ENVIRONMENTAL IMPACT ASSESSMENT OF PUMP NOISE

S. M. Abdel-Rahman

Mechanical & Electrical Research Institute, National Water Research Center,
Delta Barrage, Egypt
E-mail: Samir4@yahoo.com

ABSTRACT

Noise and vibration present increasing environmental problems to society. Noise and vibration are hazards to human when they occur at high levels, or continue for a long time. High noise levels can cause hearing loss, headaches, dizziness, high blood pressure, loss of concentration, heart disease...etc. There are many researches addressed effect of pumping stations' noise and vibration on performance, efficiency, reliability, and maintenance cost. Vibration and noise are a result of machine faults. This paper focuses on impact of noise produced from pumping stations on the most important element in the pumping system, human. The objective of the research is to enhance environmental conditions for the pumping stations' workers and avoid human damage.

Noise level and noise spectrographs were recorded and analyzed for three main pumping stations: El-Serw, Old El-Max, and New El-Max Pumping Stations. Contour maps of noise distribution were to determine locations of high noise level and to assist in designing comfort and safe places for workers inside the station. Noise level ranges from 92 dB to 100 dB at different locations inside El-Serw P.S. and allowable exposure time at these locations ranges from 5 to 2 hours daily according to Egyptian environmental law for noise. Where, noise level ranges from 94.5 dB to 106 dB inside New El-Max P.S. with allowable exposure time ranges from 4 to 1 hour. On the other hand, noise level ranges from 92 dB to 104 dB inside Old El-Max P.S., where allowable exposure time ranges from 5 to 1 hour. Audiogram tests done for four workers show hearing loss ranges from moderate hearing loss to severe mixed hearing loss (90%). Hearing loss level ranges from 30 to 80 dB for the different workers. Audiogram test should be done periodically and the workers should be trained, awared of safe and dangerous locations, and supplied by ear protection. Sources of high noise in the tested stations are diagnosed due to minor mechanical problem as well as hydraulic pump problem. Regular maintenance and lubrication of the pump units improve dynamic performance and reduce noise to acceptable levels maintaining reliable and safe operation for both human and pumping stations.

Keywords: Noise, pumps, human, health, control, environment

1. INTRODUCTION

Noise in the working environment constitutes a serious human, social and economic problem. Actions on an international scale would contribute to solving this problem and would be particularly useful to the developing countries. Noise, which is often referred to as unwanted sound, is typically characterized by the intensity, frequency, periodicity (continuous or intermittent) and duration of sound. Sound is the result of pressure changes in the air caused by vibration, **Thompson [1]**. More people are affected by noise exposure than any other environmental stressor. However, because its associated health effects are not as life-threatening as those for air, water and hazardous waste, noise has been on the bottom of most environmental priority lists (**Cowan, [2]**).Traditionally, much of the scientific evidence has been based on studies of occupational exposures. These noise exposures tend to be of greater intensity over longer periods of time as compared with exposures to community noise. In earlier research, investigators also tended to assume that noise produced direct health effects, such as hearing loss with noise exposures above 90 dB, and paid little attention to individual differences in response to noise, and noise as a stressor (**Thompson [3]**). More recently, research has focused on noise as an auditory stressor that can produce both direct and indirect health effects. The direct health effect known to be attributable to noise is hearing loss (resulting from damage to the inner hair cells of the organ of corti) with noise exposure higher than 90 decibels. There are several non-auditory physiological effects of noise exposure including a possible increase in cardiovascular disease from elevated blood pressure and physiological reactions involving the cardiovascular endocrine system. **Table (1)** shows the physiological effect of noise and the critical frequencies **(Emad, [4])**. In addition, community noise has been shown to adversely affect performance and behaviour, memory acquisition, and mental health **(Talbott [5], Darbont [6]).** With continual noise exposure, the ear will lose its ability to recover from temporary hearing loss, and the damage will become permanent. Such damage can be caused by long-term exposure to loud noise or, in some cases, by brief exposures to very loud noises.

Table (1) Physiological effect of noise and exciting frequencies

Symptoms	Frequency range(Hz)
Restlessness Muscle cramps	4-9 4-9
Headache Muscles tremors	13-20 13-20
Lower jaw pain	6-8
Dysarthria	13-20
Chest pain	5-7
stomachache	4-10
Urinary urgency	10-18
Dyspnea	4-8

The effects of noise on performance are complex and have been widely studied in the laboratory and to some extent in work situations by many researchers **(Broadbent [7 & 8])**. It is evident that when a task involves auditory signals of any kind, noise at intensity sufficient to mask or interfere with the perception of these signals will also interferes with the performance of the task. From the economical point of view, reducing the level of noise emitted from machines in industrial plant to be within the recommended criteria is very powerful tool for decreasing the production cost and realize success on the continued sale and productive operation of rotating machinery and the benefits of doing that are:

- Physiological effect of noise
- Prolongs machinery life.
- Minimizes unscheduled downtime.
- Eliminates unnecessary overhauls
- Eliminates standby equipment
- Provide more efficient operation.
- Increases machinery safety.
- Assure a high quality level.

2. SOUND CHARACTERISTICS AND ENVIRONMENTAL NOISE

Sound may be defined as any pressure variation that human ear can detect. Depending on the medium, sound propagates at different speeds. The number of pressure variations per second is called the frequency of the sound, and is measured in hertz (Hz). The frequency of a sound produces its distinctive tone. Sound is described by its frequency and amplitude of the pressure fluctuations. Sound pressure level (SPL or L_p) is measured in decibel (dB). As sound is a form of energy, the hearing damage potential of a given sound environment depends not only on its level, but also its duration. So to assess the hearing damage potential of a sound environment, both the sound level and the duration of exposure must be measured and combined to provide a determination of the energy received.

When a wall is struck by sound, only a small portion of the sound is transmitted through the wall, while most of it is reflected. The wall's ability to block transmission is indicated by its transmission loss (TL) rating, measured in decibels. Noise reduction (NR) is the number of decibels of sound reduction actually achieved by a particular enclosure or barrier. This can be measured by comparing the noise level before and after installing an enclosure over a noise source. NR and TL are not necessarily the same. Sound is absorbed when it strikes a porous material. Commercial sound-absorbing materials usually absorb 70 percent or more of the sound that strikes them. Vibrations in solids and liquids can travel a great distance before producing airborne sound. Such vibrations can cause distant structures to resonate. The best solution is to stop the vibration as close to the source as possible. Sound spreading in open air and measured at a certain distance from the source is reduced by about 6 dB for each doubling of that distance. Sound is reduced less when spreading inside a room.

