Imperial Journal of Interdisciplinary Research (IJIR)
Vol-2, Issue-12, 2016
ISSN: 2454-1362, http://www.onlinejournal.in

Climate Change Resilient Geothermal Production In Eburru And Olkaria, Nakuru County, Kenya

Joseph Karanja[1] & Innocent Ngare[2]

Abstract: *Climate change is inevitable for years to come. This reality dictates that development paths should build social, economic and ecological resilience for sustainability to be attained. In Kenya, 70 % of total formal employment is from natural resource sectors. This paper focused on technological inadequacies in the course of geothermal production in Olkaria and Eburru geothermal sites which are fragile ecosystems. The physical and chemical characteristics of waste geothermal fluids, physical and chemical properties of rain water were analyzed as well as gaseous emissions from the plants. Simple random sampling and purposive sampling were used in determining samples. Focused group discussions, interviews, observation guides and key informant were used to collect data. Most of the data was collected from Kengen for a five year duration between 2011 and 2015. 81 wells were sampled out for analysis. Analysis was done using Statistical Package of Social Sciences. One sample t- test was integral in comparing averages of observations against recommended national standards. The results indicated that waste geothermal fluids were unsuitable for discharge into the environment. Apart from this, rain water at geothermal sites was acidic due to emission of gases. More so, geothermal exploration undermined quality of underground water and could not be used for recreation. The flash system of production had inherent inadequacies that resulted in imposing the characteristics of geothermal formations to the surrounding. The gases emitted exceeded the maximum values permissible for controlled zones. The ideal situation would contain the waste fluid in a closed loop system so as to minimize its interaction with the surrounding. The results were integral in informing resilient pathways that could facilitate climate compatible development which in essence would bolster climate change resilience.*

Key Words*: Climate Change, Resilience, Geothermal, Development, Flash System*

1. Introduction

Sustainable development is the only viable path towards safeguarding the planetary systems. (Barasa, 2015) advised that there was an urgent need to transform from reactive compliance based environmental management to proactive impact predicting resource management. This would foster climate compatible development. (KIPPRA, 2013) corroborated this argument by emphasizing that the contemporary challenges of poverty eradication, social inclusivity, economic prosperity and attainment of ecological integrity could be achieved simultaneously through efficient and effective utilization of the natural capital. Climate Change is the defining challenge of our time whose cascading impacts are broad with stark consequences. In this regard, (Miola, *et al*., 2015) indicated that adaptation would not be optional but a paramount necessity for future survival. (ADB, 2012) illustrated that past prediction about Climate Change had taken effect including receding glaciers, loss of ice, extreme heat waves, stronger hurricanes and sea level rise. In addition, they cited that the world was getting warmer with ten warmest years having occurred in the last decade. Such a trend in their view could lead to extinction of 20% to 30% of all plants and animals whereas developing countries would require between 28 to 67 billion dollars to adapt. (Christopher, *et al*., 2014) argued that humans are the dominant drivers of global warming. Further to this, they cited that there was need to reduce greenhouse gases emissions by 50% to 80% to stabilize them. These arguments depicted that climate change is unavoidable. However, its impacts could be mitigated by rational policies that integrate economic, social and environmental needs.

Kenya's transformation to the year 2030 is anchored on stable and reliable energy provision. To this effect, geothermal exploration has been intensified to cater for the energy deficit. (Alfredsson, 2011) classified geothermal as clean energy. However, he espoused that the energy choices we make could be the key determinant of our welfare to the long term. Further, he argued that the ecological challenges we face today including climate change are the logical and rational consequences of a 'cowboy economy.' (Mazza, *et al*., 2012) therefore postulated that working with nature should be the core intent of every economic model to eliminate chances of environmental despotism. (KIPPRA, 2013) highlighted that Kenya's future progress was pegged on the status of its natural capital. To support this assertion, it was illustrated that 42% of the country's GDP is derived from natural resource sectors. To this effect, 70% of total formal employment is natural resource based. In addition, poverty reduction of 15% could be achieved by the year 2030 if benign utilization of resources is embraced. How then can Kenya ensure that energy provision to power economic progress does not jeopardize integrity of fragile ecosystems where geothermal production is done? The answer to this question would be imperative in facilitating the transition to a green economy that would be climate resilient.

