NOISE LEVEL ASSESSMENT IN GEOTHERMAL PROJECTS: A CASE STUDY OF MENENGAI GEOTHERMAL PROJECT, KENYA

Henry Wamalwa and Rose Kiama
Geothermal Development Company, P.O Box 17700-20100, Nakuru
hwamalwa@gdc.co.ke; rkiama@gdc.co.ke;

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ABSTRACT

Noise emission is a challenging environmental issue in the implementation of development projects as it constitutes an environmental impact if the area is inhabited by humans or wildlife. In Menengai geothermal project potential noise emission sources include generators supplying power to the rig, discharging wells, electric motors, air compressors, mobile machinery, mud pumps, drilling operation, all of which operate on a 24 hour basis. This study scientifically will assess noise emission and potential pollution through analysis of parameters such as day and night levels (Ldn).The analysis considers two temporal ranges, namely day time (6AM-9PM - 15hours)and night time (9PM-6AM - 9 hours) in the year 2013 at 9 monitoring sites namely Pump House, Lay down Area, Camp Site, Menengai Well 12 and Menengai Well 13. The residential areas monitored were AIC Tulimoi Primary, Marigo community, Rigogo community and Kipng'ococh. Results from noise emission in the residential areas which were monitored at night time indicate that they were within the recommended standards of WHO and occupational exposure limits and community noise of 85 and 50 dB(A) respectively. The levels also complied with the maximum allowable limits of World Bank of 55dB (A) for residential areas. Noise emission levels at Laydown area, Pump house and Campsite which have several operations were all within the recommended World Bank for industrial installations and WHO threshold limit value of 70 and 85 dB(A) respectively.

1.0 INTRODUCTION

Noise can be defined as the level of sound which exceeds the acceptable level and creates annoyance. (Narendra, 2004). Frequent exposure to high level of noise causes severe stress on the auditory and the nervous system. Extended exposure to excessive sound has been proven to cause physical and psychological damage. Because of its annoyance and disturbance implications, noise adds to mental stress and hence affects the general well-being of those exposed to it (Sabranmani, (2012). Hence this justifies the need to carry out an environmental monitoring.

Then assessing the problem and programming actions for controlling its adverse effects have become the main goal of immediate concern for Geothermal development Company and community as evidenced by the large number of laws, ordinances and regulations decreed by governments. The following were the objectives for this study; to verify the environmental impact predicted in the ESIA studies, to determine compliance with regulatory requirements, standards and government policies, to enable taking remedial action if unexpected problems or unacceptable impacts arise and to provide data for environmental audits

1.1 Noise Terminology and Fundamentals

Noise is customarily measured in decibels units related to the apparent loudness of sound. A weighted decibels dB (A) represent sound frequencies that are normally heard by the human ear. On this scale the normal range of human hearing extends from about 3 dB (A) to 140 dB (A). Speech normally occurs between 60 dB (A) and 65dB (A). A logarithmic scale is used to measure sound, because sensation increases with logarithmic of the stimulus intensity (Kubo, 2008). Each 10-dB (A) increase in the level of a continuous noise is ten-fold, increase in sound energy, but is judged by listeners as only a doubling of loudness. For example 60 dB (A) is judged to be about twice as loud as 50dB (A) and four times as loud as 40dB (A). Each 3 dB (A) increase in sound is a doubling of sound energy, such as doubling the amount of traffic on street, but is judged only about a 20% increase in loudness, and is just –noticeable difference to most people .Increases in average noise of about 5dB (A) or are more noticeable to most people and is the level required before any noticeable change in community response would be expected. A 10dB (A) change would almost certainly cause an adverse change in community response (EPA 1981).

2.0 ADVERSE HEALTH EFFECTS OF NOISE

2.1 Hearing impairment

Hearing impairment is typically defined as an increase in threshold of hearing deficits may be accompanied by tinnitus (ringing in the ears) Kubo, 2008). Noise induced hearing impairment occurs predominantly in the higher frequency range of 3 000- 6 000 Hz, with largest effect at 4 000 Hz. But with increasing LAeq 8h and increasing exposure time noise induced hearing impairment occurs even at frequencies as low as 2 000 Hz. However, hearing impairment is not expected to occur at LAeq, 8h levels of 75dB (A) or below, even for prolonged occupational noise exposure. Worldwide noise induced hearing impairment is the most prevalent irreversible occupational hazard and it is estimated that 120 million people worldwide have disabling hearing difficulties.

