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THE EFFECT ASSESSMENT OF INDUSTRIAL ACTIVITIES ON AIR POLLUTION AT CIMERWA AND ITS SURROUNDING AREAS, RUSIZI-DISTRICT-RWANDA

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ABSTRACT

In the last three decades, considerable efforts to protect people from ambient air pollutants exposure have been made. However, vulnerable populations groups, including the elderly, children, and pregnant women, and other people present with respiratory problems are most concern as their immune system is weak. The main aim of this paper was to assess the effect of industrial activities on air pollution at CIMERWA Cement factory, one of the biggest industries in Rwanda and its surrounding areas. Portable air quality sensors (Pockets $PM_{2.5}$ Sensors) were used for monitoring the concentration levels of $PM_{2.5}$ and PM_{10}. Questionnaire method was also used for investigating the presence and potential sources of pollution across the site. Survey results indicated that dust; noise pollution and Particulate Matter come up as the main pollutants in the areas where industrial activities and vehicle emissions are the potential sources. Sampling activities showed that the average concentration levels of $PM_{2.5}$ are in range of 28.0–32.0µg/m^3 during morning hours and 46.0-50.0µg/m^3 during evening hours while that of PM_{10} are in range of 51.0-55.0µg/m^3 and 69.0-73.0µg/m^3 during morning and evening hours respectively. Results showed that air pollutants were present around the considered area that is why the appropriate mitigation and management strategies concerning these pollutants were highly recommended as the contribution of this paper.

Contribution/Originality: This study is one of very few studies which have investigated the effects of industrial activities on air pollution in Rwanda.

1. INTRODUCTION

Particulate Matters, the complex mixture of small particles and liquid droplets are completed with organic chemicals; metals; acids and dust particles. They are taken as among the major common air pollutant of concern (Defra, 2008; GBD, 2017; Lee et al., 2002; Seinfeld & Pandis, 2006; WHO, 2016). With aerodynamic diameters Particulate Matters are classified into two types that are: $PM_{2.5}$ which are particles which are less than or equal to 2.5 µm (micrometers) in diameters and PM_{10} which are also particle that are 10micrometer in diameter or less (Pugliese, Murphy, Geddes, & Wang, 2014; Seinfeld & Pandis, 2006; WHO, 2016). Most common known source of Particulate Matters is both human activities and natural process. Between $PM_{2.5}$ and PM_{10} particulate matters, $PM_{2.5}$ pollutants are very hazardous pollutants to human health, due to their capacity of penetrating to lungs then continue entering the blood stream (Biggs & Graves, 1962; Coker & Kizito, 2018; Dockery, 2009; Geddes, Murphy, & Wang, 2009; Halonen et al., 2009; Hayden et al., 2011; Krewski, 2009; Pope, Ezzati, & Dockery, 2009; Pugliese et al., 2014; WHO, 2014, 2018). Several research about Particulate Matter indicated that personal exposure to Particulate Matters is associated with well documented long-term and short-term human health effects (Biggs & Graves, 1962; Coker & Kizito, 2018; Dockery, 2009; Halonen et al., 2009; Krewski, 2009; Pope et al., 2009). Current Particulate Matters are taken as an important point of concern in developing countries due to its health effects. In Rwanda, present few studies concerning air quality showed that Particulate Matters, Sulfur Oxides (SO_x); Nitrogen Oxides (NO_x) and Ozone (O_3) are the most pollutant of disquiet in country. Whereas the majority of air pollution emissions in country came from transport sector including vehicle emissions; manufacturing industrial activities such as cement, and steel mills; quarrying activities which introduce dust in air; domestic cooking; soil-blown dust: and waste combustion (Elisephane, 2019; Nduwayezu, Ishimwe, Niyibizi, & Ngirabakunzi, 2015; Rema, 2018). In this Paper the main objective was focused on the effect assessment of the industrial activities on air pollution at CIMERWA cement factory one of the biggest industries in Rwanda and its surrounding areas.

2. MATERIAL AND METHODS

2.1. Study Area Description

The cement factory, called Ciment du Rwanda Limited (CIMERWA) is among the biggest industries in Rwanda. It is located in Shala-Muganza Sector; Rusizi-District of Western Province of Rwanda. The following Figure 1 illustrates the location of the factory in Rwanda.