(Wanqig, 2012) revealed that geothermal energy is not free of adverse impacts. This means the fragile ecosystems endowed with geothermal resources are at risk. (Cannady, 2009) however advised that climate compatible technologies could be a panacea in averting global climate catastrophe. (Muchangi & Kagweni, M., 2014) argued that half of Hell's Gate National park had been paralyzed. The unique landscape had been transformed and dotted with a multiplicity of geothermal wells. Geothermal plants emit substantive amounts of boron, mercury, arsenic and other heavy metals that could increase the toxicity of the adjacent environment. (Wanqig, 2012) acknowledged that substantive amounts of greenhouse gases were also emitted by the power plants. It is these reservations that this study seeks to explore. The chemical characteristics of geothermal fluids from the power plant were analyzed. In addition, other areas of discharge such as discharging wells, Direct Use and Demonstration Center, Borehole water, infiltration ponds and well sites physical and chemical characteristics were ascertained. In addition, physical and chemical properties of rainfall received in the geothermal settings was also analyzed. Apart from these, levels of gaseous emissions and technological inadequacies of the flash system were ascertained. The results of the analysis were to be compared with standards set by National Environmental Authority of Kenya (NEMA). The intent was to ascertain whether geothermal exploration could help in building climate resilience or could be a propellant in enhancing climate change vulnerability. The analysis showcased the status of the ecosystems that formed the premise for the conclusions to be made.

This study informed on suitability of waste geothermal fluid for recreational purposes. Apart from this, the characteristics of borehole water revealed whether underground water was affected by geothermal exploration. The waste fluid from power plants indicated its suitability for discharge into the environment. More so, analysis of discharging wells ascertained what characteristics of the geothermal formation found their way into the immediate environment. Analysis of well sites espoused to what extent geothermal exploration could have impacted on the vegetation, soils and water found within the well sites. Levels of emissions of greenhouse gases informed on the contributions of geothermal exploration to ongoing global warming. The results helped make a judgement on how geothermal exploration impacted on climate change resilience to the long term.

2. Study Area

The study was carried out in Olkaria and Eburru geothermal sites in Nakuru County. Olkaria lies within latitude 0^{0}54'57"S, and longitude 36^{0}18'48" E. (Mutia, 2010). Hell's Gate had 103 wells as of 2012 according to (Muchangi & Kagweni, M., 2014). It is a semi-arid region experiencing warm dry climate. The areal extent of the park was about 68.25 km^2. (Barasa, 2015) established that the park had over 100 bird species including the endangered Ruppell's vulture. The big mammals prevalent included Zebras, Giraffes, Reedbuck, Impala, Gazelles, Buffalos and Elands. All these species had witnessed tremendous decline in their numbers. The major economic engagement of the local community was pastoralism and provision of ancillary touristic services.

Olkaria fields are located in Hell's Gate National Park. (Muchangi & Kagweni, M., 2014). Geothermal exploration had the potential of wiping out this integral resource. The rig sites, well pads, power plants and other ancillary structures had seen massive vegetation clearance. (Mutia, 2010) weighed by suggesting that proposed industrial park within this setting could mean its eventual de-gazettement as a park renowned for its fascinating features. This was the case for Eburru, it was a gazetted forest with unique species hat faced extinction owing to massive human intrusion in the course of geothermal development. (Barasa, 2015) highlighted the importance of conserving these two unique settings that play crucial ecological functions. The primary resource endowed in them could be crucial for building climate resilience and provide adequate platforms for adaptation and mitigation. Their ecological instability could weaken social and economic systems of the local population hence increasing their vulnerability to climate change.

