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Mapping Environmental Health Injustice in Chuka Town Through Land Use Refinement Method and Dispersal Modeling GIS Based Techniques

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Abstract: As the world population becomes urbanized, issues of environmental health, justice and equity are growing in interest. In developing countries, improper waste management contributes to environmental related health risks. In Kenya particularly, dumpsites are located close to residential blocks in urban areas exposing surrounding communities to olfactory nuisance, toxic smokes and diseases. To document cases of local environmental health injustice, sub population at exposure risk to smoke plume was assessed using a case study of Chuka town open dump site. Framework adopted in evaluating potential health risks was that on principles of risk assessment and Geographic Information System (GIS) based modeling. In this study, land use refinement and dispersal modeling methods were used to estimate population at exposure risk. The findings shown about 55,162 persons living along the smoke dispersion route were at high risk of exposure to hazardous smoke plumes. The exposure risk showed a spatial variation across the blocks in relation to land use and terrain. Over 73 percent of population in the affected blocks engaged in informal sector employment and were the less advantaged groups of this town's urban community. The results of this study are consistent with those of related studies which have shown that location of noxious facilities is often within neighborhoods of minority urban poor. For the case of Chuka town, relocation of the dumpsite to a less populated block and the engagement of affected communities in mitigating the injustice will ease the ecological burden currently borne by these sub population.

Keywords: Exposure Risk, Environmental Health Justice, Blocks, Dispersal Modeling, Land Use Refinement Method

1. Introduction

Management of Municipal Solid Wastes (MSW) is a big problem in developing countries despite increased efforts to reduce wastes stream. The major challenge is mainly lack of appropriate waste handling facilities as open dumping remains the principal way for managing MSW in many urban centers. In most cases, these open dump sites are located near residential neighborhoods and have often been linked to health risks and problems. Environmental health concerns related to olfactory nuisance and respiratory tract infections have been reported commonly among communities living near these facilities [1], [8]. Environmental justice refers to the fair treatment and meaningful involvement of all people with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies [14]. However, the reality is that most people continue to be exposed to environmental conditions that can adversely affect their health or expose them to health problems. In developing countries, proximity of open dumpsites to residential areas is a basic form of environmental health injustice to the surrounding communities who in most cases are not protected from toxic gases, waste smokes and odour pollution. Today, both theoretical and applied research in the areas of environmental risk assessment and environmental equity analysis are taking increasing advantage of Geographic Information System (GIS) technology and advanced methods of data visualization [4], [7]. This is because all issues considered are spatial in nature and the application of GIS provides opportunity for geographers to contribute to the ongoing debate of environmental health justice vis-à-vis equity. GIS to be precise has been utilized in

environmental equity analysis because it allows for the integration of different data sources needed for analysis, application of spatial analytic techniques as well as supporting cartographic representation of geographic information. To that extent, many studies have applied GIS in the assessment and management of municipal solid wastes with such studies as: Identification and mapping of radioactive sites, analysis of the geographic proximity between population characteristics and pollution sources, geographic toxic plume analysis [2], [5], [12], [3], [9]. Recently the focus shifted from the traditional mapping of affected population's socio-demographic attributes and assessment of risks to using GIS techniques to show the correspondence amongst contributing factors. Globally, many community based resistances associated with municipal solid waste management has been over potential health risks posed by noxious land uses and facilities to the sub populations in the neighbourhood [13], [10], [7], [11], [6].

1.1. Problem Contextualization

In Kenya however, there is minimal activism and debate over environmental health injustice associated with noxious land uses and in particular open waste dumping largely due to lack of empirical studies to determine whether principles of environmental justice have been applied in the first place or violated generally. At the same time, many studies in the area of MSW management have focused majorly on: characterization and quantification of solid wastes, environmental impact assessments and site suitability mapping analysis. Broadly speaking, studies of environmental justice with focus on exposure risks to toxic hazards and emissions among target populations have not been undertaken or adequately publicized in Kenya. This has to a larger extent limited the identification, documentation and mitigation of environmental health burdens borne by the community especially the poor where these facilities are located. With GIS, it is becoming a common practice to map instances of environmental injustice by geo-referencing facilities or even land uses posing an environmental and human health risks. Locally no studies on exposure risks to population from toxic hazards or assessment of spatial relationships between pollution hotspots and the socio demographic characteristics of the affected sub population have been done in chuka town. Therefore this study forms a first attempt to try quantifying the population at exposure risk from open dumpsite smoke plumes. Then evaluation of potential health risks across land uses from the dumpsite hotspot was done using the principle of risk assessment and GIS based dispersion modeling.

