ISSN 2348 – 7968

Noise from Site Power Systems and Its Mitigation

Selvaraman Ramalingam

M tech HSE, HSE Department

University of Petroleum and Energy Studies, Dehradun, India

1.1 Abstract: Generator sets for power system is one among the important equipment used in the construction industries, used in large numbers and as clusters and also located very near to the work area. The noise levels produced by these generators are much higher than the permissible limit. In the first step of this paper assesses the potential noise emissions associated with two unclosed caterpillar power generators used in a construction site. In the second step, combined noise effects of generators and other activities are studied over a 12-hour period to establish background environmental noise levels. The study shows large number of construction workers working nearby generators are exposed to 100 dB (A) or more noise. The chain of noise control at the source- along the noise path or at the receiver and what effective steps could be done to mitigate the noise exposure at each stage is considered.

1.2 Introduction

Noise: "any loud, discordant or disagreeable sound." Noise intensity is measured in decibel units [1], [2]. The decibel scale is logarithmic; each 10-decibel increase represents a tenfold increase in noise intensity [6]. Human perception of loudness also conforms to a logarithmic scale; a 10-decibel increase is perceived as roughly a doubling of loudness. Thus, 30 decibels is 10 times more intense than 20 decibels and sounds twice as loud. OSHA health and Safety regulations [17] provide the maximum permissible noise exposure limit; it should not exceed 90 dBA. Any noise greater than 90 dBA can cause hearing loss, lack of sleep, irritability, heartburn, indigestion, ulcers, high blood pressure, and possibly heart disease [3], [4]. Prolonged or frequent exposure to noise tends to make the physiological disturbances chronic. In addition, noise-induced stress creates severe tension in daily living and contributes to mental illness.

Background: The project involves the reclamation for the construction of a new refinery. The project involves dredging and reclaiming some 40 million cubic metres of sand and executing extensive ground improvement. The project will also include constructing various channels, a basin for a future jetty, a barge dock and roads. It deploy large trailing suction hopper dredgers and cutter suction dredgers.

A dredgers is a piece of equipment, which can dig, transport and dump a certain amount of underwater laying soil in a certain time. Dredgers can dig hydraulically or mechanically. Hydraulic digging make use of the erosive working of a water flow. For instance, a water flow generated by a dredge pump is lead via suction mouth over a sand bed. The flow will erode the sand bed and forms a sand-water mixture before it enters the suction pipe. Hydraulic digging is mostly done with special water jets. Hydraulic digging is mostly done in cohesion less soils such as silt, sand and gravel. Mechanical digging by knives, teeth or cutting edges of dredging equipment is apply to cohesive soils. The transport of the dredged soil can be done hydraulically or mechanically too, ether continuously or discontinuously. Deposition of soil can be done in simple ways fi by opening the grab, turning the bucket or opening the bottom doors in a ship. Hydraulic deposition happens when the mixture is flowing over the reclamation area. The sand will settle while the water flows back to sea or river. Dredging equipment can have these three functions integrated or separated. The choice of the dredger for executing a dredging operation depends not only on the above mentioned functions but also from other conditions such as the accessibility to the site, weather and wave conditions, anchoring conditions, required accuracy and so on.

1.3 Booster pump

A booster pump is a machine, which will increase the pressure of a fluid, generally a liquid. It is similar to a gas compressor, but generally a simpler mechanism, which often has only a single stage of compression, and is used to increase pressure of an already pressurised gas. Two-stage boosters are also made. Boosters may be used for increasing gas pressure, transferring high pressure gas, charging gas cylinders and scavenging.

1.3.1 Safety Factors Should Be Considered

Nowadays safety and sustainability are considered part and parcel of every seagoing vessel and CSDs are no exception. The newest CSDs take advantage of the high-tech possibilities to insure technical and constructional features that comply with the highest standards. For instance, because of the type of work they do – breaking hard rock and soils – CSDs are known for their high sound and vibration levels. The intensity of sounds varies depending on the amount or hardness of the material to be removed. To ensure that the crews have comfortable working environment and living quarters, new ships have better insulated living areas.

1.3.2 Construction and function

Booster pumps are usually piston or plunger type compressors. A single-acting, single-stage booster is the simplest configuration, and comprises a cylinder, designed to withstand the operating pressures, with a piston, which is driven back and forth inside the cylinder. The cylinder head is fitted with supply and discharge ports, to which the supply and discharge hoses or pipes are connected, with a non-return valve on each, constraining flow in one direction from supply to discharge. When the booster is inactive, and the piston is stationary, gas will flow from the inlet hose, through the inlet valve into the space between the cylinder head and the piston. If the pressure in the outlet hose is lower, it will then flow out and to whatever the outlet hose is connected to. This flow will stop when the pressure is equalised, taking valve opening pressures into account.