The frequency range of human hearing is generally considered as 20 – 20,000 Hz. The upper range varies greatly among individuals and decreases with age and noise exposure. The amplitude of our sensation ranges from the threshold of hearing (~0 dB) to thresholds of discomfort and pain (above 140 dB). However, infrasound in the range from 1 to 20 Hz and ultrasounds between 20000 to 40000 Hz can affect other human senses and cause discomfort. With age, the human perception of the highest frequencies decreases gradually. When exposed to excessive levels, hearing can be damaged, causing reduced sensitivity for hearing low sound levels. The damage can also be restricted to distinct frequency ranges. The level of damage to the ear can be determined by hearing tests called "audiograms." The shape of the average hearing frequency response is determined by the mechanical characteristics of the ear. Human beings are least sensitive to low frequencies and are most sensitive in the 3-4 kHz region, corresponding with the first resonance of the ear canal.

Figure (1) illustrates the limits of the human auditory system. The solid line denotes, as a lower limit, the threshold in quiet for a pure tone to be just audible. The upper dashed line represents the threshold of pain. However if the Limit of damage risk is exceeded for a longer time, permanent hearing loss may occur. This could lead to an increase in the threshold of hearing as illustrated by the dashed curve in the lower right-hand corner. Normal speech and music have levels in the shaded areas.

The Robinson-Dadson curves are one of many sets of equal-loudness contours for the human ear, determined experimentally by **Robinson et al. [9].** It became the basis for ISO standard (ISO 226: 2003). **Figure (2)** shows the normal equal loudness contours for pure tones. The dashed curve indicates the normal binaural minimum audible field. Note the very non-linear characteristics of the human perception. Almost 80 dB more SPL is needed at 20 Hz to give the same perceived loudness as at 3-4 kHz.

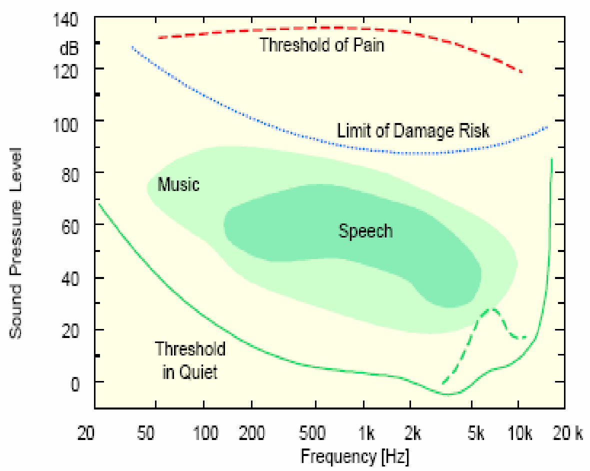


Fig. (1) Audible sound range

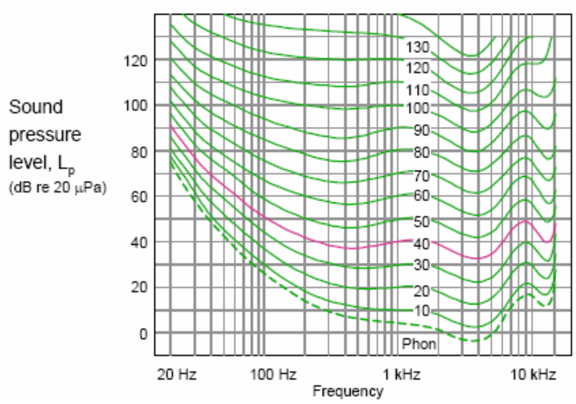


Fig. (2) Equal Loudness Contours

Loudness is a subjective response to the amplitude of sound. It is a judgment of the intensity of a sound by a human being. It is not linearly related to either sound pressure (Pa), sound pressure level (dB) or sound power level. Doubling of sound power raises pressure level by 3 dB but only produces a barely noticeable increase in loudness. A 10 dB increase in SPL approximately results in twice the subjective loudness. The implications for these trends are important to the noise control engineer. If the intent is to achieve a noticeable decrease in loudness, sufficient noise control measures must be added to obtain 5 dB or more of improvement. An improvement of one or two dB may not even be noticed. Achieving a 10 dB improvement can be a serious challenge, since it means that the sound energy must be decreased by 90%, as shown in **Table (2).**

Table (2) Relation between Loudness, sound pressure level, and sound power

Increase source Power, watts	**Change SPL, dB**	**Change apparent loudness**
2 (doubled)	3	Just Perceptible
3	5	Clearly Noticeable
10	10	Twice as Loud
100	20	Much Louder

3. PUMP NOISE PROBLEM: PREDICTION AND CALCULATIOINS

Noise generated by pumps can be divided into fluid noise and mechanical noise. Fluid noise has two components. The first, rotary noise is produced by the interference of the wake from the impeller with the casing tongue parts. The frequencies of component are (a) the product, ZN, of the number of impeller blades Z, and the pump speed N, plus (b) the higher harmonics of ZN. It is this component that is liable to cause pulsation. The second component is vortex flow noise, caused by turbulence in the flow between the impeller blades or inside the casing. The spectrum of this component shows a wide range of frequencies scattered at random. Phenomena such as cavitations and stalling are other possible causes of fluid noise; however, design and planning of pumps should eliminate such phenomena. Mechanical noise also has two components, one resulting from vibration caused by imbalance of the impeller, shaft, or shaft coupling, etc., and the second generated by the rotation of the bearings **(Ebara [10]).**

Sound power (W) is the acoustic power of a sound, expressed in watts. Sound power level (L_W) is the acoustic power radiated from a given sound source as related to a reference power level (typically 10^{-12} watts) and expressed in decibels.

$$L_w = 10 \log (W/10^{-12}) = 10 \log W + 120 \quad (1)$$

Sound pressure is fluctuation in air pressure caused by presence of sound waves. Sound Pressure Level (**L_p or SPL)**, and is also called noise level, is the ratio in dB of mean–square sound pressure (**P**) to reference men-square pressure (**p_{ref}** = $2*10^{-5}$ N/m^2 = 20 μPa) which has been selected to be equal to the assumed threshold of hearing:

$$L_p = 10 \log (p/p_{ref})^2 = 20 \log (p/p_{ref}) \qquad (2)$$

Under far field/free field conditions, sound intensity varies inversely with the squares of the distance from the source. The difference in sound pressure level **(L_{p2} - L_{p1})** between two far field locations is expressed as:

$$L_{p2} = L_{p1} - 20 \log (R_2/R_1) \qquad (3)$$

R1 & R2 are the distance from noise source to point 1, and point 2 respectively.

