International Journal of Engineering & Scientific Research
Vol.5 Issue 10, October 2017,
ISSN: 2347-6532 Impact Factor: 6.660
Journal Home page: http://www.ijmra.us, Email:editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

IDENTIFICATION AND ANALYSIS OF ALTERNATIVE ENERGY SOURCES USEDIN DOMESTIC SCALE (LUBUMBASHI, DR CONGO)

Banza Wa Banza Bonaventure [*]
Ilunga Sapembi[**]
Kanyimbu Koj**
Milambo Kasumba David**

Abstract

The main objective of this study was to identify and analyze the different energy sources used in household scale in Lubumbashi. A total of 5270 households were surveyed in the 26 districts grouped into seven municipalities. The results revealed two main sources of energy used for cooking, four for lighting and three as alternative sources of electricity. In the case of cooking, households mainly prefer charcoal than wood heaters. Only some households of outlying districts still use wood for cooking. These preferred sources however result in multiple negative consequences for both human health and the environment. Regarding the sources of energy for lighting, candles are the most preferred because of easy accessibility while producing poor quality light.In case of load shedding or lack of electricity, some households are implementing alternative sources such as the generator and solar panels. Indeed, the use of these sources varies from one to another, with a

Keywords:
Lubumbashi,
Alternativeenergy,
Charcoal.

[*] **School of Industrial Engineering, University of Lubumbashi, Lubumbashi ,Congo & Centre de Compétences en Planification et Gestion Urbaine (CCPGU), Lubumbashi, DR Congo**

[**] **School of Industrial Engineering, University of Lubumbashi, Lubumbashi ,Congo**

higher frequency of generator use. In this context, programs that would target improving and increasing access to sustainable and clean energy, should take account of geographical disparities due to population growth and sprawl of Lubumbashi.

1. Introduction

Urbanization has become an integral part of the socio-economic growth of developing countries. Its levels vary across countries and continents, but population growth is faster in cities than rural areas due to both natural increase and migration). Although urbanization and rising per capita incomes usually lead in intensive use of modern fuels, such as gas and electricity and a decline of the traditional biomass in developed cities [1] this is not the case in many African cities [2] . In Sub-Saharan Africa for example, more than 500 million people are not connected to electricity grid [3]. Thus, Africa remains the least electrified region of all developing regions. Approximately 85% of energy needs in Sub-Saharan Africa (excluding South Africa) are covered by wood use[4].

Although the electricity access rate is 61.6% at urban scale in Lubumbashi, it is poor quality is deplorable [5]. Today in most developing cities, households opt for the use of multiple sources of energy which provides a sense of energy security. Indeed, the complete dependence on a single fuel or technology alone can make households vulnerable to price changes and unreliable service However, these energy security measures in most households are more expensive compared to the cost that would be required for a permanant access to electricity services Frequent load shedding in Ontario (Canada) for example, led households to use private generators to ensure continuous supply of electricity;resulting for them in additional costs. Such irregularities are counted in billions dollars in annual losses. In some cases, the relief measures implemented by the population in domestic scale or neighborhoods are effective technically and economically inefficient compared to electricity grid access. For some developing cities, the community or

individual initiatives helped ensure a technically efficient service. Photovoltaics for example is today, although expensive, a way to ensure access to clean and sustainable energy.

The analyze of various alternative sources of energy is an effective way to identify sustainable and recoverable resources and those that have a negative impact on either human health or the environment. In a context of rapid urban growth, this study has the general objective to identify and analyze various alternative energy sources used at the household level in Lubumbashi. The study verifies the hypothesis that the sources of readily available energy sources are most used by households in Lubumbashi, although their poor sustainability.

2. Study area, Materials and Methods

2.1. Study area

Located at 11 ° 40 'latitude and 27 ° 29' longitude, Lubumbashi is the capital of the former province of Katanga. The city had 413,000 inhabitants in 1973 and 700,000 in 1988. Recently, the city counted 1,480,152 inhabitants in 2009[6].

In beginning, the city was supplied in electricity by power plants of UMHK (Union Minière du Haut Katanga). In 1930, connection to the interconnection network of hydroelectric plants of Lufira was performed [7]. The distribution was therefore ensured by SOGELEC (actual SNEL). Regarding urban growth, Lubumbashi is considered as a fragmented city from a new population explosion [7] under the double influence of natural increase and net migration supported by the euphoria of course- copper ceilings [9].

