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Analysis of the Environmental Impacts of Geothermal Drilling on Livelihoods of Adjacent Communities in Menengai Geothermal Power Project

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Abstract: *Geothermal energy has been termed as one of the world low cost and sustainable source of energy. It provides a green and renewable source of energy most common within areas with active volcanic activity. Kenya as a country has numerous geothermal resources deposited along the Great Rift Valley therefore making it among the countries in the world with high potential for geothermal power generation. Currently four geothermal sites have been explored and wells drilled that is Olkaria, Menengai, Eburru and Longonot. Geothermal power generation projects occupy large geographical area therefore have the potential to alter the livelihood patterns of the surrounding communities by shirking land, and resettlement. Further, geothermal drilling produces toxic chemical wastes such Hydrogen sulfide gas that is toxic, irritating to human therefore if not well handled it leads to significant environmental damages. Geothermal Development Company has been implementing the Menengai Geothermal project for five years and other than the initial feasibility study, there has been no other study done to evaluate the impact of the project to the surrounding communities. Five years into the implementation phase the projects is expected to have contributed substantially to the livelihood of the adjacent communities both positively and negatively. This study therefore sought to assess the environmental impact of the Menengai Geothermal Project on the livelihoods of the adjacent communities. The study was done among the residents of Bahati Division, Nakuru County, Kenya using the descriptive research design. The target population comprised selected members of the community drawn from the Nakuru North Youth Sacco from which a sample size of 96 was selected. Questionnaires were used to collect data from the selected respondents from the Nakuru North Youth Sacco. The data collection tools were validated in a pilot study in a sample of 10 selected technical staff of the Olkaria Power Plant in Naivasha. The study found out that there were severe environmental concerns cited by the residents of Bahati Division originating from the Menengai Geothermal projects such as air pollution, noise pollution and waste disposal. The study therefore recommended for company in collaboration with National Environment Management Authority to relook into the environmental concerns of the residents of Bahati Division following the implementation of the Menengai geothermal project.*

Keywords: *Geothermal, Environment, Impact, Sustainable livelihood*

I. Introduction

Geothermal energy is the natural heat stored within the earth's crust. The energy is manifested on the earth's surface in the form of fumaroles, hot springs and hot and altered grounds. To extract geothermal-generated electricity, wells, sometimes a mile deep or more, are drilled into underground reservoirs to tap steam and very hot water that drive turbines linked to electricity generators. The first geothermal generated electricity was produced in Larderello, Italy in1904. Geothermal energy is generated in over 20 countries. The United States is the world's largest producer, and the largest geothermal development in the world is The Geysers north of San Francisco in California (Geothermal Energy Association (GEA), 2013). In Iceland, many of the buildings and even swimming pools are heated with geothermal hot water. Iceland has at least 25 active volcanoes and many hot springs and geysers. World over, there have been different mechanisms for enforcing responsible sustainable mining practices (Adey, Shail, Wall &Varul, 2010).

Kenya is the first country in Africa to tap geothermal resource for energy. In response to the increasing demand for power, the Kenya government has commenced the process of realizing 5000 MW of geothermal energy over the next 20 years (Ngugi, 2012). Currently, projects whose total capacity exceeds 800 MW are under implementation and an additional 800 MW projects are scheduled to commence in the next five years. It is estimated that the development of the 5000 MW will cost about 18 billion US$. The Geothermal Development Company Limited (GDCL), a special government vehicle was formed to spearhead exploration and development of geothermal resource in the country. GDCL is partly facilitated by the Government of Kenya to meet its mandate and raises the other part of the required resources through credits, external financiers and in future through steam sales revenues. Kenya Electricity Generating Company Limited (KenGen) and other

independent power producers (IPP) will raise the balance of 12 billion for the power infrastructure development and installation of the power plants through steam purchase agreements with GDCL.

The Government has assumed the responsibility through GDCL to prepare bankable projects that will qualify for financing by multilateral, bilateral, and private entities by addressing the various issues which form the criteria for financial approval. According to Oduor (2010), in Kenya, Geothermal resources are mainly located along the Kenyan Rift, which is part of the eastern arm of the African Rift. Olkaria, in Naivasha District, south of Lake Naivasha, is currently the main source of geothermal electricity in Kenya. The terrain is irregular and is characterized by volcanic hills, valleys, gorges, bolders and weathered rocks. Vegetation is mainly shrubs and short trees. The area has been exploited for geothermal power generation and harbors the Hells gate National Park. The neighboring Oserian farm has tapped the geothermal resource for horticultural farming and has an animal Sanctuary within the same environment. There are spontaneous settlements by the Maasai, a pastoral community, who are the indigenous inhabitants of the land and private land owners whose interest is mainly ranching and conservancy.

