Iranian Journal of Geophysics, Vol 18 No 3, 2024, Page 59–67 (Research Article)
DOI: 10.30499/IJG.2023.380804.1482

Reducing environmental noise pollution by improved control methods at power plants (case study: Mazandaran power plant)

Marzieh Makaremi[1*], Fereshteh Ghomi Avili[2] and Narges Afsari[2]

[1]*Assistant Professor, Department of Civil Engineering, Institute of Science and Technology, Ministry of Science, Research and Technology, Babol, Iran*
[2]*Associate Professor, Department of Civil Engineering, Nowshahahr Branch, lslamic Azad University, Nowshahr, Iran*

(Received: 09 February 2023, Accepted: 30 July 2023)

Abstract
Noise pollution is an important environmental problem and in comparison, to other pollutants, the control of environmental noise has been hampered by insufficient knowledge as well as a lack of criteria. Power Plant industries have worldwide substantial progress and noise pollution is one of the considerable environmental impacts of various processes of these industries. This cross-sectional research aimed to study the sound levels to control noise pollution at different sections of the Mazandaran Thermal Power Plant in Iran. Sound pressure level measurements and frequency analysis were performed using the net" method where the results were compared with ACGIH Threshold Limit Values. It was found that inside the factory most of the measuring stations have high sound levels in comparison to industrial standards of 85 dB(A). Office buildings have the lowest sound pressure among measured areas. As 43% of measured stations are located in danger areas. Also, environmental noise measurements around Mazandaran Power Plant as an industrial residential area have revealed that sound levels were not higher than the admissible standards in Iran. The electricity generator's fan and Feed Water Pump section produce high levels of noise; therefore, a silencer and an enclosure were designed respectively. The amount of noise reduction for the enclosure was 38.7 dB(A) while the values of insertion loss and for the silencer 63.9 dB(A) reduction has been achieved.

Keywords: Enclosure, environmental pollution, noise control

*Corresponding author: makaremi20@yahoo.com

1 Introduction

Noise pollution adversely affects the lives of millions of people. Studies have shown that there are direct. Links between noise and health. Problems related to noise include stress-related illnesses, high blood pressure, speech interference, hearing loss, sleep disruption, and lost productivity (EPA, 1990). According to the International Programm on Chemical Safety, an adverse effect of noise is defined as a change in the morphology and physiology of an organism that results in an impairment of functional capacity, or an impairment of capacity to compensate for additional stress, or an increases the susceptibility of an organism to the harmful effects of other environmental influences. This definition includes any temporary or long-term lowering of the physical, psychological, or social functioning of humans or human organs (Berglund et al., 1999). Increasing need for electricity throughout the world, particularly among developing countries is seeking to develop power plants (Srinivasan, 2003; Joshi et al., 2017). The mentioned trend has been rapidly accelerated within the last decades in Iran (Ghobadianet al., 2019; Ghorashi, 2007). Power plants including thermal power plants are considered the main centers for electricity generation as one of the basic forms of modern life. The production and consumption of electricity lead to environmental impacts which must be considered in making decisions on the way in which to develop energy systems and energy policy (IAEA, 1999). In developing countries, continuous and cheap electricity production can play a vital role in industrial and social development (Ismail et al., 2009). During industry activities, several environmental problems such as water, soil, air, and noise pollution may be occurred. The power plants, according to their production process and machinery produce various degrees of noise pollution counted among harmful physical agents of the workplaces and are regarded as part of the professional hazards causing damage to the workers' health. the harmful effects of noise pollution, nervous disorders, nervous headaches, impatience, aggression, depression, dizziness, insomnia, and so on can be named (Dzhambov et al., 2018; Lusk et al., 2002). Nowadays, following the rapid progression in application of the renewable energies as well as the increasing trend of power plant construction, workers' health maintenance has been regarded significantly, so a lot of research have been done to diagnose the noise generation sources in various parts of the power plants and seek to find out appropriate control tools or strategies (Hashemian, 2011; Ma and Jiang, 2011). In this way, several conventional methods have been presented for reducing vibration and noise pollution in the power plant (Jena et al., 2018). By sound pollution identification, the emitted acoustic noise can be controlled and secondary effects prevented. Post-processing methods can be adapted for the disposition of the different acoustic power and pressure levels, especially as far as the impact on the environment is concerned (Seutche et al., 2019). In 2006, Kisku and Bhargava assessed the noise level of a medium-scale thermal power plant in India. They conducted the noise monitoring process using the "Cirrus sound level" Method within 30 min at a height of 1.5 m and 1 m away from the chest and investigated the noise pollution sources separately. Finally, the lowest and highest avg. noise equaled to 70.37 dB(A) and 95.91 dB(A) was respectively found by them in control room and Brittain (2005) carried out research to assess the indoor noise propagation and prediction in power plants. He focused on reviewing the basic room theory and outlined inefficiencies for application in predicting noise propagation inside power plant buildings. Ahmed and Zulquernain (2009) presented an expert system to predict the effects of noise pollution on operators of power plants a neuro-fuzzy approach. They aimed to developing a neuro-fuzzy model to predict the impact of noise pollution on human professional efficiency. For the mentioned purpose, they regarded factors including noise level, exposure time, and age of the operators doing complex types of tasks. Rodríguez et al. (2010) examined noise pollution generated from a Turbo gas Power Plant within commissioning service using a Continuous Emissions Monitoring System installed in situ. Finally, they concluded that the Turbogenerator complies with all noise levels and contaminant emissions requirements and regulations regarding the limits determined by the domestic and international standards.

