Noise Reduction in a Plastic Recycling Plant a Case Study in Lebanon

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ABSTRACT

The aim of this study is to investigate the noise levels in a plastic recycling plant representing the medium sized industries in Lebanon in order to generalize the case in Lebanese industry.

No prior study has been done on industrial noise exposure in Lebanon. The occupational Health and Safety rules in Lebanon states that handling high noise levels, watching individual exposure and reducing long shifts are the responsibility of the employer. It was noted that in this company none of the regulations are being followed.

Being exposed to high noise level can cause different health problems such as stress, speech interference, high blood pressure, temporary or permanent hearing loss and sleeping problems.

Sound level meter was used to measure sound in the factory. Questionnaires were distributed to workers as well and their structure was designed to determine the hazards of high noise levels on workers. Occupational Health and Safety standards were used as a guiding reference in the analysis. The data was analyzed using statistical package for the social science program (SPSS).

The data obtained from the distributed questionnaires confirmed the noise levels measured inside the plant. Workers have proved being annoyed by the high noise levels.

Future studies can be applied by using a dosimeter to a check the noise level in the plant or in many other plants in Lebanon and therefore generalize the case of industries in this country

Keywords: Noise exposure, hearing loss, Occupational Health and Safety.

ÖZ

Bu çalışmanın amacı Lübnan’daki orta ölçekli sanayileri temsilen bir plastik geridönüşüm fabrikasındaki gürültü seviyelerini incelemek ve bu vakayı Lübnan sanayisi için genellemektir.

Lübnan’da daha önce endüstriyel gürültü maruziyeti üzerine herhangi bir çalışma yapılmamıştır.Lübnan’daki mesleki sağlık ve güvenlik kurallarına göre; yüksek gürültü seviyelerini idare etmek, kişisel maruziyeti takip etmek ve uzun vadiyaları azaltmak işverenin sorumluluğundadır. Bu çalışmadaki firmanın, bahsedilen düzenlemelerin hiçbirini uygulamadığı belirlenmiştir.

Yüksek gürültü seviyesine maruz kalmak; stress, konuşma bozukluğu, yüksek tansiyon, geçici veya kalıcı işitme kaybı ve uyku problemleri gibi sağlık sorunlarına neden olmaktadır.

Fabrika içerisindeki gürültüyü ölçmek için ses seviyesi ölçüm cihazı kullanılmıştır. İşçilere anket dağıtılarak yüksek gürültü seviyesinin işçiler üzerinde yarattığı tehlikelerin ölçülmesi hedeflenmiştir. Bu çalışmada İş Sağlığı ve Güvenliği standardları kılavuz kaynak olarak kullanılmıştır. Toplanan veri SPSS kullanılarak analiz edilmiştir.

Dağıtılmış olan anketlerden toplanan veri, fabrika içerisinde ölçülen yüksek gürültü seviyesini teyit etmiştir. İşçilerin yükske gürültü seviyesinden dolayı rahatsız oldukları kanıtlanmıştır.

İleriki çalışmalarda dozimetre kullanılarak bu fabrikadaki gürültü şiddeti control edilebilir veya Lübnan’daki diğer fabrikalarda gürültü şiddeti ölçülerek, bu ülkede bulunan sanayideki gürültü sorunları incelenebilinir.

Anahtar kelimeler: Gürültü maruziyeti, işitme kaybı, İş Sağlığı ve Güvenliği.

DEDICATION

I would like to dedicate this thesis to my parents Hazem&Racha whose love is like no other, to my brothers and sister and to my beautiful Lama

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INTRODUCTION

1.1 Background

1.1.1 What is Ergonomics

Ergonomics/human factors isabove anything else, a systems discipline and profession, applying a systems philosophy and systems approaches (Wilson, 2014).

Ergonomics has a wide range of application especially in industrial and product design, architecture and health and safety (Radjiev*et al.*, 2015).

Operational performance and employee well-being are automatically improved once ergonomics knowledge is integrated. To maximize success, organizations must have a climate that supports operational performance as well as employee well-being (Hoffmeister*et al.*, 2015).

1.1.2 Noise in Ergonomics

In various working environments labors are being subjected to different elements that can alter their performance among which noise, vibration and stress. The environmental stimulus can directly interfere with the mechanics of performing a task and so more effort should be put on to carry out specific tasks which make it harder.