Delivery rate starts at very close to swept volume when there is no pressure difference, and drops steadily until there is no effective transfer when the pressure ratio reaches the maximum boost ratio.[1]

Compression of gas will cause a rise in temperature. The heat is mostly carried out by the compressed gas, but the booster components will also be heated by contact with the hot gas. Water jackets or external fins to increase convectional cooling by the ambient air cool some boosters, but smaller models may have no special cooling facilities at all. Cooling arrangements will improve efficiency, but will cost more to manufacture. Boosters to be used with oxygen must be made from oxygen-compatible materials, and use oxygen-compatible lubricants to avoid fire

Once the flow has stopped, the booster is started, and as the piston withdraws along the cylinder, increasing the volume between the cylinder head and the piston crown, the pressure in the cylinder will drop, and gas will flow in from the inlet port. On the return cycle, the piston moves toward the cylinder head, decreasing the volume of the space and compressing the gas until the pressure is sufficient to overcome the pressure in the outlet line and the opening pressure of the outlet valve. At that point, the gas will flow out of the cylinder via the outlet valve and port. There will always be some compressed gas remaining in the cylinder and cylinder head spaces at the top of the stroke. The gas in this "dead space" will expand during the next induction stroke, and only after it has dropped below the supply gas pressure, more supply gas will flow into the cylinder. The ratio of the volume of the cylinder space with the piston fully withdrawn, to the dead space, is the "compression ratio" of the booster, also termed "boost ratio" in this context. Efficiency of the booster is related to the compression ratio,

ISSN 2348 – 7968

and gas will only be transferred while the pressure ratio between supply and discharge gas is less than the boost ratio, and delivery rate will drop as the inlet to delivery pressure ratio increases.

1.4. Noise by Power Generators

Like many types of rotating machinery, reciprocating engine-powered generator sets produce noise and vibration. Whether these generator sets run continuously in prime power applications or only occasionally in standby applications, their operating

sound levels often must be reduced to comply with local, state or federal ordinances. In North America, maximum permitted overall noise levels range from 45 dBA to 72 dBA, depending on location and zoning. In fact, recently, some states and communities have begun to specify property line noise restrictions using octave band frequencies to reduce the amount of low-frequency noise that reaches community neighbourhoods. Since untreated generator set noise, levels can approach 100 dBA or more, both the location of the generator set and noise mitigation take on great importance. Combined Noise Effects of Generators and Other Activities

CSDs can discharge dredged material either via a floating pipeline to shore (above) or by discharging it into a barge with a special loading system (below).

In general, two forms of regulations affect the volume of noise to which individuals or the public may be exposed state or municipal noise ordinances and Occupational Safety and Health Administration (OSHA) federal safety regulations. The former regulations address noise that may migrate beyond property lines and disturb the public but that is seldom sufficiently loud to constitute a safety hazard. The latter addresses standards for noise exposure in the workplace to protect the health of workers. OSHA regulations normally only apply to workers who may be exposed to generator set noise that is above 80 dBA for any appreciable time. Workers can limit exposure by wearing proper hearing protection when working around operating generator sets. Europe and Japan, as well as numerous other countries, have also set standards to control noise in the workplace and in the environment at large.

1.4.1 Sources of generator set noise

Generator set noise is produced by six major sources (see Figure 2):

• Engine noise – This is mainly caused by mechanical and combustion forces and typically ranges from 100 dBA to 121 dBA, measured at one meter, depending on the size of the engine.

ISSN 2348 – 7968

• Cooling fan noise – This results from the sound of air being moved at high speed across the engine and through the radiator. Its level ranges from 100 dBA to 105 dBA at one meter.

Alternator noise – This is caused by cooling air and brush friction and ranges from approximately 80 dBA to 90 dBA at one meter.

• Induction noise – This is caused by fluctuations in current in the alternator windings that give rise to mechanical noise that ranges from 80 dBA to 90 dBA at one meter.

• Engine exhaust – Without an exhaust silencer, this ranges from 120 dBA to 130 dBA or more and is usually reduced by a minimum of 15 dBA with a standard silencer.

• Structural/mechanical noise – This is caused by mechanical vibration of various structural parts and components that is radiated as sound.

1.4.2 Measuring noise

Before you can begin to determine what mitigation might be required, you have to collect accurate sound measurements of both the existing ambient noise and the noise contributed by the generator set. Accurate and meaningful generator set sound-level data should be measured in a "free field environment." A free field, as distinguished from a "reverberant field," is a sound field in which there are negligible effects from sound being reflected from obstacles or boundaries. Noise measurements should be made using a sound level meter and an octave band filter set, at a minimum, to allow for more detailed analysis by acoustical consultants.