The current study aims to address the major noise sources generated by various sections and machines in the thermal power plant. Furthermore, a decrease in sound levels of main noise sources by introducing control methods is included in this study. The findings of the study will be so helpful in recognizing noisy units of thermal power plants as well as presenting mitigation measures to control them.

2 Materials and Methods

Mazandaran Power Plant is one of the most important power plants as it supplies about 4 percent of the total electricity of Iran (Fig.1). This power plant, located in north of Iran nearthe Caspian Sea, is 45 km away from Sari city, center of Mazandaran province which is operated by natural gas fuel.

The Mazandaran Power Plant comprises four steam units of 440 MW power and two synthetic cycle units (steam and gas) of 137.5 MW power.

The empirical acoustic method used here is based on an experiment, which consists of measuring the sound impulses produced by vibration, propagation, and reflection of sound waves. Sound levels at different locations of Mazandaran Power Plant including steam, synthetic cycle (steam and gas), and official parts were measured. Environmental impact assessments were also performed at ten stations near Mazandaran Power Plant.

The location of noise pollution sources and the pause areas of employees were first identified and then measurement stations were defined according to ISO 9612 (2009).

Figure 1. The location of Mazandaran(Neka) Power Plant in Iran.

To estimate the sound levels, the power plant area was divided into equivalent stations by net method. At each station, Sound Pressure Level (SPL), Equivalent Sound Level (Leq), and frequency analysis were performed at one-octave band. The total number of stations in the steam unit, synthetic cycle unit, and lateral installment were 77, 87, and 22, respectively.

Also, nineteen stations were specified in official parts to measure the SPL, Leq, and background noise in ten stations were also considered for environmental noise measurement around Mazandaran Power Plant. The measurements were conducted applying Cell-450 Sound Level Meter where it was calibrated with Cell 110/1. By identification of the main noise sources and their critical frequency, results were evaluated and applied for noise control measures. For each noise source, different aspects were determined to reduce the sound levels by theoretical methods. For instance, the applied absorptive material of the enclosure in the Feed Water Pump and the area of the silencer for the electricity generator are among the important factors that should be considered in control methods.

