URBAN CLIMATE AND AIR POLLUTION IN KIGALI, RWANDA

Sascha Henninger*
Technical University of Kaiserslautern, Dept. of Physical Geography, Germany

Abstract

Rwanda is a landlocked republic in Equatorial Africa. The capital Kigali can be mentioned as a typical African city due to its rising population and the rising rate of motorization. Different pollutants produced e.g. by a high-usage rate of mopeds or open fireplaces burning woods for cooking and household chores could be detected. Climatological parameters as well as air pollutants were measured within the urban area. These values indicated an UHI, which tends to rise from 1971 till 2008. Also a temporary phenomenon for the air pollution indicators is visible during the hours before sunrise. The distinctive relief caused an accumulation within small valleys called "Marais". Unfortunately, these are the favourite places of living and agriculture.

Key words: urban heat island, air pollution, suspended particulate matter

1. INTRODUCTION

Kigali (1°57`S, 30°04`E), the capital of the equatorial African country Rwanda, indicates a fast growing population by approx. 970,000 inhabitants. This rising population and the coherent rising rate of motorization were a reason for a sustainable degradation of the urban air quality. Poorly maintained, old mopeds, motorcycles and vehicles cause an increasing concentration of different air pollutants. Apart from the traffic emissions there is another source of air pollution representative for the developing world: the usage of simple stoves and open fireplaces. Burning wood for domestic energy, cooking and household chores produce a lot of emission, indoor and outdoor (Han, 2006). Considering Rwanda shows a distinctive relief, Kigali is situated in the central highlands. The main business and residential districts are on top of the ridges, which are enclosed by small valleys called "Marais". The lack of space forces more and more people to settle along the slopes and on the bottom of the hills. Though the existence of air pollution depends on the spatial distribution and of course on the intensity of the sources. But pollution is not necessarily bound within the area of strongest emission. Topographical and meteorological conditions could have a very strong influence on spatial climatic modifications and the spatial distribution of air quality. So Kigali with its distinctive relief could be a good example for these matter of facts.

2. RESEARCH STRATEGY

Analyzing the urban temperature and air quality of Kigali is one part of the ReCCiR-Project (**Re**cent **C**limate **C**hange **i**n **R**wanda). The aim of this project is to analyze the development of meteorological conditions and air quality in Rwanda. One important issue of the Kigali-part of the project is to map the temporal and spatial variations of air pollutions within the urban area and to show how it is affected by meteorological parameters. Another part of ReCCiR is the aspect of human health. There is an investigation about the influence of global warming on the behavior of malaria for the whole country. For Kigali it is the question of air quality which humans were exposed to. Most of the housing units in the city are using firewood and leaves as fuel material, also dung and kerosene.

Fig. 1: City impressions of the streets in Kigali, Rwanda;
paved (left) and unpaved (right) areas within the urban area.

* Corresponding author: Jun.-Prof. Dr. S. Henninger; Technische Universität Kaiserslautern; Physische Geographie; Pfaffenbergstr. 95, 67663 Kaiserslautern; Email: henninger@rhrk.uni-kl.de

3. RESULTS

This paper presents some preliminary results from the pilot phases performed by stationary and mobile measurements in February 2008 and 2009. Air temperature, air humidity, precipitation, wind speed and direction, carbon monoxide and suspended particulate matter (PM_{10}) were measured at three fixed stations within the urban area of Kigali (Fig. 2; black dots). CO and PM_{10} were additionally detected by mobile measurements using a car traverse which started in the north-western outskirts of Kigali following paved and unpaved roads through the urban area (Fig. 1). A mixture of different types of land use composed the measuring route where different commercial, industrial, residential and mobile sources could be expected (Fig. 2; black line). Unfortunately, it is not possible to find a real rush hour and a time of slow traffic in Kigali. So the car measuring trips were made at three different times of the day (9 a.m. – 10 a.m.; 4.30 p.m. – 5.30 p.m.; 2.30 a.m. – 3.30 a.m.). Finally, a total of 30 trips were completed (10 for each time of the day).