Direct sound is sound which reaches a given location by direct, straight line propagation from the sound source. In the far field, direct sound behaves according to the inverse square law. For a non-directional source located on or near the centre of the wall or floor in a room, the theoretical relationship between source sound power level and sound pressure level at distance R (m) from the source is:

$$L_p = L_w - 20 \log R - 8 \qquad (4)$$

At or near ground level, at distance R from receiver, under free field conditions:

$$L_p = L_w - 20 \log R + DI - A_B - A_G - A_A - 8 \qquad (5)$$

A_B is attenuation due to barriers, partition, enclosures,
A_G is attenuation due to ground absorption,
A_A is attenuation due to air absorption and wind, and
DI is directivity index

Noise level (L_p) for pumps is a function of pump output, can be obtained by the following equation **(JAAEE [11])**:

$$L_p = L_p (A) + 10 \log L \qquad (6)$$

L is pump output (kW), L_p (A) is reference noise level

Estimated noise at sound receiving point (near the interior wall of the pump room):

$$L_p = L_w + 10 \log \left(\frac{4}{R} + \frac{Q}{4\pi.r^2}\right) \qquad (7)$$

R: room constant = $S\alpha/(1-\alpha)$
S: sound absorbing area in room (m^2) = $\sum si$
r: distance between sound Source and sound receiving point (m)
Q: directivity factor (~2)
α : Sound absorption coefficient in room ($\sum \alpha i - \sum si$) / S

si : Areas of parts divided by difference in sound absorption
α_i : sound absorption coefficients of the parts above

Sounds through air from the pump room to other rooms can be obtained by

$$L_p\,(e) = L_p\,(S) - TL + 10 \log \left(\frac{A_t}{L_w} \right) \qquad (8)$$

L_p (e) : transmission noise level in sound receiving room
L_p (S) : noise level in sound source room
TL : transmission losses of walls and ceilings
A_t : transmission areas of walls and ceilings
L_w : sound absorption power in sound receiving room

4. NOISE EXPOSURE STANDARDS

There are several international institutes that set up laws and limits for vibration and noise values. The NIOSH (National Institute Occupational Safety and Health) recommended exposure limit of 85 dBA for occupational noise exposure.

British Occupational Hygiene Society (BOHS) criterion, 1971 set limits of noise intensity for a period of 8-hours work per day, and 5-days work a week at 30 years working life. BOSH recommends 8 hr/day for maximum noise level 90 dBA, 6 hr/day for 91 dBA, 5 hr/day for 92 dBA, 3 hr/day for 94 dBA, 2 hr/day for 96 dBA, 1hr /day for 99 dBA, and 0.5 hr/day for 100 dBA.

The international standards organization (ISO) 1999 defines a method which uses only the energy criteria and makes no allowance for the recovery of hearing. A 3 dB increase in the sound pressure level halves the permissible exposure period. So, an increase in sound level from 90 dB(A) to 93 dB(A) must be accompanied by a halving of the permissible exposure duration from 8 hours to 4 hours, as shown in **Fig. (3).**

On the other hand, Occupational Safety and Health Administration (OSHO) defines another relationship which permits a 5 dB increase in sound level for each halving of the allowable exposure period. An increase in sound level from 90 dB(A) to 95 dB(A) is accompanied by a halving of allowable exposure duration from 8 to 4 hours, as shown in **Fig. (3).**

And finally the Environmental Egyptian law (Law Number 4 / 1994 Appendix number 7) defines the allowable limits for sound intensity and safe exposure time as shown in **Table (3)**, **Ghoniem [12].**

Table (3) Allowable exposure time (Egypt environmental law for noise)

Noise level (dBA)	Exposure time (hrs)
95	4
100	2
105	1.00
110	0.5
115	0.25

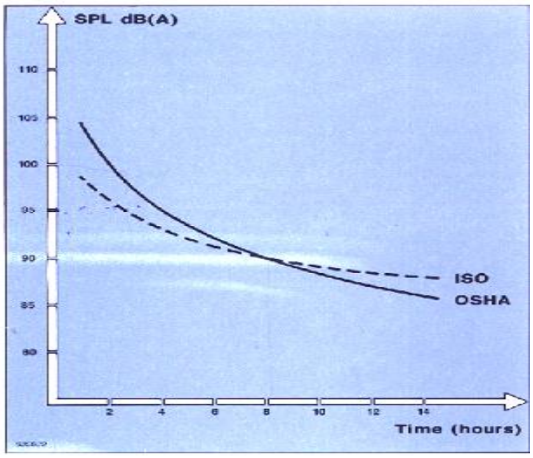


Fig. (3) Allowable exposure duration according to ISO & OSHA Standards

5. NOISE CONTROL

Since the 1940 s, extensive technologies have been developed to control unwanted man-made noise and sound. Noise can create physical and psychological stress. Luckily, noise exposure can be controlled. No matter what the noise problems may be in a particular workplace, technology exists to reduce the hazard. In the field of noise control, where there's a will, there's a way. The damage done by noise depends mainly on how loud it is and on the length of exposure. The frequency or pitch can also have some effect, since high-pitched sounds are more damaging than low-pitched ones. Noise control usually involves three elements: source of noise, receiver of noise, and various paths noise can travel between source and receiver. If a given noise emission cannot be reduced at the source, noise control engineering entails inhibiting the propagation of sound between source and receiver. The Human ear is less sensitive to low frequency noise than to high frequency noise. If it is not possible to reduce the noise, it may be possible to change it so that more of it is at lower frequencies.

If noise levels are found to be above 85 dBA for an 8-hour shift, 40-hour work week, the employer is required by law to reduce the noise levels. Controls at the source of the noise are the most effective means of reducing noise. The controls should always reduce the loudest source of the noise first. Engineering controls include:

- redesigning equipment to reduce the speed or impact of moving parts;
- maintaining equipment to replace worn parts and to lubricate all moving parts;
- isolating equipment either by distance, by enclosures or by barriers;
- damping noise sources by using rubber pads to reduce vibration and noise; and
- installing absorptive baffles in work areas to absorb generated sounds.

Noise and vibration are best controlled at their source and it may be more advantageous, economical and certain to incorporate controls in the civil engineering structures. Thus, a wide study is necessary, based on full data passed from the mechanical to the civil engineers. For pumping station noise control, it is necessary to make plans by recognizing the sources of noise from pumps and motors, and studying their characteristics and routes of propagation such as through building structures and their openings.