When measuring sound levels from a distance of 7 meters, microphones are placed in a circular array with measurement locations at 45-degree increments around the generator set. The measurement array is 7 meters from an imaginary parallelepiped that just encloses the generator set, which is usually defined by the footprint dimensions of the skid base or chassis.

When measuring sound power levels for European applications, a parallelepiped microphone array is typically used, as defined in International Standards Organization standard ISO 3744. Sound performance data for generator sets from Cummins Power Generation Inc. are available on the company's design software CD (called "Power Suite"). Sound performance data is also available in the Power Suite Library on the company's Web

Initial noise measurements are usually made in eight octave bands from 63 Hertz to 8000 Hertz, although the highest sound power generated is typically in the range of 1,000 Hertz to 4,000 Hertz – the range of sound to which the human ear is most sensitive.

While measurements are taken across a spectrum of frequencies, the logarithmic sum of all the frequencies is the most important reading. However, when the overall sound level exceeds the allowable level for a project, frequency band data is used to determine what design changes are necessary to lower the overall sound level to comply with requirements.

1.4.3 Noise Dosimeter or Sound Level Meter

Noise Meters and Kits CEL-633 Series

The measurement of complex noise sources requires a complete knowledge of the noise climate over an extended time period. The CEL-633 series of 4 different analyzers is designed to satisfy this need by providing a choice of instruments to suit almost any measurement requirement. A super wide 120 dB dynamic range means that the user does not need to worry about selecting measurement scales as the meter will always be on the right range. The simultaneous provision of all the popular frequency and time weightings and exchange rates allow many different types of noise measurements to be taken by new and experienced users alike. The full-color, high-precision, graphic LCD enhances the user experience with this new meter. For measurements of outdoor noise levels over extended periods of time, the CEL-633 will be the most appropriate model. It provides all the required parameters for comprehensive EPA, HUD or similar studies. It provides the popular max, min, and time average levels in addition to the statistical or LN% parameters. The CEL-633 is designed to provide all the key results for these difficult environmental noise climates. Regular periodic recording at fixed intervals is provided in the CEL-633 model plus the addition of extra time history profile recording. The changing noise intervals are stored with the overall time average answer and displayed annotated with the time they occurred. Significant events can be triggered by noise level exceedances providing even more detail about what has happened. The audio signature is captured and can be used to identify the cause. Additionally, octave and third octave band filters in the B and C versions can provide frequency analysis of tonal noise levels that are important for the correct prescription of hearing protectors or noise reduction applications.

II. NOISE EXPOSURE LEVEL

Noise by Power Generators

Power Generators are essential in construction sites where electricity is not supplied, used to power electric equipment's, welding machines, for general and task lighting. The workers involved in various works has exposed to various levels of noise by the machinery which they works [10]. In construction industry all the required electricity is supplied by the power generators, which also producing huge noise, the workers ultimately exposed to double effect.

The usual sound sources of an electrical power generator are fan, bearing and sound radiation from the surface. In an electric generator the magnetic field produces the circumferential forces required for the energy transfer. In addition, the field creates radial forces, these forces interact with stator is in contact with the frame, which also is excited. The vibration of the frame accelerates the surrounding air, which is heard as noise [11].

A. Noise Permissible Exposure Limits

The OSHA, 29 CFR 1926.52 and 1926.101 gives the permissible exposure limits (PEL) and requirements for an 8- hour time-weighted average exposure level (TWA) of 90 dBA with a 5-dB exchange rate between allowable duration and noise level.

Table 3: Permissible Noise Exposures Limits

Sound Level (dBA)	Permitted duration per workday (hrs)	Sound Level (dBA)	Permitted duration per workday (hrs)	Sound Level (dBA)	Permitted duration per workday (hrs)

ISSN 2348 – 7968

90	8.00	99	2.30	108	0.66
91	6.96	100	2.00	109	0.56
92	6.06	101	1.73	110	0.50
93	5.28	102	1.52	111	0.43
94	4.60	103	1.32	112	0.38
95	4.00	104	1.15	113	0.33
96	3.48	105	1.00	114	0.28
97	3.03	106	0.86	115	0.25
98	2.63	107	0.76	116	0.21

B. Equivalent Noise Exposure Factor

Noise levels are expressed in terms of the energy-equivalent continuous noise level, Leq, which normalizes the Leq to an 8 hour day. This could only be accomplished given a worker's pattern of exposure to noise; workers switch to different jobs/tools/sites, and their shift length is variable and seasonal. Exposure to different levels for various periods of time shall be computed according to the formula [16].

$$L_{eq} = (T1 / L1) + (T2 / L2) + \ldots\ldots\ldots\ldots + (Tn / Ln)$$

where: Leq = The equivalent noise exposure factor.