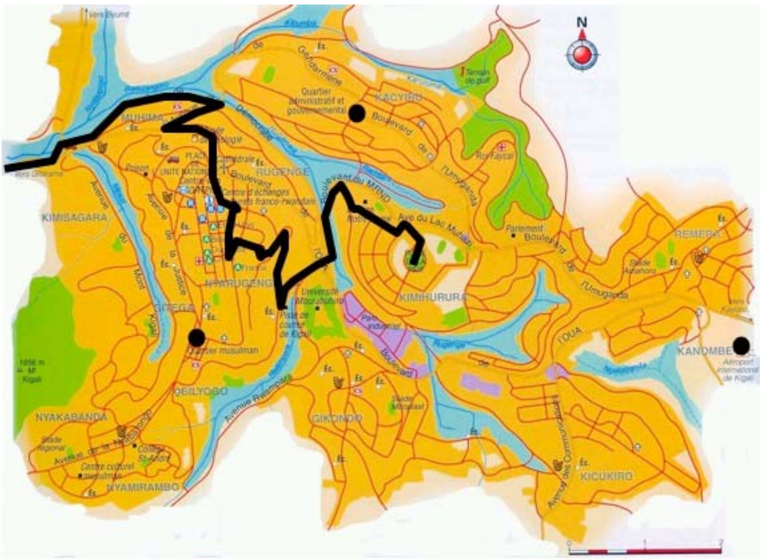


Fig. 2:
City map of Kigali, Rwanda, with the mobile air quality measuring route (black line) and three fixed air quality and meteorological stations (black dots) within the urban area.

3.1. Temperature trend

The temperature trend for the urban area of Kigali was analyzed by data from three meteorological stations maintained by the “Service Meteo du Rwanda”. To have a common measuring period of all three meteorological stations the years between 1971 and 2008 were observed. Fig. 3 indicates an increasing annual mean temperature of 2.6 K for a period of nearly 40 years. Mainly, for the last 10 years a warming in Kigali is evident. In the first instance, this development could be attributed to global warming, because more or less rising temperatures could be recognized all over Rwanda during the last decades. But it could also be related to the ongoing urbanization, because the temperature trend of Kigali is much higher and faster than in other parts of the country. All three stations display a mean urban temperature modification of ≈ 2 K in relation to the rural stations outside of Kigali.

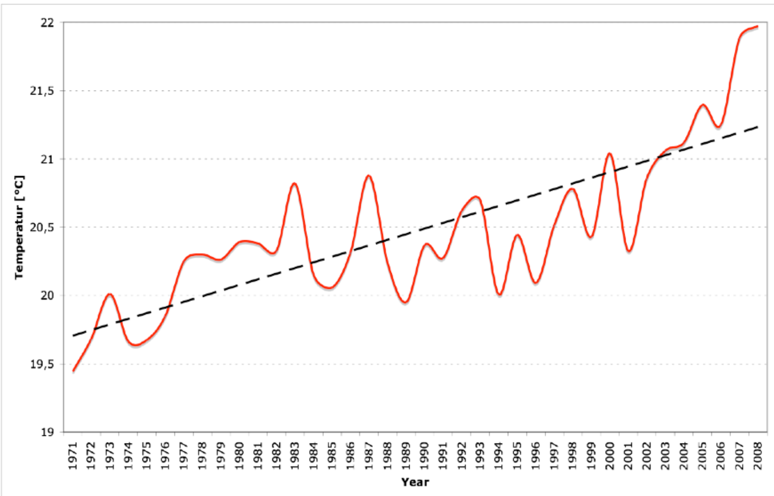


Fig. 3:
Temperature trend for the measuring period 1971 – 2008; city of Kigali, Rwanda.