6. TEST FACILITIES AND APPROACH

Noise was measured by using two systems. A sound pressure level meter, **Fig. (4),** Type Bruel & Kjaer (B&K 2236), measures sound intensity in dB, is used for measuring noise level. A multi-channel Pulse System, Fig. (B), Module Type B&K 3032 with LAN Interface Module7533, is used to perform frequency analysis obtaining spectra graphs (noise level as a function of frequency). Noise was measured during normal operation of the pumping stations tested with operating maximum pumps as possible and according to water requirements. Measurements were done at three large scale pumping stations: El-Serw (East Delta), Old El-Max, and New El-Max (West Delta) Pumping Stations. An audiogram testing has performed for 4 workers of old ages in El-Serw Pumping Station to evaluate their hearing performance. Detailed of the tests and the results are found **(MERI, [12]**.

El-Serw Pumping Station is an axial flow mixed pump, constructed in 1971 and has been renovated and replaced recently. El-Serw Pump Station, as shown in **Fig. (5),** consists of 3 units each of 8 m^3/s discharge, 2.1m static head, and the service area is 50,000 feddans. There are two pumping stations at El-Max, West of Alexandria: Old El-Max, and New El-Max. Old El-Max P.S. was constructed in 1963 and replaced in 1999. New El-Max Pump Station was constructed in 1983. Each station consists of 6 pump units; discharge is 14 m^3/sec for each unit with 4.0 m static head. Old and New El-Max stations serve 400,000 feddans, discharging 2.3 Billion m^3/year and consuming 25 MW power per year.

The housing of the pumping station has two levels, one is the pump unit level (underground level) and the other is motor level (ground level), as shown in **Fig. (6).** The area of the building was divided into divisions in the horizontal planes and measurements were taken at these intersections at different levels: at underground level, ground level, +1 meter above, and +2 meters above ground level. Distribution of noise measured was done in contour maps to determine the locations of high noise level and to assist in designing comfort and safe places for workers inside the station.

Fig. (4) SPL meter B&K 2236

Fig. (5) Photograph of the El-Serw P.S.

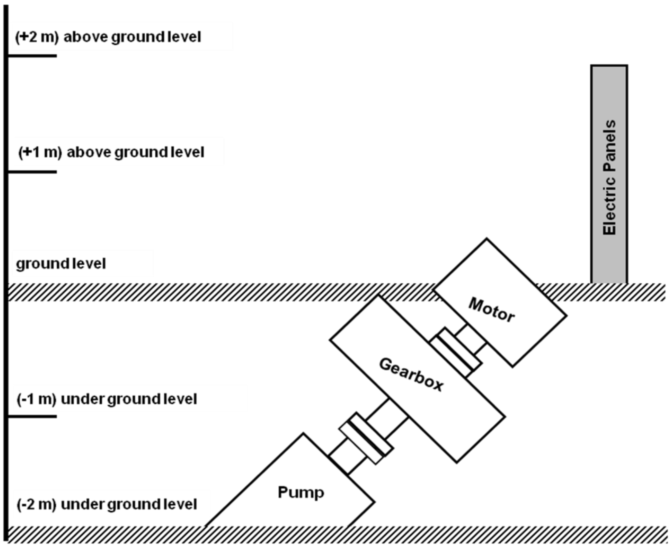


Fig. (6) Locations of the pump unit components with the vertical axis

7. RESULTS OF NOISE MEASURENETS FOR EL-SERW P.S.

Noise level was measured and spectrographs were recorded inside the pumping station in the shown locations in **Fig. (7)** around the three pumping units at different ground elevations. **Figure (8)** shows levels of noise measured inside the station. Noise level at ground level, (+1m), and (+2m) over ground level is identical and ranges from 92 dB to 96 dB. However, noise level reached to 100 dB at ground level between the pump units close to the motors. Noise level close to the gear box at (-1m) under ground is 100 dB, similar to that close to the motor at the ground level. On the other hand, noise level close to the pump (-1m) underground level is smaller and in the average of 96 dB. It is conclude that noise source is the motor, where noise level is 100 dB, and transmitted to 96 dB at the pump. Noise level in the area between pump units is higher than that at the other ends.

Distribution of noise inside the pump station is shown, **Fig. (9)**, at the ground elevation. Noise distribution is different at different ground elevations. Locations of high noise are determined around and between the pump units. Low noise areas are located at the edges of the station housing. Noise spectrum measured at the ground level, **Fig. (10)**, determines the noise source and exciting frequencies. Exciting frequencies (frequency at maximum noise level) measured at the different locations are 20, 63, 100, 160, 200, 250, 400,500, 1500, and 3500 Hz. These are the dominant frequencies measured at all noise spectrographs. Fortunately, there are no critical frequencies affecting human physiologically. The sources of noise are mainly due to minor mechanical problems those can not be avoided at all due to operation. Regular maintenance and lubrication enhance dynamic performance and reduce noise greatly.

7.1 Result of Audiogram Tests

Audiogram tests were done for four samples of workers operating at El-Serw P.S showing different hearing capabilities as shown in **Fig. (11)**. The numbers under the graph represent the various frequencies of sound hearing during the test. The numbers to the left indicate how many decibels loud the sound is in the ear when it is first perceived by the person taking the test. The lower the line is the worse is the hearing. The normal limits of hearing are about 10-15 dB across the whole range of frequencies. Many people with good hearing actually have audiogram results at zero and in the minus range. Any change at high frequencies and any results worse than 20 dB is cause for concern.

As these workers are of age higher than 55 years old and they are exposed to noise more than 90 dB for a long time, they have apparent hearing loss. However, hearing loss levels are different for the four workers and ranges from moderate hearing loss to severe mixed hearing loss (90%). However, the two ears have not affected with noise in the same manner. The workers are more sensitive to the high frequencies and hearing loss occurs apparently for the high frequencies greater than 2 kHz. Hearing loss ranges from 30 to 80 dB for the different workers. As, there is no previous audiogram test done before, it is difficult to relate this hearing loss to the noise in the station only. So, the audiogram test should be done for the new operators in the station, repeated periodically, and they should be supplied by ear protection.