2.2 Speech intelligibility.

Speech intelligibility is affected adversely by noise. (Ali, 2007) .Most of the acoustical energy of speech is in the frequency range of 100-6 000 Hz , with the most important cue bearing energy being between 300-3 000 Hz. Speech interference basically is a masking process, in which simultaneous interfering noise renders speech incapable of being understood. Environmental noise may also mask other acoustical signals that are important for daily life such as doors, bells telephone signals, alarm clocks, fire alarms and other warning signals, and music. Speech intelligibility in everyday living conditions influenced by speech level; speech pronunciation, talker- to listener distance, sound level and other characteristics of the interfering noise; hearing acuity; and by the level of attention. In doors speech communication is also affected by the reverberation characteristics of the room. Reverberation times over 1s produce loss in speech discrimination and make speech perception more difficult and straining. For full sentence intelligibility, listeners with normal hearing the signal to noise ratio i.e (the difference between speech level and sound level of interfering noise should be at least 15dB (A). Since the sound pressure level of normal speech is about 50 dB (A), noise with sound levels of 35 dB (A) or more interferes with intelligibility of speech in smaller rooms. For vulnerable groups, even lower background levels are needed and reverberation time below 0.65 is desirable for adequate speech intelligibility even in quiet environment.

2.3 Sleep disturbance.

Sleep disturbance is a major effect of environmental noise it may cause effects during sleep, and secondary effects can be assessed by the day after night time noise exposure. An interrupted sleep is a prerequisite for good physiciological and mental functioning and the primary effect of sleep disturbance are; difficult in falling asleep, awakening and alteration of sleep stages on depth, increased blood pressure heart rate and finger pulse amplititude, vasoconstriction, changes in respiration, cardiac arrhythmia and increased body movements. The difference between levels of noise event and background sound levels, rather than absolute noise level may determine the probability. The probability of being awakened increases with the number of noise events per night. The secondary after effects for the following moving or day(s) are reduced perceived quality; increased fatigue, depressed mood or well- being and decreased performance.

For a good night sleep, the sound level should not exceed 30 dB (A) for continuous background noise and an individual noise events exceeding 45dB (A) should be avoided. In setting limits for single night time noise exposures, the intermittent character of the noise has to be taken into account. This can be achieved by measuring the number of noise events, as well as the difference between the maximum sound level and the background sound level. Special attention should be given to noise sources in an environment with low background sound levels; combinations of noise and vibrations, and noise sources with low- frequency components.

2.4 Physiological functions

In workers exposed to noise, and people living near airports, industries and noisy streets, noise exposure may have a large temporary as well as permanent, impact of physiological functions (Asamoah, 2004). After prolonged exposure, susceptible individuals in the general population may develop permanent effects such as hypertension and ischaemic heart disease associated with the high sound levels. The magnitude and duration of the effects are determined in part by the individual characteristics, life style behaviour and environmental conditions. Sound also evokes reflex responses, particularly when are unfamiliar and have sudden onset. Workers exposed to high levels of industrial noise for 5-30years may show increased blood pressure and an increased risk for hypertension. Cardiovascular effects also have been demonstrated after long-term exposure to air and traffic with the LAeq, 24 hours values of 65-70 dB (A). Although the associations are weak, the effect is somewhat stronger for ischemic heart disease than for hypertension. Still this small risk increment is important because a large number of people are exposed.

2.5 Mental illness

Environmental noise is not believed to cause mental illness directly, but it is assumed that it can accelerate and intensify the development of latent mental disorders. (Ali, et al, 2007).Exposure to high levels of occupational noise has been associated with development of neurosis, but the findings on environmental noise and mental health effects are inclusive. Nevertheless, studies on the same drugs such as tranquilizers and sleeping pills, on psychiatric symptoms and on mental hospital admission rates, suggest that community noise may have adverse effects on mental health

2.6 Performance

It has been shown that, mainly in workers and children, that noise adversely affects performance of cognitive tasks. Although noise induced arousal any produce better performance in simple tasks, in the short term, cognitive performance substantially deteriorates for more complex tasks. Reading, attention, problem solving and memorization are among cognitive effects most strongly affected by noise. Noise can also act as a distracting stimulus and impulsive noise events may produce effect as a result of startle responses