T = The actual time of noise exposure by person at a constant noise level.

L = The duration of the permissible noise exposure at the constant level

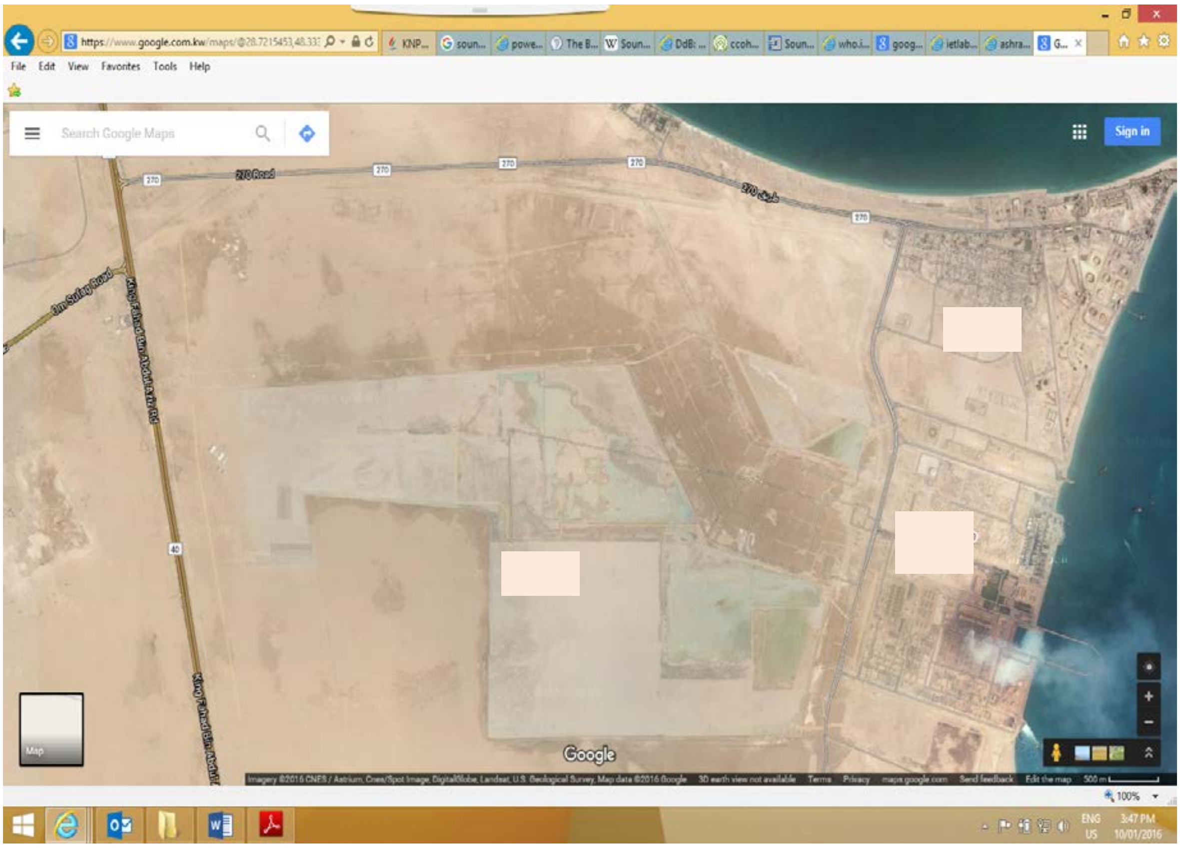
If the value of Leq exceeds unity (1) the exposure exceeds permissible levels.