3.2 Suspended particulate matter

To realize the preliminary results the recommended values of the WHO for PM_{10} short time exposure (50 µg m^{-3}) is visualized in the graphs of fig. 4 and 5 (WHO, 2006). Measurement results of PM_{10} detected by car traverses were exemplarily shown. On first sight the morning trips indicated a lower concentration than in the evening hours. Whereas no one could really talk about low concentration. For the morning measurements suspended particulate matter concentration ranges between 175 µg m^{-3} and 900 µg m^{-3} (Fig. 4; lower, blue lines). The course of the measuring route is replicably very good. Highest values were reached between route sections 10 and 16, where the route climbs up the hill, goes straight through the center of the city and leaves it on the other side of the ridge. The same behavior is visible for the evening hours (Fig. 4; upper, red lines). For instant, the concentration increases from 1,400 µg m^{-3} up to 2,400 µg m^{-3}. Although highest levels were measured in areas with paved roads in business and commercial areas with the highest traffic rates this result is not reassuringly, because all measured residential districts in Kigali exceeded the recommendations of the WHO, too. This suggests that the inhabitants of Kigali are exposed to enormous levels of PM_{10} during most of their time outdoors. So PM_{10} levels are increasing in areas with high rates of traffic due to the exhaust of the vehicles and the stirring up of dust from the ground, but also in fact of burning wood for cooking etc. within the residential districts. As a matter of fact for the measurements in February daily mean PM_{10} levels from sunrise till sunset reached 1,013 µg m^{-3}.

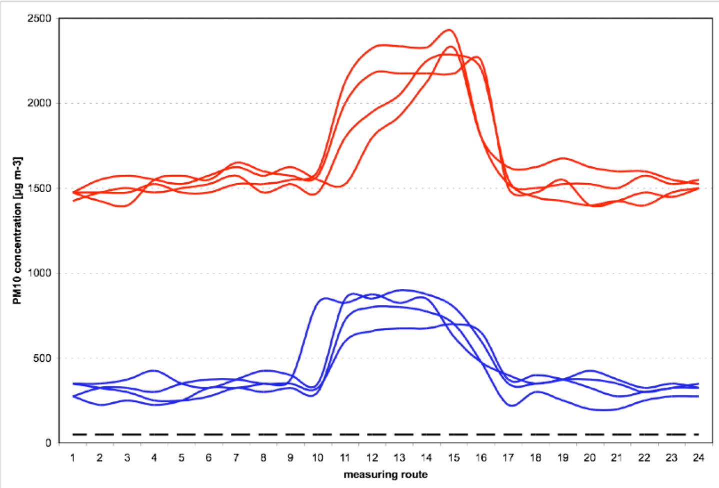
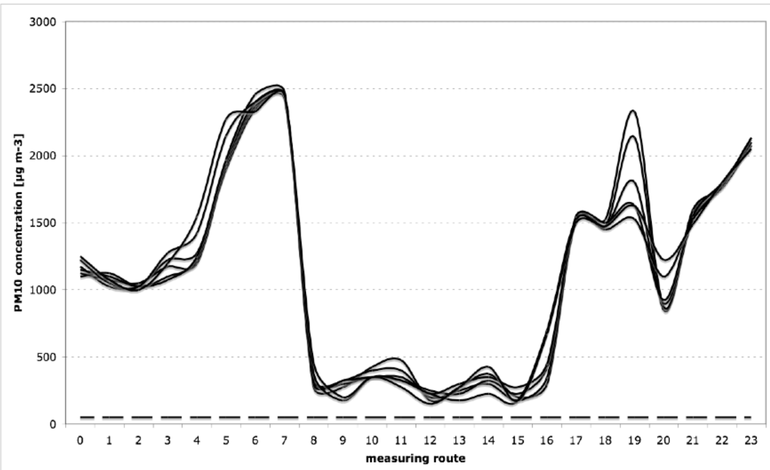


Fig. 4:
Results of PM_{10} measuring route for morning (lower, blue lines) and evening measuring trips (upper, red lines).