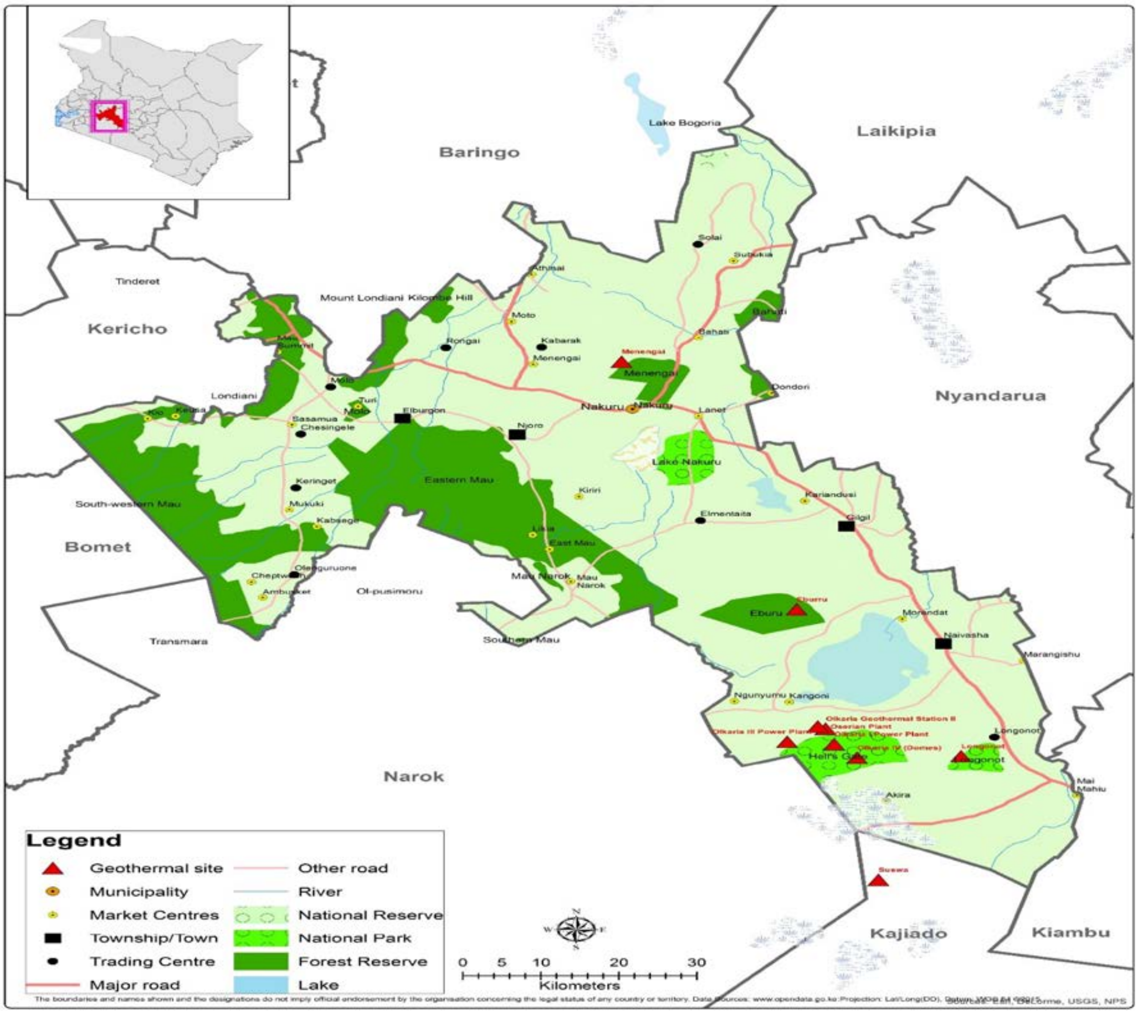

Figure 1: Map of Study area. Note the geothermal sites are located in conservational areas represented in green

3. Materials and Methods

Three sampling techniques were used in the study including purposive sampling, simple random sampling and snow balling sampling. 7 bore holes were sampled in areas adjacent to geothermal producing sites. Purposive sampling was used. The bore holes included Mai Mahiu, Keekonykie, James Mange, Florensis, DCK, Jikaze and Rubiri. Purposive sampling was also used for determining infiltration points. Pond 1, 1B, 2, 3 and 3B were selected. They all derive their constituents from Olkaria 1 power plant that utilizes the old flash technology. Well site analysis entailed selecting 81 wells randomly selected across the various Olkaria fields. Purposive sampling was used in determining points of analysis for precipitation. 14 points were selected all of which were rain collection centers across the Olkaria fields. For air quality determination, purposive sampling of 4 gases was done informed by their contribution to global warming and occupational duration exposure. The gases were carbon dioxide, hydrogen sulphide, methane and particulate matter. Snow balling sampling was used for interviewing of top personnel of various departments. Sessions with 1 personnel could have rising issues that could determine the next personnel to be interviewed.