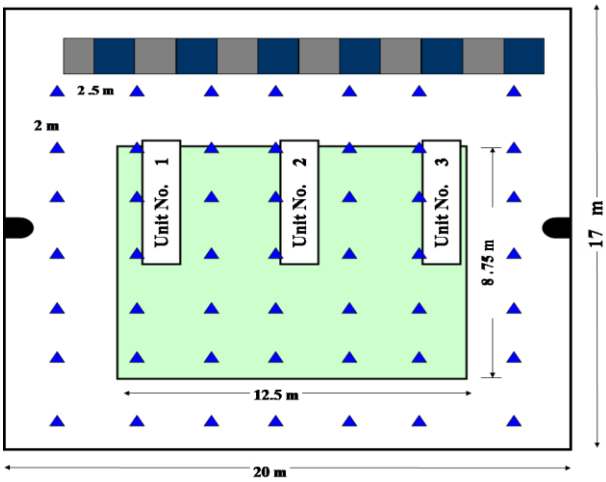


Fig. (7) Plan view showing locations for monitoring noise inside El-Serw Pumping Station

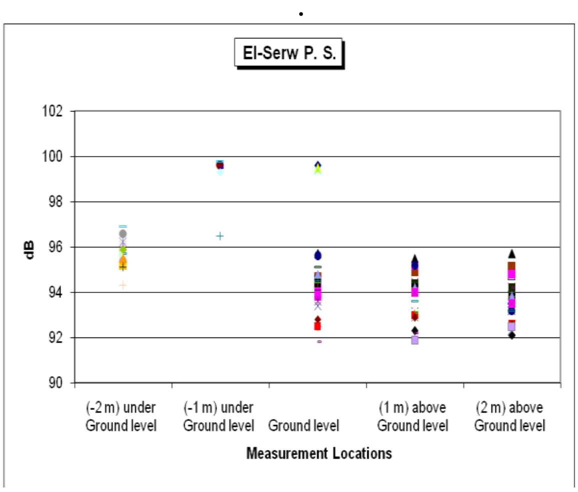


Fig. (8) Noise levels at different ground elevations inside El-Serw Pumping Station

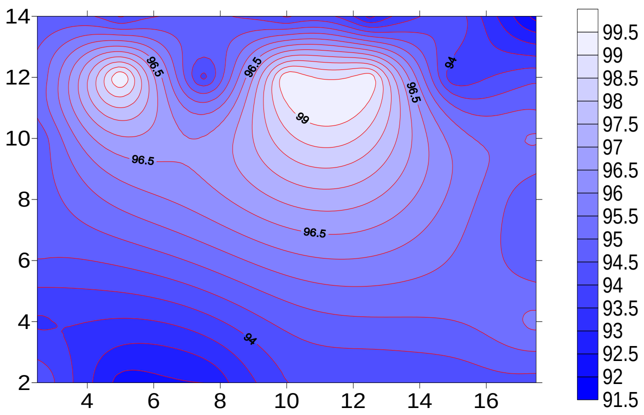


Fig. (9) Noise contour map for El-Serw P. S. at the ground level

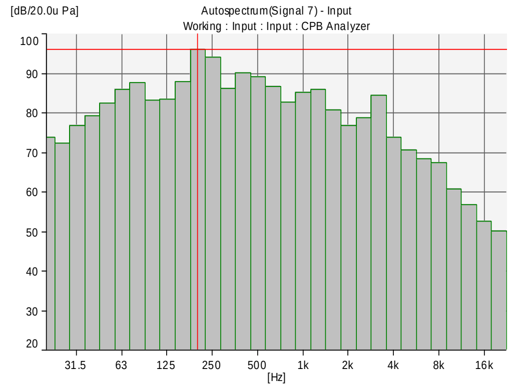
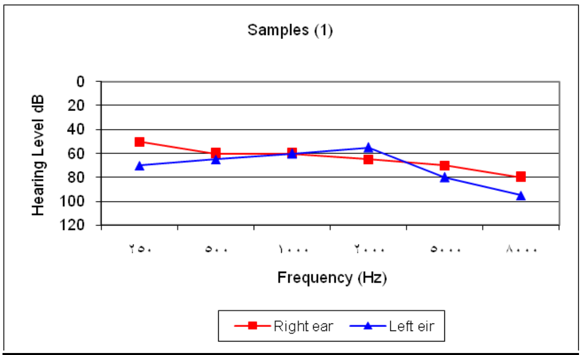
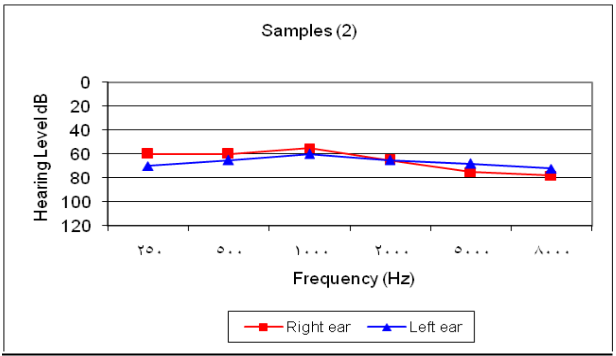


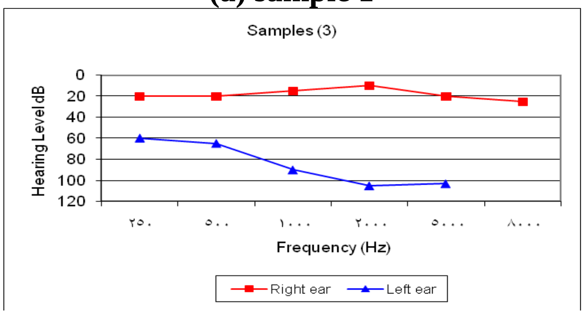
Fig. (10) Noise spectrum recorded at ground level for El-Serw P.S.



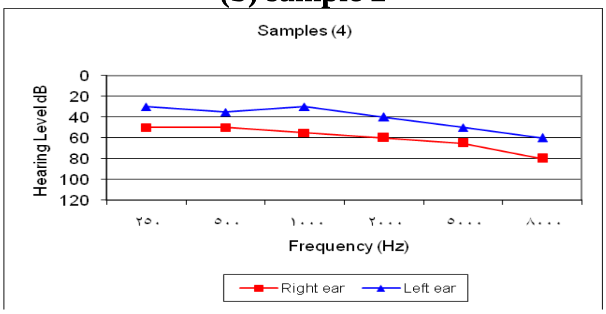
(a) sample 1



(b) sample 2



(c) sample 3



(d) sample 4

Fig. (11) Audiogram test results for four samples of workers at El-Serw P.S.

8. RESULTS OF NOISE MEASURENETS FOR NEW EL-MAX P.S.

Noise was measured and analyzed inside the housing of the pumping station in the shown locations in **Fig. (12)** for the Old and New El-Max Pumping Stations around the six pumping units at different ground elevations. **Figure (13)** shows levels of noise measured inside the building of New El-Max P.S. Noise level at ground elevation (motor location) is in the order of 100 dB and decreases slightly in the above ground elevations (+1m, and +2m). However, noise level reached to 106 dB at (-1m) underground elevation (gear box location). Noise level at (-2m) under ground elevation (pump location) is similar to that measured at the motor location (100 dB).

On the other hand, noise level close to the pump (-1m) underground level is smaller. It is conclude that noise source is the gearbox, where noise level is 106 dB, and the lowest noise level is 94.5 dB measured +1 m above ground elevation. At the same ground elevation, noise level varies considerably and the highest noise level is measured between the pump units.