1.2. Conceptual Framework for Exposure Risk and Vulnerability Assessment

To address issues of hazards, better understanding of the interplay components and relationship between different factors is important. This study adopted a framework based on hazard assessment, control analysis, strategy selection, implementation and evaluation as proposed by Kasperson, Kates and Hohenemser [7] as shown in figure 1 below. The framework was found adequate for this particular study because it integrates concepts of assessment, planning and management of risks and disasters from both technical and social perspectives.

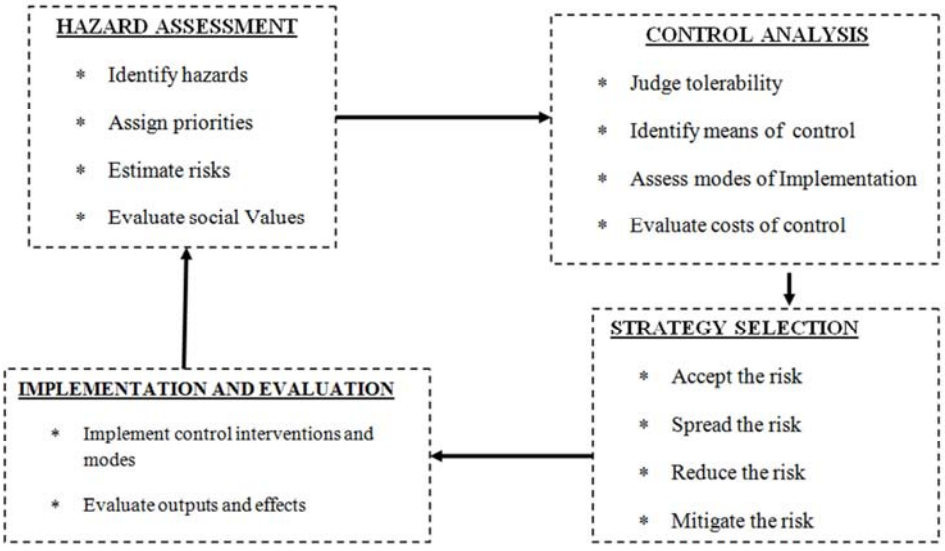

Figure 1. *Assessment and Management of Hazards framework as envisaged by Kasperson (Source: Kasperson et al., 1985).*

2. Case Study: Chuka Town Open Dumpsite

This particular study focuses on Chuka town dumpsite which has generated controversy owing to its current location and the open burning of the dumped wastes (Figure 2). This disposal site currently receives unsorted solid wastes from all land uses within chuka town and adjoining areas. Open incineration of wastes releases toxic smoke into the air

forming a thick cloud of poisonous plume over the residential areas and the nearby district hospital. In the past this dumpsite had been earmarked for relocation owing to increasing public acrimony and considerable community resistance over its associated potential health risks but it is yet to be relocated. It is hoped that this study will be useful for Tharaka-nithi county directorate of environment and natural resources, department of county public health, environmental policy makers, town planners, researchers and the affected communities because health issues widely discussed in this research work comprise important factors to consider when choosing particular options for managing any municipal solid wastes. The objectives of this study were four fold: (i) Estimate the number of people at risk of exposure from dumpsite smoke (ii) Identify and map environmental health risk zones within Chuka town (iii) Asses the socio-economic characteristics of the affected sub populations. By carrying out this study we aim to popularize the utilization of GIS based methodologies in the analysis of environmental equity for sustainable social, economic and ecological development of Chuka town.

