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Research Paper

Geothermal well Site Characteristics from Climate Resilient Technologies in Nakuru County, Kenya

Joseph Karanja[1], Ezekiel Ndunda[2], Daniel Mang'uriu[3], Innocent Ngare[4]

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ABSTRACT: *Geothermal energy is regarded as a clean energy source. This assertion has a degree of truth subject to technological interventions applied in its extraction. This paper focuses on quality of vegetation, soils and water points at well sites. The concentrations of trace elements at the well sites is mainly determined by adequacy of technological interventions. Geothermal energy is classified as renewable source and climate changeresilient. However, ineffective interventions andreservoir characteristics could result in undesired effluents to the surrounding rendering it unsustainable. More so, the resource is located in fragile ecosystems pivotal in climate change resilience. Simple random sampling of 81 wells was done. Samples were collected and analyzed in the laboratory. The results indicated that contamination of the vegetation, soils and water was evident. Boron concentrations in the soils for instance resulted in a sigma value of 5.99 and p- value of 0.00. This meant its concentration was significantly higher as compared to recommended standards set by Kenya's environmental Authority. Therefore, undesirable environmental impacts were a reality in geothermal production and hence could jeopardize efforts for building climate resilience.The choice of technology thus has a bearing on climate resilience for a geothermal facility especially those located in fragile ecological set ups.*

Keywords: *Climate Change, Geothermal, Resilience, Technology, Well site*

I. INTRODUCTION

Kenya is an energy deficient nation as expressed by (KIPPRA, 2013). To this extent, alternative energy sources considered climate friendly have been accelerated including geothermal energy. (Alfredsson , 2011) illustrated that energy choices we make at present would be absolute determinants of our welfare to the future. This in our opinion emphasized that energy provision is the basis for industrial ignition. In addition, the energy source has to embrace tenets of conservation in the face of climate change and its cascading impacts. (Berrizbeittia, 2014) highlighted that geothermal systems are environmentally favorable. In this regard, it has been classified as a renewable resource that is climate change compatible. In our opinion, this is a subjective argument. Geothermal energy is climate compatible to the extent of the adequacy and appropriateness of the technologies employed. The geothermal reservoir has abundance of lethal metals. The methodology of extraction has to be a closed loop that ensures no undesirable effluents are discharged to the surrounding. As such, a conclusive statement about geothermal energy can only be reached after the characteristics of the reservoir are ascertained, the adequacy of the technology is assessed as well as its location compatibility. (Christopher, et al., 2014)highlighted that human endeavors have been the dominant drivers of climate change and hence any development venture should embrace precepts of climate compatibility.

The conundrum facing geothermal exploration in Nakuru County is that production areas are fragile ecosystems that harbor unique species of plants and animals. In this regard, extra caution is required in developing such areas. (Mutia, 2010) acknowledged that the greatest challenge is to develop geothermal production while protecting and conserving the delicate biodiversity existent in the setting. For instance, Olkaria area is located within a gazetted National park; Hell's gate park that boasts of a wide variety of bird species, large mammals and unique touristic sites that entail Maasai cultural village, a gorge, Devil's kitchen and Central tower. In addition, there are a number of indigenous plant species. On the other hand, Eburru area and Menengai are also gazetted forests and are adequately endowed with massive geothermal resources. How then can geothermal exploration be enhanced while sustaining the ecological integrity? Apart from this, the mentioned areas are essential in carbon sequestration. They are crucial in abating ongoing warming. They offer the primary resource upon which climate change adaptation and mitigation are realized, hence climate resilience. How then does geothermal exploration affect building of climate resilience? These questions form the primary focus of the study. The characteristics of the soils, vegetation and water points at the wells were determined and their extent of contamination determined the possible consequences the geothermal projects could have on climate

*Corresponding Author: Joseph Karanja

resilience. Apart from these, how adequate are the technological interventions to mitigating against climate change? This is imperative to explore since geothermal technologies have been vaunted as climate resilient. This should be the intent of benign planning as explained by (Miola, et al., 2015). Building of climate resilience should be at the core of our plans.