The research instruments were determined by nature, scope and extent of data sought. Interviews were administered to various plant operators, technicians, geologists, engineers and safety officers. A key informant was integral in giving the background information of the area, community occupation, impacts of geothermal exploration to the local community and community engagement with Kengen. Focused group discussion was done by employees of the environmental section. Observation guides and photography were also used. Document analysis was done where several periodicals, reports, legislations and company's data records were consulted.

Both qualitative and quantitative data were derived. Qualitative data was analyzed based on a thematic approach. Quantitative data was analyzed using Statistical Package for Social Sciences, maximum values, minimum values, mean observations and standard deviations were used in analysis. In addition, 1 sample t-test was imperative in determining whether the waste fluids or gaseous emissions had exceeded the maximum permissible values set out by NEMA in its various legislations and policy documents.

4. Results

The study had hypotheses which formed a basis for communication of the research findings. The findings entailed characteristics of underground water, properties of discharging wells and suitability of waste geothermal fluid for direct use for recreation. In addition, metallic concentrations in vegetation was ascertained as well as rain water characteristics.

Physical and Chemical Properties for Keekonyokie Borehole

Fluoride and cadmium average values for this borehole were above the maximum permissible limit for drinkable water as recommended by Kebs (Kenya Bureau of Standards). The pH values measured ranged between 6.09 for minimum value and 7.09 for maximum value respectively. The test of significance further affirmed that fluoride and cadmium levels were significantly high as compared to recommended values by Kebs. Their p-values were less than 0.05 whereas their sigma values were positive as shown in table 1. This was the trend for the other 6 boreholes.

Table 1 : Physical and chemical properties of borehole water

Parameter	Mean	WHO Stds	Kebs Stds	Sigma value	P - value
TDS	156.00	1200.00	1500.00	-138.78	0.00
Cl^-	69.35	250.00	250.00	-62.37	0.00
SO_4^{2-}	148.40	400.00	400.00	-72.72	0.00
F^-	2.88	1.50	1.50	10.05	0.00
Zinc	0.78	5.00	5.00	-83.57	0.00
Cadmium	0.02	0.03	0.05	6.77	0.00
Lead	0.01	0.01	0.05	-7.82	0.00
Boron	0.04	0.50	1.00	-2.25	0.04
Barium	0.56	1.00	1.00	-26.14	0.00

TDS - Total Dissolved Substances, Cl^- - Chloride, SO_4^{2-} - Sulphate, F^- - Fluoride

Physical and Chemical Properties for Discharging Wells

Six discharging wells were analyzed. The mean values for boron, cadmium and zinc were high compared to standards for discharge of waste fluids into the environment by NEMA (National Environmental Management Authority). Further, the test of significance as illustrated in table 2 affirmed that the concentrations of Boron, Cadmium and Zinc were significantly high as compared to set standards by NEMA. Their p-values were less than 0.05 and had positive values for sigma value.

Table 2: Physical and chemical properties of discharging wells

Parameter	Ba	B	Cd	Cu	Pb	Zn	Cl^-
Maximum	0.94	14.84	0.11	0.95	0.67	13.66	455.60
Minimum	0.01	1.44	0.42	0.29	0.06	2.37	159.05
Std Dev	0.39	4.52	0.25	0.24	0.25	4.30	112.50
Mean	0.48	9.16	0.07	0.52	0.22	7.48	291.75
NEMA Std	1.00	1.00	0.01	1.00	0.01	0.50	250.00
S Value	-3.31	4.42	5.55	-4.81	2.04	3.97	0.91

P - Value	0.02	0.01	0.00	0.01	0.10	0.01	0.40

Ba – Barium, B – Boron, Cd – Cadmium, Cu – Copper, Pb – Lead, Zn – Zinc, Cl^- - Chloride

Physical and Chemical Properties for Direct Use and Demonstration Center (DUDC)

This is a point where waste geothermal fluid was utilized for recreational purposes. A spa had been sunk to allow for the public to enjoy the warm fluid from geothermal plants. The mean values for Zinc, Cadmium, Boron, Sulphate and Chloride were all high compared to standards for recreational facilities set by NEMA. This was further ascertained by the t-test that showed the p- values for the mentioned parameters were less than 0.05 whereas their sigma values were of positive value. Table 3 gave a detailed breakdown of the analysis.