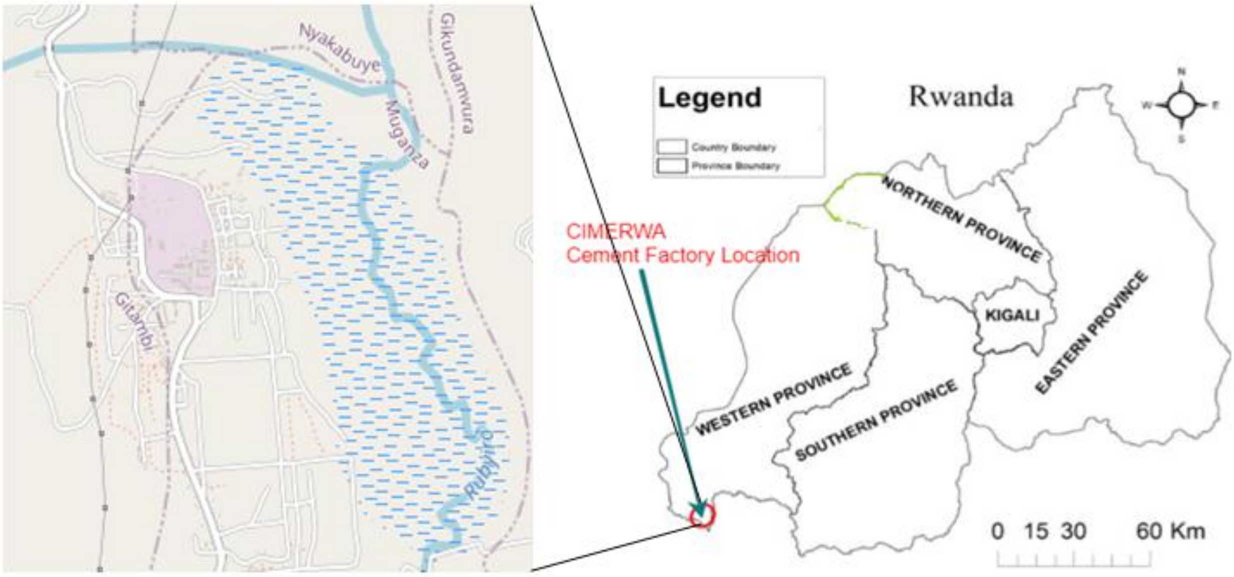

Figure-1. This map indicating the location of the CIMERWA Cement Factory location in Rwanda.

This factory is located also at 02º36'25"S, 29º01'03" E geographical coordinate. The surrounding areas of this factory have many living populations; infrastructures like churches; hospitals; Secondary and Primary schools Figure 2; evening market and common economic centre known as CIMERWA Figure 3. The main economic activities present in this center are transports (where there is a paved road joining this centre and Bugarama centre and also Kamembe centre (City of Rusizi-District)) and Trading activities. In its surrounding also there is trucks station Figure 3 where cement factory distribution trucks used to park.

Figure-2. CIMERWA Cement factory and Primary school pictures captured during sampling activities using ASUS smart phones used in data collection, these pictures also show the presence of people living houses in factory's surrounding areas.

Figure-3. Pictures of evening market with blue iron sheet followed by the north side of the factory (that is in RUNANIRA and KABARORE cells) with many people's houses and trucks station near trading centre.

2.2. Data Collection and Analysis

This research was conducted from the starting of July-2019 to January-2020. Where the first two months (July and August of 2019) was the period of questionnaire method, this later a sample of 80 respondents including people living in factory surrounding areas and factory workers were invited to answer question-papers where all questions were based to investigate the presence of air pollutants in the areas before the starting of sampling activities.