2.7 Social and behavioural effect of noise –annoyance

Noise can produce a number of social and behavioural effects as well as annoyance. Then effects are often complex, subtle and indirect and many effects are assumed to result from the interaction from a number of non-auditory variables (Ndetei, 2010).It should be recognized that equal levels of different traffic and industrial noises cause different magnitudes of annoyance. This is because annoyance in populations varies not only with their characteristics of noise, including the noise source, but also depends to a large degree or many non-acoustical factors of psychological or economic nature. The correlation between noise exposure and general annoyance is much higher at group levels than at individual levels. Noise above 80dB (A) may also reduce helping behaviour and increase aggressive behaviour. There is that particular concern that high level continues noise exposures may increase the susceptibility of school children to feelings of helplessness. Stronger reactions has been observed when noise is accompanied with vibrations and contains low frequency components or when the noise contains, such as with shooting noise. Temporarily with stronger reactions when the noise exposure increases overtime, compared to a constant noise exposure related to annoyance.

2.8 Guideline values

2.8.1 Specific health effects (interference with speech perception)

A majority of the populations is susceptible to speech interference by noise and belongs to vulnerable groups most sensitive are the elderly and persons with impaired hearing. Even slight hearing impairments in the high frequency range may cause problems with speech perception in a noisy environment. From above 40 years of age, the ability of people to interpret difficult spoken messages, with low linguistic redundancy is impaired compared to people 20-30years old. It has also been shown that high noise levels and long reverberations times have more adverse effects in children, who have not completed language acquisition, than in young adult.

2.8.2 Hearing impairment

Noise gives rise to hearing is by no means restricted to occupational situations. The ISO standard 1999 gives a method of estimating noise –induced hearing impairment in populations exposed to all types of noise (continuous, intermittent, impulse,) during working hours. The standard implies that the long term exposure to LAeq, 24h noise of up to 70dB (A) will not result in impairment. To avoid hearing loss from impulse noise exposure peak sound pressures should never exceed 140 dB (A) for adults and 120 dB (A) for children

2.8.3 Sleep disturbance

Measurable effects of noise begin at LAeq levels about 30dB. However, the more intense the background noise, the more disturbing is its effect on sleep. (Nathaniel et al, 2007). Sensitive groups (elderly, people with physical and or mental disorders and other individuals who have sleeping difficulties when noise is continuous, the equivalent sound pressure level should not exceed 30dB (A) indoors to avoid negative effects. For noise with a low frequency sound a still lower guideline value is recommended. When background noise is low, noise exceeding 45dB (A) LAMax should be limited it is possible and for sensitive persons an even lower limit is preferred.

2.8.4 Annoyance

During daytime, few people are highly annoyed at LAeq levels below 55dB(A), and few people are moderately annoyed at LAeq levels below 50dB(A).Sound levels during the evening and at night should be 5-10 dB(A) lower than during the day. There is evidence that fairly 80dB (A), causes helping behaviour (Naredraetal 2004).

2.9 Previous Work

Noise levels were studied at Olkaria Geothermal project, using data collected from the year 1995-2010, it was found out that major sources were; power stations and turbines. The levels exceeded the WHO recommended levels of 85dB(A) at the power station but decayed as you moved further away. However, at residential areas, it was below 50dB(A) (Ndetei, 2010)

3.0 REGULATORY FRAMEWORK RELEVANT TO NOISE EMISSION AND EXPOSURE LIMITS

The legislative controls relevant to noise associated with any development is outlined in the public health and Environmental management and coordination Act, 1999 (Excessive vibrations and noise control 2009. The noise regulations of 2009 under EMCA of 1999 recognizes that the fact that any person emitting noise in excess of noise emission standards commits an offence. With these standards established , it is a requirement to obtain a temporary permit not exceeding three months from National Environment and Management Authority (NEMA).Besides the local established standards, other with the local, international guidelines are also used. In this work international guidelines have been utilized; (WHO), World health organization and World Bank.
Occupational Health and safety of Kenya also specify limits on maximum occupational exposure for noise emission for work environment. Different categories of ear mufflers have been recommended for use under different noise emission levels as shown in the tables below

Table 1: International Ambient noise levels criteria at work places and residential areas

Receptor	Maximum allowable Leqdb(A)			
	World bank		**World health Organization**	
	Day time 0700-2200	Night time 2200-0700	Day time 0700-2200	Night time 2200-0700
Residential institutional and educational	55	45	50	45
Industrial and commercial	70	70	85	85

Table 2: Occupational health and safety exposure limits for noise.