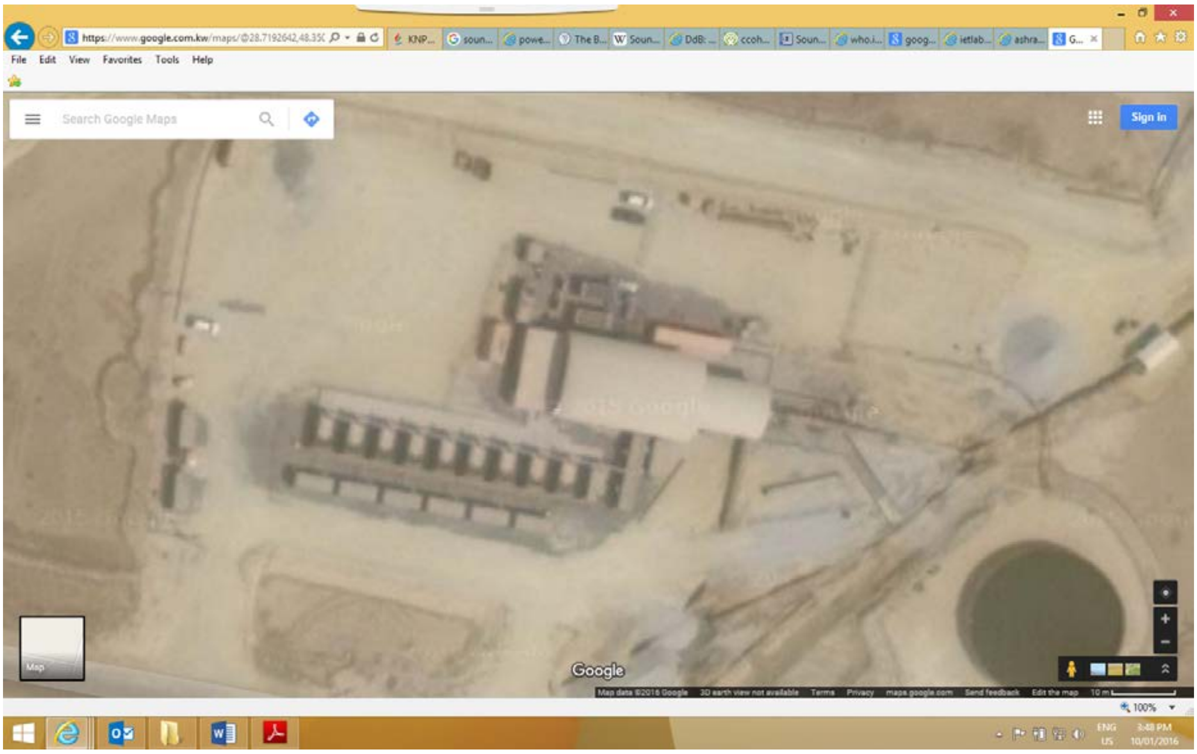
III. STUDY WORK

SITE LAYOUT

The study area spread over 200 meter length and 120 meter breadth gives 24000 m2 area. In the first step environmental noise measurements were made for two individual generators at locations G1 & G2 which was shown in [Figure 1]. At the time the noise measurement equipment was set up, the sky was clear, temperatures were in the mid 22 C, and the wind speed was light and variable. But actually the noise environment fluctuated greatly from hour to hour and location to location, depending on work activity within the study area. So in second step another measurement was made at six locations during a normal working day over a period of 12 hours, which indicates that the working area is typically noisy throughout a normal working day.

ISSN 2348 – 7968





A. Noise Effects of Individual onsite Generators

The environmental noise readings were taken from two standard caterpillar diesel generators, one generator (G1) with 3500KVA, 1500 rpm and 440V output and the other (G2) with 5000KVA, 1500 rpm and 440V output. These two generators are not covered or provided with any acoustic shield; hence the entire noise generated will be transmitted to the environment. All other activities in this area were stopped in order to eliminate the noise effect of other work activities. The noise level was observed on 21-04-2013 in a calibrated standard digital sound level meter with RS232 and noted from various distances. [Table 4] presents the summary of noise levels measured at various distances from the source of noise, i.e. generators.

Table 4: Noise in dBA from Generator sets

Distance from the Generator (m)	Noise Level, dBA		Distance from the Generator (m)	Noise Level, dBA	
	Generator G1, 3500 KVA	Generator G2, 5000 KVA		Generator G1, 3500 KVA	Generator G2, 5000 KVA
	Max	Max		Max	Max
1.0	103.7	104.3	11.0	87.6	89.3
2.0	100.0	101.3	12.0	87.4	88.3
3.0	97.6	99.6	13.0	87.1	87.4
4.0	94.9	95.8	14.0	86.0	86.4
5.0	92.5	94.3	15.0	85.1	85.6
6.0	91.2	93.5	16.0	84.6	85.1
7.0	89.7	91.9	17.0	82.7	83.6
8.0	89.4	90.6	18.0	81.3	83.2
9.0	88.7	90.2	19.0	80.2	82.6
10.0	87.7	90.1	20.0	79.9	81.8

B. Combined Noise Effects of Generators And Other Activities

Noise exposure levels of construction workers are difficult to determine due to the day to-day variation in occupation and shift length of each worker and the itinerant and seasonal nature of the job. Another set of readings were taken to study combined noise effects of generator and other activities. Six locations (Points P1 to P6) were identified or selected to cover the entire construction area and the study locations were marked in [Figure 1].The readings were taken on 25-04-2013 for every one hour for a period of 12 hours (7 am to 7 pm). The measured values were tabulated in [Table 5].