By the starting of September-2019 to January-2020 was the period of Particulate Matter pollutants concentration levels monitoring using air quality portable monitors, Pocket $PM_{2.5}$ Sensors produced by Yaguchi Electric Co., Ltd., Miyagi, Japan. Principle of Pocket Sensor Module was shown in Figure 4a. The sensor has a laser LED (light-emitting diode), a PD (photodiode) sensor, a fan, amplifier, and USB (Universal Serial Bus) encoder. The sensor can generate log data in CSV (comma-separated values) of Google KML (Keyhole Markup Language) format including GPS (Global Positioning System). The portable sensor has to be connected to a smart phone with android system Figure 4b. The phone displays PM2.5/PM10 concentrations levels in microgram per cubic meter and phone screen color changes from blue, yellow, red, purple to black with increasing values of PM Figure 4c. The validity or specification of Pocket PM2.5 Sensor provided by Yaguchi Electric Corp. is expressed in Table 1. All Pocket PM2.5

Sensors were also calibrated with constantly observed PM2.5/PM10 counter (PM-712, Kimoto Electric Co., Ltd.) of Air Quality Research Station, National Institute for Environmental Studies (NIES), Tsukuba, Japan. Power requirement: Voltage: 4.7 ~ 5.3 V; Power supply: > 1 W and Supply voltage ripple: < 20 mV.

Figure-4. Pocket PM2.5 Sensor. **a)** Principle of Pocket PM2.5 Sensor Module, LED, light-emitting diode; PD photodiode; USB, Universal Serial Bus. **b)** Pocket PM2.5 Sensor connected to a smart phone with android system. **c)** Color variations for different levels of PM2.5 concentration.
Source : Yi et al. (2018).

Two well settled and calibrated sensors were used in this research, one was for morning hours from 6:00AM to 11:59AM and the other one was for evening hours from 2:00PM to 9:00PM local time. Figure 5 illustrates the state of Pocket, $PM_{2.5}$ Sensors in sampling activities.

Table-1. Specification of Pocket PM2.5 Sensor (Yaguchi Electric Corp.)

No	Item	Parameter
1	Measurement parameters	PM2.5 and PM10
2	Measurement range	0.0–999.9 µg /m3
3	Rated voltage	5 V
4	Rated cu□rent	60 mA ± 10 mA
5	Sleep current	< 4 mA laser and fan sleep
□	Temperature range	Storage environment: − 10 ~ + 50 ° C Work environment:− 20 ~ + 60 °C
7	Humidity range	Storage environment: max 90% Work environ□ent: max 70%
8	Air pressure	86 KPa ~ 11□ KPa
9	Corresponding time	1 s
10	Serial data output frequency	□ Hz
11	Minimum resolution of particle	< 0.3 µm
12	Counting yield	70%@0.3 µm 98%@0.5 µm
13	Relative error	Maximum of ± 15% and ± 10 µg/ m3 25 °□, 50%RH
14	Product size	42.5 × 32 × 24.□ (mm)

Source: Yi et al. (2018).

Figure-5. Pocket $PM_{2.5}$ Sensors and ASUS Smart Phones with android system used in data collection, USB cables used to link Pocket $PM_{2.5}$ Sensors and ASUS Smart Phones.
Source: This picture was captured during field sampling activities.

During February-2020, survey data-sets were statistically analyzed while field monitored data-sets were extracted and analyzed using statistical analysis by python programming language, where Figure 6 illustrate the version used.

Figure-6. Python 2.7.6 used in data analysis.

3. RESULTS AND DISCUSSIONS

3.1. Results from Survey

Figure 7; Figure 8; Figure 9 and Figure 10 indicates statistical survey results from a total of 80 respondents where 60 of them live in surrounding areas of the factory and 20 others work in the same factory.

Respondents indicate that the most pollutants present in the surrounding area of the factory are dusts and noise pollution Figure 7. The potential source of these pollutants they mentioned that industrial emissions and vehicle emission are the major source of pollutant in the site Figure 8.

