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Odor Concentration Analysis in Karengata and Ongata Rongai; a Case Study of Karen Brooks Area

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Abstract: *Sanitation and hygiene promotion is an integral part of national development strategy. Karengata and Ongata Rongai are peri-urban areas that have undergone rapid urbanisation and population growth and has created a need for purchase of large plots of land that are subdivided and developed without the consideration of the physical development plan leading to heavy pressure on sanitation services. Using Slovin's formula a representative sample of 400 people was obtained. They were sampled from eight zones in Ongata Rongai and Karengata using spatial stratified systematic random sampling. This has resulted in odor emissions. The complaints of people, often not systematic and variously distributed, in general do not allow us to quantify the perceived annoyance. This study sought to perform odor analysis in Karengata and Ongata Rongai areas, with a case study of Karen Brooks area. The combination of olfactometric analyses allowed both the quantification of the emissions and the evaluation of their impact in the area. Analysis of the results showed that at night, the pungent plume moves much faster due to increased wind velocity and less air resistance at night, thus the residences furthest from the pond experience horrific odours during the night when they are sleeping.*

Key words: *Odor annoyance, Olfactometry analysis, Sanitation*

I. Introduction

Odor is special scope of air pollution which can make dislike feeling or unpleasant taste in the air and water below law standards. And this feeling of disgust is different from one person to another one. In the last 30 years odors have become a serious environmental concern, and the discussion about the possible negative effects of odors on human health is still a widely studied and debated issue (Harreveld, 2013). Studies prove that the exposure to odors may cause different effects on human beings, ranging from emotional stresses such as states of anxiety, unease, headache or depression to physical symptoms (Aatamila et al., 2011). Odor nuisance problems are particularly worrying when more industrial activities exist near residential areas (WHO/UNICEF, 2012).

In Karengata and Ongata Rongai areas, the use of the onsite sanitation systems and open disposal of waste has resulted in formations of faecal coliforms. In most homes, sewer gas may have a slightly unpleasant odor, but does not often pose a significant health hazard. Residential sewer pipes primarily contain the gases found in air. Often, methane is the gas of next highest concentration, but typically remains at nontoxic levels, especially in properly vented systems. Exposure to low levels of this chemical can irritate the eyes, cause a cough or sore throat, shortness of breath, and fluid accumulation in the lungs. Prolonged low-level exposure may cause fatigue, pneumonia, loss of appetite, headaches, irritability, poor memory, and dizziness.

II. Literature Review

Olfactory annoyance is felt to be an indicator of an unhealthy environment by the population (Bakhtari, 2014); as this considerably complicates the overall assessment of odor pollution, more innovative methodologies compared to simple air quality monitoring are needed (VanHook, 1998). The continuous exposure to odor emissions could cause undesired reactions such as physiological symptoms (respiratory problems, nausea, headache, eye irritation) and psychological stress (anxiety, depression) (Wilderer, 2001). Moreover, olfactory pollution could also produce effects about social context, such as impairment of the environment quality, damages to properties, harm or discomfort, injury, loss of enjoyment of normal use of property, or interference with business activities (Bakhtari, 2014).

Therefore, the acceptability of industrial plants and agricultural farms, very often a source of bad odors, is limited and their closer and closer proximity to residential areas leads to several citizen's complaints (Brattolli et al. 2011). Due to the strict connection of odor pollution to human perception, the only application of standardized methodologies for the monitoring and control of emissions is not sufficient to provide useful information about the overall understanding of odor phenomena (Henshaw et al. 2006). For this reason, where industrial plants causes olfactory annoyance to the population, it should be fundamental to endorse the role of people participation to assess exposure to odors (Sironi et al., 2010).

In recent years, even international regulations about odor emissions tend to consider the employment of human assessors as a valuable method to assess the odor impact of an industrial plant on the territory (Yuwono & Lammers, 2004). For example, German VDI 3940 standardizes a method of field inspection by using trained assessors, applied by several researchers in order to get quantitative indexes of annoyance (Nicell, 2009).
Another common qualitative investigation to evaluate the perception of odors within an area of study can be conducted by means of administration of questionnaires addressed to the residents (Stellund et al. 2009), the purpose of which is to understand the level of stress within a community and to characterize the occurrence of the events. Even in this case, the evaluation requires long periods of investigation to achieve statistically significant results, necessary to overcome the intrinsic subjectivity of resident responses (Griffiths, 2014).