For example, if a machine is emitting a high sounds worker might be confused and not hear an important signal. In other cases, however, performance may be negatively affected because the mental capacity of the worker is being taxed by the unwanted environmental stimulus. Both cases may lead to a much higher risk of injuries or accidents and can affect performance negatively (Ljungberg and Neely, 2007).

Over one third of employees in the European Union, i.e, ~60 million people, are exposed to high levels of noise during a quarter of their working day (Parent-Thirion*et al*., 2007) ; (Eurofound, 2012) ; (Antoniak M., 2011).

Therefore, noise induced hearing loss is still the most common reported occupational disease.

1.1.3 Industrial Noise Solutions

(Pleban, 2014) suggested different solutions for the industrial high noise levels including:

- Eliminating risks arising from exposure to noise at their source
- The design of workstations places of work that are ergonomic and can reduce level of exposure, selecting machines and work equipment as well as procedures and methods characterized by reduced noise emissions
- Locating machines, work equipment and workstations properly
- Applying technical measures of noise reduction to the used technology and working environment such (automation and remote operation of machines as well as soundproof cabins for personnel, sound-absorbent and isolating enclosures for machines, vibrio-isolation of machines, acoustic dampers, acoustic shields and acoustic adaptation of industrial rooms) as well as

organizational measures (decreasing working hours and increasing workers efficiency during the left hours, lunch-breaks , coffee break that could motivate workers)

- Selecting proper, using and inspecting the use of hearing protectors

1.2 Motivation

In a developed country such as Lebanon where no strategic plans are being imposed on plants to guarantee the safety of workers, and after reviewing the various hazards that high noise level can cause on worker's health; a study concerning noise reduction is a must.

Therefore, this study was conducted to generalize the worker's case in Lebanon and to investigate the amount of noise exposure and the effect of high noise on their health.

Exploring the actual noise level in the plant is the initial step to apply noise control and noise reduction technics. Various noise protections were proposed depending on the each machine and the working situation.

Noise being reduced can have a great effect on working environment inside the plant. Employees working in a less noisy atmosphere tend to show higher productivity. In addition, machines having regular maintenance are less likely to break-down or emit higher noise.

1.3 Thesis Objectives

The objectives of this thesis are as follows:

- Distribute noise questionnaire on workers

- Investigate the noise symptoms among workers
- Investigate worker's knowledge about the side effects of high noise levels
- Investigate worker's knowledge regarding ergonomics
- Collect noise data from machines
- Compare the data collected from the machines and the data collected from the questionnaires
- Propose appropriate solutions for noise reduction and noise control

1.4 Thesis Organization

Thechapters of this thesis will include the following: In Chapter 2, a literature review of previous work related to the noise topic is presented for better understanding; in Chapter 3, the methodology followed to explore high noise in the plant is described; in Chapter 4, the collected data from distributed questionnaires and the data collected form machines were analyzed and different tables, figures and graphs were used to explain the results obtained. Chapter 5 is the discussion of the results which highlighted the main topics concluded from various tables and graphs and finally Chapter 6; the conclusion that talks about a brief summary of the results obtained and the future work for such field of study.

Chapter 2

LITERATURE REVIEW

Thelarge variety of working conditions that can affect worker comfort and health is covered by a broad science called ergonomics. Ergonomics include many factors such as lightning, noise, temperature, humidity, workstation design, tool design, machine design, etc. (Aluclu*et al.*, 2007).

However, in this study, the main focus will be on noise.Noise is considered one of the most common occupational and environmental hazard (Robinowitz, 2000). In 2004,1.1 million people were exposed to excessivenoise at work and of which 170 000 will suffersignificant ear damage as a direct result of the noise this estimationwas done in the UK (South, 2004).

2.1 Noise

When any vibration stimulates an auditory system, it is called a sound (Kroemer, 2001). As for the noise it is defined in its simplest form as the undesirable sound (Mihailovic*et al*., 2010). Another better definition of noise is the one proposed by (Burrows, 1960) in which it is considered as "that auditory stimulus or stimuli bearing no informational relationship to the presence or completion of the immediate task" (Sanders and McCormick, 1993). Farther more for better noise understanding one should understand its fundamentals (frequency, wavelength, amplitude, decibel, intensity, etc.)