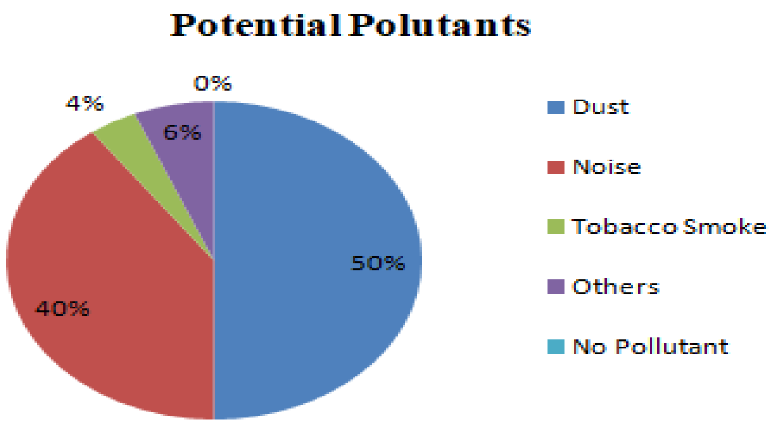

Figure-7. Investigating the potential pollutants in the factory surrounding areas dust and noise come up as the first pollutants.
Source: Data analysis.

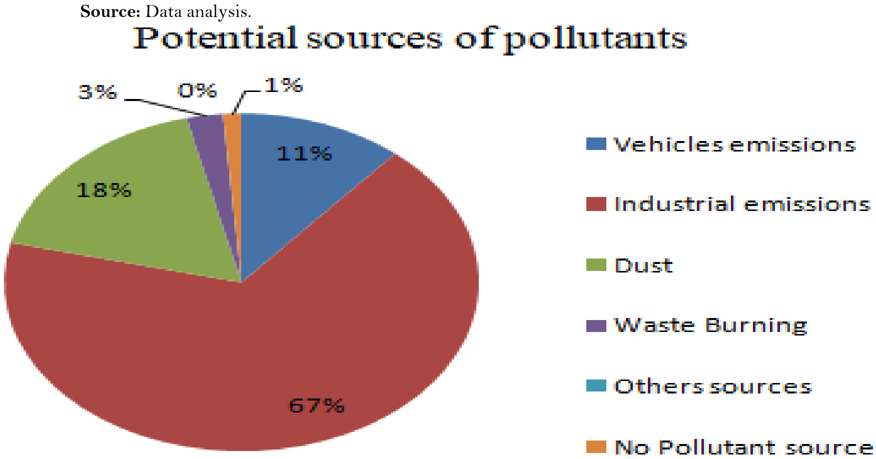

Figure-8. Investigating the potential source of pollutants in the factory surrounding areas where industrial and vehicle emissions are at the top of others.
Source: Data analysis.

Concerning health effects of pollutants knowledge assessment, respondent show that they know how air pollutants are very bad for human being and environment in general Figure 9. Based on that knowledge respondents suggested different options about the present air pollutant in the sites, where either people or the factory to shift from the area were the most of their concern Figure 10.

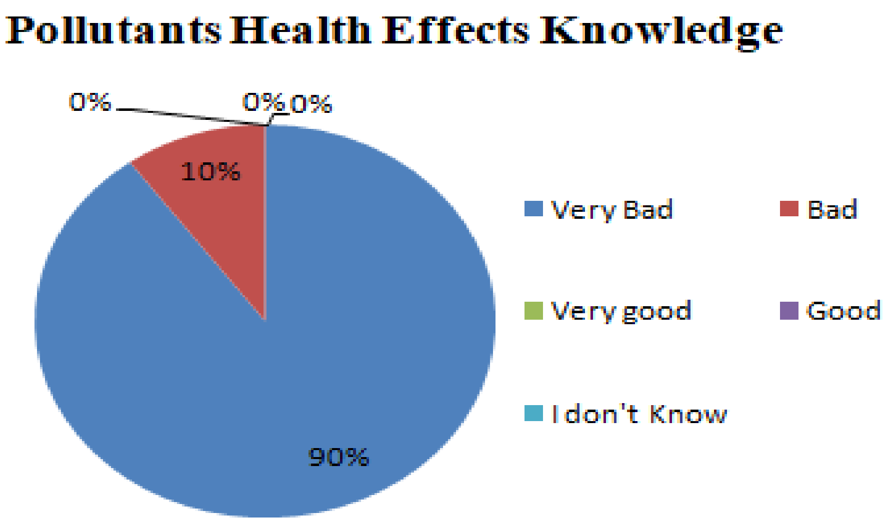

Figure-9. Investigating pollutant health effect knowledge in people living around the factory surrounding and factory workers.
Source: Data analysis.

