., & Rosland, P. (2006). Relation between concentration of air pollution and cause-specific mortality: four-year exposures to nitrogen dioxide and particulate matter pollutants in 470 neighborhoods in Oslo, Norway. American journal of epidemiology, 165(4), 435-443.

NCASI, (1994) Alternatives for management of pulp and paper industry by-products: Production of ethanol. Tech. Bull. No. 685. National Council for Air and Stream Improvement, Inc.

Nowak, D. J., Hirabayashi, S., Bodine, A., & Greenfield, E. (2014). Tree and forest effects on air quality and human health in the United States. Environmental Pollution, 193, 119-129.

Nowak, D. J., Civerolo, K. L., Rao, S. T., Sistla, G., Luley, C. J., & Crane, D. E. (2000). A modeling study of the impact of urban trees on ozone. Atmospheric environment, 34(10), 1601-1613.

Mulaku,C., and Kariuki, L. W. (2001) Mapping and Analysis of Air Pollution in Nairobi, Kenya International Conference on Spatial Information for Sustainable Development Nairobi, Kenya 2–5 October 2001

Odhiambo, J. A., Mungai, M. W., Gicheha, C. M., Nyamwaya, J. K., Karimi, F., Macklem, P. T., & Becklake, M. R. (1998). Urban-rural differences in questionnaire-derived markers of asthma in Kenyan school children. European Respiratory Journal, 12(5), 1105-1112.

Omanga, E., Ulmer, L., Berhane, Z., & Gatari, M. (2014). Industrial air pollution in rural Kenya: community awareness, risk perception and associations between risk variables. BMC public health, 14(1), 377.

Ongoma, V., Otieno, G., & Onyango, A. O. (2014). An investigation of the transport and dispersion of atmospheric pollutants over Nairobi City. Journal of Environment and Agricultural Sciences, 110.

Panwar, R., Rinne, T., Hansen, E., & Juslin, H. (2006). Corporate responsibility: balancing economic, environmental, and social issues in the forest products industry. Forest Products Journal, 56(2), 4-13.

Patel, M. M., Quinn, J. W., Jung, K. H., Hoepner, L., Diaz, D., Perzanowski, M., ... & Miller, R. L. (2011). Traffic density and stationary sources of air pollution associated with wheeze, asthma, and immunoglobulin E from birth to age 5 years among New York City children. Environmental research, 111(8), 1222-1229.

Pokhrel, D., & Viraraghavan, T. (2004). Treatment of pulp and paper mill wastewater—a review. Science of the total environment, 333(1), 37-58.

Puett, R. C., Hart, J. E., Yanosky, J. D., Spiegelman, D., Wang, M., Fisher, J. A., ... & Laden, F. (2014). Particulate matter air pollution exposure, distance to road, and incident lung cancer in the Nurses' Health Study cohort. Environmental health perspectives, 122(9), 926.

Pöyry Jakkoo. (Pöyry Magazine January 1992, World paper markets, page 6-7)

Raaschou-Nielsen, O., Hertel, O., Thomsen, B. L., & Olsen, J. H. (2001). Air pollution from traffic at the residence of children with cancer. American journal of epidemiology, 153(5), 433-443.

Staudt, J. (2010, March). Costs of emission control technologies. In Jim Staudt, ICAC-LADCO Meeting, Chicago.

Silva, L. T., & Mendes, J. F. (2012). City noise-air: an environmental quality index for cities. Sustainable Cities and Society, 4, 1-11.

Schauer, J. J., Rogge, W. F., Hildemann, L. M., Mazurek, M. A., Cass, G. R., & Simoneit, B. R. (1996). Source apportionment of airborne particulate matter using organic compounds as tracers. Atmospheric Environment, 30(22), 3837-3855.

Smook, G.A., 1992. Handbook for Pulp and Paper Technologists, vol. 11, second ed. Angus Wilde Publications, pp. 163–183.

Sumathi, S., & Hung, Y. T. (2006). Treatment of pulp and paper mill wastes. Waste treatment in the process industries, 453-497.