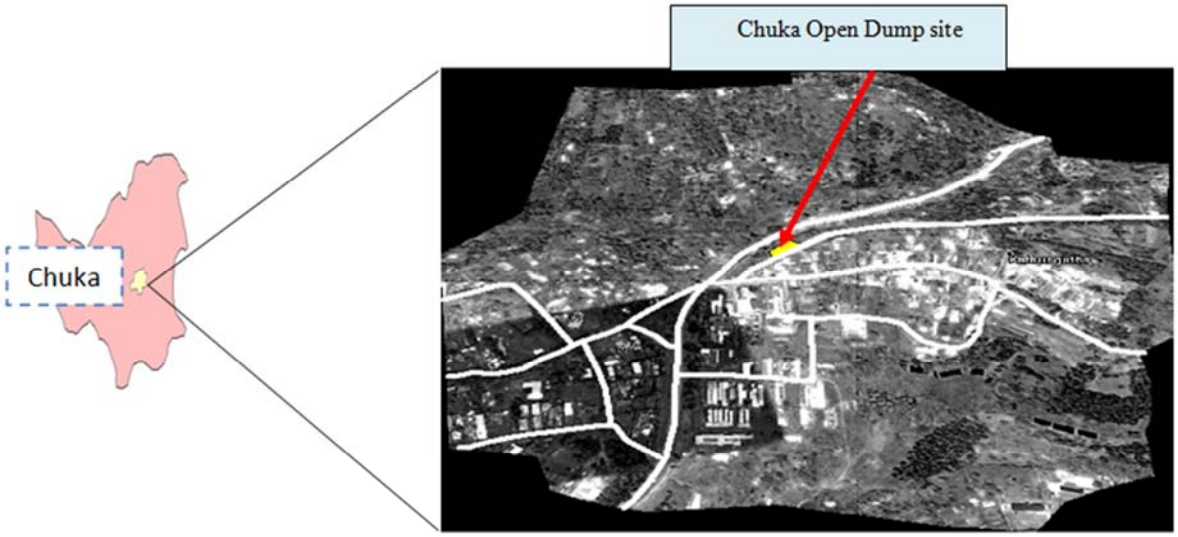

Figure 2. *Location of Chuka town dumpsite.*

3. Data and Techniques

3.1. Data

The study used various types of data. Access routes dataset was digitized from the area's imagery. Dumpsite location was digitized as a polygon from the satellite image and its positional coordinate captured with a Trimble Juno 3D GPS receiver. Administrative blocks were digitized and then rasterised. Population for the wards was gotten from the Kenya National Bureau of Statistics 2009 report captured as attribute data for the blocks. Respective ward size was vectorised from the administrative town wards. Land uses were developed as land use land cover map from Geo eye satellite image using the township physical land use zoning plan and ground truthing. Socio-economic data was collected using questionnaires administered randomly across the study area.

3.2. Population Estimation

Land use refinement method was used to calculate the number of people at risk of exposure to waste plumes from Chuka open dumpsite. Although there are other techniques for estimating the population like uniform density technique, land use refinement method was used because it assumes that population in a block group is present only in residential areas unlike the uniform density method which assumes that population is uniformly distributed throughout entire the block group.

3.3. Modeling Exposure Risk

To determine the intensity and duration of exposure to waste smoke, dispersion modeling was used. In assessing smoke exposure risk, a risk zone was created using dispersion method. The model used data on wind speed and wind direction as forces acting to disperse smoke across the study area. Other data sets applied in modeling the duration and magnitude of exposure were the digital elevation model and obstructing structures along the dispersal zone.

4. Methodology

4.1. Development of Source Data Layers

The study area was subsetted from an image downloaded from Google earth virtual globe. The study area comprise of four administrative wards created from the Kenya National Bureau of Statistics 2009 census summary report. Population data for each ward was retrieved from the 2009 census summary report and later the values were assigned to the administrative wards to create the respective ward population. Access roads and the dumpsite were digitized as vector data layers from the satellite image. Land Use and

Cover map was created from geo referenced image of the study area with four categories as: Residential, Crop land, Open land and vegetation.

4.2. Creation of Smoke Dispersion Risk Zone

The dumpsite vector data layer showing the source of the smoke was rasterised into an image. Force magnitude and direction images for dispersion modeling were created using local wind speed and wind direction data respectively. Using Initial module in Idrisi software, parameters for creating wind speed and direction images were copied from those of the rasterised dumpsite image as the source feature image. The resultant images of dumpsite, wind speed and wind direction were used to calculate the smoke dispersion distance from the dumpsite. Risk zone was then created as a Boolean image through reclassification.

4.3. Calculation of Population At Exposure Risk

To calculate the number of people at risk of exposure to smoke plumes from chuka open dumpsite, the study applied land use refinement method. In this case, residential land use was created as a Boolean image from the study area LULC map and then combined with administrative wards to get the residential land use in each ward. Then each ward's residential land use area was calculated as cells and then combined with population for the ward to get population density per cell. Population at exposure risk was then extracted as an attribute value of total population density based on the dispersal risk zone.

4.4. Characterization of the Affected Sub Population

Information on the level of education, source of income and the number of family members for the affected sub population formed part of socio-economic attributes. These factors were collected from the fifty four questionnaires administered and comprised important criterion factors in the assessment of spatial variation in environmental health risk spread across the study area.