Table 5: Combined noise effects during working hours, dBA

Time (Hrs)	Noise Exposure Levels, dBA					
	Point, P1	Point, P2	Point, P3	Point, P4	Point, P5	Point, P6
7.00 am	140.8	152.3	118.1	137.9	140.1	126.5
8.00 am	139.6	148.3	140.8	137	139.2	122
9.00 am	138.7	144.1	139.6	136.2	138.6	118.1
10.00 am	137.9	141.6	136.5	152.3	136.5	140.8
11.00 am	137	140.1	134.1	148.3	134.1	139.6
12.00 Noon	136.2	139.2	132.8	144.1	126.5	138.7
1.00 pm	135.8	138.6	129	129.1	122	129
2.00 pm	133.4	136.5	148.3	122	118.1	125.1
3.00 pm	131.6	134.1	144.1	141.6	112.4	115.1
4.00 pm	129.1	132.8	122	140.1	135.8	139.2

5.00 pm	126.5	129	141.6	137.9	135.8	138.6
6.00 pm	122	125.1	140.1	137	133.4	136.5
7.00 pm	118.1	120.3	139.2	136.2	131.6	132.8

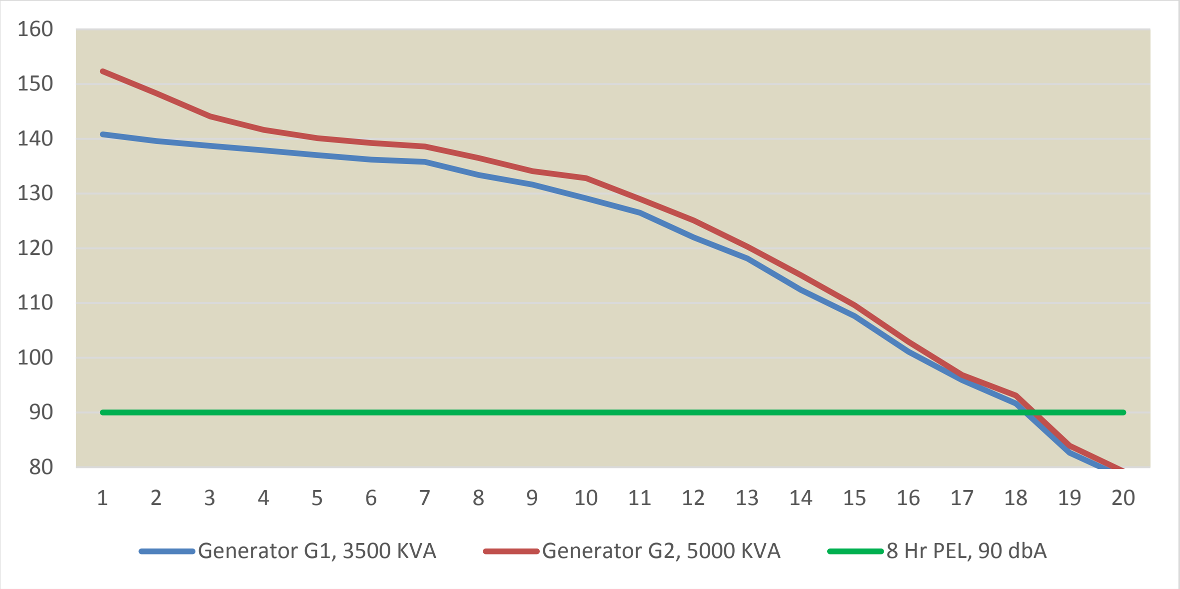
IV. RESULT AND DISCUSSION

A. Sound Pressure Level from Generators Vs Distance

Based on the noise level observed from the generators, the noise level was higher than the OSHA, 29 CFR 1926.52 permissible level of 90 dBA. At 1.0 m from the generator; the values noted are 140.8 dBA and 152.3 dBA for G1 and G2 respectively. These values decreases with increase in distance and it reaches the permissible level of 90 dBA at 18.0m for G1 and 18.0m for G2 generator. Even though the permissible level is 90 dBA; hearing damage begins at a much lower level, about 85 decibels. This value is observed at 18.5m and 19m for G1 and G2 generators respectively. The relationship between the measured noise level and distance from generators were given in [Figure 2].

The attenuation of sound pressure with respect to distance was shown in [Figure 3]. When there were no reflecting walls to magnify the noise produced by the generator set, the noise level will decrease by approximately 3 dB(A) every time the distance is doubled. If the property line is within the near field of a generator set, however, the noise level may not be predictable.