The Geothermal Development Company in its bid to integrate with the community has flagged a number of community development projects at the Menengai Project Site along three pillars water, health, and education. For the water pillar, a project to supply the surrounding community with clean domestic water was started in 2012. The water was to be supplied from GDCL borehole No. 5 at the water intake site and pumped to two areas: Wanyororo on the Eastern side – Phase 1, and Kabarak areas on the Western side – phase 2. So far water pipes have been laid out on the Wanyororo side and water storage tanks are under construction at the village level. On the health pillar, GDCL focuses on the rehabilitation of existing health facilities to enhance service delivery. So far, one health center has been rehabilitated at Wanyororo – St John's, some medical equipment procured for the health center and procurement of consumables for the facility is in process while an incinerator has been constructed for safe disposal of toxic materials.

Further, the construction of a maternity ward and procurement of an Ambulance for Bahati District Hospital in progress. On the education pillar, GDCL has donated cement to schools to assist in infrastructure development. Surrounding Schools have been involved in tree planting during World Environmental Days inside the Menengai Crater. In addition to these, students are given free access to visit the project area and hold career talks facilitated by GDCL staff. Other areas of CSR fronted by the GDCL include economic empowerment where GDCL has encouraged the formation of Saccos to assist the local youth in getting labour contracts with the organization. The Saccos also help in developing a saving culture among the youths and in-turn they can borrow. The loans empower them to start small business enterprises using the acquired skills. As part of Social afforestation, the company donates tree seedlings to CBO (Community Based Organizations) and buys back from them after to plant in the project area and part given back to the community. To enhance security surveillance around Menengai project, GDCL has installed Solar powered Security floodlights at Wanyororo, Bahati and Maili Kumi areas specially concentrating on Boda Boda operation points.

Problem Statement

Geothermal energy has been termed as one of the world low cost and sustainable source of energy. It provides a green and renewable source of energy most common within areas with active volcanic activity. Kenya as a country has numerous geothermal resources deposited along the Great Rift Valley therefore making it among the countries in the world with high potential in geothermal power generation. Kenya's Vision 2030 targets to produce 5000MW of geothermal energy by the year 2030 but currently exploits just over 390 MW of geothermal capacity which is 13% of proven capacity. By their nature, geothermal sites are located in rural areas with communities established before the exploration takes place. Geothermal power generation projects therefore due to the large area they occupy alter the livelihood patterns of the surrounding communities by shirking land, resettlement among other aspects. Further, geothermal drilling produces a number of toxic chemical wastes and Hydrogen sulfide gas that is toxic, irritating to human therefore if not well handled it leads to significant environmental damages. The principles of sustainable mining require that drilling and power generation companies operate in a socially responsible way that is sensitive to the environment and the communities living in there. The GDCL has been implementing the Menengai Geothermal project for five years and other than the initial feasibility study, there has been no other study to evaluate the impact of the project especially on the surrounding communities. Five years into the implementation phase the projects is expected to have contributed substantially to the livelihood of the adjacent communities both positively and negatively. This study therefore sought to assess the environmental impact of the Menengai Geothermal Project on the livelihoods of the adjacent communities.

Research Objective

The objective of this study was to assess the environmental impacts of Menengai Geothermal Project on the livelihoods of the residents of Bahati Division in Nakuru County, Kenya.

Research Hypotheses

H_0: Menengai Geothermal Project has no significant environmental impact on the livelihoods of residents of Bahati Division, Nakuru County.

H1: Menengai Geothermal Project has a significant environmental impact on the livelihoods of residents of Bahati Division, Nakuru County.

II. Literature Review

Environmental Impacts in Geothermal Drilling

The Chemical environment in geothermal drilling also has an impact on the human wildlife surrounding it. The main impacts come from odors during well tests and power plant operation. Gas emissions from the geothermal power station are predominantly carbon dioxide (80%) and hydrogen sulfide (9.5%). The other gases, which include hydrogen, methane, nitrogen and oxygen, form 0.5% of the total non-condensable gas fraction. Total geo-gas from existing geothermal station forms about 2% of geothermal effluent (Sinclair & Knight, 1994).

According to Tole (1996), annual carbon dioxide emission from the Olkaria I 45 MWe is estimated to be 21,850 tonnes and a coal-fired power plant of the same rating releases 349,143 tonnes of the gas to the atmosphere. Therefore, carbon dioxide emission from geothermal plant is not high compared to one from coal-fired plant. The carbon dioxide produced by geothermal power stations is approximately seven times less than the ones produced by coal-power station. However, long exposure of high concentration of carbon dioxide has serious impact on human beings.