This paper would be integral to policy makers in determining long term development paths. (KIPPRA, 2013) postulated that Kenya's progress was pegged on the status of her natural capital. This meant that all development ventures have to integrate ecological and economic systems. Such a development paradigm was projected to reduce poverty levels by 15% by the year 2030. In this context, climate resilient pathway is the pro-growth strategy to the future. As such, climate compatible development is a necessity and not optional. (Jappinen & Helioh, 2015) affirmed this by emphasizing that the focus of ecosystem management should be on facilitating climate change resilience as it is the greatest challenge of this century. To this end, (Bromley, et al., 2010) postulated that since geothermal energy sources off set carbon dioxide emissions that would have been alternatively been emitted by fossil fuels, they are fit in the face of climate change. However, (Wanqig, 2012) differed with this by revealing that geothermal exploration was not completely free of adverse impacts to the environment.

II. STUDY AREA

The focus of the study was in Eburru and Olkaria geothermal projects in Nakuru County. (Mutia, 2010) established that Olkaria lies within latitude $0^{o}54^{'}57^{''}$S, and longitude $36^{0}18^{'}48^{''}$E. The approximate number of wells as of 2015 was about 156 wells. Further, (Mutia, 2010) established that Olkaria was located in a semi-arid region experiencing warm dry climate. The areal coverage of the National Park was 68.25 Km^2. The park harbored the Ruppell's vulture that is enlisted as an endangered species. Over 100 bird species could be identified within the park. Other than this, the large mammals included buffaloes, Klipspringer, Giraffes, Zebras, Reedbuck, Impalas and Elands among others. From this description, it was indeed evident that the ecosystem was essential and needed great conservational efforts. The area is pre-dominantly inhabited by the Maasai community whose major occupation is pastoralism. (KIPPRA, 2013) deduced that natural capital accounted for 70% of total formal employment. In this context therefore, the efforts to rid the country of energy deficit should not render ecological set ups unsustainable as this could lead to enhanced climate change vulnerability and depletion of resources crucial for our survival. (Mazza, et al., 2012) emphasized that working with nature has to be the core functionality of every economic model.

III. METHODOLOGY

Simple random sampling was done for 81 wells distributed in the various fields in Olkaria inclusive of the only existent well in Eburru for wellhead generation. Samples were collected at the well sites consistently within the well pad. The well pad is the first point of interaction of the effluents with the environment. Samples for vegetation, soils and water were picked. The vegetation had to be crushed and digested using aquaregia solution prepared in the laboratory before being subjected to analysis. Laboratory experiments entailed determining concentrations of trace elements within the samples collected. This was done using electrodes configured to a digital component that displayed concentrations of the various metals. The elements of interest included Barium, Boron, Copper, Zinc and Cadmium.

Other methods of data collection entailed use of observation guides, photography and document analysis. Photography and observation guides captured physical impacts of effluents to the surrounding manifested by change of colour of the vegetation at contact points between the effluents and the vegetation. A key informant was integral in explaining changes over time and the challenges encountered in the course of carrying out pastoralism since the start of explorative activities.

The data collection resulted in both qualitative and quantitative data. Qualitative data was analyzed, edited and organized in a thematic context. On the other hand, quantitative data was analyzed using Statistical Package for Social Statistics (SPSS). Averages of observations were established.In addition, maximum and minimum values were determined. Apart from these, inferential statistics of sigma values and p- values were derived. These values were as a result of comparison to NEMA (National Environmental Management) standards for discharge into the environment. The analysis thus informed whether the concentrations of metals was significantly different from set standards. The conclusion from this was corroborated with data from observations, photography and key informant.

IV. RESULTS AND DISCUSSIONS

4.1. Analysis Of Soil At Well Site

The t – test analysis for the soils at well site yielded p – values for all the parameters as less than 0.05 other than cadmium as shown in table 1. Barium, Boron, Copper, Lead and Zinc all had p – values of 0.00. Cadmium had a p – value of 0.01. For sigma value, the analysis indicated values of 6.00, 5.99, 2.77, -73.55, -

5.08 and 6.63 for Barium, Boron, Cadmium, Copper, Lead and Zinc respectively. This analysis was imperative so as to ascertain whether there were any direct contamination of the soil as a result of waste fluid getting into contact with the soil. The mean observations taken over time were as reflected in table 1. The means for barium, boron, cadmium and zinc were higher than their respective test values. More so, the test of significance for barium, boron, and zinc were established to be significantly higher than the set values for NEMA. Copper and lead concentrations were significantly lower as compared to their test values.