Sound level dB(A)	Max permitted duration(hours/day)
80	16
85	8
90	2
100	1
105	0.5
110	0.25
115	1/8
>115	0

Table 3: Hearing Protectors (Ear Mufflers)

Sound level dB(A)	Max class of hearing protection
85-95	C
96-105	B
106-over	A

4.0 METHODOLOGY

4.1 Noise Sources and Measurement

Physically there is no distinction between sound and noise. Sound is a sensory perception and the complex pattern of sound waves is labelled noise, music, speech etc. Noise is defined as unwanted sound. Most environmental noises can be appropriately described by several simple measures. All measures consider the frequency content of the standards, the overall sound pressure levels and the variation of these levels with time. Sound pressure is a basic measure of vibrations of air that make up sound. Because the range of sound pressures that human listeners can detect is very wide, these levels are measured on logarithmic scale units' decibels. Consequently, sound pressure levels cannot be added or averaged arithmetically. Also, the sound levels of most noises vary with time, and when sound pressure levels are calculated, the instantaneous pressures fluctuations must be integrated over some time interval.

Most environmental sounds are made of a complex mix of many different frequencies. Frequencies refers to the number of vibrations per second of the air in which the sound is propagating and is measured in Hertz (Hz), .The audible frequency is normally considered to be 20-20,000 Hz for young listeners with un impaired hearing (Ndetei, 2010).However, our hearing systems are not equally sensitive to all sound frequencies, and to compensate for this, various types of filters or frequency weighing have been used to determine the relative strengths of frequency components making up a particular environment noise. The A- weighing is most commonly used and weights lower frequencies are less important than mid- and higher frequencies. It is intended to appropriate the frequencies response of our hearing system. The effect of a combination of noise events is related to the combined sound energy of those events (the equal energy principle). The system of the total energy over some time period gives a level equivalent to the average to the sound energy over that period. Thus, LAeq, T is the energy average equivalent level of the A-weight sound over a period T. LAeq, T should be used to measure continuous sounds, such s road traffic noise or types of more-or less continous industrial noises. However, `when there are distinct events to the noise, as with aircraft or railway noise, measures of individual events such as the maximum noise level (LAMax) or the weighted sound exposure level (SEL) , should also be obtained in addition to LAmax to LAeq, T. Time varying environmental sound levels have also described in terms of percentile levels. Currently, the recommended practice is to assume that the equal energy principle is approximately valid for most types of noise and that a simple LAeq, T measure will indicate the expected effects of the noise reasonably well. When the noise consisting of a small number of discrete events, the A- weighted maximum level (LA max) is a better indicator of the disturbance to sleep and other activities. In most cases, however, the A- weighted sound exposure level (SEL) provides a more consistent measure of single- noise events because it is based on integration over the complete noise event. In combining day and night LAeq, T. values and night – time weightings are often added. Night- time weightings are intended to reflect the expected in increased sensitivity to annoyance at night, but they do not protect people from sleep disturbance. Where there are no clear reasons for using other measures, it is recommended that LAeq, T be used to evaluate more-or less continous environmental services where the noise is principally composed of a small number of discrete events, the additional use of LAmax or SEL is recommended here are definite limitations to simple measures but there are also many practical advantages, including economy and benefits of standardized approach.

4.2 Potential noise sources within the Menengai geothermal project.

There are several potential sources of noise in the Menengai geothermal project. They include generators supplying power to the rig, discharging wells, electric motors, air compressors, mobile machinery, mud pumps, drilling operation, all of which operate around the clock. The environmental noise impact of geothermal drilling operations results from a combination of noise from all these sources propagated to some point beyond the boundary of Menengai to the surrounding areas. During well discharge tests, geothermal fluids and gases are released to clean the well-off debris during well management periods. This process involves the use of a well separator attached to a silencer to reduce noise impacts during horizontal discharge. Also, during drilling, where geothermal fluids are extracted for the purpose of energy extraction for electricity generation noise impacts may arise. Localized noise also arises from generators that supply power to the rig and to the campsite.