Studies have shown that exposure of various concentrations of carbon dioxide have effects on human breathing (Kubo et al, 1999).Although geothermal power plants are environmentally active because of their renewable energy status, they pose an environmental threat because of hydrogen sulfide gas that is contained in most geothermal steam sources. If not correctly disposed of, this gas can cause health and safety problems. Hydrogen sulfide is a dangerous gas and standard quality varies from country to country. Air quality criteria, has been formulated by regulatory bodies in other countries to maintain acceptable environmental quality. Hydrogen sulfide is a noxious and potentially poisonous gas with odour of rotten eggs.

About 90% of global emissions are estimated to be from natural occurrences, the remaining 10% is from industrial wastes, which include sewage treatment plants petroleum refineries and Kraft paper mills (Sinclair & Knight, 1994). Other chemical related impacts come from possible brine or mud spills. These must be foreseen during the design stage, and there must be monitoring of contaminants to ensure compliance with legal and moral obligations. Adequate disposal of drilling mud and adequate reinjection infrastructure should ensure that all effluents are properly contained (Rodríguez & Arévalo, 2007).

Apart from the physical and chemical environments, biological environment is a critical component of geothermal drilling. This comes from the impacts to the local flora and fauna originating from cutting trees and reducing wildlife habitat to make way for infrastructure. As a result of the highlighted changes, if the relationship with local communities is not managed properly, the locals will see the geothermal developers as invaders who will exploit "their" subsurface for profit, give nothing in return to the community, and damage the environment. News of bad experiences with one project, even one by another developer in a neighboring country, will spread quickly, and spark resistance to all geothermal developments. This therefore calls for programmes to integrate the community with the projects through sharing of facilities and benefits and also through socio economic developments. One powerful strategy that has been used in geothermal projects is the corporate social responsibility approach.

Livelihood Assessment

The livelihoods approach differs from conventional evaluations in its central focus on people's lives rather than on resources or defined project outputs. The approach is based in the precedence that well-being is not only about increased income. Other dimensions of poverty that must be addressed include food insecurity, social inferiority, exclusion, lack of physical assets, and vulnerability. Further, household poverty is determined by many factors, particularly access to assets and the influence of policies and institutions.

In addition, livelihood priorities vary; outsiders cannot assume knowledge of the objectives of a given household or group. Project impact assessment must therefore be based upon a prior understanding of people's objectives as well as on an informed view of how their livelihoods are constructed and which factors are the essential causes and manifestations of their poverty. The sustainable livelihoods approach to development and poverty reduction tries to take all these concerns into account. It aims to promote development that is sustainable not just ecologically, but also institutionally, socially and economically and to produce genuinely positive livelihood outcomes (Ashley & Carney, 1999).

According to Carney, (1998), a livelihood comprises the capabilities, assets including both material and social resources and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base. When it comes to impact assessment, this means that changes in measurable must be assessed not in their own right, but in terms of the contribution they make to livelihoods. In light of the current study, the impact of the Menengai geothermal will be evaluated in relation to its contribution to livelihood contribution in individual households.

III. Methodology

Research Design

The study was conducted using the descriptive research design. The research design would be applicable in the study because it allows the researcher to study phenomena that do not allow for manipulation of variables. By applying this design, the study provided in depth insights on how the environmental outcomes from the implementation of Menengai geothermal projects affects the livelihoods of adjacent communities in Bahati Division

Target Population, Sample Size and Sampling

The study target population comprised selected members of the community around the Menengai Geothermal project. Community members were drawn from 2456 Nakuru North Youth Sacco from which a sample of 96 residents was selected. Selection on individuals was done using the simple random sampling criteria. Members were selected from the membership register randomly following the assigning of random numbers.

Instruments of Data Collection

Questionnaires were used to collect data from the selected respondents from the Nakuru North Youth Sacco. The questionnaires were designed using both open ended and closed ended questions. Respondents' opinions were measured on a five point lickert scale. The data collection tools were validated in a piloted study in a sample of 10 selected community members in the community neighboring Olkaria Geothermal Project in Naivasha. The piloting questionnaires were subjected to analysis for reliability using Cronbach's reliability coefficient. A coefficient of 0.75 was obtained, therefore the tools were considered adequate according to (Gay, 1992).

Data Presentation and Analysis

Analysis of data was done according to the research objective. The responses were summarized into frequencies and Percentage, and a computation of the mean for the purposes of weighting them. Relationship between the impacts and the livelihood of residents were achieved using chi square analysis to detect any association between the two parameters.

IV. Findings and Discussion

The objective in this study sought to determine the environmental outcomes and impacts as a result of the Menengai Geothermal project based on the opinion of the community living in Bahati Division. Table 1 presents the findings on the community opinions.