The rate of access to electricity in Lubumbashi varies from a municipality to other. Municipalities with a high percentage of electrification are those located in the center of the city, namely Kenya and Kamalondo which record 80.4 and 79.7% respectively. In contrast, Annexe municipality grouping new districts has the lowest electrification rate. At the urban scale the current electricity access rate is over 60% [8]. Meanwhile, the number of hours and days of cuts per hour and per week is very high, which deteriorates the quality of service (Figure 1).

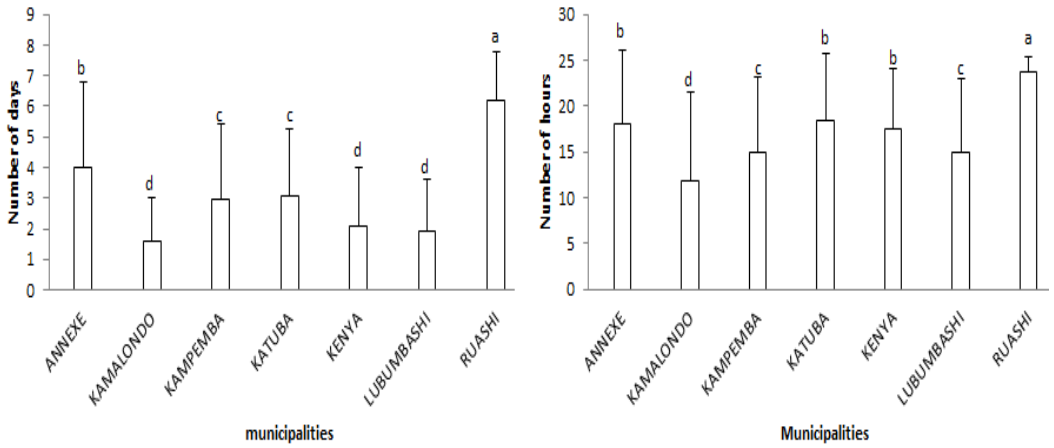


Figure 1. Number of hours and days of load shedding per day and per week in the different municipalities of the city of Lubumbashi. Source: [5].

2.2. Methodology

2.2.1. Sampling and data collection

Random Sampling Method of Laminate (RSML) was chosen because this type of sampling (probability) provides a representative sample. Moreover, each individual in the population (household) has an equal probability of being included in the sample [10]; [11]. The survey covered 26 districts of the city of Lubumbashi on a total of 43.

The size of the initial sample was obtained using the following formula:

$$n_1 = \frac{z^2 P(1-P)}{e^2} \quad \text{(Eq. 1)}$$

Where z is the value type of confidence level, P is the proportion of the actual population and *e* is the margin of error.

The adjustment taking into account the size of the population *N*, was made using the following equation:

$$n_2 = n_1 \frac{N}{N+n_1} \quad \text{(Eq. 2)}$$

Ultimately, the adjustment to the response rate to determine the final size of the sample, *n:*

$$n = \frac{n_s}{r} \quad \text{(Eq.3)}$$

Where *r* is the expected response rate.

The final sample was well distributed among the strata (municipalities of the city). The proportion of the sample allocated to the stratum h is $a_h = n_h / n$. In each stratum h, the sample size n_h is equal to the result of the size of the total sample *n* and $_h$ *the*proportion of the sample from that particular stratum. As in the case of these investigations all strata were not the same size, an apportioning *N* was well used ([12] the sample size (n_h) each stratum is proportional the population size (N_h) of the stratum [13]. A larger share of the sample was therefore assigned a higher stratum on a smaller stratum. The following equation was obtained:

$$n_h = \frac{N_h}{N} n \quad \text{(Eq. 4)}$$

The level of accuracy has been retained to +/- 5% [13] considering a margin of error of 0.05, confidence level of 95% for each stratum and a response rate of 50% [14]. A total of 5270 households were surveyed in the 26 districts in 7 municipalities. In each municipality the number of households to be surveyed was previously defined.

2.2.2. Data processing

The survey data were stripped and encoded in binary form using Excel software. After encoding, data were subjected to analysis of variance (ANOVA) to highlight the differences between municipalities [15] with a *post-hoc* Tukey test ANOVA helped differentiate the average use of different sources in the different municipalities.

3. Results

Overall, in the city of Lubumbashi, the main source of electricity in case of failure or lack of electricity is the generator. It is clear from Figure 2 that 29.2% of the surveyed population use the generator, 13.1% for the *dynamo* and only 3% for solar panels. This implies that the surveyed household have become distrustful of the service provided by the National Electricity Company and make use of alternative sources although much more expensive in most cases. Apart from these three sources of energy mentioned above. It is observable that 55.8% of households use either the eclectic energy only or they are not connected to the grid and so these households are naturally subjected to the whims of SNEL.