4.3 Noise emission level assessment sites

A total of 9 noise monitoring sites have been established in the project area. These sites were based on the type of activities that go on around the area site. These sites include discharging wells, (MW12, MW13,) workshop area (Laydown), at booster pump area (pump house), camp power supplying genesets (Camp Site). In addition other monitored sites were located ouside of the caldera. These include AIC Tulimoi Primary, Marigo community (Marigo B), Rigogo community (Rigogo), and the Kipng’ococh community (Kipn). Data obtained from GDC’s meteorological section reveals that the general trend of wind direction annually is from East to west and formed the basis of locating the community monitoring sites where monitoring was done at night. The monitored sites were as shown in figure 1 below.

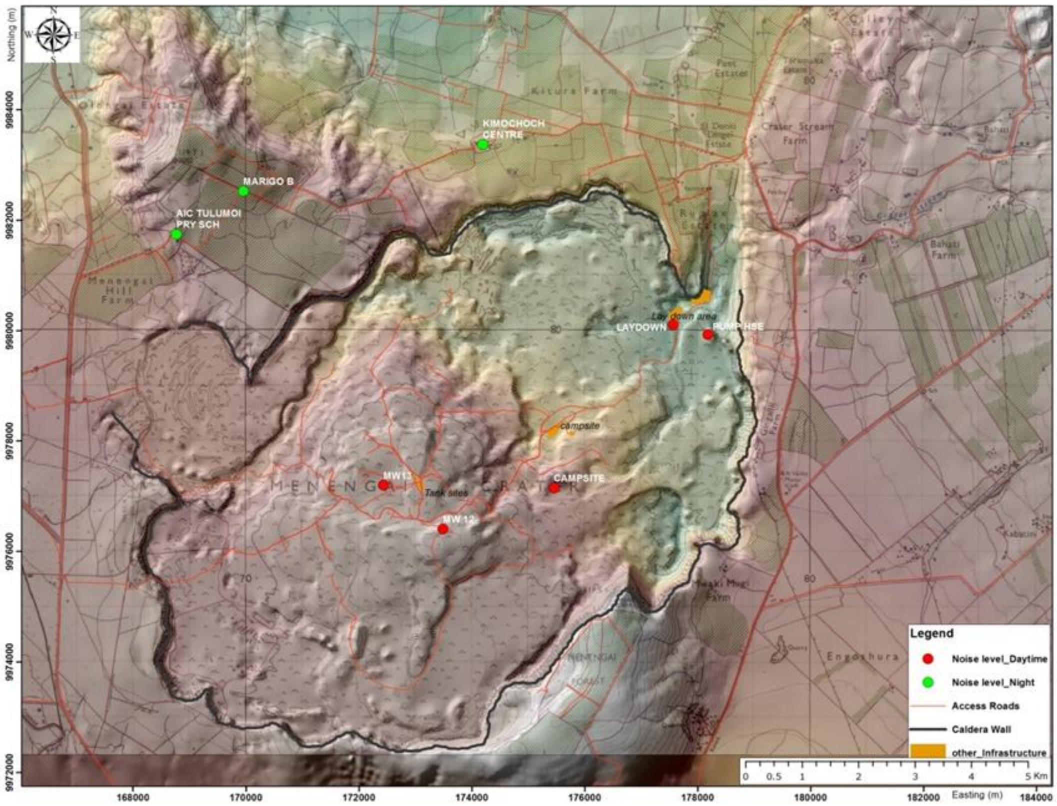

Figure 1: Location of monitored sites.

4.4 Noise measurement procedure

The noise were measured by use of a hand held integrating averaging sound level meter (Extech instruments 407768) set to frequency weighting ‘A’.(Subramani et al 2013), The sound levels measurements were done from Jan –Dec 2013 at least 1m from the wall and 1.5m above the ground during day and night. Microphones were held by hand as far from the body as possible facing the noise source.(Kubo 2008), (Subramani et al, 2013,) (Marisol et al ,2004).

5.0 RESULTS AND DISCUSSION

5.1 Assessment

The results of noise level assessment as shown in the tables below indicates that noise levels fall within the recommended standards of WHO and occupational exposure limits and community noise of 85 and 50 dB(A) respectively. The levels also complied with the maximum allowable limits of World Bank of 55dB (A) for residential and educational facilities and 70dB (A) for commercial and industrial premises during day time and night time (0700.200) and 2200-0700hrs respectively.

Table 4: Noise emission levels at the residential areas

dB(A)	AIC.T.P	MARIGO.B	RIGOGO.J	KIPN
Mean(dB(A)	43	43	43	43
Median	43	43	43	43
Max	47	48	45	47
Min	36	38	38	37
Mode	44	42	45	40
WHO TVL	45-50	45-50	45-50	45-50
WB Limits	55	55	55	55

WB- World Bank; WHO- Worls health Organization; AIC.T.P- African Inland church, Tulimoi Primary; KIPN- Kipng'ochoch centre.