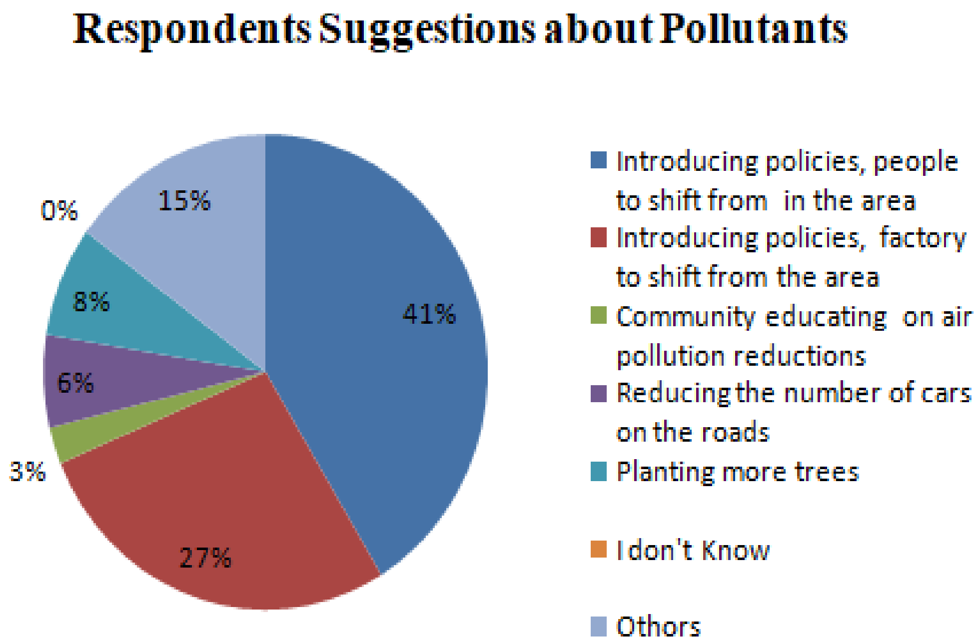

Figure-10. Investigating responding suggestions about pollutants in the factory surrounding.
Source: Data analysis.

3.2. Results from Field Sampling

All data sets collected from September-2019 to January-2020 were in two periods per day: morning and evening hours, where morning hours started at 6:00AM to 11:59AM and evening hours stared at 2:00 PM to 9:00 PM Rwanda local time whereas the sampling days were Monday, Wednesday, Friday and Sunday of a week. The considered areas were the surrounding of the factory, after sampling activities all data sets collected were statistically analyzed with respect to morning and evening hours Table 2.

Table-2. Particulate Matter monitoring statistical results during morning and evening hours sampling periods.

Sampling Time	Pollutants	Average range in µg/m3	Average value in µg/m3	Standard deviation
Morning hours	PM2.5	28.0 - 32.0	30.7	7.9
	PM10	51.0 - 55.0	53.2	8.4
Evening hours	PM2.5	46.0 - 50.0	48.5	8.0
	PM10	69.0 - 73.0	71.0	9.2

Source: Data analysis.

The bar-graph, representation of these results were made using python 2.7.6 where the standard deviation values are indicated by the small vertical lines in blue color and average values were represented by bars in red color Figure 11 and Figure 12.

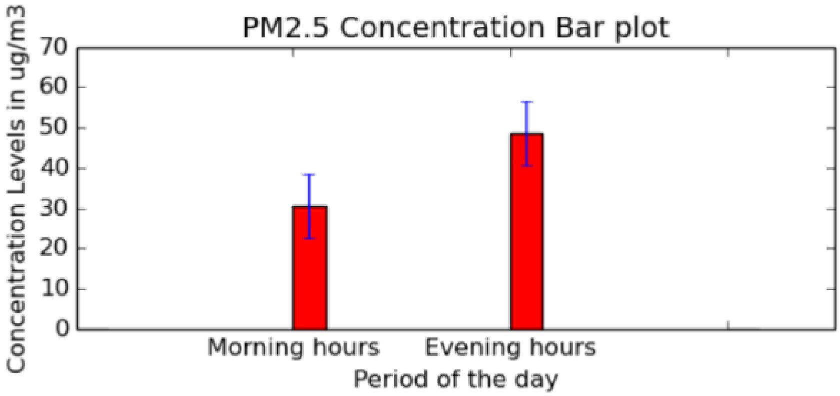

Figure-11. Concentration levels of $PM_{2.5}$ plot during morning and evening hours with its standard deviation. This figure was plotted from the averaged field data sets.
Source: Data analysis.