5. Findings and Discussion

5.1. Population at Risk of Exposure

There were variations in the number of people exposed to smoke from the open dumpsite. Based on the smoke dispersion region, different administrative wards were seen to have varying proportions of exposure rates depending on terrain, the direction of wind flow as well as the speed of blowing wind at the time. The affected blocks were found within Ndagani, Rukindu and Kathunguthe as they fell within the smoke dispersion zone. The total population at risk of exposure to the toxic smoke plumes was estimated at 55,162 persons. The number of vulnerable persons varied spatially across the identified plume dispersion zone as 3,304 persons in Rukindu, 44,155 persons in Ndagani and 8,703 persons in Kathunguthe block respectively as shown in figure 3 below.

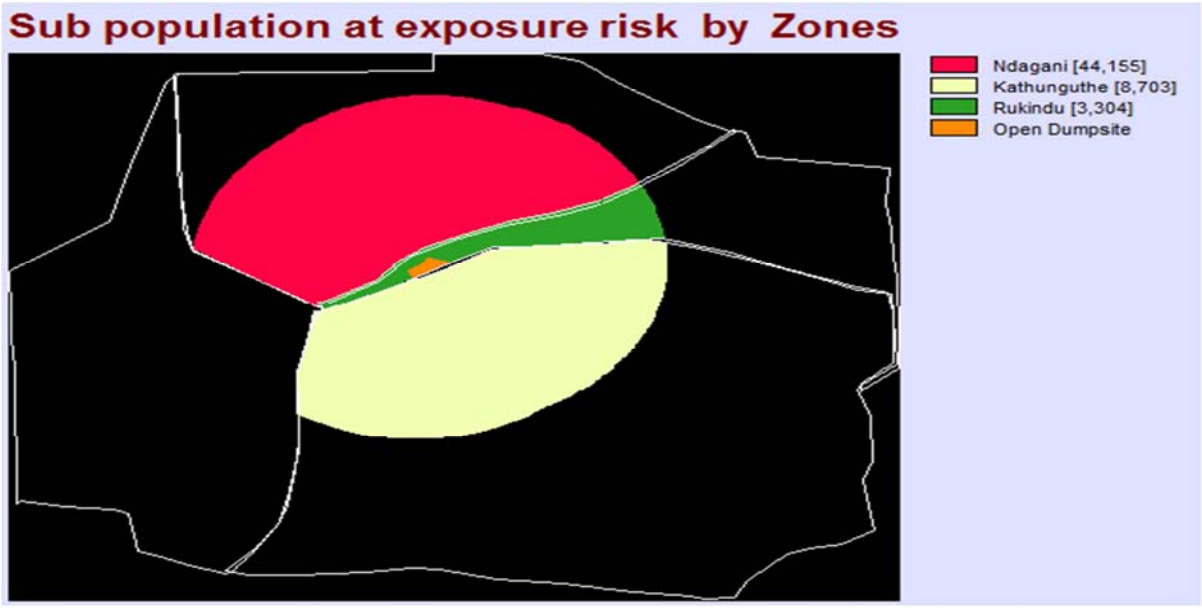

Figure 3. *Map the location of vulnerable sub populations to waste smoke plume exposure.*

5.2. Mapping Environmental Health Risks Based on Smoke Dispersion

Proximity of residential land uses to the risk source varied in magnitude and distance as the intensity of smoke decreased from source region. Using spatial autocorrelation, areas close to another were grouped as cluster zones with similar exposure risks. Applying the principle of risk estimation based on residential land use and terrain, the risk was spread across the entire area resulting to six risk zone cluster regions as can be seen in figure 4. Very high exposure risk zones were identified as areas within 1500 meters distance from the dumpsite, High risk zone represented areas within a range of 1500meters to 1900meters from the target

source with regions within a range of between 1900meters and 2000meters classified as moderate risk zones. Areas extending from 2000meters to 2500meters were categorized as low risk regions while zones from 2600meters to 2800meters represented a transition buffer area between risk and non risk prone zones. Regions falling beyond the transition zone were classified as a non exposure risk areas.