World Bank maximum permissible noise level for industrial/commercial and residential/ institutional and educational area are 70 and 55 dB (A) respectively.
WHO maximum permissible noise in work places assuming 8-hr, 5 day week and residential areas are 85, and 45-50 dB(A) respectively.

Table 5: Noise emission levels at Pump house, Laydown, Campsite, MW12 and MW13

SITE	dB(A)	Pump house	Laydown	Campsite	MW12	MW13
Max		70	68	70	70	70
Min		38	40	52	37	58
Mode		44	58	65	69	68
Median		54	59	66	68	68
Mean		54	57	65	66	67
WHO TVL		85	85	85	85	85
WB		70	70	70	70	70

5.2 Environmental noise emission base on max mode levels

Evaluation of noise emission impacts from the activities require examination of mode and maximum levels recommended at a given site. Their evaluation over a given long period is of relevance especially when assessing the impact of noise on human health. The mode and maximum noise emission levels in the project and its surrounding is as shown in the table 4 and table 5 respectively. At all monitoring sites, the highest emission was 68 dB (A) and 69 dB (A) respectively.

5.3 Emissions based on mode

Noise emissions on mode at AIC Tulimoi Primary, Marigo B, Rigogo junction and Kipng'ochoch center were all within the permissible limits of World Bank and WHO thresh value limits for residential of 45dB(A), 50dB(A) respectively.

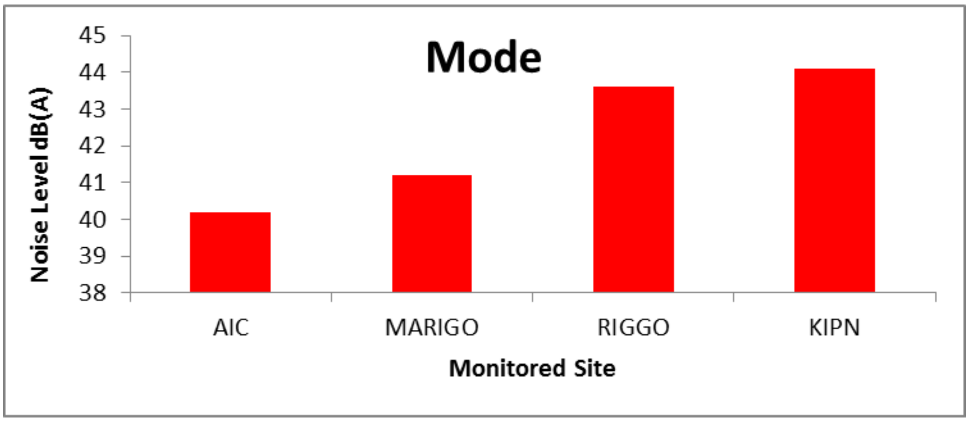

Figure 2: Mode of Noise levels at residential monitored sites

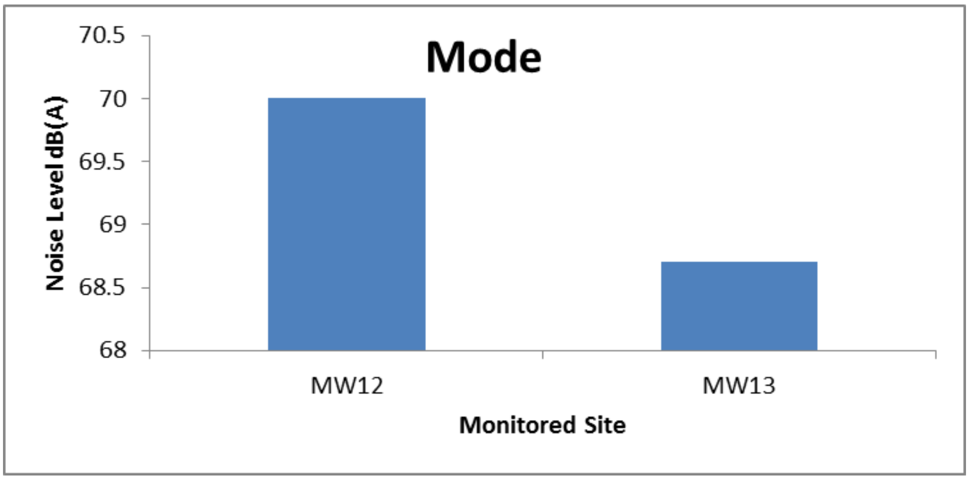

Figure 3: Noise level on mode at discharging wells

The levels were equally within the permissible limits of World Bank for industrial installations and WHO threshold limit value.