3 Results and Discussion

3.1 Industrial and Environmental Noise Measurements

As was stated in the previous section, SPL and Leq were measured at different stations of Mazandaran Power Plant. Also, to do some control design for the reduction of noise pollution at different sound sources, frequency analysis was performed. Table 1 represents the results of sound measurements at four different units including the steam unit, synthetic cycle unit, lateral installment unit, and, office buildings. As it can be seen, stations in rectifiers, battery homes, condensed turbines, and office buildings have lower sound levels compared to the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) which is 85 dB(A) for 8-hour duration per day (30) All stations of Emergency electricity generator, Condenser-Turbine, Turbine-Feed Water Pump, Turbine-Turbines and Boiler-Fuel distribution have higher sound levels compared to the standard while the sound levels in some stations of Boiler and all stations of level Rectifier, Battery home and Condensed turbine were lower than the permissible level. Considering the Synthetic cycle unit, the 8-hour weighted sound pressure level in sections 1 and 2 of the Generator, Boiler Room, Oil Tank, Compressor Duct, Turbines, Water Cooling System, Filter House, Boiler Feed Pump, and also in Compressor House, Boiler Aid, Diesel House were higher than 85 dB(A). However, due to the application of acoustic materials on the ceiling and interior walls and using ceramic on the ground as well as the distance between the following areas to predominant noise sources, the sound levels in the Control Room, Security Room, and Shift Engineer Room were lower than the standard ones. The Water Pump Home and the main workshop of turnery of Lateral Installment were the only areas that had higher SPL than 85 dB(A).

Moreover, a noise impact assessment was also performed at ten stations near Mazandaran Power Plant during daytime. Sound levels at the A-weighted network were measured using the environmental Sound Level Meter (Table 2). As Mazandaran Power Plant is located in a Residential and Industrial area, sound pressure levels in all these stations were lower than Environmental noise standards in Iran (Table 3).

According to a net method, of the total 205 measurement stations, results represent that 74 (37%), 42 (20%), and 89 (43%) stations were safe, cautious, and dangerous areas, respectively. As only quite less than 50 percent of Mazandaran Power Plant is exposed to sound levels higher than 85 dB(A).

Table 1. Mazandaran Power Plant units noise level measurement

Unit	Stations	Number of Stations	SPL (dB(A))	Leq (dB(A))
Steam	Emergency Electricity Generator	8	91.90 *(2.14)	91.73 (2.12)
	Condenser-Turbine	16	92.13 (1.29)	92.21 (1.27)
	Turbine -Feed Water Pump	6	96.88 (2.47)	96.60 (2.13)
	Turbine-Turbines	20	93.32 (1.06)	93.20 (1.23)
	Boiler-Fuel distribution	4	90.70 (2.22)	90.72 (2.02)
	Boiler	7	87.10 (2.17)	86.17 (2.95)
	Rectifier	6	80.00 (1.78)	80.13 (1.73)
	Battery home	6	79.55 (1.63)	79.66 (1.62)
	Condensed Turbine	4	83.55 (13.91)	83.80 (14.08)
Synthetic Cycle		87	109.06 (14.20)	109.14 (14.23)
Lateral Installment		22	95.93 (7.82)	95.93 (7.82)
Office Buildings		19	76.04 *(4.18)	75.99 *(4.10)

*The number in Parentheses is the standard deviation.

Table 2. Environmental noise level measurements around Mazandaran Power Plant

Station	Geographical situation	Leq 30 min (dB(A))	Explanation
A	South	65.0	Roadside
B	Southwest	64.0	Roadside
J	South	63.2	Roadside
F	North	63.1	Seaside
C	West	59.4	Roadside
I	South east	59.3	Roadside
G	North east	59.1	Seaside
D	West	58.2	Roadside
H	East	58.2	Roadside
E	North west	57.0	Seaside

Table 3. Ambient Noise Standards of Iran (31).