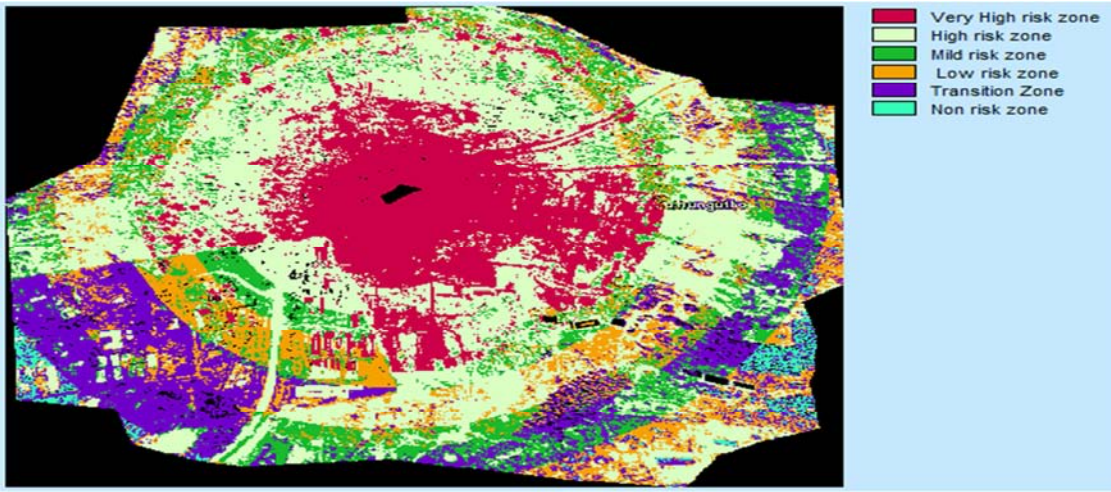

Figure 4. *Spatial distribution of environmental health risks based on terrain and distance from the source*

5.3. Socio-Economic Characteristics of the Affected Sub Populations

Some of the social and economic variables considered in this study included level of education, marital status and income earning activities. At least 56% of the sampled sub populations were married persons with at least two children and that a large population of these persons was residing in Hospital and Kibumbu residential blocks as shown in figure 5 below. Over 80% of these families had at least one child and mostly were youthful couples.

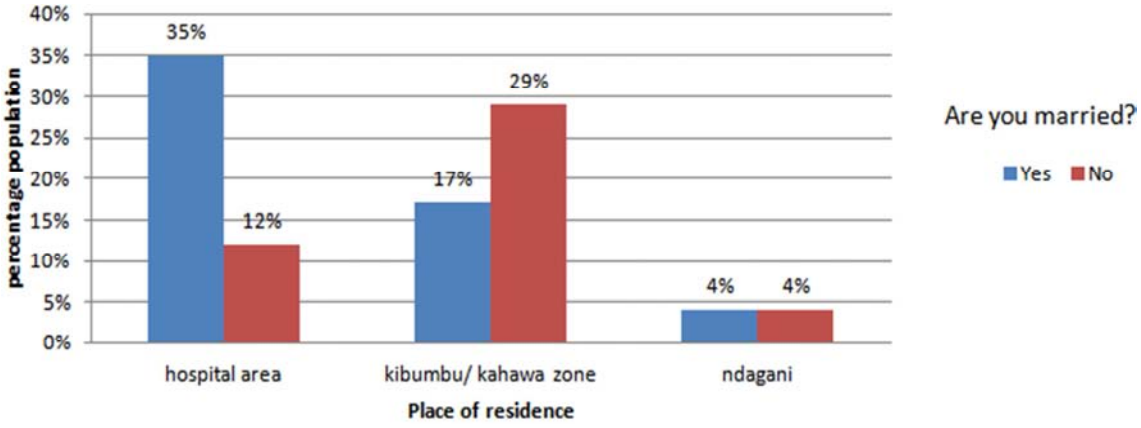

Figure 5. *Percentage marital status of the affected sub population in respect to residential blocks.*

It was observed that over 73% of the person in the sub population had not been employed and that they were engaged in informal income earning activities. These informal sector activities comprised of street food vending, casual labourers in the construction sites and small scale service shops. Slightly above 46% of the persons lived within hospital area residential block and about 27% these residents had O-level education. In general the affected sub-population had similar social and economic characteristics of minimal employment and with dependant families. This confirms the vulnerability of marginalized population of urban residents to environmental injustice due to their low economic power and social status.

6. Conclusion

Environmental health injustice is common amongst the low density residential blocks in many towns especially in Kenya. There is a need for the county governments to embrace public involvement especially those directly affected by these ecological injustices in the formulation of waste management policies and by laws. As the world's population becomes more urbanized especially in the transitional societies, issues of environmental health justice will become more prominent in urban areas. Utilisation of technologies especially GIS has proven valuable in scenario modeling and a breakthrough in simulation of the possible

implications of many decisions made on the urban communities by the concerned urban local authorities. It is therefore imperative that the county government of Tharaka-nithi stop open burning of the wastes as is the case and reconsider other ways of minimizing the town's waste stream. There is a need to relocate the current dumpsite to another site away from the residential land uses.

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