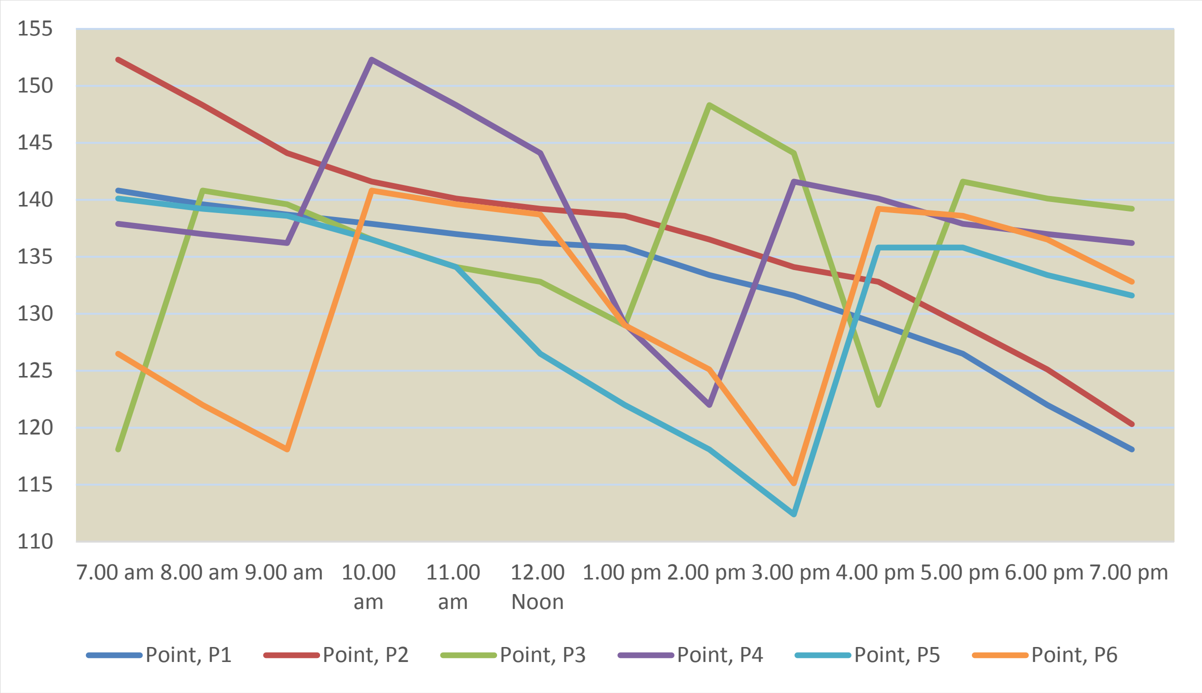
Figure 2: Noise level versus distance from generators



A. Analysis of Combined Noise Exposure Effect

Figure.4 presents a graphical analysis of combined noise effects and it shows the noise levels are greater than 90 dBA at locations closer to the generators. But the value decreases with locations away from the generators. The maximum noise emission noted was 92.5 dBA at point P6.

Figure 4: Graphical analysis of combined noise effects



As shown in this graph, the majority of inhabited (community) receptor -related noise levels that would be from P1 to P2. For these locations, construction noise would be expected to be clearly audible during most of the daytime hours, depending on the actual, onsite construction activities. These points of perceptibility are not considered significant, however, based on the temporary nature of the construction phases and the intermittent duration of the worst-case activities. Other locations P1 and P2, would have construction-related noise levels, but below to any other location.

V. STRATEGIES FOR REDUCING GENERATOR SET NOISE

Regardless of the type of generator set that needs sound attenuation, there are basically seven strategies for reducing generator set noise: 1) Reduce the sound level of the source 2) Acoustic barriers 3) Acoustic Insulation 4) Isolation mounts 5) Cooling air attenuation 6) Exhaust silencers 7) Efforts to maximize the distance between the generator set and the property line (or people).

When locating generator sets in outdoors, the use of enclosures, particularly sound-attenuating enclosures shall combines all these strategies into a convenient package that provides weather protection as well as sound attenuation.

VI. CONCLUSION

Construction work is inherently noisy. This study explained untreated generator set noise levels were 100 dBA or more, it was clear that generator set noise mitigation is a subject of great importance. The permissible exposure level 90 dBA was reached at 7.0m from G1 and 10.5m from G2 generator. This noise effects from generators can be mitigated by introducing noise reduction screens or acoustic shield around or provide hard barricade’s to exclude the employee’s entry and minimizes the exposure in noisy zone. The combined noise exposure to workers ranges from 76.2 dBA to 92.5 dBA, this represents a cautionary risk of hearing damage to construction workers involved in this work area.