Category of Zones	Leq 30 (dB(A))	
	Day [1]	Night [2]
Residential	55	45
Residential and Commercial	60	50
Commercial	65	55
Residential and Industrial	70	60
Industrial	75	65

[1] Day Time (7.00 AM-10.00 PM)
[2] Night Time (10.00 PM - 7.00 AM)

3.2 Control methods

A. Silencer for Electricity Generator

As the fan of the emergency electricity generator produces a high level of noise, a silencer is proposed; the capacity and static pressure of the fan are 96500 cfm and 34 inches of water, respectively. According to the measurements, the dominant frequency of the generator is 1000 Hz presented in Table 4. The proposed of generator is an absorptive parallel baffle in which the thickness ratio of lateral canals to mid canals is two to one. The applied absorptive material is stone wool, while the walls are covered by steel sheets with holes of 3 mm thickness at every 2 cm distances. The outlet and inlet of silencer is aerodynamic and installed vertically near the fan.

Table 4. Frequency analysis of Electricity Generator Fan at one octave band.

Frequency (Hz)	63	125	250	500	1000	2000	4000	8000
Sound level (dB)	61.9	79.1	80.7	86.3	92.1	90.4	80.3	74.6

Overall sound level 94.5 dB

Table 5. The Insertion Loss (IL) values and predicted sound pressure levels by silencer installation at octave band center frequencies.

Frequency (Hz)	63	125	250	500	1000	2000	4000	8000
IL (dB)	11	19	24	40	52	49	27	17
Sound level (dB)	50.9	60.1	56.7	46.3	40.1	41.4	53.3	57.6

The proposed silencer has four parts and every two parts are connected with the entrance of one of the inlets. These parts of the silencer are attached to an anti-vibration frame. The total flow Vs of these four parts is 96500 cfm which for each part is 24125 cfm. The flow area of each part is twelve square feet and its height is 5 ft.

According to instructions of the applied silencer (model 5Es), the insertion loss values were extracted, and then by installing the silencer set the expected sound pressure levels were estimated and presented in Table 5. The insertion loss for this set would be 63.9 dB(A) after the silencer installation.

B. Designation of enclosure for Feed Water Pump

The following steps are performed to decline the noise level of the Feed Water Pump:

B.1) Computation of critical frequency f_c of main enclosure insulation (steel of 2 mm thickness) from equation 1(Golmohammadi & Aliabadi, 2016).

$$f_c = \frac{C^2}{1.8 \times U \times t \times sin^2\alpha_i} \quad (1)$$

U is the speed of sound in steel, which is 5050 m/s, and C is the speed of sound in air, which is 3٤١ m/s in standard atmospheric air conditions (Kinsler et al. 2009). t is steel thickness in meters and α_i is the angle of incident, which is taken to be $\pi/2$ radians. So in normal conditions:

$$fc = \frac{341^2}{18.2} = 6389 \text{ Hz} \quad (2)$$

As it can be seen the resonant frequency is higher than the measured field dominant frequency.

B.2 Classification and characteristics of sandwich layers of enclosures:

B.2.1) Absorptive material: slag wool with a surface density of 2.5 kg/m^2 and thickness of 25 mm. Reflective surfaces around the source will increse sound levels in one of the important steps to 150. decline noise pressure is to use an appropriate absorptive material considering the main frequency.

B.2.2) Steel with a surface density of 17 kg/m^2 and thickness of 2 mm. The noise source was isolated by steel to prevent any sound from inside the enclosure to the outdoor.

B.2.3) Plasto foam of 20 mm thickness.

B.2.4) A Door with 43 mm thickness and surface density of 9 kg/m^2 is used for the entrance of the enclosure. The dimension of the door is designed to be 1.9 by 1 m. The location of the door is on the side of 3×10.5.

B.2.5) Window: one double-layer glass window of 9 mm thickness and surface density of 7 and dimension of 1 by 1.5 m is used for the enclosure. The location of the window is on the side of 3×6.

B.3) The dimension of the designed enclosure consists of length, width, and height is 10.5×6×3 m where an area of ceiling, floor, walls, door, and window were 63, 63, (36+63), 1.5, and 1.9 m, respectively. Thus, the total surface of the enclosure is 226.4 m^2.