Contour maps showing distribution of noise inside the housing of New El-Max pump station are shown in **Figs. (14 &15 & 16)** at (-2m) under ground elevation, ground elevation, and (+2m) above ground elevation. Noise distribution is different at different ground elevations. The lowest noise level inside the station building is 94 dB and is measured at the entrance side of the building at the ground and over ground elevations. However, the maximum noise distribution area is the pump area at the (-2m) underground for the pump units 1, 2, 3, and 4 constituting two-thirds of the pump housing. Noise spectra measured are shown in **Figs. (17 & 18)** at the ground level, and underground level respectively to determine the noise source and exciting frequencies. Exciting frequencies measured at ground elevation are the motor running speed (960 rpm) and its harmonics (16, 32, 64, 48, 96 Hz,….etc). The motor operation is the source of the high noise in the ground elevation. Regular lubrication of the motor and the gearbox reduces noise greatly. Noise spectrum recorded at underground level (pump area) is completely different than that at ground level (motor area), as shown in **Fig. (18)**. The exciting frequencies are due to motor running speed and vane passing frequency of the pump. Pump running speed (3.25 Hz) multiply by number of the pump blades and its harmonics are the source of low exciting frequencies. Sources of high noise are due to minor mechanical problem as well as hydraulic problem due to blockage of the pump intake. Regular maintenance of the pump intake and lubrication of the pump units improve dynamic performance and reduce noise to acceptable levels.

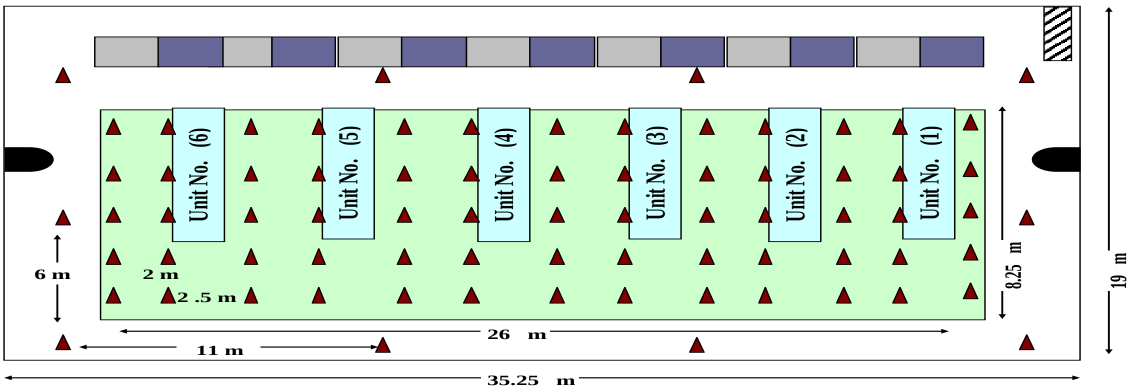


Fig. (12) Locations of noise recorded inside New and Old El-Max P.S.

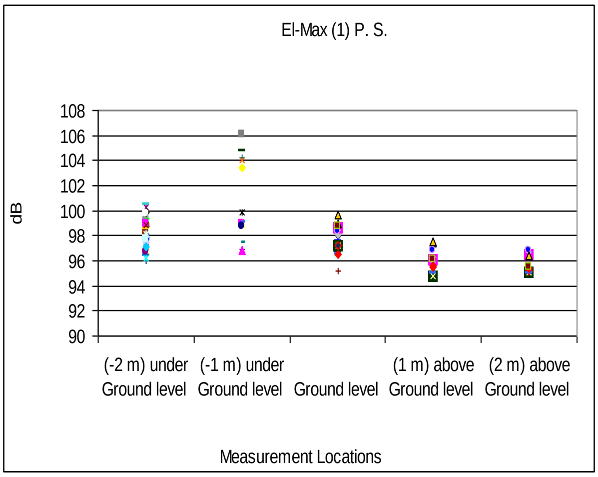


Fig. (13) Noise levels at different ground elevations inside New El-Max P. S.