Table 3 : Physical and chemical properties of fluid at Direct Use and Demonstration Center

Parameter	**Zn**	**Cd**	**Pb**	**B**	**Ba**	**SO_4^{2-}**	**F**	**Cl^-**
Maximum	6.87	1.46	0.01	5.38	0.13	135.50	63.75	739.54
Minimum	2.78	0.00	0.00	2.31	0.00	103.10	27.76	179.82
Std Dev	1.13	0.42	0.00	0.80	0.03	8.64	11.16	153.25
Mean	5.35	0.12	0.00	3.90	0.03	123.71	42.94	425.42
NEMA Std	0.50	0.01	0.01	1.00	1.00	1.50	1200.00	400.00
S - Value	14.80	0.92	-9.17	12.56	-98.26	12.86	4.59	-110.75
P - value	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00

Physical and Chemical Properties of Vegetation at Well Sites

Table 4 indicated that the means for Barium, Boron, Cadmium and zinc were high as compared to recommended values set by NEMA. The one sample t-test further affirmed this as the p-values of these parameters were less than 0.05 whereas their sigma values were positive integers. This statistics depicted that the vegetation around the well sites had been contaminated.

Table 4 : Physical and Chemical Properties of Vegetation at well sites

Parameter	**Ba**	**B**	**Cd**	**Cu**	**Pb**	**Zn**
Maximum	5.40	12.55	1.18	3.13	2.64	25.10
Minimum	0.40	0.03	0.00	0.05	0.00	0.18
Std Dev	1.20	2.58	0.32	0.87	0.76	5.70
Mean	2.29	2.92	0.18	1.08	0.94	8.68
NEMA Std	1.00	1.00	0.02	10.00	2.00	5.00
Sigma Value	6.63	4.58	3.12	-63.26	-8.66	3.98
P - Value	0.00	0.00	0.00	0.00	0.00	0.00

Ba – Barium, B- Boron, Cd – Cadmium, Cu – Copper, Pb – Lead, Zn - Zinc

Physical and Chemical Properties of Rain Water at Olk Oserian

For rain samples collected at this point, most of the parameters analyzed for all the 14 sites had desirable concentrations as set out by NEMA for discharge of fluids into the environment. The only concern for rain water was the pH values which mostly tended to be mildly acidic. Even maximum values recorded all fell below the value 7.00 which is the pH neutral point.

Table 5 : Rain water characteristics at Olk Oserian

	TDS	**Chloride**	**pH**	**Sulphate**

Maximum	44.80	65.10	6.48	29.54
Minimum	7.36	6.50	5.73	10.32
Std Dev	11.25	15.26	0.27	6.18
Mean	17.47	24.38	6.13	19.03
NEMA Std	1200.00	250.00		400.00
Sigma Value	-364.08	-51.23		-213.48
P value	0.00	0.00		0.00

Levels of Carbon Dioxide Emissions inn Eburru and Olkaria

The test for carbon dioxide was done at three levels. For controlled zones, industrial zones and occupational exposure. The three settings had different Maximum permissible limits. For controlled zones it was 0.56 ppm, 5.56 ppm for industrial zones and 5000 ppm for OSHA (Occupational Safety and Health Act). Table 6 indicated that levels of carbon dioxide emitted at geothermal sites exceeded recommended values for controlled zones and industrial zones. However, it was not harmful for occupational exposure.

Table 6 : Levels of Carbon Dioxide Emissions

Minimum	Maximum	Mean	Std dev	Test value	Sigma value	P - Value
19.29	466.84	122.11	103.61	0.56	6.32	0.00
				5.56	6.06	0.00
				5000.00	-253.53	0.00

5. Discussion

The characteristics of waste geothermal fluids had differing levels of toxicity depending on the characteristics of the formation. Inefficient technologies translated to the characteristics of the formation being imposed on the immediate environment which is contrary to what many researches have discussed. Previous researches have focused on gaseous emissions and comparative analysis with other energy sources. However, each reservoir has unique properties that require independent study. In addition, this source of energy should not be deemed eco-friendly simply from a comparative perspective, rather based on rational and independent study carried out. In addition, technological variations applied at different sites results in difference in the extent of impacts to the surroundings. These factors discussed should form a basis for classification as to whether the production of geothermal energy is clean or not.