Table 1: Environmental Impacts of Menengai Geothermal Project

	N	Min	Max	Mean	SD
1. There is unrestrained land dilapidation as a result of exploratory projects thus making the land unproductive	93	1	5	3.11	1.13
2. The Bahati community's ecosystem balance has been interrupted by the Geothermal exploration projects	93	1	5	3.57	1.23
3. Geothermal exploratory projects have led to increased air pollution	93	1	5	4.11	0.96
4. Waste disposal in the Geothermal exploration sites has led to contamination of available water sources	93	1	5	2.76	1.08
5. There is massive deforestation as a result of the creation of access routes to new areas and sites thus minimizing sources of pasture	93	1	5	3.30	1.28
6. Environmental pollution caused by geothermal drilling has resulted in a destruction of livelihoods of local communities	93	1	5	3.33	1.21
7. Destruction of forest cover by geothermal projects has affected the availability of energy sources	93	1	5	2.67	1.15

The findings in Table 1, above shows that the project has had adverse negative impacts on the surrounding communities in Bahati Division. The most severe negative environmental outcome cited was the increased air pollution which was highly rated at (Mean = 4.11, SD = 0.96). Further the community cited serious interruption of the ecosystem balance by the Geothermal exploration projects (Mean = 3.57, SD = 1.23). There was also agreement among community members that environmental pollution caused by geothermal drilling has resulted in a destruction of livelihoods of local communities (Mean = 3.33, SD = 1.21). The massive deforestation in the process of creation of access routes to new areas also caused a shrinkage in the sources of pasture (Mean = 3.30, SD = 1.28) in a community where 12.9% of the members earned their living from livestock farming.

The community members also cited that there was unrestrained land dilapidation as a result of exploratory projects thus making the land unproductive (Mean = 3.11, SD = 1.13). Further the waste disposal in the Geothermal exploration sites has led to contamination of available water sources (Mean = 2.76, SD = 1.08) therefore endangering the health of the local community. Finally the community members noted that destruction of forest cover by geothermal projects has affected the availability of energy sources (Mean = 2.67, SD = 1.15) such as firewood and charcoal. It is key to note that all the environmental effects of the geothermal projects were rated fairly high which implies that the community was already experiencing the negative environmental outcomes of the geothermal drilling at Menengai. When the community was asked to indicate whether there were other environmental risks eminent in the project, majority 54.8% agreed. Some of the environmental risks cited by the community included: the noise pollution especially at night, and the ultimate impact of the project in the climate of the area.

Sustainable Livelihood Status of residents of Bahati Division

The study assessed the livelihood status of the residents in order to determine whether these were attributable to the activities of the projects. The findings are presented in Table 2.

Table 2: Livelihood Status of residents of Bahati Division

	N	Min	Max	Mean	SD
1. House hold income	93	1	5	4.01	0.93
2. Food security	93	1	5	3.12	0.83
3. Use of natural resources	93	1	5	3.23	1.00
4. Health status of residents	93	1	5	3.10	1.43

On a five point scale, residents of Bahati division rated fairly high their house hold income at (Mean = 4.01, SD = 0.93). In other indicators of sustainable livelihoods, the residents rated themselves moderate in the sustainable use of natural resources (Mean = 3.23, SD = 1.00) food security (Mean = 3.12, SD = 0.83) and the health status of the general population (Mean = 3.10, SD = 1.43).

Association between Environmental Impacts & Sustainable Livelihoods

Table 3: Association between Environmental Impacts & Sustainable Livelihoods

	Value	**df**	**Asymp. Sig.**
Pearson Chi-Square	294.234[a]	234	.005
N of Valid Cases	92		

The test results on Table 3 indicate that there was a significant association between environmental impacts of Menengai geothermal project and the Sustainable Livelihoods of residents of Bahati Division (χ^2 = 294.234, $p < 0.05$).

The study therefore rejected $\mathbf{H_0}$ and accepted $\mathbf{H_1}$. Menengai Geothermal Project has a significant environmental impact on the livelihoods of residents of Bahati Division. This finding concurs with Sinclair & Knight, (1994) who indicated that the Chemical environment in geothermal drilling has an impact on the human wildlife surrounding it**.** The main impacts come from odours during well tests and power plant operation as well as gas emissions.

V. Conclusions

There are severe environmental concerns cited by the residents of Bahati Division originating from the Menengai Geothermal projects such as air pollution, waste disposal as well as the interference with vegetation cover, and the general eco system. Further, there is significant association between the negative environmental outcomes and the livelihoods of the locals. This implies that the projects have had a negative impact on the sustainable livelihoods of residents. As a result the GDCL in collaboration with NEMA should relook into the

environmental concerns of the residents of Bahati Division following the implementation of the Menengai geothermal project. Further, in future geothermal explorations and mining, the government should have an environmental surveillance mechanism not only at the drilling sites but also to the adjacent communities to minimize the exposure to toxic chemicals and ensure their livelihoods are sustained as they were before the projects.

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