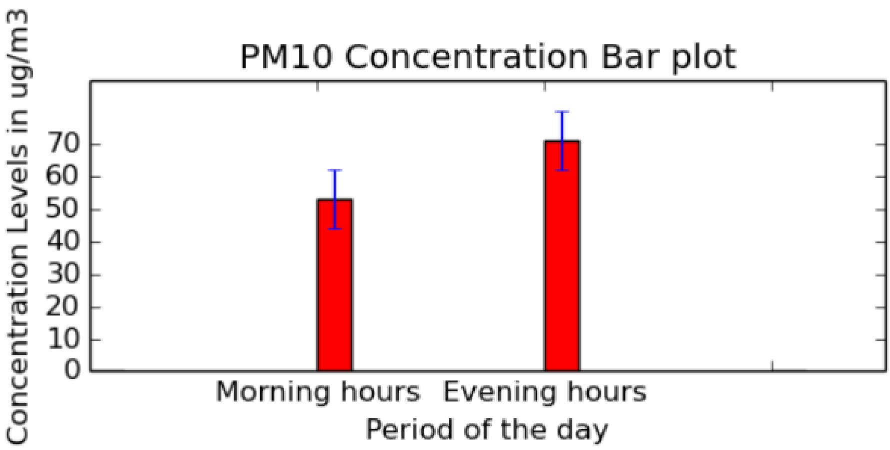

Figure-12. Concentration levels of PM_{10} plot during morning and evening hours with its standard deviation. This figure was plotted from the averaged field data sets.
Source: Data analysis.

These results indicates that the average values of $PM_{2.5}$ are low compared the values of PM_{10} for both periods morning hours and evening hours. Staring on $PM_{2.5}$ average values, results indicate that the pollution during morning is less than that of evening hours. The same case for PM_{10} pollutant concentration levels, during evening hours we have high levels compared to morning hours. The standard deviation is almost the same value which is 8 during morning hours and 9 during evening hours.

3.3. Pollutants Distribution around the Factory

During sampling activities in surrounding areas of the factory, data sets were recorded simultaneously with geographical coordinate of the exact location. Figure 13 and Figure 14 represents $PM_{2.5}$ concentration levels around the factory for a sample random walk during sampling activities. The $PM_{2.5}$ concentration levels for such walk are represented by different colors where each color stands for specific concentration range Table 3.

Table-3. Used color in Fig-12, indicating distribution of $PM_{2.5}$ concentration levels in factory surrounding for a random walk.

Colors	Range of $PM_{2.5}$ concentration levels in µg/m³
Green	0.0 - 15.4
Yellow	15.5 - 40.5
Orange	40.5 - 65.4
Red	65.5 - 150.4
Purple	150.5 - 250.4

Source: Data analysis.