The statistics revealed alarming concentrations of the metallic components in the soil. It was evidenced that soil contamination was a reality. Such concentrations could undermine the growth of plants. The plants are essential as they are major habitats for the wildlife. In addition, they offered source of food for the wildlife too. More importantly, vegetation is imperative in carbon sinking hence decelerates global warming. High concentration of cadmium leads to retarded growth in plants. It also depreciates biomass production as well as reduces chlorophyll content. (Christopher, et al., 2014). On the other hand, zinc degrades the fertility of the soil as it decimates micro-organisms and earthworms essential for breakdown of components that enrich the soil. The heavy metals are thus a deterrent to plant growth and vegetation cover. The net impacts from this would be reduced ecological goods and services essential for building climate change resilience and facilitating adaptation to climate change.

Table 1: Analysis of the soil at well site

Parameter	**Barium**	**Boron**	**Cadmium**	**Copper**	**Lead**	**Zinc**
Maximum	28.34	3.54	1.49	3.32	3.23	27.06
Minimum	0.90	0.03	0.00	0.00	0.00	1.05
Standard Dev.	6.43	0.88	0.36	0.75	0.90	6.16
Mean	7.30	1.86	0.18	1.01	1.27	11.63
NEMA Standard	1.00	1.00	0.02	10.00	2.00	5.00
Sigma Value	**6.00**	**5.99**	**2.77**	**-73.55**	**-5.08**	**6.63**
P - Value	0.00	0.00	0.01	0.00	0.00	0.00

4.2. Analysis Of Vegetation At Well Site

Table 2 shows the t – test analysis that resulted to a sigma value of 6.63 for barium with a p – value of 0.00. Boron had a sigma value of 4.58 and a p – value of 0.00. Cadmium had a sigma value of 3.12 and a p – value of 0.00. For copper, the analysis indicated a sigma value of -63.26 and a p – value of 0.00. Lead had a sigma value of -8.66 and a p – value of 0.00. For Zinc, its sigma value was 3.98 and p – value 0.00.

This analysis was imperative so as to determine whether the vegetation was fit for wildlife consumption. Toxic vegetation if ingested could have direct or cumulative impacts for wildlife that ingest it. The population of the wildlife over time could be negatively affected. The statistics shown in table 2 established that barium, boron, cadmium and zinc mean concentrations were way high above the test values for each of the parameters. More so, the test of significance affirmed this. The p - values for barium, boron, cadmium and zinc were all below 0.05. This meant that at 95% confidence level, the concentrations of the mentioned metals were found be significantly higher as compared to set limits by NEMA. The source of this high metallic concentration could be attributed to soil contamination as already established in the analysis preceding this. More so, it could be due to direct absorption by vegetation from pond overflows. The key informant corroborated this by ascertaining that the density of the vegetation had shrunk. This had resulted in diminished population for wildlife that are integral to bolstering touristic activities in the park.

From the test of significance carried out, it was evident that indeed geothermal production leads to high concentrations of metallic components in the vegetation. This scenario could hamper adequate plant growth. In addition, the wildlife population could be at risk if they continuously fed on the contaminated vegetation. With regard to this, the hypothesis stated as follows: Geothermal production leads to high metal concentration in vegetation was thus accepted. The affirmation of this hypothesis portends that vulnerability to climatic changes was enhanced thereby strangling efforts for building of resilience. Plate 1 indicates the contamination of vegetation by effluents from the piping system.

Table 2: Analysis of vegetation at well site

Parameter	**Barium**	**Boron**	**Cadmium**	**Copper**	**Lead**	**Zinc**
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
Standard 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 Standard	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

Plate 1: Leaking steam gathering system

4.3. Analysis Of Water Points At Well Site

The test of significance as shown in Table 3 established that barium had a sigma value of -4.59 and a p – value of 0.00. Boron had a sigma value of 2.99 and a p – value of 0.01. For cadmium, the sigma value was 1.23 whereas its p – value was 0.23. Copper had a sigma value of -17.67 and a p – value of 0.00. For lead analysis, its sigma value was 2.39 whereas its p – value was 0.02. Zinc had a sigma value of -2.26 with a p – value of 0.03.