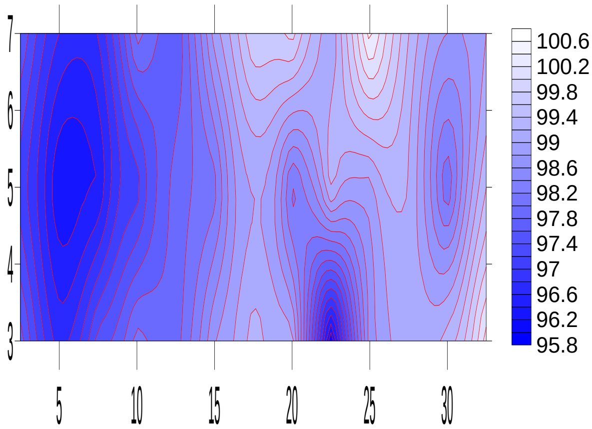


Fig. (14) Noise contour map for New El-Max P. S. at (-2) m under ground level

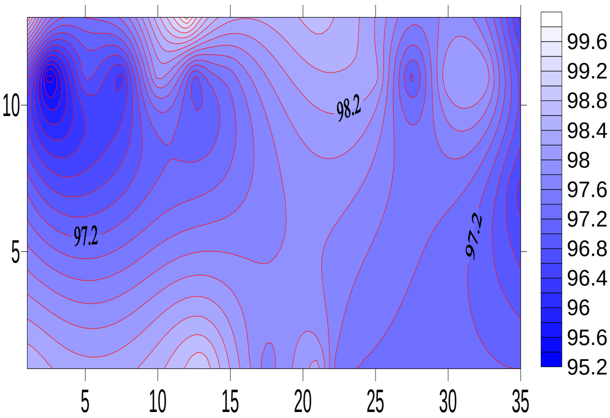


Fig. (15) Noise contour map for New El-Max P. S. at ground level

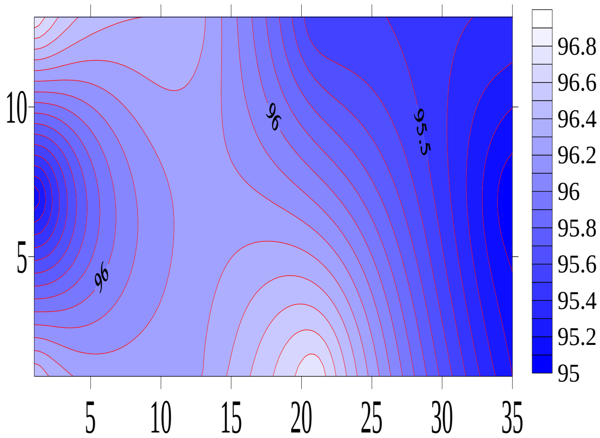


Fig. (16) Noise contour map for New El-Max P. S. at (+2) m above ground level

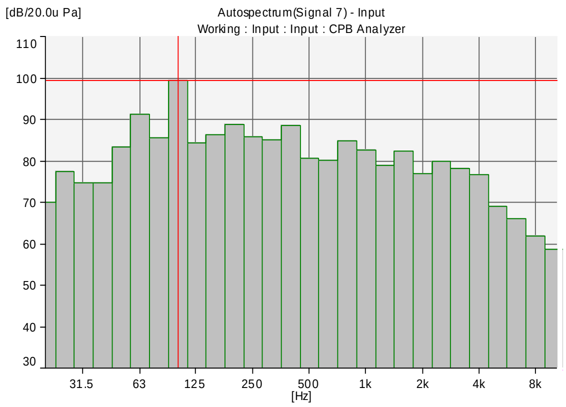


Fig. (17) Noise spectrum recorded at ground level of New El-Max P.S.

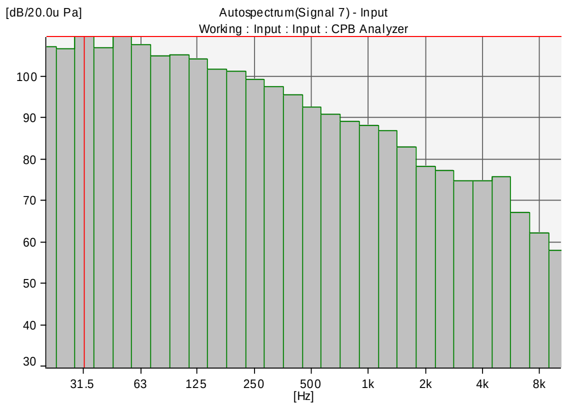


Fig. (18) Noise spectrum recorded at under-ground level of New El-Max P.S.

9. RESULTS OF NOISE MEASURENETS FOR OLD EL-MAX P.S.

Levels of noise measured inside the building of Old El-Max P.S at different ground elevations are shown in **Fig. (19).** The lowest noise level inside the station housing is 92 dB, where the highest noise level is 104 dB. Noise level at the ground elevation (motor location) ranges from 93 dB to 104 dB and is exactly similar to that measured at (-1m) underground level (gear box location). On the other hand, noise level measured above ground level is in the range of 92 dB to 95 dB. It is conclude that noise source is the motor and the gearbox, where noise level is 106 dB, and the lowest noise level is 92 dB measured (+1 m) obove ground elevation.

Distribution of noise inside the housing of Old El-Max pump station is shown in **Figs. (20 &21 & 22)** at (-2m) under ground elevation, ground elevation, and (+2m) above ground elevation respectively. Noise distribution is different at different ground elevations. Maximum noise distribution area is the pump area at (-2m) underground for the pump units 3, 4, 5, and 6 constituting two-thirds of the pump housing. Noise distribution at ground elevation show maximum noise levels measured around pump unit (3) indicating that the motor of the pump unit (3) is the source of the high noise. Noise spectrum measured is shown in **Fig. (23)** at the ground level. Exciting frequencies measured at ground elevation are mainly due to the motor running speed (960 rpm) and its harmonics. The motor is the source of the high noise in the station. Regular maintenance and lubrication of the motor reduces noise to an acceptable level.

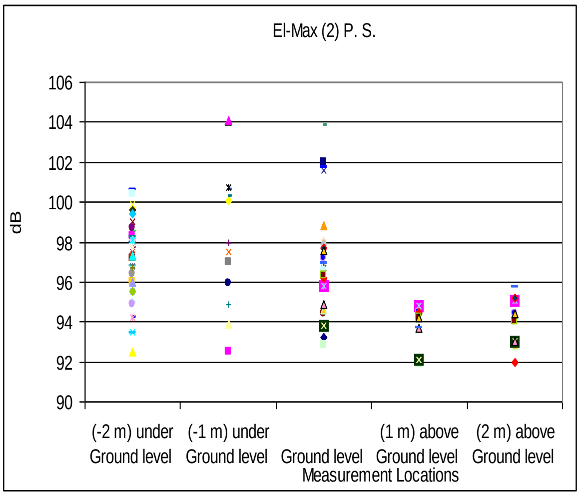


Fig. (19) Noise levels at different ground elevations inside Old El-Max P. S.