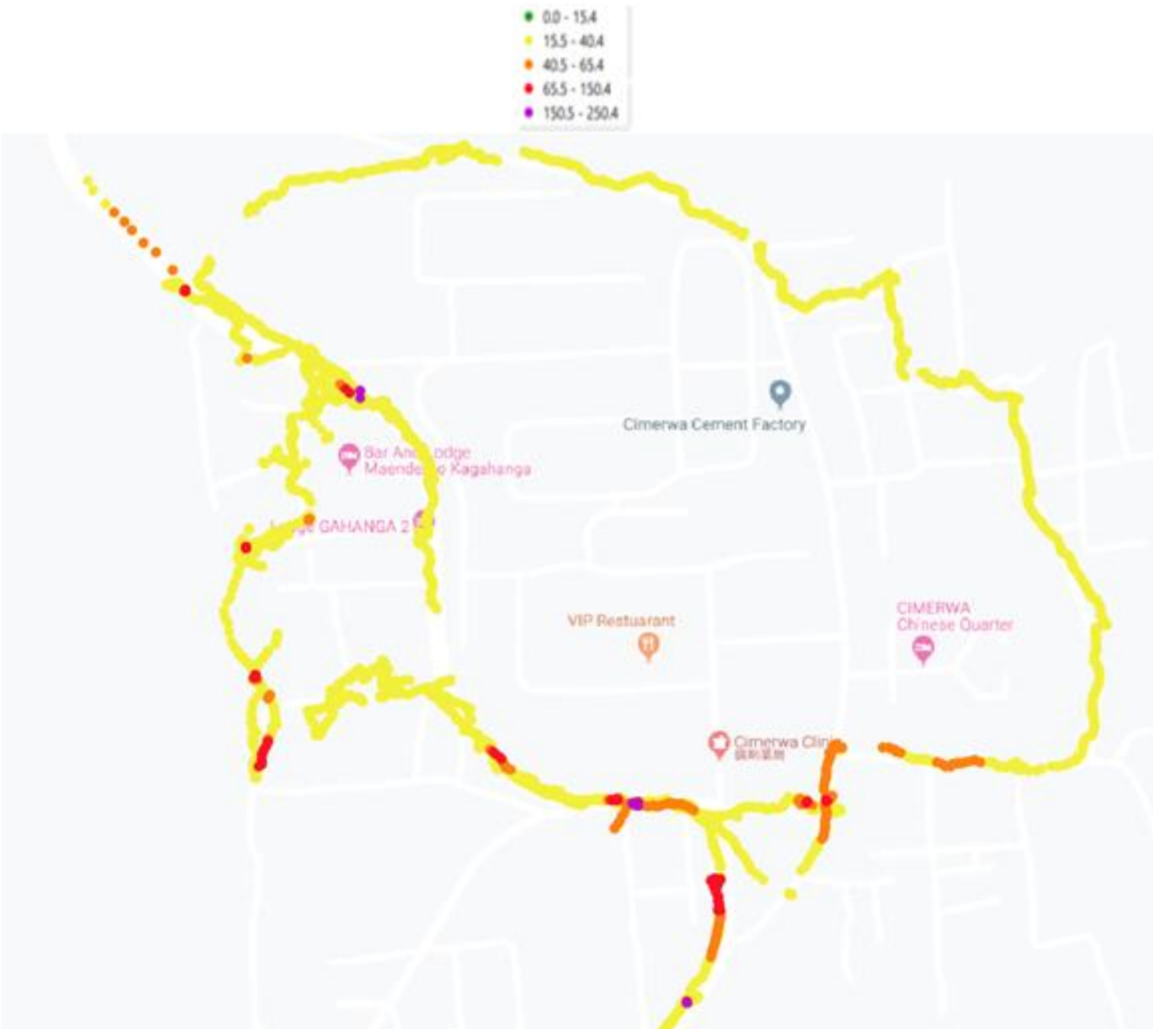

Figure-13. Distribution levels of $PM_{2.5}$ pollutant in factory surrounding areas for a random walk during sampling activities. The $PM_{2.5}$ concentration levels for such walk are represented by different colors Table-3. This Figure indicates that high level of $PM_{2.5}$ is located at CIMERWA Clinic and Lodge GAHANGA-2 and in the road from the factory to MASHESHA center.
Source: Data analysis.