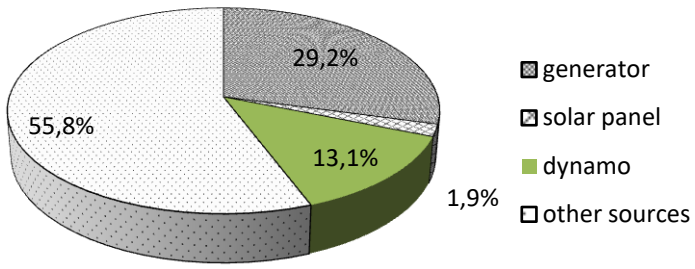


Figure 2. Main sources of electrical energy in Lubumbashi (the graph above figures represent the percentage of the use of each energy source)

Taking into account the different municipalities of the city Lubumbashi, Figure 3 reveals large disparities in the use of the generator. The highest percentage is observed in Ruashi municipality while the use of generators in Katuba and Kenya municipalities is lower (respectively 6.58 and 3.98% of the households). As a result, among the municipalities of the city center some use less the generator unlike other. Although the town which records the highest percentage regarding the use of generators gathers new districts, Figure 3 shows, however, that the Annexe municipality (also home to the recently born sprawl districts) presents low percentage (8.3%).

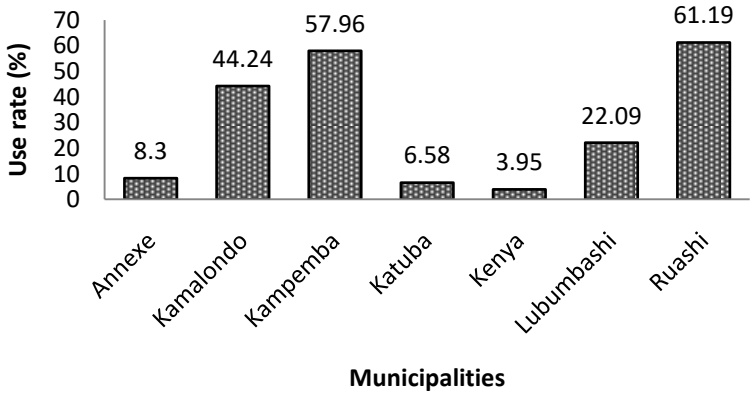
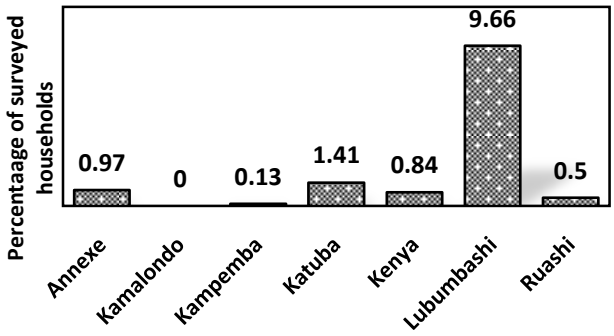


Figure 3. Use of generators in the various municipalities

Regarding the use of solar panels in the different municipalities of the city of Lubumbashi, Figure 4 shows that Lubumbashi leads with 9.6% of households using this energy source. By cons in Kamalondo municipality, none of the surveyed uses the solar panel. In the new districts

gathered in Annexe and Ruashi municipalities, the rate of panels use does not even reach 1%. From Figure 4, the various municipalities of the city are classified in descending order of use of solar panels: Lubumbashi, Katuba, Annex, Kenya, Ruashi, Kampemba and Kamalondo.



4. Use of solar panels in the various municipalities

Figure 5 shows the rate of *dynamos* use in 7 municipalities of the city of Lubumbashi. As a result, the use rate of *dynamo* varies between 0 and 30.46%. The highest percentage is observed in the Annexe municipality while the lowest percentage is observed in Kamalondo municipality where none of surveyed households use this energy source. In addition, this figure shows two major trends as regards the use of the *dynamo.* Municipalities of the city center which gathering old neighborhoods, use less *dynamo*. We can cite Kamalondo and Kenya municipalities followed by Lubumbashi municipality. However, the municipalities gathering new districts are characterized by a high use of the *dynamo.* Under the effect of a large spreading process, the new districts forming the peripheral part of the city of Lubumbashi are not facing the problem of electricity load shedding but that of electricity lack.

