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Using Sound Mapping in Enhancing the Hearing Conservation Programmes of Geothermal Drilling Activities In Kenya: A Case Of Geothermal Development Company

Kachila, P., Njogu, P., and Makhonge, P.

Abstract— Kenya is endowed with 10,000 MWe of geothermal resource spread in 14 potential prospects along the Rift Valley. The government has prioritized geothermal power generation and specially formed The Geothermal Development Company (GDC) in 2008 to drive this agenda. GDC has purchased seven deep drilling rigs that are operated and maintained by a Kenyan crew for drilling geothemal wells. However the geothermal drilling rig has been identified as a high noise hazard workplace, exposing workers to the risk of permanent hearing damage. Traditional noise control measures that have been installed at work stations to comply with the Noise Prevention and Control Rules of 2005 includes: absorbers, sound-absorbing materials, soundproof doors, screens, vibration isolation, enclosures, silencers, sound isolated pipelines, sound-insulating cabins and sound-absorbing systems. While it may never be possible to eradicate all noise from the workplace, this study assessed the use of noise maps in enhancing the hearing conservation programmes by early detection, isolation and remedying problem areas. Noise reduction after the construction of the plant and the installation of machines and devices or during the full-scale operation stage is not only much more difficult, but also much less efficient, leading to only a slight reduction of noise at a relatively high cost. Moreover, the necessary alterations or adaptations are not always favourable to the technological process applied. It was established that the noise maps can be done for all combinations of activities and machinery at the rig site to show all the sources of noise and how it is dispersed, making it easier and cost-effective in establishing key areas for mitigation measures.

Index Terms— Calibrated noise meter, Geothermal drilling rigs, Hearing Conservation Programme, Noise control measures, Noise maps, Noise mitigation measures, Occupational noise, Sound mapping and simulation softwares, Sources of noise

1 Introduction

Geothermal well drilling is the process of sinking a hole into the earth to tap the energy stored in a steam or hot water reservoir. Drilling activities also include the casing and cementing operations that are used to case off and seal unproductive sections of the well while making a conduit through which the steam flows to the surface. The deep productive zones are cased off using slotted liners that permit the steam to flow into the tubulars and to the surface. The successful product of the drilling operation is a well that is discharging high pressure steam, hot water or a combination of both. The drilling technology used, has to a great extent, been borrowed from the oil and gas industry (Njee, 1987). Since the workplace setting and environment are similar, the occupational and safety parameters largely match.

A facility called a drilling rig is used in the drilling operations. The drill rig is an aggregate of individual systems that work together to accomplish the drilling mission. This facility is assembled on a flattened and competent ground called the drilling pad, constituting the workplace.

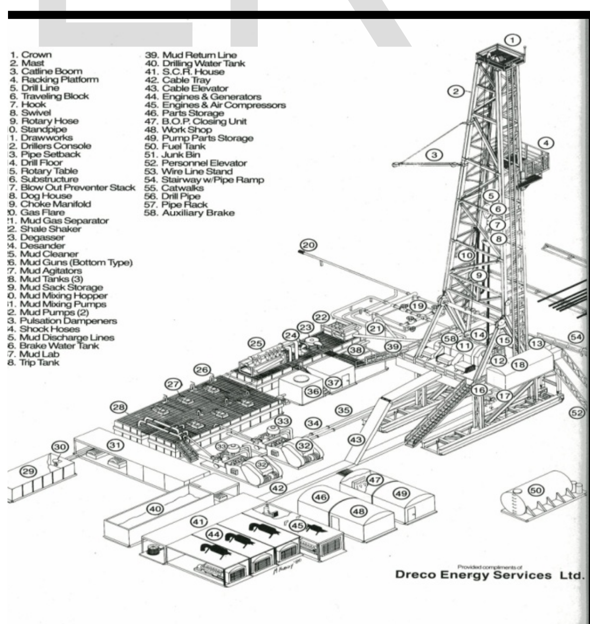

FIGURE 1: A pictorial of the main components of the drill rig (Source: Dreco ES Ltd)

A typical geothermal drilling rig consists of the following systems:

i. The power system comprise the diesel generators, start-up compressor, variable frequency drives

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(VFDs), Silicon Controlled Rectifiers (SCRs) and means of transmission and distribution of electric power to the loads.

ii. The hoisting system is used to support the rig, lift or lower the rotating drill-string. It consists of the draw-works, the crown block, the travelling block, the hook, the links and elevators, the winches, the sub-structure, the rig floor and the derrick.