Generally, people exposed to annoyance variously address their worries to the local authorities (municipalities, police, environmental agencies, etc.), who are often overwhelmed by frequent complaints; they should evaluate the reliability and objectivity of the complaints and identify the potential source, in order to start monitoring activity and give prompt answers (WHO, 2012). To achieve this task, different critical aspects have to be managed: the collection of complaints in a systematic way, the verification of odor events in the field, and their measurement.

III. Research Methodology

3.1 Research design

The study adopted a descriptive research design (Strauss et al., 1998) in the study of the implication of sanitation standards on sanitation provisions in Karengata and Ongata Rongai. Descriptive research involves observing and describing the behaviour of a subject without influencing it in any way (Strauss et al., 1998). The method aims at finding out what is, using observational and survey methods to collect descriptive data.

3.2 The Area of Study

The study covers Karengata and Ongata Rongai areas. Ongata Rongai is an area situated 17 km south of Nairobi, and lies at 1731 m above sea level. The township spans 16.5 square kilometers at latitude (0^{o} -53' 60 S), and longitude (36^{o}25'60 E). It is 50km from Kajiado district headquarters. It has two administrative wards Ongata Rongai and Nkaimurunya. It spatially consists of four areas namely Maasai Lodge, Kataka, Laiser and Kware. Ongata Rongai is located in Kajiado County and spans over an area of 16.5km^2. This region has a warm and temperate climate with mean annual rainfall of 844mm and mean annual temperature of 18.3^{0}C (Kenya Meteorological Services, 2014). Geologically the area consist of volcanic layers of tuffs, basalts, phonolites and trachytes which overly thick layers of clay soil. Mainly Ongata Rongai is considered to have poor soil structure due to the rocky and black cotton soils, which hinders drainage of water (Kazungu et al., 2011).

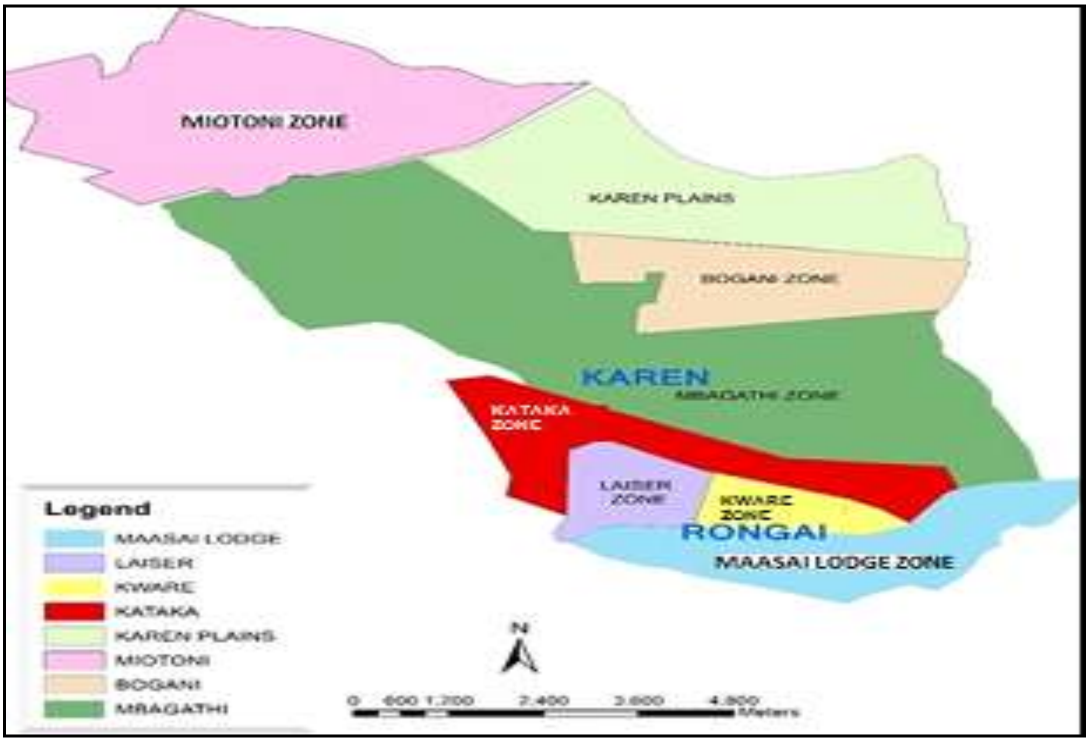

Figure 1: Area of study consisting of Karengata and Ongata (GoK, 2010)