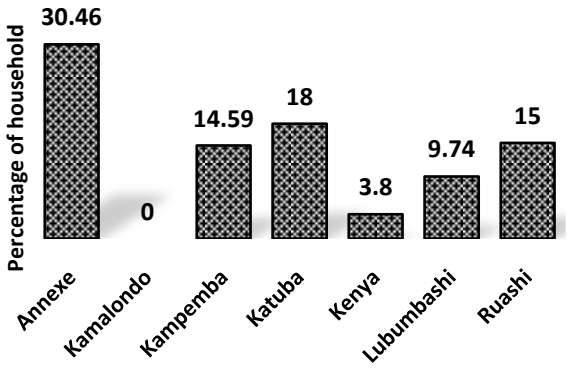


Figure 5. Use of *dynamo* in the different municipalities

Examination of Figure 6 shows clearly that candles are the most used in all municipalities of the city of Lubumbashi as a source of energy for lighting. The highest percentage is observed in Kamalondo municipality. Moreover, the figure shows that the oil lamp is used in the municipalities of the periphery, however, the highest percentage is observed in Lubumbashi municipality and the lowest percentage in Kamalondo. The flashlight is used in all areas of the city except Kamalondo municipality; the highest percentage was observed in Annexe municipality and the lowest in Ruashi. The rechargeable lamp is used in all municipalities except Kamalondo; the highest percentage was recorded in Lubumbashi municipality and the low in Kenya and Katuba municipalities. Of all the sources of energy for lighting surveyed, the most used is the candle.

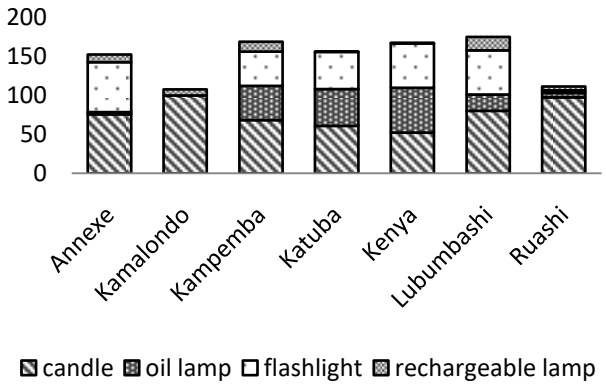
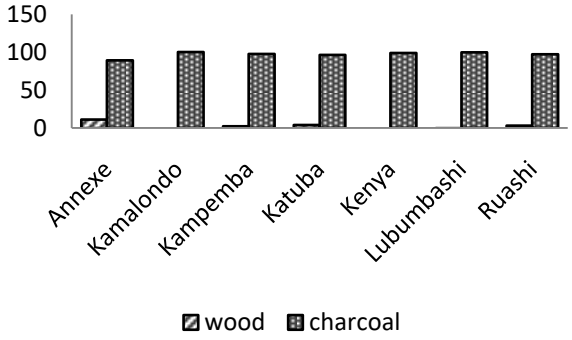


Figure 6. Main sources of energy for lighting

Looking at Figure 7, it turns out that charcoal is by far the most used source for cooking in all municipalities of the city of Lubumbashi. The highest percentage is registered in the municipality of Kamalondo. The wood is much used in Annexe municipality, but in a small percentage.

Figure 7. Main sources of energy for cooking



Discussion

Lubumbashi is as most cities in developing countries characterized by the use of diverse energy sources in domestic scale. Most households (29.2% of the surveyed population) use the generator, 13.1% using the *dynamo* and 3% using solar panels. However, generator group use causes a financial cost for the purchase of fuel and maintenance. As for the *dynamo*, it is a heat engine coupled to an alternator. It is proved by the literature that the use of these alternative methods is more expensive compared to a direct connection to the electricity grid of SNEL. However, most households try to avoid frequent and unplanned load shedding. The use of several energy sources provides a sense of energy security. Indeed, the complete dependence on a single fuel or technology alone can make households vulnerable to price changes and unreliable service Furthermore, the use of these different sources of electricity shows wide disparities in the seven municipalities of the city of Lubumbashi. Due to some geographic and socio-economic contexts, some municipalities use some sources more than others. As a result, among the municipalities of the city center some use less the generator unlike other. Although the municipality which records the highest percentage regarding the use of generators is constituted by new neighborhoods. Figure 3 shows, however, that Annexe municipality (also home to the recently born sprawl districts) presents small percentage (8.3%). Compared to Ruashi, Annexe municipality gathers more new districts. Indeed, this municipality is mainly composed of a set of suburbs surrounding the city of Lubumbashi. In addition, this municipality comes from the spread of other municipalities. Regarding solar, Lubumbashi municipality leads with 9.6% of the households that use this energy source. By cons in Kamalondo municipality, none of the surveyed households only use the solar panel. In new neighborhoods gathered in the Annexe and Ruashi municipalities, the panels use rate does not even reach 1%. The purchase cost of the panels should justify this low utilization in the suburbs, by against the high rate of access to electricity in the town of Kamalondo explain the absence of solar panels. Subsidies and improving the regulatory framework can serve as introduction programs in the market and help reduce the initial costs of deploying solar technologies and help them overcome obstacles. As for the use of the *dynamo,* it is proved that center municipalities gathering ancient districts use less *dynamo*. We can cite Kamalondo and Kenya municipalities followed by Lubumbashi municipality. By cons these municipalities gathering new neighborhoods are characterized by a high use rate of the *dynamo*. In the case of Annexe municipality where access lack is the rule,