iii. The circulation system is used to circulate the drilling fluid and ensure that cuttings are lifted to the surface while at the same time cooling the bit and maintaining well bore stability. It consists of mud pumps, standpipe, rotary hose, swivel/Kelly system or top-drive system, shale shakers, the cyclonic cleaners, mud tanks, mud pits, mixing hoppers or tanks, and associated hoses or pipes. For aerated drilling the system includes set of high pressure compressors, set of air boosters and air dryers.

iv. The rotary system is responsible for creating rotation torque on the entire drill-string and the bit. It may be a Kelly system including the rotary table and Kelly bushing or the Top-drive system, consisting of an integrated rotary, rod handling and swivel system. The drill stem transmits the rotation torque and drilling fluid to the bit.

v. The well control system consists of the Blow-out protector stacks, choke manifold system, kill manifold system, accumulator system and the associated controls.

vi. The rig auxiliary equipment includes the other components that supplement the other systems so as to enable the rig to function more efficiently. They include such components as drill-string handling tools, rig instrumentation, the driller's console, cement silos, air drilling package, diesel tanks, slings, pipe racks, drilling offices, canteen, workshops , warehouses, cranes, forklifts and trucks.

vii. The rig also includes the camp which houses the staff.

viii. The rig includes facilities for specialized services such as cementing plant and laboratories.

Kenya is endowed with 10,000 MWe of geothermal resource spread in 14 potential prospects along the Rift Valley (GOK, MOEP, 2013). The fields that are currently producing electric power are Olkaria and Eburu. Olkaria volcanic complex is the one that is best known (Langat, 2004). Other geothermal sites are at various stages of development (Omenda, 2010). The government has prioritized geothermal power generation and specially formed The Geothermal Development Company (GDC) in 2008 to drive this agenda. GDC has purchased seven deep drilling rigs that are operated and maintained by a Kenyan crew for drilling geothemal wells (Geothermal Development Company, 2016). A study identified noise as one of the most common hazard in geothermal drilling in Menengai (Fankey, Githiri, & Mburu, 2013).

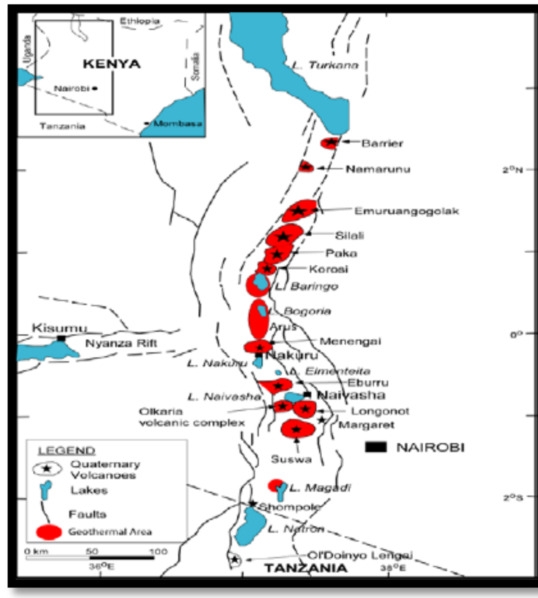

FIGURE 2: Geothermal prospects in Kenya (Omenda, 2010)

The National Institute for Occupational Safety and Health (NIOSH) estimates that 84% of carpenters, 77% of operating engineers, and 73% of construction workers are exposed to noise levels over the recommended limit (Berndt, 2018). Sudden or gradual hearing loss is not just a risk to workers health but to the employer too. Business productivity, reputation and legal standing can be eroded if proper mitigation measures are not put in place to protect workers from excessive noise. This implies that occupational noise should be part of the risk analysis and planning process for every employer.

2 EFFECTS OF EXCESSIVE NOISE EXPOSURE

When the hearing organ is exposed to excessive noise, the hearing threshold is raised. This effect may be *reversible*, a temporary threshold shift, or *permanent*, after many years of dangerous exposure, and may occur in different frequency ranges. In both cases, the symptom is difficulty in hearing. A temporary threshold shift diminishes after the noise ceases; a permanent threshold shift is irreversible and does not show any recovery over time. A permanent threshold shift is an irreversible damage to the hearing organ. The risk of permanent hearing damage begins when the sound level exceeds 80–85 dB (A). Moreover, continuous exposure to noise is more harmful than interrupted exposure, because hearing regeneration can begin even during short interruptions (Taylor & Francis Group, 2010).