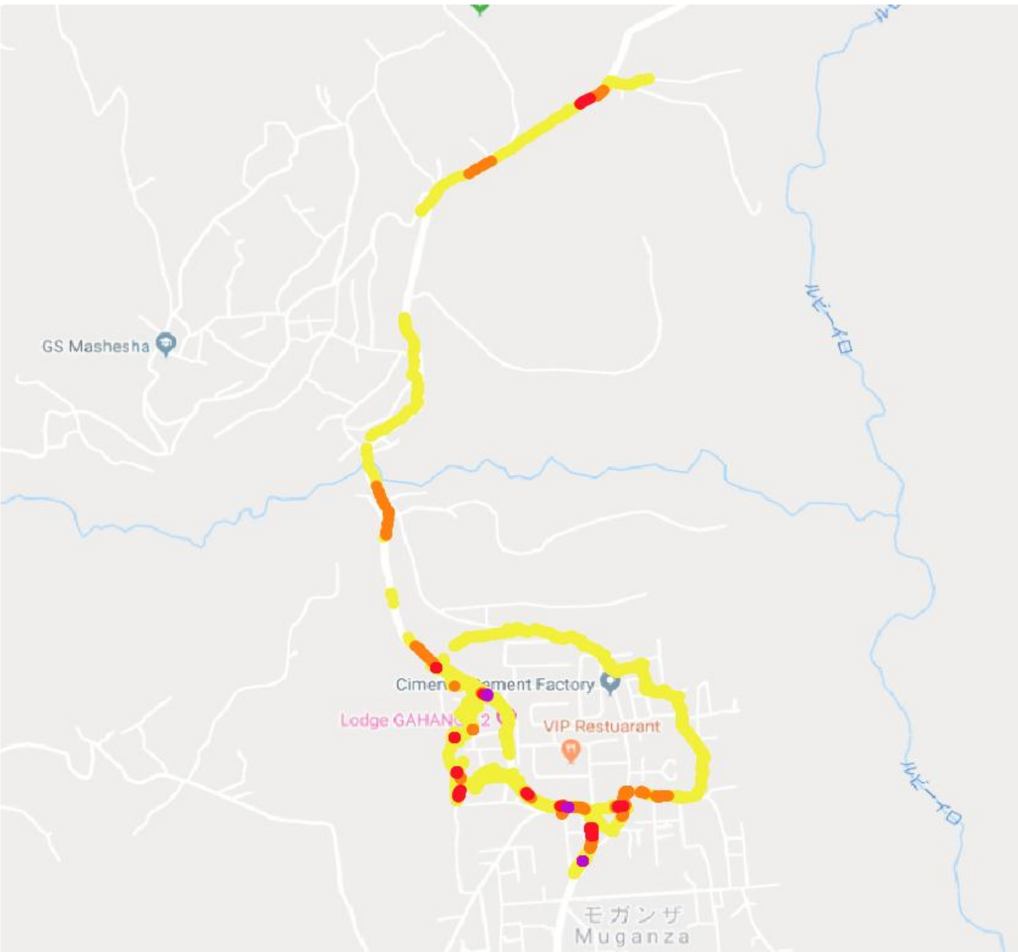

Figure-14. Distribution levels of $PM_{2.5}$ pollutant in factory surrounding areas for a random walk during sampling activities. The $PM_{2.5}$ concentration levels for such walk are represented by different colors Table-3. This Figure indicates that high level of $PM_{2.5}$ is located near VIP Restaurant and Lodge GAHANGA-2 and in the road from the factory to Muganza and Nyakabuye centers.
Source: Data analysis.

$PM_{2.5}$ pollutant distribution results in Figure 14 showed that, the East (near Lodge GAHANGA-2) and South-East (near VIP Restaurant to Muganza road) of the Cement factory indicate high levels of pollutant indicated by red and purple colors in Table 3 this could be influenced by the wind direction or the presence of car-parks across the area. This is also the same case in unpaved-road from the factory to Nyakabuye sector where factory vehicles are responsible for such emissions. Figure 13 indicates low level of $PM_{2.5}$ pollutant in North direction of the factor represented by yellow color in Table 3 this can be due to wind direction or geographical state, the place which is a hill.

4. CONCLUSION

This effects assessment of Cement factory activities on air pollution (CIMERWA) and its surrounding areas research conclude that dusts; particulate matter and noise pollution are main pollutants present in the area whereas factory and vehicle emissions are their potential sources. Measurements show that average range concentration levels of $PM_{2.5}$ pollutant during morning and evening hours are 28.0-32.0 $\mu g/m^3$and 46.0-50.0 $\mu g/m^3$ respectively while that of PM_{10} pollutant during morning and evening hours are 51.0-55.0 $\mu g/m^3$ and 69.0-73.0 $\mu g/m^3$. This indicates that for both $PM_{2.5}$ and PM_{10} results are beyond the World Health Organization guidelines (10.0$\mu g/m^3$ for $PM_{2.5}$ and 20.0$\mu g/m^3$for PM_{10}). Hence several researches in the same area for specific quantification of dust and noise pollution levels and others pollutants; the use of mask for factory workers; people's shift from the factory surrounding to other location would be our recommendations from the present research.

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