Karengata is an area found south west of Nairobi city between the City and the peri-urban areas of Ngong, Kiserian and Ongata Rongai. The boundary of the area is the Motoine River to the north, the Mbagathi River to the south, the Magadi and Forest Edge roads to the east and with Kiambu County to the west. It occupies approximately 56 square kilometers at latitude -1.32°, longitude 36.72° (GoK, 2006). Residential use is predominantly low density in Karengata area. Karen plains and Hardy and Bogani areas consist of low density housing occupying a minimum land area of 0.2 ha. The types of housing include mansions, bungalows and maisonettes averaging 10 units per hectare. There are 30 high density settlements in the area the largest being Kuwinda (GoK, 2006).

3.3 Study and sample Population

The sample population consists of 200 residents of Karengata and 200 of Ongata Rongai areas. Key informants such as officials in the Nairobi City County and the Kajiado County in particular Department of Environmental Health and Sanitation, Development Control Department, Water and Sewage department, Public health inspectorate, Environment Department and NEMA Office were interviewed. The study also targeted other key government officers in the Ministries of Lands, Health, Environment Water and Natural Resources, KNBS and WASREB; Water and Sanitation Service providers such as Olelaiser Water Company, private exhausters, and NGOs such as Netwas International were also interviewed. The educational facilities and church organizations situated in the area of study were interviewed on condition of sanitation facilities.

3.4 Sampling Technique and sample size determination

3.4.1 Sampling technique

The research used stratified probability sampling of households in the area of study because it gives` the most representative data (Kothari, 2004). Stratified probability sampling is a technique whereby the researcher divides the entire population into different subgroups or strata, then randomly selects the final subjects proportionally from the different strata (Punch, 2005).

3.4.1 Sample Size

A total of 400 respondents were sampled at a 95 % confidence level and an accuracy level of ±5. The sample size was determined using Slovin's formula. Where n is the number of samples, N represents the total population and e is the error tolerance.

$$n = N \Big/ 1 + N(e)^2$$

The study sampled approximately 40 % of zones in Karengata and 60 % in Ongata Rongai. This technique ensured that the number of respondents in the sample groups was proportional to the number of residents in each class of the population of Karengata and Ongata Rongai.

Table 1: Population of Karengata

Area		Male	Female	Population
Mokoyeti Kuwinda Karen	Karen	7450	6338	13788
Bogani/Hardy	Hardy	4848	4266	9114

Source : Population and housing census (2010)

Table 2: Population of Ongata Rongai

Area		Male	Female	Population
Maasai Lodge	Olekasasi	2402	2098	4500
Rongai Township Kware Laiser Kataka	Ongata Rongai	19271	20907	40178

Source: Population and Housing Census (2010)

3.5 Materials and methods

3.5.1 Odor source identification

The first important step for odor impact evaluation is the identification of the major odor sources to be monitored for the study. This was achieved with an accurate survey of point sources which includes; i.e. conveyed emissions, e.g. through a stack, as well as area sources, i.e. liquid or solid surfaces without an outward flow. In the case of passive area sources (e.g., wastewater treatment tanks), sampling is performed using so called "hood" methods, whereby a hood is positioned over the emitting surface and a neutral air stream is introduced at known airflow rate into the hood, thus simulating the wind action on the liquid or solid surface to be monitored (Nicell, 2009).

Figure 1. Plate of Karen Brooks settling pond with user taking odour measurements

Water samples, in one litre sample bottles, were collected from the inlet, sink and outlet (feed into Mokoyeti river) of the pond. The sink in this case is the mass of water in the settling pond. The samples were analysed at Analabs Nairobi. In this specific case, sampling on passive area sources was conducted using a neutral air stream from a synthetic air bottle, resulting in an air velocity inside the central body of the hood of 0.035 ms^{-1} (Griffiths, 2014). Samples were collected on all the identified potential odor sources.