Non-auditory noise effects are not yet fully recognized. Examples of non-auditory physiological responses include motor reflexes, such as muscle contractions, which change the body posture after an unexpected signal such as an explosion or a shot, and the reactions of other systems, such as the reduction of the respiratory rate, contraction of the peripheral blood vessels, and decreased intensity of intestinal peristalsis (Taylor & Francis Group, 2010).

3 Kenyan Legal and Regulatory Framework on Occupational Noise

The principal OSH legislation in Kenya is the Occupational Health and Safety Act (OSHA) of 2007 Under this Act, the principal subsidiary legislation used is the Noise Prevention and Control Rules of 2005 which provides the following permissible noise levels:

i. that no worker shall be exposed to noise in excess of the continuous equivalent of 90dB(A) in eight hours within any 24 hours duration
ii. that no worker shall be exposed to noise in excess of 140dB(A) peak sound level at any given time
iii. noise transmitted outside the workplace shall not exceed 55dB(A) during the day and 45dB(A) during the night
iv. where noise exceeds 85dB(A), the occupier must develop noise control and hearing conservation programme as specified in the regulations and which shall be reviewed annually to determine its effectiveness

For environmental noise the principal legislation is the Noise and Excessive Vibration Pollution Control Regulations of 2009 under EMCA, 1999.

4 Traditional interventions in high noise risk workplaces

In a high noise installation such as a drilling rig, (Health and Safety Executive, 2012) recommends carrying out a risk assessment to decide what action is needed, and develop a plan. A noise risk assessment transcends more than just taking measurements of noise. Specifically, it should:

i. identify where there may be a risk from noise and who is likely to be affected;
ii. contain an estimate of your employees' exposures to noise;
iii. identify what you need to do to comply with the law, e.g. whether noise-control measures and/or personal hearing protection are needed, or whether working practices are safe; and
iv. identify any employees who need to be provided with health surveillance and whether any are at particular risk.

The traditional methods for preventing, eliminating, or limiting noise exposure are based upon the simultaneous application of technical, administrative, and organizational solutions, which are selected based on a detailed analysis of the acoustic conditions at workstations with excessive noise. The most significant technical solutions that limit noise include the following (Taylor & Francis Group, 2010):

i. Use of low-noise technological processes.
ii. Mechanization and automation of technological processes including remote and automatic control devices for noisy machines.
iii. Construction and application of low-noise or noiseless machines, devices, and tools.
iv. Proper layout of the plant and adaptation of rooms, taking into account the acoustic aspects.
v. Use of noise control devices such as silencers, enclosures, screens, and sound-absorbing materials and systems as illustrated in Figure 9.
vi. Use of structure-related sound insulation (vibration isolators and vibroisolated foundations of machines and devices).

Noise reduction after the construction of the plant and the installation of machines and devices or during the full-scale operation stage is not only much more difficult, but also much less efficient, leading to only a slight reduction of noise at a relatively high cost. Moreover, the necessary alterations or adaptations are not always favourable to the technological process applied (Taylor & Francis Group, 2010).

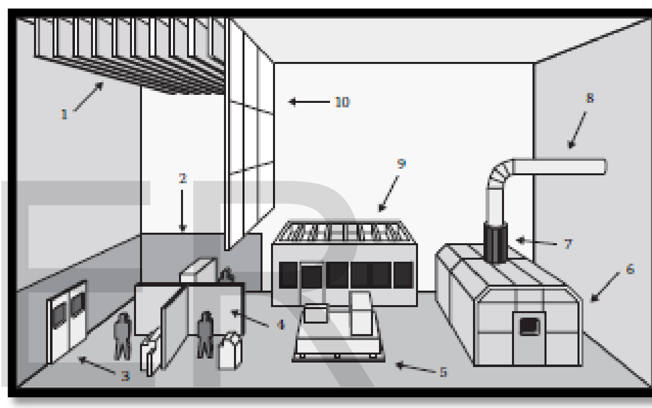

FIGURE 3: Noise control measures at work stations: (1) absorbers, (2) sound-absorbing materials, (3) soundproof doors, (4) screens, (5) vibration isolation, (6) enclosure, (7) silencer, (8) sound isolated pipeline, (9) sound-insulating cabin and (10) sound-absorbing system.