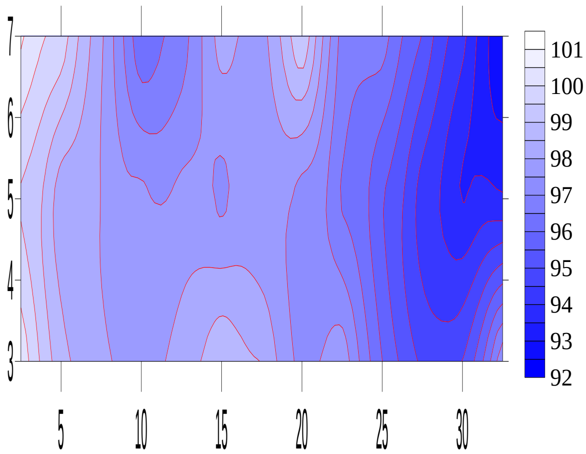


Fig. (20) Noise contour map for Old El-Max P. S. at (-2) m under ground level

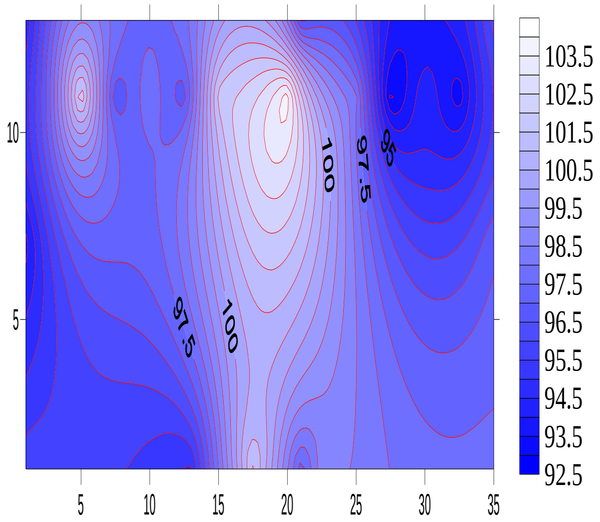


Fig. (21) Noise contour map for Old El-Max P. S. at ground level

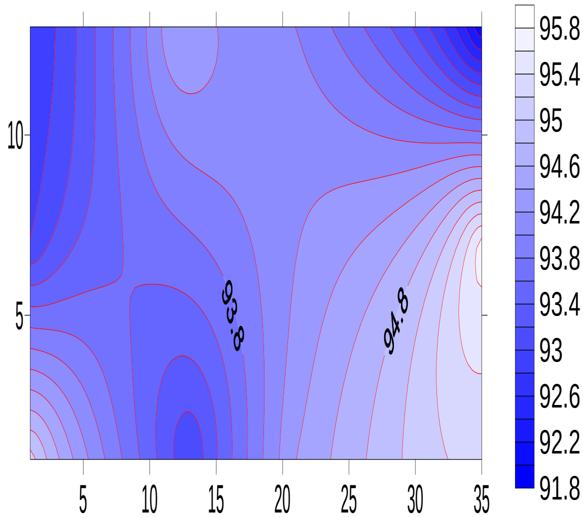


Fig. (22) Noise contour map for Old El-Max P. S. at (+2) m above ground level

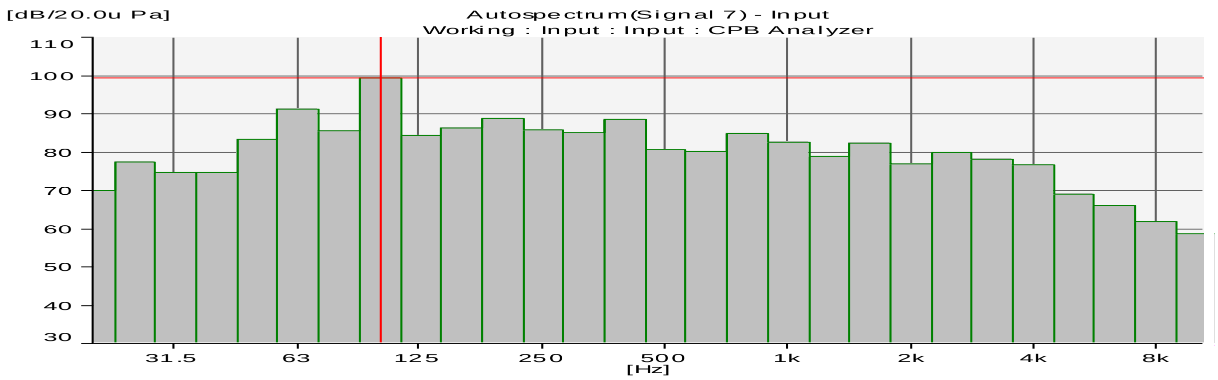


Fig. (23) Noise spectrum measured at ground level of Old El-Max P.S.

10. CONCLUSIONS AND RECOMMENDATIONS

- Noise level, noise distribution, and noise spectrographs were recorded and analyzed inside the three tested pumping stations. Noise distribution is different at different ground elevations. Locations of high and low noise levels are well defined. Safe exposure time is well defined for each pump station.
- Noise level ranges from 92 dB to 100 dB at different locations inside El-Serw P.S. and allowable exposure time at these locations ranges from 5 to 2 hours daily according to Egyptian environmental law for noise. Where, noise level ranges from 94.5 dB to 106 dB inside New El-Max P.S. with allowable exposure time ranges from 4 to 1 hour. On the other hand, noise level ranges from 92 dB to 104 dB inside Old El-Max P.S., where allowable exposure time ranges from 5 to 1 hour.
- Audiogram tests done for four workers operating in the stations show different hearing capabilities. However, hearing loss levels are different for the four workers and ranges from moderate hearing loss to severe mixed hearing loss (90%). The

workers are more sensitive to the high frequencies and hearing loss occurs apparently for the high frequencies greater than 2 kHz. Hearing loss ranges from 30 to 80 dB for the different workers. Audiogram test should be done periodically and the workers should be trained and supplied by ear protection.

- Fault diagnosis shows that sources of high noise are due to minor mechanical problem as well as hydraulic problem due to blockage of the pump intake. The results obtained for normal operation and good pump conditions with minimum faults. For other pumping stations of high power, severe faults, and abnormal operating conditions, the problem will be worse and the noise level will be very serious and dangerous to large extent. Regular maintenance and lubrication of the pump units improve dynamic performance and reduce noise to acceptable levels maintaining reliable and safe operation for both human and water management.
- It is apparent that pump noise is complex, dangerous and has many sources. It is necessary to apply an adequate control noise method for each station. It will be ended that there are many different routes by which noise is propagated in a pump station, and when considering noise in a pump station or devising countermeasures for it, it is necessary to consider different factors affecting and affected by pump station noise problem which include building, machines, human, water requirement, maintenance, control…etc. It is recommended that appropriate layouts for equipment and buildings and appropriate structures for buildings must be devised in the planning stage of constructing a new pump station.

REFERENCES

1. **Thompson**, S.J., Noise and public health, Health & Environment Digest, 8(4), 25-27, 1994.
2. **Cowan**, J.P., Educating the public on environmental and recreational noise exposure, Handbook of Environmental Acoustics, New York, 1994.
3. **Thompson**, S., Non-auditory health effects of noise: Updated review, Proceedings of Internoise, 2177-2182, 1996.
4. **Emad**, E., Effect of sound waves and sound induced vibration on human body, Technology & Armament Magazine, Egypt Armed Forces, Pub.(1), Dec. 1985.
5. **Talbott**, E., et al., Health effects from environmental noise exposure, Introduction to Environmental Epidemiology, pp. 209-219, Lewis Publishers, 1995.
6. **Darabont**, A., The meeting at the International Center for advanced technical and vocational training, Turin, December 2-10, 1974.
7. **Broadbent**, D.E., Effects of noise on behaviour, Handbook of Noise Control, New York. McGraw-Hill, pp. 10-34, 1957.
8. **Broadbent**, D.E., The effects of moderate levels of noise on human performance, In J. Tobias, Hearing: Research and Theory, New York, 1981.
9. **Robinson**, D.W., A re-determination of the equal-loudness relations for pure tones, J. Appl. Phys. 7, 166-181, 1956.
10. **Ebara**, Ebara pump system engineering handbook, Ebara Corporation, 1997

11. **JAAEE** (Japan Association of Agriculture Eng. Enterprises), "Pumping Station Eng. Handbook", Japan. 1991.
12. **Ghoniem**, E.M., Study the effect of noise and vibration on industrial plants, M. Sc. Thesis, Institute of Environmental Science, Ain Sham University, Egypt, 2003.
13. **MERI** (Mechanical & Electrical Research Institute), Auditing environmental conditions of pumping stations by monitoring noise and vibration, Technical Report, MERI, Delta Barrage, Egypt, 2005.