using the *dynamo* became the most reassuring means of assistance for these populations. This has become a business*: dynamo* owner can connect up more than ten households that must pay 1000 FC a day after paying the subscription fees that can reach 10000FC. This for a serving of 6 hours (from 17h to 23h) and for limited use of bulb and electrical appliances. In Lubumbashi, this technique has become the most spread in the new districts. Faced with the shortage of electricity, small businesses in Ontario have developed genuine electric networks across neighborhoods or small towns, serving subscribers in their homes. According to a study by the World Bank, their installed capacity would represent 38% of public company

Apart from these different sources of energy, Lubumbashi households in case of shortage or power cut also used for lighting, flashlights, kerosene lamps and candles. It appears from this study that the candle is the more used energy source for in Lubumbashi despite its multiple damages such as fire within households. In addition these fuels generate poor quality light

For cooking, two main sources are used in Lubumbashi: charcoal and wood. Almost all of the surveyed households use charcoal as a source of energy for cooking and only 11% of households in the Annexe municipality use wood. This would be justified by the fact that for these suburbs, the nearby woods compared to central areas of the city facilitate the use. Urban households prefer charcoal because they do not produce a lot of smoke and heat value is twice that of wood and may last longer, especially when used with the improved stoves. Charcoal is considered relatively affordable, economical and practical [16]. In many places, charcoal is normally considered purchased at low cost. But due to the fact that it is repeatedly bought in small quantities, it ends up being more expensive in the long term compared to other energy sources. The energy for cooking is usually 70% to 90% of total energy consumption in developing countries). It has been estimated that about 2.5 billion people in these countries depend on biomass fuels such as wood, charcoal and animal dung to meet their cooking energy needs. According to [4] without substantial change in policy, the total number of people who depend on biofuels will increase from 2400 in 2010 to 2700 million by 2030 Moreover, demand for cooking fuel, especially in urban areas amplifies deforestation[2]; [16]. Most poor countries are severely deforested at rates approaching 95% and even 98%; in Africa it is responsible for over 90% of the harvested wood biomass In addition, there are health risks linked to the use of

charcoal. Indeed, when coal is burned, it produces carbon monoxide. If coal is used in a room that is not well ventilated, it could lead to high concentrations of carbon monoxide and cause a hazard to the user [17], [16]; [18]; [19]. Besides the shortage, biofuels also affect women and children in particular, who need more time to collect these fuels; time that could be spent on other activities such as agriculture and education It is clear that lack of access to a reliable electricity system entails multiple consequences both socioeconomic and environmental. The sum of costs for energy, in the context of the city of Lubumbashi, far exceed that required for a permanant access to an electricity grid. According to the World Bank this situation tends to make the poor poorer.

Conclusion

The general objective of this study was to identify and analyze the different sources of energy used in domestic scale in Lubumbashi. After surveys in 5270 households in 26 districts and seven municipalities of the city of Lubumbashi, the results reveal two main sources of energy for cooking, four for lighting and three as alternative sources of electricity. For every need, there is the most used source. In the case of cooking, Lubumbashi households prefer more charcoal than wood heaters. Only a few households of outlying districts still use wood for cooking. These preferred sources however result in multiple negative consequences for both human health and the environment. Regarding the sources of energy for lighting, candles are the most preferred because of easy accessibility while producing poor quality light. In case of load shedding or lack of electricity, the Lubumbashi households are implementing alternative sources such as the generator, *dynamo* or solar panels. Indeed, the use of these sources varies from one joint to another, with a higher frequency of generator use. Althoughthe *Dynamo* is less used at the urban scale, however, it is for most municipalities a reassuring source of electricity in the new neighborhoods distant from town center. In these neighborhoods where SNEL interventions are becoming scarce, *dynamos* allow so little to ensure the electricity needs of these populations. The use of solar panels is less common even it produces clean and sustainable energy. Only political subsidies and improving the regulatory environment can promote the introduction of programs on the market and help reduce the initial costs of deploying solar technologies and promote this clean energy source.