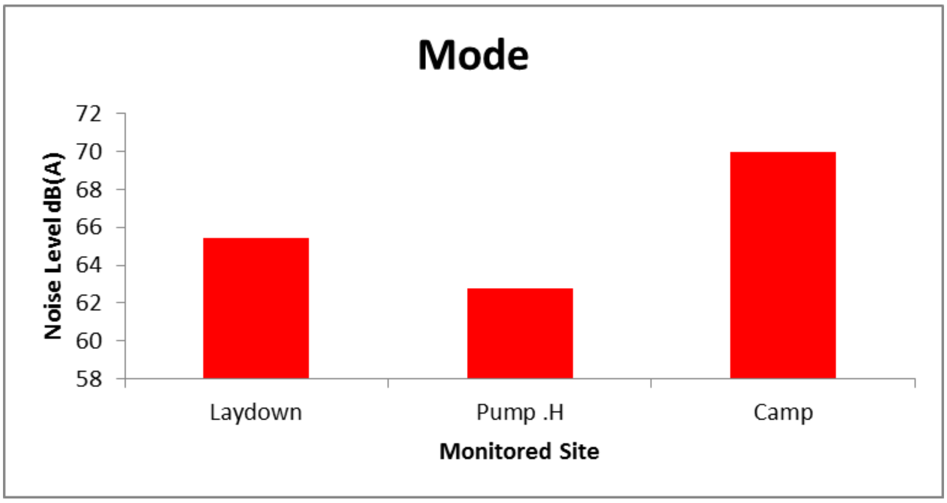

Figure 3: Noise level on Mode at Laydown, Pump house and Campsite

The noise emission levels at Laydown area, Pump house and Campsite which have several operations were all within the recommended World Bank for industrial installations and WHO threshold limit value of 70 and 85 dB(A) respectively.

5.4 Noise emission levels based on Maximum levels

The maximum noise emission levels were 70dB (A) as the highest with a frequency of 1 at MW12 and MW13, Campsite and pump house area. The Laydown area was around 68 dB (A).

5.5 Maximum noise levels at residential areas.

The noise range was between 46 -48 dB (A) all within the World Bank and WHO maximum permissible noise level for residential areas. Noise emission levels of the highest occurrence was between 37 -40 dB (A) at all residential areas

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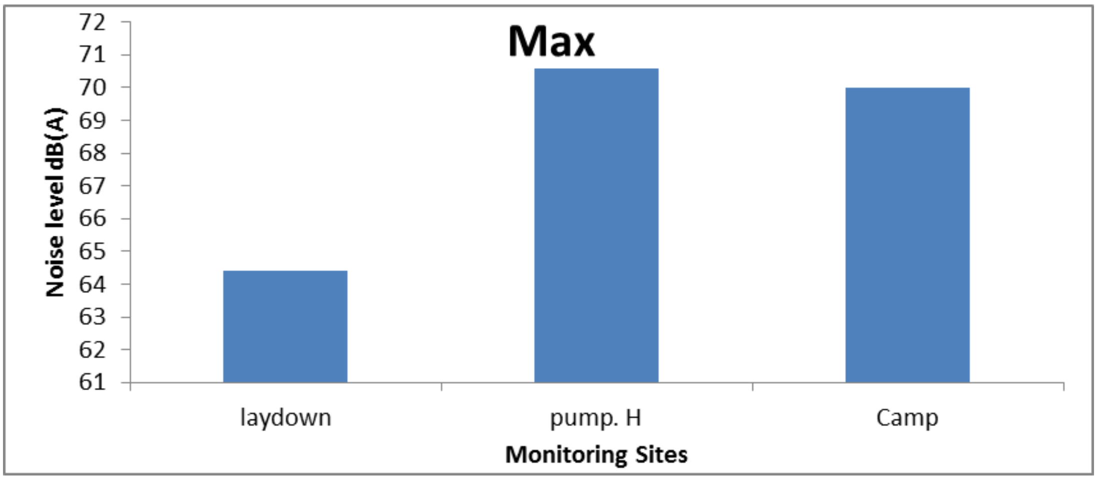