3.5.2 Odor emission evaluation

Water samples obtained at the inlet, sink and outlet of the pond were analyzed. Over a period of one week, odor samples were taken at 3-hour intervals. Equidistant intervals of 10 m were chosen and odor measurement taken. An odor scale of 0-5, provided in the Olfactometer, was used and at every interval, the user adjusted the scale until one was able to smell an odor and the reading taken down.

Dynamic olfactometry is a sensorial technique, i.e. a technique that uses the human nose as a sensor, which is most commonly used for odour measurement. Dynamic olfactometry allows the determination of the odour concentration (cod) of an odorous air sample, which is expressed in European odour units per cubic metre (ouE m^{-3}), and represents the number of dilutions with neutral air needed to bring the sample to its odour detection threshold concentration. In general, in order to characterize an odour emission, it is not enough to measure the odour concentration, but it is necessary to determine the so called "Odour Emission Rate" (OER) associated with each odour source, which is measured in ouE s^{-1}. In the case of point sources, the OER can be calculated simply by multiplying the odour concentration value (in ouE m^{-3}) by the air flow (in m^3 s^{-1}), normalized at 20°C, which is the reference temperature according to the EN13725:2003.

IV. Results And Discussion

Residents of Karen Brooks, a location within Karen plains zone of the study area, are livid over the odour emanating from a settling pond within the locality and all give various reasons as to why this occurs. Being a secure location, it was easy to carry out odour measurements past unsocial hours. Thus, Karen Brooks was chosen as an ideal location for further odour analysis and to ascertain what was the main cause of the odour. Odour was quite problematic within the study area.

Respondents were asked to indicate whether odour was a problem. The answers to this are seen in Table 1.

Table 1: Percentage of respondents experiencing odour problems within the study area

Zone	Yes (%)	No (%)
Bogani	3	97
Karen plains	47	53
Mbagathi	15	85
Miotoni	21	79
Kataka	35	65
Kware	33	67
Laiser	29	71
Maasai lodge	39	62

From the analysis of the findings, a 39% of the individuals living in Maasai lodge area experiences odor problems. The bad smell is exacerbated by wastewater and decomposing solid waste that are continuously deposited into the pond. An interesting phenomenon is observed on analysis of odour readings. During the day, the residences closest to the pond experience the highest concentrations of odour whereas during the night, the houses furthest from the pond experience the highest concentrations of odour. Figure 1 shows the results of the odour intensity measurements.

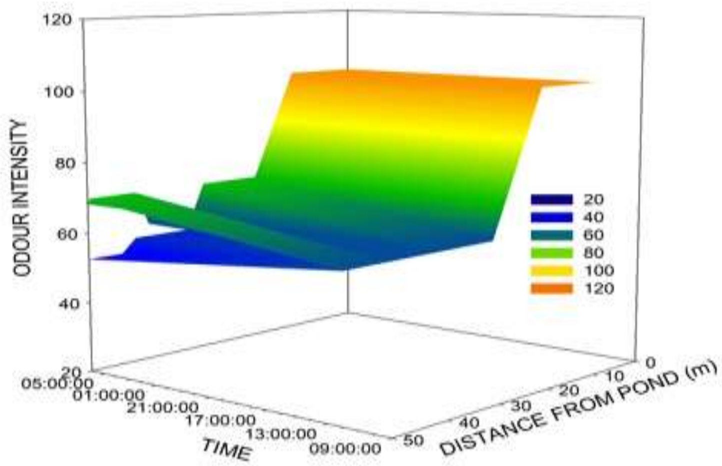

Figure 1: Karen Brooks' odour intensity measurements

Further analysis of the odour intensity measurements shows that during the day, the wind velocity is low compared to the night. Daytime temperatures are highest compared to the night. This would account for the odour intensity being high closest to the houses nearer the pond during the day. Because of high air resistance during the day, the pungent plume does not move far owing to less wind velocity during the day as observed. At night, the pungent plume moves much faster due to increased wind velocity and less air resistance at night, thus the residences furthest from the pond experience horrific odours during the night when they are sleeping. On analyzing the distribution of the odor concentration within the study area, thirty six percent of the blank concentration were lower than the instrumentation quantification limit and 74% lower than 20 ouE/m^3 . The criterion of 30 ouE/m^3 was used to define the significance of an odor event. The analysis of the distribution samples were as shown In Table 2 below.