2.1.1 Frequency

The mechanical energy transmitting vibration of the molecules through whatever medium is a form of sound. Noise travels faster as the medium is denser. A pure sound wave of a single frequency takes the shape of a sine wave. A frequency is the number of cycles per second made by a sound wave and it is expressed by Hertz (Hz) (Aluclu*et al.*, 2007). A sound is a mixture of frequencies.

2.1.2 Wavelength

The distance traveled between two successive peaks is called a wavelength and its usually expressed in λ.

2.1.3 Intensity

Intensity in broad term is defined as the power of sound. However, it is better defined as the amplitude of the sound. The amplitude of a sound is usually expressed by its sound pressure level. Nonetheless, if two sounds have equal frequencies or same wavelength they might have different loudness. Intensity is a form of logarithmic scale given the unit known as decibels (dB)(Kroemer, 2001).

2.1.4 Decibel (dB)

dB in fact represent the ratio between a given sound pressure and a reference sound pressure. Where the relation is as follows:

$$L_p = 10\log(\frac{P}{Pre})^2$$

Lp: noise level in dB

P: noise pressure in Pa

Pre: noise pressure at the threshold of hearing in Pa (0.00002 Pa)

2.2 Sources of noise

In general, noise is a combination of sounds coming from one or different sources. As (Buratti,2006) mentioned in his study: acoustic comfort may result from different conditions such as:

- Noise source characteristics in terms of sound power, acoustic spectrum, directional properties, time, and collocation.
- The propagation of the noise in term of indoor and outdoor sound field characteristics (direct and reverberating), materials and building elements favoring the easy transmission of sound.
- Interior and exterior user's activity.

However, in this study the main focus will be on the indoor activities and noise propagation. For a better understanding of this propagation, one should define the possible sources of indoor noise in a plant.(Hansen and Bies, 1995), present some possible origins of noise:

- Unexpected mechanical shock between solids particles
- Unstable rotating gear
- Friction between various metal parts
- Large plats vibration
- Unstable flow of various fluids

2.3 Effect of noise

Noise is a tremendous phenomenon where everything in a workplace is affected by its cons whether directly or indirectly. Passive and active noise reduction method can present the perfect solution for the extensive usage of industrial equipment since acoustic noise is becoming a serious problem.At low frequenciesactive methods outperform passive methods by being more effective and able to block noise selectively(Aslam& Raja, 2015). In industrial facilities, the main interest in noise contribution is its high impact on workers and machines.

2.3.1 Effect of noise on humans

2.3.1.1 Effects on health

In order to understand the human response to different noises, there should be a better understanding of how the sound enters the human body and becomes an unwanted one or as defined before a noise. (Aluclu*et al.*, 2008) stated in their research that the sound pressure changes in the air are detected by the human earthat transmits a signal, which is related to the sound pressure changes to the brain where it is perceived as sound. There is no direct proportionality between the sound pressure stimulus which first entered the ear and the perceived signal by the person.

The threshold for noise annoyance differs based on multiple conditions of which sensitivity and mental state of the individual. The exposure to noise can have many side effects on human health as stated by (Kromer, 2001) noise can create negative emotions, feelings of surprise, frustration, anger and fear. Also, individuals exposed to noise present a delay in normal sleep hours and changes in the physiology of the worker. He is more likely to produce temporary or permanent alterations in body chemistry including cardiac problems, sickness-related absenteeism and self-reported fatigue.

Hearing loss is usually linked with exposure to noise.Noise-induced hearing loss represents a much heavier burden in developing countries than in developed regions of the world. The difference is in general related to absence of noise prevention plans and awareness campaigns regarding the consequences of high noise exposure (Nelson *et al*., 2005). According to the Maltese Labor Force Survey of October to

December 2007out of atotalworkingpopulationof155 968therewere at least 43 670 (28%) workers in noisy industries.Also, when mentioning hearing loss the two types of deafness should be mentioned: nerve deafness and conduction deafness. As for nerve deafness it is usually related to damage or degeneration of the hair cells of the organ of Corti inn the cochlea of the ear. One of its examples is aging and continuous exposure to high noise levels. This type of nerve damage can rarely be remedied (Sanders and McCormick, 1993).

(Sanders and McCormick, 1993) also states in their book, that conduction deafness is a lack of transmission of sound waves between the outer or middle ear and the inner ear. Different conditions may cause it, for example: adhesions in the middle ear that prevent the vibration of the ossicles, middle earinfection, substances at the outer ear such as wax, or scars resulting from a perforated eardrum. In such type of deafness people are able sometimes to hear reasonably well, if the intensity of the sound in noisy places is too high as long as it is above the background noise. The difference between nerve deafness and conduction deafness is that conduction deafness can be fixed using hearing aids.