Taha, H. (1996). Modeling impacts of increased urban vegetation on ozone air quality in the South Coast Air Basin. Atmospheric Environment, 30(20), 3423-3430.

Tarnawski, W. (2004). Emission factors for combustion of biomass fuels in the pulp and paper mills. Fibres and Textiles in Eastern Europe, 12(3), 91-95.

Thompson, G., Swain, J., Kay, M., & Forster, C. F. (2001). The treatment of pulp and paper mill effluent: a review. Bioresource technology, 77(3), 275-286.

Thurston, G. D., Ito, K., & Lall, R. (2011). A source apportionment of US fine particulate matter air pollution. Atmospheric Environment, 45(24), 3924-3936.
Viana, M., Querol, X., Alastuey, A., Gil, J. I., & Menéndez, M. (2006). Identification of PM sources by principal component analysis (PCA) coupled with wind direction data. Chemosphere, 65(11), 2411-2418.
Xu, J., Ma, J. Z., Zhang, X. L., Xu, X. B., Xu, X. F., Lin, W. L., ... & Ma, Z. Q. (2011). Measurements of ozone and its precursors in Beijing during summertime: impact of urban plumes on ozone pollution in downwind rural areas. Atmospheric Chemistry and Physics, 11(23), 12241-12252.
Zeka, A., Zanobetti, A., & Schwartz, J. (2005). Short term effects of particulate matter on cause specific mortality: effects of lags and modification by city characteristics. Occupational and Environmental Medicine, 62(10), 718-725.
Zhao, Y., Wang, S., Nielsen, C. P., Li, X., & Hao, J. (2010). Establishment of a database of emission factors for atmospheric pollutants from Chinese coal-fired power plants. Atmospheric Environment, 44(12), 1515-1523.

Table 1. The capitals, assets and revenue in listed banks

	Total capital stock	Income of main business	Total assets
Pudong Development Bank	39.2	214.7	5730.7
Bank of China	459.4	3345.7	59876.9

Description for the above table.

Table 1: Pulp and paper emission concentration rates for pollutants

Study	Mill/ Country	Monthly Pollutant emission rate Max µg/m3		
		Sulphur dioxide (SO_2)	Oxides of nitrogen (N_2/NO_2)	Particulate MatterPM_{10}
Pöyry (1992)	Finland	32.8	73.3	89.65
	Sweden	32.3	66.8	88.7
	Norway	33.9	69.3	82.9
Girard and Jaegel, (1994)	Samoa pulp mill	41.2	66.5	96.13
NCASI (1994)	US	42.1	69.1	80.41
Laplante and Rilstone (1996)	Cascades East Angus inc., East Angus	38.6	71.4	87.15
	Emballages Smurfit-Stone Canada inc., La Tuque	40.2	69.8	89.39
	Papiers Fraser inc., Thurso	39.2	67.1	83.3
	Spexel inc., Beauharmois	37.7	69.9	84.71
Salo(1999)	Austria	39.4	70.4	79.51
Hekkert (2002)	Belgium	39.9	66.9	81.92
	Netherlands	40.5	68.2	83.4
	France	41.3	62.8	82.5
Tarnawski (2004)	Poland	41.7	69.7	84.9
Mean		38.63	68.66	85.33
Std. Deviation		3.30	2.64	4.64
EPA (US)		4.0-7.0	30.0-35.5	40.0-70.2
BAT(EU)		4.0-8.0	32.0-36.0	30-75

Table 2: Mean study site emission rates pollutants in µg/m3

	Sulphur dioxide (SO_2)		Particulate Matter (PM_{10})		Oxides of Nitrogen (NO_2)		
Study site	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	n
Chimoi	41.7881	2.2264	92.0531	3.8730	64.9	.25358	8
Lugulu	44.3862	2.57801	86.9562	4.4846	65.2	.29361	8
Matisi	43.9875	2.3436	78.6875	4.0769	65.8	.2669	8
Webuye town	47.9052	2.7655	102.171	4.8107	66.1	.3149	8