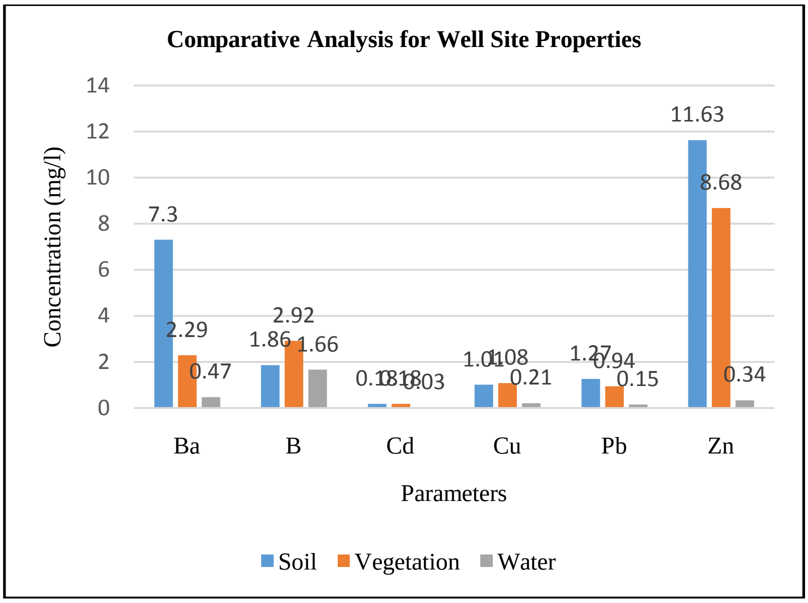
This analysis was conducted from samples derived from 81 water points within the geothermal producing zones. The mean observation for boron, cadmium and lead were higher as compared to their respective test values based on the evidence adduced from the test of significance. However, the test of significance revealed that none of the parameters was significantly higher as compared to the set limits by NEMA. As such, in this context the null hypothesis cannot be rejected. This was despite of some of the mean values having been higher than their respective test values. Table 3 indicates the summary statistics for the water at various well sites.

Parameter	Barium	Boron	Cadmium	Copper	Lead	Zinc
Maximum	2.93	6.24	0.53	1.02	2.05	2.69
Minimum	0.00	0.24	0.00	0.00	0.00	0.02
Standard Dev.	0.71	1.36	0.11	0.28	0.37	0.44
Mean	0.47	1.66	0.03	0.21	0.15	0.34
NEMA Std	1.00	1.00	0.01	1.00	0.01	0.50
Sigma Value	**-4.59**	**2.99**	**1.23**	**-17.67**	**2.39**	**-2.26**
P - Value	0.00	0.01	0.23	0.00	0.02	0.03

4.4 Comparative Analysis Of Well Site Properties

Figure 1 illustrated that Barium concentration was highest in soil with a value of 7.3 mg/l and lowest is water samples at 0.47 mg/l. For boron, the highest concentration was in vegetation with a value of 2.92 mg/l and lowest in water samples with 1.66 mg/l. Cadmium levels were highest in soils and vegetation which had mean values of 0.18 mg/l. Copper concentration was highest in vegetation with a value of 1.08 mg/l and was lowest in water samples where the concentration was 0.21 mg/l. Lead concentration was 1.27 mg/l in soils which was the highest whereas lowest concentration was in water samples that had a mean value of 0.15 mg/l. Zinc concentrations were highest in soil with a mean value of 11.63 mg/l while it was lowest in water samples with a mean value of 0.34 mg/l.

The comparative analysis illustrated that the most vulnerable point of accumulation for toxic parameters was the soil. Fig. 1 represented that in most of the parameters, the concentrations in the soil was higher compared to that in vegetation and water accumulation points. This could be explained in that most explorative activities entail soil extraction and hence are easily contaminated in this process. In addition, the waste fluids eventually found their way to the surrounding and percolated down the soil profile. Once the soils have been contaminated, the toxicity is easily transferred to the vegetation which up took most of the nutrients from the soils. Therefore, the process of vegetation growth in itself inevitably enhanced transfer of toxicity from the soils to the vegetation. For water accumulation points, concentrations of the metals was low. This could be attributed to limited contact with points of discharge. More so, it is dependent on precipitation and which was subject to dilution in the process. Fig. 1 gives a summary of the comparison.



V. CONCLUSION

Geothermal energy is indeed a favorable energy source from a comparative perspective with fossil fuel energy sources. However, this competitive advantage is diminished if the soils, vegetation and water points are contaminated in the course of its production owing to technological deficiencies. Contaminated soils and vegetation would hinder proper vegetation cover that would in essence result in deforestation. This would work against the capacity of the vegetation to sequester carbon dioxide form the atmosphere resulting in carbon build up. In the end, global warming would be enhanced thereby subjecting the populace to increased climate vulnerability. This would be ironical as it is hugely expected that geothermal energy has to accelerate climate change resilience. Development ventures have to embrace benign technologies that are climate change compatible for them to have long term advantages to the people even in the face of climate change. Technologies adopted have to be closed loop to ensure that reservoir characteristics are not imposed onto the immediate environment.

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