Table 2 Distribution of odor concentration

Odor concentration (ouE/m^3)	Frequency(Number of events)	Percentage(%)
<12	33	36
12-20	39	42
21-30	10	11
41-50	5	5
51-60	0	0
61-70	4	4
71-80	2	2

Moreover, during the analysis, for significant events, they defined the odor as similar to "rotten eggs" or "gas," typical descriptors of odors deriving from waste garbage deposition. The number of significant odor events, out of 70 events in total, produced by remote sampling, suggests that the odor concentrations measured could be underestimated with regard to population perception.

The summary of the recorded odor concentration in Karen Brooks is as shown in figure 3. The empty bars indicates the events for which no odor concentration was observed. From the study results, a record of 40 (ouE/m^3) was observed in a given instant. This shows that the area experiences high density of odor concentration, of which should be a major concern to the local authorities.

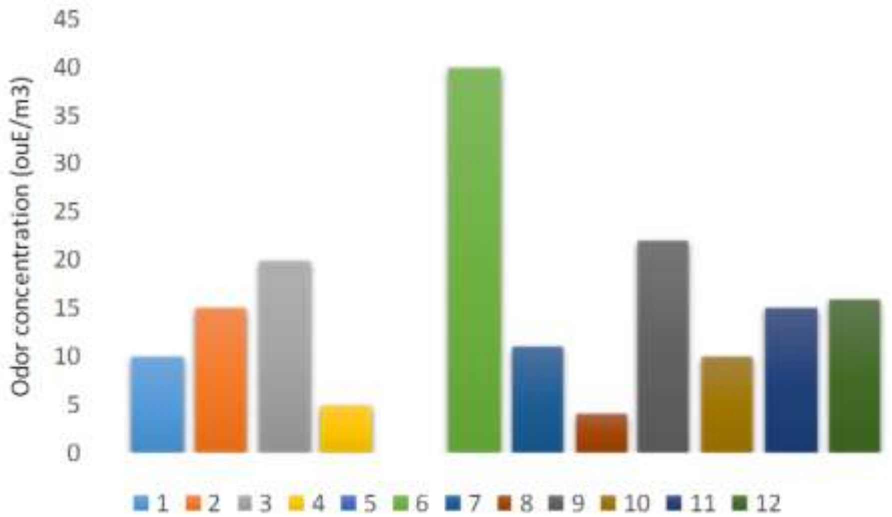

Figure 3 Olfactometric results on odor concentration

Analysis of the sink and outlet water from the number of residences, restaurants and farms observed within the locality, show excess phosphorous, which contaminates water bodies resulting in rapid build-up of algae, a lot of algae is observed, which in turn affects aquatic life. High fluoride levels, very high faecal coliforms, high total suspended solids and an oil film on the surface of the water are observed. The high algae levels mean a lot of decomposition due to high microbial activity. The decomposition of these effluents results in high odor concentration within the area.

Odours typically arise from complex mixtures of gases, which stimulate the olfactory, or smelling sense. Human response to odour is not easily predicted, however, because there are many factors which can affect the determination of whether an odour is detected and/or recognised, and whether it is deemed to be pleasant or unpleasant. Apart from pollution caused by haphazard excreta disposal, water from elevated parts of the settlements usually flows with a lot of solid waste. A distinctive characteristic of this water is that it smells bad and blocks downstream drainage systems. The bad smell is worsened by waste water and the rotting solid waste that get deposited in the low-lying part of the settlement. This is caused by faecal coliforms. Faecal coliforms are bacteria that are naturally present within the bodily waste of all warm-blooded animals. The presence of faecal coliforms usually indicates extent of contamination of groundwater by human sewage or animal droppings, which could contain other bacteria, viruses, or disease caused by micro-organisms.

V. Conclusion

A successful management of complex cases of olfactory annoyance cannot disregard the key role of social participation, to be considered as a tool to characterize the phenomenon and correctly identify the emitting source. Based on the olfactometric measurements results, the impact of odor to the residents is worth investing and calls for the stakeholders to act on it. Exposure to odours may cause strong physical reactions like nausea and vomiting without being present at toxicologically significant concentrations. A case in point is the odour associated with protein hydrolysis and the putrefaction of animal tissue. Furthermore, the active involvement of the exposed population also promotes awareness about odor phenomena.

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