Table 3: Hypothesis testing difference between mean for emission in study sites

Analysis of Variance					
Sulphur dioxide (SO_2) emission					
Source	SS	df	MS	F	Prob > F
Between groups	20.241309	3	6.74710301	84.08	0.1102
Within groups	2.24681916	28	.080243542		
Total	22.4881282	31	.72542349		
Particulate Matter (PM_{10}) emission					
Source	SS	df	MS	F	Prob > F
Between groups	5907.63348	3	1969.21116	105.20	0. 201
Within groups	524.139325	28	18.7192616		
Total	6431.77281	31	.72542349		
Oxides of Nitrogen (NO_2) emission					
Source	SS	df	MS	F	Prob > F
Between groups	490.303759	3	163.434586	26.42	0.122
Within groups	173.207706	28	6.18598949		
Total	663.511464	31	21.4035956		

Table 4: Hypothesis testing between the means of study site and control site

	Sulphur dioxide SO_2	Particulate Matter PM_{10}	Oxides of nitrogen NO_2
n	40	40	40
Mean-ss	42.451406	91.075	63.595
Mean cs	33.575	40.467	32.51678
SE	.304624	6.744094	1.964928
df	38	38	38
t	-19.2907	-19.4934	-17.4292
p value	0.0000	0.0000	0.0000

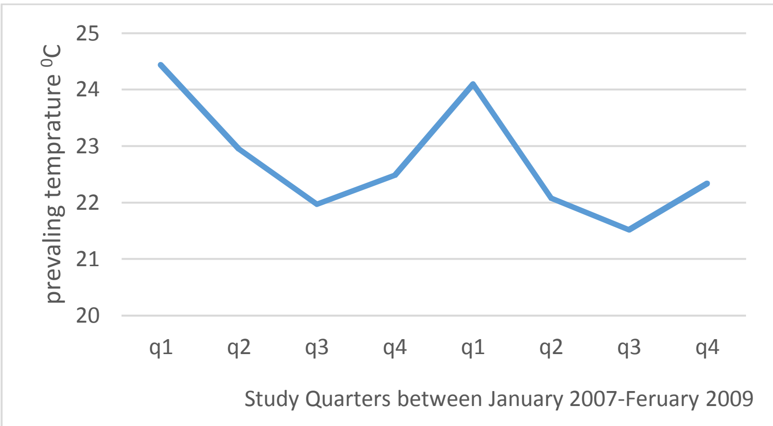

Figure 1(a): Prevailing temperature in Webuye and its environs

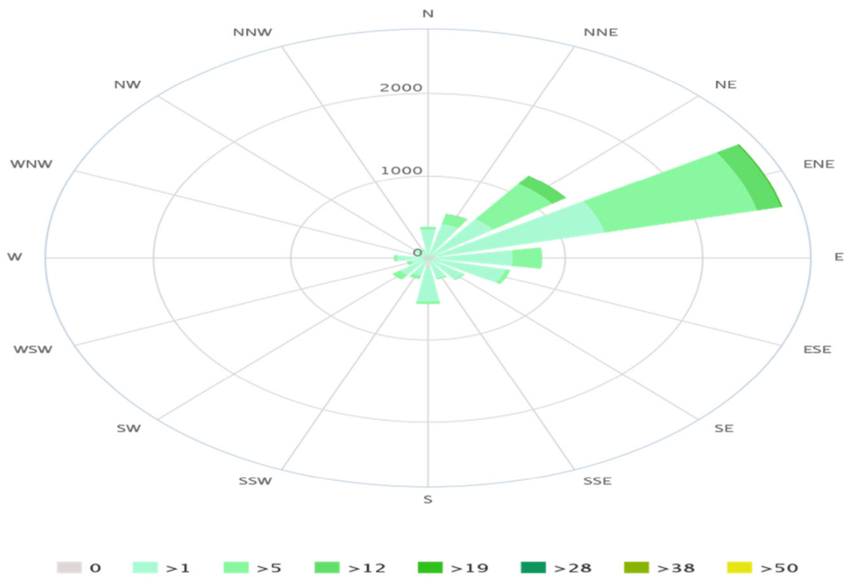

Figure 1(b) Wind speed and directions for Webuye and its Environs