The borehole analysis done around Olkaria indicated that underground water is susceptible to geothermal exploration. Seven boreholes were analyzed and none of them had optimum conditions for drinkable water as set out by (Kenya Bureau of Standards) Kebs. For this paper, Keekonyokie borehole had significantly higher concentrations of fluoride and cadmium compared to Kebs standards. The interpretation to this was that the borehole water was unsuitable for human consumption. Most parts of Naivasha sub-County had no piped water and therefore solely relied on the boreholes for drinkable water. In the face of climate change, drier conditions could mean insufficient water and heavy reliance on the boreholes. The net impact could be increased water borne diseases for the local populace. In addition, if this water could be used for irrigation it would lead to stunted plant growth. High cadmium levels leads to browning of root tips, it interferes with photosynthetic activities as well as water balance in plants. This scenario would translate to increased vulnerability to climate change. This discussion differed with results presented by (Alfredsson, 2011) that geothermal exploration does not interfere with underground water since such sites do not have underground water resources. However, this study established that underground boreholes around geothermal sites all lacked optimum conditions for drinkable water. Based on the discussion presented, the hypothesis that stated that geothermal exploration contaminates underground water resources is thus accepted at 95% confidence level. The t-test statistics has been presented in table 1.

Discharging wells refers to wells undergoing tests of viability and readily discharge their constituents directly to the immediate atmosphere. Table 2 illustrated that the concentrations of boron, cadmium and zinc were significantly high as compared to NEMA standards for discharge into the environment. These wells are lethal if the formation has undesirable levels of metallic components. The reason to this is that the steam is not utilized but simply discharged into the surrounding. Apart from this, the ponds meant to hold the waste fluid emanating from these wells are poorly done enabling its direct interaction with the vegetation. Most of the outflow find their way into the natural flow. This means that the immediate vegetation are likely to absorb the properties inherent in the waste fluid. More so, by joining the natural flow, the population downstream could be exposed to highly toxic fluid. Other than the dangers cited, these wells could initiate energy perturbations owing to thermal pollution they propagate. The heat from the interior is brought up without any utilization and left to be discharged to the immediate surroundings. In as much as geothermal energy could have less gaseous emissions, the thermal pollution could be reversing the gains made. Therefore geothermal energy exploration could be propagating global warming. The key informant explained that this waste fluid found its way to the gorge which was frequented by tourists. High cadmium levels hamper plant growth. This would be diminishing resources for climate change adaptation and mitigation. Apart from this, the capacity of the vegetation to sink carbon would be impaired. This interpretation deeply questioned the assertions that geothermal energy is clean simply from low gaseous emission perspective. How does one account for vegetation lost and their diminishing ability to sequester carbon and offer other ecological services? The discussion presented leads to the acceptance of the hypothesis that effluents from discharging wells are toxic to flora and fauna. The results proved the sentiments by (Barasa, 2015) that there is need for transformation from incrementalism to real systemic changes for desirable results to be obtained.

The Direct Use and Demonstration Center is a recreational facility meant to showcase direct usage of geothermal fluids. This is premised on the assumption that the constituents of the fluid meet the quality threshold for recreational site as set by NEMA. However, the study established that concentrations of chloride, fluoride and Total Dissolved Substances (TDS) were significantly high as compared to NEMA standards for recreational site. This has been highlighted in table 3. A high concentration of TDS meant that other substances not analyzed could potentially be significantly higher compared to desirable standards. Based on the statistics presented, the study concluded that at 95% confidence level, the hypothesis stated as follows: Waste geothermal fluid is suitable for recreation, was thus rejected. The results reflect the observations by (Muchangi & Kagweni, M., 2014) that such discharges were bound to increase Park toxicity.