Figure 4: Maximum noise levels at Laydown, Pump house and Campsite

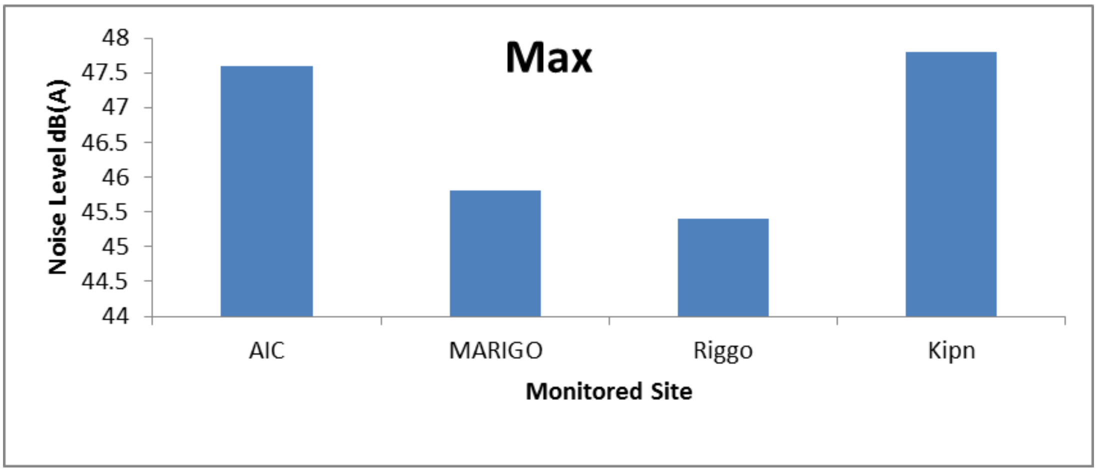

Figure 5: Maximum Noise levels at residential areas.

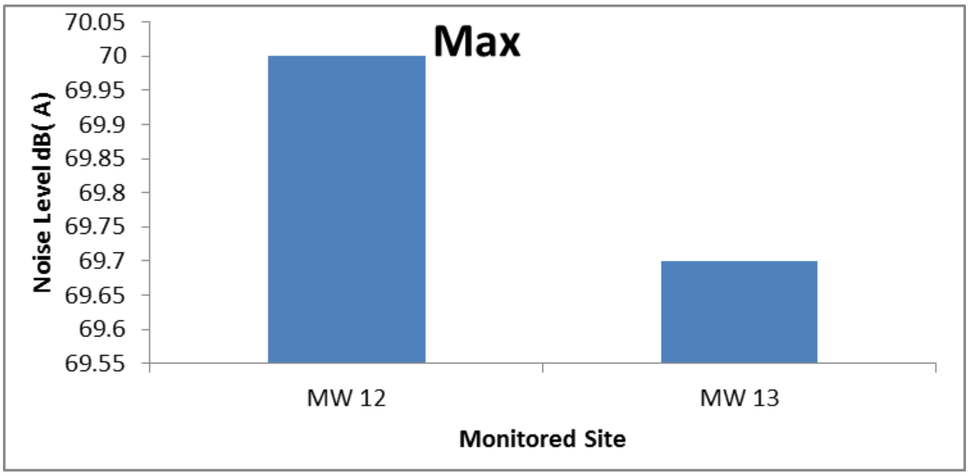

Figure 6: Maximum Noise levels at residential areas.

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 ConclusionS

Noise level assessment at the Menengai geothermal project was assessed. Noise pollution is controlled at the source of generation in the project area. This has been made successful by installation of silencers during horizontal well discharge tests, regular maintenance of all machinery working at the project and provision to staff PPEs working at site with possible emission levels exceeding 90dB(A). Besides, job rotation is practiced so that no worker spends more hours than required at a noise emission site

The levels were comparable to the occupational health and safety, World BANK and WHO maximum permissible limits for both industrial installation and residential. The noise levels were within the acceptable standards, i.e World Bank (45-50 dBA), and WHO of 55dBA for residential areas and 85dBA occupational health and safety exposure limits.

6.2 Recommendation

However, we strongly recommend the continued use of personal protective equipments where noise levels might be above the national and international recommended standards. Besides, other additional noise control strategies especially at source should be designed.

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