Finally, programs that would target improving and increasing access to sustainable and clean energy, should take account of geographical disparities due to population growth and urban sprawl of Lubumbashi.

References

[1] IEA 2004: International Energy Agency: *World Energy Outlook,* Paris.

[2] Chambwera, M., H. Folmer, 2007. Fuels witching in Harare: anal mostideal demand system approach. *Energy Policy* 35 (4), 2538-2548.

[3] Clerici A. 2007. *The Inga Development – What in the last 40 years, what in future*, conference au Conseil mondial de l'énergie International Forum on Grand Inga Project, Gaborone, Botswana, 16-17 March, 2007, http://www.worldenergy.org/wecgeis/global/downloads/africa/AFRICAInga0307a .pdf.

[4] International Energy Agency (IEA), 2009. *Cities, towns & Renewable Energy* **,** Report, 2009, Paris France, 194pp.

[5] Banza BB, Kiseya TF & P Bouillard, 2016. Electricity Access in Lubumbashi, DR Congo: Influence of Household Socioeconomic factoring, *Submitted*.

[6] INS, 2009. *Estimated population of DR Congo by province, city, district and commune / territory and area of residence*, INS / work DSDS-Document.

[7] Bruneau J.-Cl. Mbuyu & M., 1987. *Administrative division. In Lubumbashi Atlas*, pages 39-40. Centre for Geographical Studies on Black Africa.

[8] World Bank, 2007. *Little Data Book on Africa* 2007, Washington DC, The World Bank

[9] Nsiami MC, 2009. *Picture textural analysis of panchromatic QuickBird very high spatial resolution. Application to the differentiation of land cover types Lubumbashi*, PhD Thesis, University of Lubumbashi, 206p.

[10] Gerville-Réache L. & Couallier V., 2011. *Echantillon représentatif (d'une population finie) : Définition statistique et propriétés. Echantillon représentatif, sondage, quotas, probabilité d'inclusion*, hal-00655566.

[11] Lessard C., 2013. L'enquête québécoise sur l'accès à internet 2012. Présentation et analyse des résultats, Institut de la statistique du Québec, septembre 2013, p. 157.

[12] Laurencelle L., 2012. The representativeness of a sample and test by chi-square, *Tutorials in Quantitative Methods for Psychology* , Vol. 8 (3), pp: 173-181.

[13] Levron E., 2009 . *Identifying vulnerable urban* ACF International, p. 96.

[14] Ndongo B., E. & Nguikam Mbouendeu SL, 2012. Analysis of unconventional water services in squatter neighborhoods: the case of EBA'A district in the outskirts of Yaoundé (Central Region Cameroon) *journal of Water Science* , vol. 25 (2), pp:

[15] Durin B., 2006. *Transfer and transportation of colloidal metal pollutants: Application in road drainage* . PhD thesis, University of Nante., Graduate School mechanical, thermal and general civil, 213p.

[16] Karekezi S., J. Kimani, Onguru O., 2008. *Energy Access Among the Urban and Peri-Urban Poor in Kenya*, Global Network on Energy for Sustainable Development (GNESD) . Nairobi, Kenya.

[17] Clancy J., 2004. *Enabling urban poor livelihoods policy making: understanding the role of energy services*, UK Department For International Development (DFID) Inception Report, 2004.

[18] Njong AM & Johannes TA, 2011. An analysis of domestic cooking energy choices in Cameroon, *European Journal of Social Sciences* , vol. 20, no. 2, pp. 25-36.

[19] Kumlachew G., G. Molla, Zewdu D., J. Dube, 2014. Current Level and Correlates of Traditional Cooking Energy Sources Utilization in Urban Settings in the Context of Climate Change and Health, Northwest Ethiopia: A Case of Debre Markos Town, Hindawi Publishing Corporation, *BioMed Research International* Volume 2014, Article ID 572473, 11 pages http://dx.doi.org/10.1155/2014/572473 .