Therefore, hearing loss is a factor of the intensity of sound which worker has been subjected to, also the duration and the nature of exposure whethercontinuous or discontinuous. As (Kroemer, 2001) mentioned exposure to intense sounds may result in a temporary threshold shift (TTS) from which the hearing eventually returns to normal with time away from the source; or it can cause a permanent threshold shift (PTS), which is an irrecoverable loss of hearing. For example the sound of high intensity produced by a cannon or an explosion can cause immediate, severe, and permanent hearing loss.

In a normal working day, humans are exposed to sound levels of less than 100dB over a certain period of time that may initially cause only short-term hearing loss, measured as a temporary threshold shift (TTS). Whenever they rest during quiet periods, hearing returns to its normal level. For better understanding some OSHA regulations in the United States will be represented. OSHA allows 16 hours of exposure to 85 dBA, 8 hours to 90 dBA, 4 hours to 95 dBA, etc.(Kroemer, 2001).

The Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) have established regulations for maximum allowable noise exposure. The regulations are generally described as the duration per day (hours) one can be exposed to a sound level (dBA) before damage may occur. For example, regulations set by OSHA state that exposure to a 110 dBA sound level for longer than half of an hour may result in damage. Noise-induced hearing loss can be temporary or permanent, depending upon these two parameters of sound levels, duration and intensity. The symptoms of NIHL (noise induce hearing loss) will increase with louder and longer exposure time (Rabinowitz, 2000).

2.3.1.2 Effects on performance

When evaluating a worker's performance, supervisors usually link it with his capacity of completing assigned tasks or as better defined his productivity rate. For having an optimum productivity level several managerial decisions should be taken as well as the technological development of the process and most importantly the ambiance or physical environment of the workplace. (Aluclu*et al.,* 2008) mentioned that auditory communication of information (speech, warning signals, etc.) is directly affected by noise and therefore this can result in decreasing the ability to perform tasks. Once the human being is exposed to high-intensity noise, the auditory system immediately reacts and increases the threshold of the system. This dynamic reaction can have an excellent effect on completing the performed task. (Kroemer, 2001) explains this point and several others when talking about the effects of noise on human performance. He mentioned that when noise becomes more intense people become more aroused and their performance of certain tasks can improve. Nonetheless, when this intensity reaches certain level it has been noticed that task performance degrades. More effects where noticed as well, such as a startle response that interrupts one's concentration and physical performance of a task when facing a sudden and unexpected noise. As for continuous periodic or aperiodic noise effects on complex tasks such as visual tracking; performance diminishing with the increase of noise level has been noticed.

2.3.2 Effects on machines

Normal noise discussed in the previous sections,which have an enormous impact on worker's health and productivity are not considered as an important issue when talking about its effect on machines. As for machinery noise study in a plant, engineers are more interested by the noise emitted by machines then the effects of external noise on them. Noise emitted by machines can come in several forms such as: vibration, high intensity noises, mechanical friction, etc. In that matter, different standards were imposed by global organizations such as the European Committee for Standardization to impose restriction on machine's manufacturer for noise reduction. (Kurtz and Lazarus, 2003) mentioned in their study that a distinction is drawn between the emission (noise, vibration and radiation) from the machine and the emission or exposure at the location where persons are present or could be present. In order to better understand the noise risk one should know that noise risk analyzing compromise two elements: the manufacturer and the user.

The manufacturer uses only the emissions values for the risk analysis of their machines and do not determine the emission or exposure value.

The first step taken in a risk analysis for a workplace by an occupational safety specialist is the determination of emissions or exposure as A-weighted continuous sound pressure level or rating level. Afterward, the measurement of sound pressure level is done to check whether the measured sound level exceeded any noise limits (Council Directives 86/188/EEC, 2003/10/EC), or to check if it is too high compared to the target values according to the regulations and standards.

As a rule it is not necessary to determine potential hearing loss or other impairment (Kurtz and Lazarus, 2003).