This scenario shall exist in many construction sites wherever open generators are used for power generation and seeks implementation of an effective hearing protection and awareness program. Furthermore, the high cost of retrofitting a site for noise reduction makes it imperative to assess noise performance requirements early in the on-site power system design stage.

ISSN 2348 – 7968

Working closely with local regulations, consulting engineer or acoustic specialist shall allow in achieving the sound-attenuation goals.

VII. MITIGATION MEASURES AND SCOPE FOR FUTURE WORK

Once the construction work is in progress, it is essential to monitor the implementation of the noise control plan. The following mitigation measures will be implemented to reduce noise and ensure that the noise impacts are less than significant.

- Checking if equipment brought onto site complies with specifications. This could be done by obtaining information available from suppliers or by noise assessments.
- Reducing noise from identified noise sources by exchanging equipment and/or processes for a quieter alternative or by engineering control methods to quieting the existing one.
- Ensuring that all plant is properly maintained e.g. all noise control measures like silencers and enclosures are intact [13].
- Keep machinery covers and panels closed and well fitted. Bolts/fasteners done up tightly avoid rattles
- Monitoring work schedules to check that noisy work is carried out as specified, away from other workers, outside hours, etc
- Locate noisy machines away from main areas of activity. Otherwise, screen plant from work areas by using noise reduction screens or material stacked to form barriers [12].
- Monitoring whether noisy areas are identified and well marked so employees avoid entering them unnecessarily.
- Monitoring whether training and hearing tests have been carried out and if personal hearing protectors are adequate and are being worn and maintained correctly.
- Utilizing safety toolbox meetings to provide feedback on effectiveness of noise control measures and personal hearing protectors to employees and employers.
- Posting warning signs in high noise areas and implement hearing protection program for work areas where noise levels exceed 85 dBA, display on safety notice boards results of noise assessments conducted and additional noise information [15].

REFERENCCES

[1] Eaton S., "Noise & Vibration in Work safe Industries", WCB of BC Engineering Report WCB-99006, pp.25- 31, 1999.

[2] Bares L.F., Salyers E.F., "A New Material Systems Approach for Controlling Heavy Equip. Operator Noise Exposure", pp 80-84, 1980.

[3] Suggs C.W. "Noise Problems of Hand and Power Tools", Noise-con 81, pp.339-42, 1981.

[4] Singh, P., Noise pollution. Every Man's Science. 25(1&2), pp.231-235, 1984.

[5] Ringen, K. and Seegal, J. Safety and health in the construction industry. Annual Review of Public Health. Pp.165–88., 1995.

[6] The Columbia Encyclopaedia, Sixth Edition. Columbia University Press, pp.105-133., 2008.

[7] NIOSH, National Occupational Exposure Survey (1981-1983). Cincinnati, Ohio. pp.17-23.,1998.

[8] Sinclair, J.D.N., And W.O. Haflidson: Construction noise in Ontario. Appl. Occup. Environ. Hygene., pp.457-460., 1995.

[9] Anon., "Exposure of Construction Workers to Noise", Construction Ind. Research and Information Association, UK, pp. 96-102, 1984.

ISSN 2348 – 7968

[10] Ontario Ministry of Labour: Regulations for Industrial Establishments (Reg.851). Toronto, Canada: Ministry of Labour, pp.122-27, 1986.

[11] Legris, M., and P. Poulin: Noise exposure profile among heavy equipment operators, associated labourers and crane operators. Am. Ind. Hyg. Assoc. J, pp.774-778, 1998.

[12] Paul Klinge. Symposium on “Modeling and Simulation of multi technological machine systems”, ESPOO 2000, pp.17-24, 2000.

[13] Bartholomae, R.C., and R.P. Parker: Mining Machinery Noise Control Guidelines, U.S. Department of the interior, pp.29-42, 1983.

[14] Toth, W.J.: Noise Abatement Techniques for Construction Equipment. pp. 79:45. 1979.

[15] Ingemansson, S.: Noise control: Principles and practice (Part 7). Noise/News Int., pp.237-343, 1995.

[16] Greenspan, C.A., R. Moure-Eraso, D.H. Wegman, and L.C. Oliver: Occupational hygiene characterization of a highway construction project: A pilot study. Appl. Occup. Environ. Hyg. Pp.50-58,1995.

[17] OSHA, Occupational Noise Exposure, Safety and Health Regulations for Construction, 1926.52(d) (1, 2), 2002.

First Author: Selvaraman Ramalingam, Safety Engineer in Kuwait National Petroleum Company, Kuwait, with B Tech Chemical Engineering, pursuing M Tech HSE from University of petroleum and Energy Studies. The paper is submitted for the award of M.Tech HSE.