Well site analysis indicated that geothermal exploration had waste fluids that found their way into the surrounding. In this regard, the vegetation around the well site easily absorbed this toxicity resulting into high metallic concentrations in them. The threat this poses is immense. The exploration is done in fragile ecosystems. The high concentrations of barium, cadmium and zinc derailed plant growth. In addition, the wildlife feeding on the vegetation were likely to ingest the harmful concentrations. The net impact of this would be reduced plant and animal numbers. The habitats that the vegetation provides could also be sabotaged. A decline in this primary resources deprived the ecosystem its stability. It is the natural stock that offers a robust platform for climate change adaptation and mitigation. This would mean that the local populace could be subjected to enhanced vulnerability. Their ability to build climate resilience would be jeopardized. The popular belief had been that geothermal exploration can exist in tandem with conservation. However, this was not true for this study. Different technological applications and follow up procedures yield different impacts. Based on this discussion, the hypothesis that stated; geothermal production increases toxicity in vegetation was accepted. (Wanqig, 2012) had observed that geothermal production was not free of adverse impacts.

Rain water samples collected and analyzed indicated a compromised quality. Table 5 showed that pH levels were below 7.00. This depicted that mild acidity was confirmed in rain water. The cause to this was attributed to emission of gases such as carbon dioxide, methane and hydrogen sulphide. The diesel powered rigs emitted huge quantities of carbon. It should be noted that these carbon emissions had not been captured in previous studies. The actual emissions were simply captured from power plants. Therefore, in comparing emission levels for geothermal against other energy sources, the diesel powered rigs are part of geothermal assembly and hence their gaseous output have to be incorporated in emissions computations. All the other parameters analyzed were below the maximum permissible limits set by NEMA for discharge into the environment. The t-test for carbon dioxide affirmed that carbon dioxide levels were significantly high for controlled zones which was where Hell's Gate Park could be classified.

Conclusion

Geothermal production had been deemed as a clean energy source that would power Kenya towards achieving its Vision 2030. However, the technological inadequacies have provided grounds for reservations for this energy source. The adverse impacts it has on the local surrounding could jeopardize existence of flora and fauna that could be a stable basis for climate adaptation and mitigation. Failure to contain the fluid in a closed loop system meant that geothermal production could exacerbate climate change vulnerability as it could wipe out necessary resources thereby making it climate change incompatible to the long term.

Acknowledgement

I appreciate the guidance availed to me by Dr. Manguriu Daniel and Dr Ndunda Ezekiel in the preparation of this paper. Sincere gratitude to Mr. Evans Ondiek and environmental technician at Olkaria geothermal project for his guidance and support in data acquisition. My colleagues at the department of Environmental Education were also instrumental in enhancing the content and formatting of the paper.

References:

Alfredsson, E. (2011). A Transition to a Green Economy. A Change in Paradigm or Greener Shade of Brown.

Bank, A. D. (2012). *Climate Risk Adaptation in the Electric Power Sector.* . Mandaluyong, Phillipines. .

Barasa, P. (2015, January). Integration of EMS in Monitoring of Environmental and Social Aspects Associated with Operation of Olkaria II Geothermal Power Plant in Naivasha Sub-County. *Geothermal Reservoir Engineering.*

Cannady, C. (2009). Access to Climate Change Technology by Developing Countries. A Practical Strategy : ICTSD Global Platform on Climate Change, Trade Policies and Sustainable Development. *5*.

Christopher, B., Vicente, R. B., Mastrandrea, M., Mach, K., Adger, N., & Mohammed, A. (2014). *Climate Change 2014: Impacts, Adaptations and Vulnerability. Summary for Policy Makers.* IPCC Report, IPCC.

KIPPRA. (2013, January). Kenya Economic Outlook: Transformation of Kenya's Economy Key to Realization of Vision 2030. A Green Growth Path for Kenya, Opportunities, Challenges and Risks . *Policy Monitor, 2*(5).

Mazza, L., Brink, , T., Badura, T., Kettunen, M., & Withan, S. (2012). Nature and its Role inn the Transition to a Green Economy. The Economics of Ecosystems and Biodiversity.

Miola, A., & Paccagnan, V. P. (2015). *Climate Resilient Development Index: Theoretical Frameworks, Selection Criteria, and Fit for Purpose Indicators.* . Joint Research Center. doi:10.2788/07628

Muchangi, J., & Kagweni, M. (2014, May Wednesday 7). Hell's Gate Facing Death. *The Star Newspaper*.

Mutia, T. (2010). *Biodiversity Conservation and Geothermal Energy.* United Nations University, Island.

Wanqig, C. (2012). Environmental Impact of Geothermal Development in the Isafjardabaer Area Iceland. Iceland: United Nations University.