B.4) Computation of Noise reduction of enclosure: Expected sound pressure level inside and measured mean sound pressure level outside of the enclosure were 58.5 and 97.2 dB(A), respectively. Thus, the calculated noise reduction is predicted to be equivalent to 38.7 dB(A). Fig. 2 represents the amount of noise level in octave band centre frequencies before and after installing the enclosure.

4 Conclusion

According to the above results, it can be stated that the sound levels around the Mazandaran Power Plant area are not higher than the Ambient Noise Standards of Iran, however, inside the factory most of the measuring stations have high sound levels in comparison to industrial standards 85 dB(A). Office buildings have the lowest sound pressure among measured areas. As 43% of measured stations are located in danger areas, some control methods, for example, the application of hearing protection devices such as earmuffs and earplugs, should be considered.

The results of this study indicated that in Mazandaran Power Plant the noise levels were higher than admissible noise levels of 85 dB(A) in most areas in which various methods were applied to reduce the noise levels. Installing the designed enclosure for the Feed Water Pump (Fig. 2) resulted in a 38.7 dB(A) reduction has shown that the applied absorptive material, the thickness, and dimensions of doors and windows are appropriate to decline the noise level. Also, after reviewing the noise characteristics of the electricity generator (especially the dominant frequency), an appropriate silencer was proposed in which 63.9 dB(A) reduction has been achieved. Finally, it should be mention that although the results of enclosure are approved in Mazandaran Power Plant environments, the results of silencer should be validated with field research.

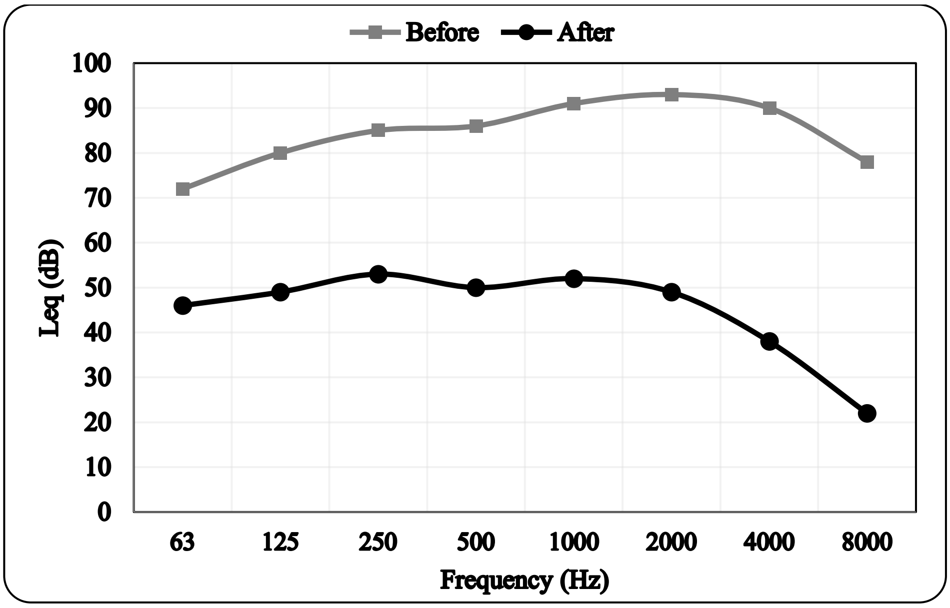

Figure 2. Sound Pressure Level variations at frequency band before and after enclosure installation.

References

ACGIH Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs), 2020, American Conference of Governmental Industrial Hygienists.

Ahmed, K.H., Zulquernain, M., 2009, Expert system to predict effects of noise pollution on operators of power plant using the neuro-fuzzy approach. Noise and Health, 11(**45**), 206-216.

Jena, B. P., Jagdev, A., Satapathy, S., Nayak, B. B., Patel, S., Mohapatra, T. K., 2018. An Investigation on noise reduction by natural acoustic materials. Materials Today: Proc, 5(**9**), 19237-19241.