Hazardous measuring trips could be detected for some nighttime measurements in February 2008. Because of high temperatures, high solar radiation and a non-typical missing cloud cover the urban surface could heat up extremely, which produced a cold-air flow from the ridge and the slopes down to the "Marais". Exemplarily, the results are shown in fig. 5. So PM_{10} concentration reached the highest levels of the day in nighttime hours. But the cold-air flow takes away the suspended particulate matter, which tends to accumulate within the "Marais" on the bottom of the hills, the places where most residential neighborhoods could be found and agricultural fields were used. Of course this is not the rule, but it is also no snap-shot, because these phenomena showed up in four of ten measuring trips in 2008 and two in 2009.

Fig. 5:
Measurements of PM_{10} for nighttimes with cold-air dynamic from the ridge to the "Marais".



3.3 The blessing effect of precipitation

Though rain could have a washout effect is already known. By high-level concentration heavy tropical rain events could have a blessing for the people due to the exposure of suspended particulate matter. Fig. 6 offers a precipitation event starting at the end of the measuring trip. So the car was turned and driven the reverse direction. The washout effect resulted in a concentration decrease of more than 1,300 $\mu g\ m^{-3}$. As it was expected, reconfirming tests approved this effect of a short-term, but obvious slow-down of suspended particulate matter concentration. In dependence of the temperature and solar radiation this effect was absorbed quickly. Indeed, PM_{10} concentration revives faster along the paved streets due to soil of the unpaved streets, which does not dry off so fast.

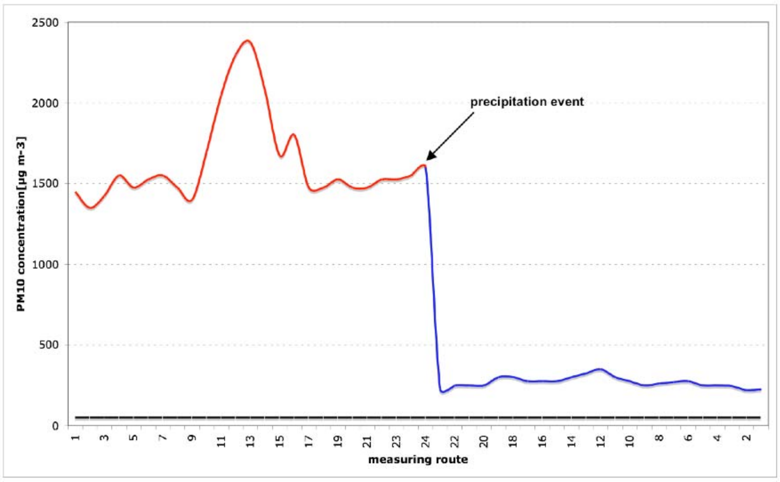


Fig. 6:
PM_{10} measurements before and after a heavy tropical rain event.

4. CONCLUDING REMARKS AND FURTHER RESEARCH

By the preliminary results of the project it could be concluded that air pollution in Kigali has reached an incredible level. Generally, the concentration is far above those recommended by the WHO. Particularly, this PM_{10} concentration in the air suggests that air pollution creates a great risk to the inhabitants' health. The meteorological conditions in Kigali further contribute to this health risk due to an expected higher stability of the urban atmosphere because of an increasing UHI. This results in a lower transportation and dispersion of the polluted air, hence causing accumulation of the airborne pollutions within the small valleys and the residential areas respectively. The increasing rate of urbanization of Kigali is a matter of great attention.

Future research includes comprehensive field studies of outdoor air quality, but also indoor exposure to air pollutants for humans should be focused. Additionally, the air quality measurements should be expanded for a minimum of a one-year measuring period to have an overview about the behavior of e.g. suspended particulate matter due to rainy and dry seasons.

References

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