5 Noise mapping using MS Excel at a GDC drill rig in Menengai

The traditional interventions of protecting workers against the adverse effects of exposure to noise are majorly reactive in nature. The objective of this study was to assess the practicability of proactively using noise maps to effectively and efficiently enhance the noise control and hearing conservation programmes at the rig site.

To measure the noise levels at the drill sites and map out the noise levels, a properly calibrated sound level noise meter was employed to carry out general noise mapping of the entire workplace. With regard to averaging time value, noise was recorded using the Short-term averaging method (of 1 second) of particular significance for the assessment of unsteady and short-term noise, lasting several seconds (maximum A-weighted sound level).

To carry out the exercise, the well pad was divided into arbitrary 7 by 10 sectors and the researcher took noise

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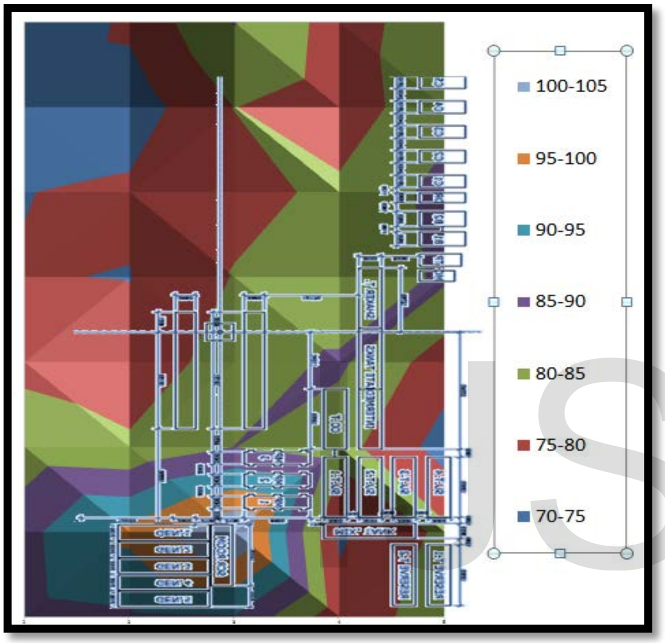
measurement taken for each sector. These readings were input in MS Excel and a colour coded noise contour was generated. This noise contour was thereafter overlaid on the rig layout map (rig foot print) to produce the noise map shown in figure 4. For this particular case the drilling rig number 4 was doing a drilling ahead activity. This is a complete ZJ 70D Drilling Rig (2000 HP DC Electric Land Rig). It was found out that dangerous noise hazard of above 100dB (A) was identified inside the generator; high noise levels of above 95dB (A) was exhibited around the generators, at mud pump and mud mixing area; the cellar area had noise levels in the range of 80-85dB (A); operational compressors exhibit high noise of above 85dB (A); while non-running compressors registered a noise level of



between 80 and 85dB (A).

FIGURE 4: Noise Map for Rig 4 while drilling ahed on 5th October 2016, 1200hrs -1300hrs

The findings therefore imply that the occupier should, in accordance with the Noise Prevention and Control Rules of 2005, enforce a noise and hearing conservation programme as the workers are exposed for 12-hour shifts and the entire rig site is hazardous for noise. The noise maps can be done for all combinations of activities and machinery at the rig site to show all the sources of noise and how it is dispersed, making it easier to establish key areas for mitigation measures.

6 Discussion and Conclusion

According to (Berndt, 2018), accurate mapping using noise-mapping softwares can ensure that everything possible is done to mitigate excessive exposure in a cost-effective manner. A continuum of noise-mapping softwares of varying levels of sophistication exists in the market. Many of these are able to allow for simulations to be done for various other rig activities and diverse combinations of machinery at the rig site. Other more sophisticated mapping and simulation softwares exist which give the option of developing "what-if scenarios". Such programs can also be deployed so that the noise impacts of developments or activities can be assessed in advance. The colour coding used on the maps makes it easy to interpret the noise dispersion by the non-technical decision makers.

The study specifically recommends that the GDC management should enhance the Hearing Conservation Programme (HCP) based on regulatory standards and best practices and premised on the following 7 elements: Measure, Control, Protect, Check, Train, Record and Evaluate.

The use of sound mapping software as opposed to direct measurement enhances the Noise Control and Hearing Conservation Programmes of deep-hole drilling operations (both geothermal, and oil and gas) by proactively allowing for predictions of the overall noise situations of the proposed plant and informing the requisite pre-emptive corrective measures.

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