Berglund, B., Lindvall, T., Schwela, D. H., 1999. World Health Organization, Occupational and Environmental Health Team. Guidelines for community. https://apps.who.int/iris/handle/10665/66217

Brittain, F. H., 2005. Critical assessment of indoor noise propagation and prediction in power plants, J. Acoust. Soc. Am, 118(**3**), 1870.

Dzhambov, A. M., Markevych, L., Tilov, B., Arabadzhiev, Z., Stoyanov, D., Gatseva, P., Dimitrova, D. D., 2018. Pathways linking residential noise and air pollution to mental ill-health in young adults, Environ. Res., 166, 458-465.

EPA, Clean Air Act, United States Environmental Protection Agency., (1990). https://www.epa.gov.

Ghobadian, B., Najafi, Gh., Rahimi, H., Yusaf, T. F., 2009. Future of renewable energies in Iran, Renewable Sustainable Energy Reviews, 13(**3**), 689-695.

Ghorashi, A. H., 2007. Prospects of nuclear power plants for sustainable energy development in Islamic Republic of Iran. Energy Policy, 35(**3**), 1643-1647.

Golmohammadi, R., Aliabadi, M., 2016. Empirical Feasibility of an Acoustic Cabin for Reduction the Workers' Exposure to High Frequency Noise in Typical Metal Industry, International Journal of Occupational Hygiene, 8, 31-38.

Hashemian, H. M., 2011. On-line monitoring applications in nuclear power plants, Progress in Nuclear Energy, 53(**2**),167-181.

IAEA., 1999. Health and Environmental Impacts of Electricity Generation Systems: Procedures for Comparative Assessment, International Atomic Energy

Agency, Vienna, Austria.

Ismail, A.R., Mansor, M. R. A., Tahir, M. F. M., 2009. Environmental Noise Assessment and Modeling in Malaysia: A Comparative Monitoring Study, European J. Sci. Res., 30(**2**), 236-244.

ISO 9612., 2009. Acoustics - Determination of occupational noise exposure - Engineering method. American technical committee.

Jena, B. P., Jagdev, A., Satapathy, S., Nayak, B. B., Patel, S., Mohapatra, T. K., 2018. An Investigation on noise reduction by natural acoustic materials, Materials today: Proceeding, 5(9),Part 3, 19237- 19241.

Joshi, M. P., Pande, P. K., Mungantiwar, P.V., 2017. Noise level at coal based thermal power plant, IJEDR, 5(3): 966-977.

Kisku, G. C., Bhargava, S. K., 2006, Assessment of noise level of a medium scale thermal power plant. Indian J. Occup. Environ. Med, 10(**3**), 133-139. https://doi.org/10.4103/0019-5278.29575.

Kinsler, L. E., Frey, A. R., Coppens, A. L., Sanders, J, V., 2009, Fundamental of Acoustic, Wiley, Fourth Edition.

Lusk, S. L., Hagerty, B. M., Gillespie, B., Caruso, C. C., 2002. Chronic effects of workplace noise on blood pressure and Heart rate, J. Arch. Environ. Health, 5 (**4**), 273-281.

Ma, J., Jiang, J., 2011. Applications of fault detection and diagnosis methods in nuclear power plants: A review. Progress in Nuclear Energy, 53(**3**), 255-266.

Rodríguez, N. P., Rosado, E., Illescas, R.G., 2010. Emissions and Noise Pollution Diagnosis of a Turbogas Power Plant During Commissioning Service, ASME Turbo Expo 2010: Power for Land, Sea, and Air,8(2): 1269-1276.

Seutche, J. C., Nsouandélé, J. L., Njingti-Nfor, Tamba, J. G., Bonoma, B., 2019. Geographical mapping and modelling of noise pollution from industrial motors: a case study of the Mbalmayo Thermal Power Plant in Cameroon, Environmental Monitoring and Assessment, 191(765). doi.org/10.1007/s10661-019-7940-z.

Srinivasan, C. S., 2003. Concentration in ownership of plant variety rights: some implications for developing countries. Food Policy, 28(**5-6**), 519-546

www.google.com/earth