2.4 Measurements of noise

(Sanders and Mc Cormick,1993) stated in their book the details and considerations that should be followed in order to achieve the best possible noise data collection. The procedure is as follows:

First of all, an overall sound-pressure level measurement of the situation or work station should be done (usually in dBA). Second, several principles should be followed when collecting data such as the proper usage of the equipment and microphone, the proper knowledge of equipment calibration according to working order. Third, the device should be held at arm length to avoid sound reflections from the body and the blocking of sound from particular directions. If wind noise is present, shield the meter.

If the sound emission is being determined from a single source such as a machine, the reading should not be taken close to the machine because the readings will vary significantly with small changes in the position of the meter. This miss-estimation is assumed to happen within a distance of about twice the greatest dimension of the machine being measured. This area is known as the near field. Similarly, if the measurements are being taken too far away from the machine, the sound coming from the desired machine can hardly be measured because it is affected by other reflected sounds coming walls and other objects. This area is called the reverberant field. So, the best region to take precise measurements and where the appropriate sound-pressure level reading should be taken is the area between near field and reverberant field which is called the free field. However, in many industrial cases engineers are limited with the space. This limitation enables them to take measurements from the free field. Being restricted with space engineers can do some corrections to account for the effects of the reflected sound. Recent technological advances have made it possible to measure sound power by measuring sound intensity directly, rather than by measuring sound pressure as is done with a sound level meter. Sound intensity describes the rate of energy flow through a unit area and is measured in watts per square meter (W/m^2). Yet, this type of measurements have its own characteristics where it is valuable for determining the sound pressure power of individual sources (such as a single machine) under real-world conditions (such as in a machine shop with other machines), it can also be used for pinpointing the surface of a machine most responsible for the noise.

Another thing to keep in mind is that applying noise test in acoustical laboratories is much easier than applying those tests in industry. Large, high horsepower compressors, pumps, gas turbines, and similar machinery must be tested where they are installed, under less than ideal conditions, and the main problem is to obtain the" true" sound power levels , against which the measured values can be compared (Leasure, 1977).

2.5 Noise control

The best way to efficiently control noise is to inspect and exactly locate the noise problem and afterward built excellent fundaments for the control plan adopted.The following factors as mentioned by (Hansen and Bies,1995) should be considered:

- The nature and type of noise
- The existing noise levels
- Frequency dispersion and distribution
- The exact noise source (place, intensity, directivity)
- The paths taken by the noise along its propagation
- Room acoustical criteria

In addition, other factors have to be considered; for example: number of exposed workers, type of work, etc.

A noise problem can be controlled by attacking the noise at the sources, along its path from the source to the receiver, and at the receiver. However, to achieve the desired level of abatement, a combination of noise control techniques is required (Sanders and McCormick, 1993).

2.5.1 Control at the source

The noise source is usually caused by vibration, which is caused by any physical phenomenon, such as mechanical shock, turbulent airflow, impacts and high friction. As for a single machine, most of experiments suggested that when noise source is located it is essential to produce a quieter process. The noise can be reduced by decreasing either the amount of vibration or the surface area of the vibrating parts. Maintenance, lubrication and alignment of equipment can also be very helpful in the reduction of vibration. Clearly, the best controls are those implemented in the original design. It is often more economical to pay extra for quieter equipment than to purchase noisier equipment that will require additional expenditures for noise control. Low frequency noise is less annoying and is tolerated better than high-frequency noise. Therefore, where possible, equipment that generates low-frequency noise should be selected over equipment that generates high-frequency noise. As an example, the usage of a large, slow-speed blower would be preferred over a smaller, high-speed blower. Unfortunately, engineers related to the occupational safety and health issues have no intervention in the design of new less noisy machines. Instead they are limited to the material they are supplied with where they have to use in the most effective possible way. These limitations make the control at the source very hard and therefor they focus on the control along the path or at the receiver.(Sanders and McCormick, 1993),(Hansen and Bies, 1995).

2.5.2 Control along the path

Once the control is difficult at the source due to the previously stated reasons, attempt should be made to control it at its propagation path.This path isdefined as the path along which the sound energy from the source travels. Different paths may exist such asair, liquid or solid. In order control noise in this stage the path taken must be studied well and understood. (Sanders and McCormick, 1993), states that high-frequency noise is more directional than low-frequency noise when interrupting its propagation path (Arezes& Miguel, 2013).

2.5.3 Control at the receiver

Final stage of noise control can be done at the level of the receiver if both the control at the source and along the path failed. In this particular study the receiver is the exposed worker(s).Controlling noise at the receiver involves different elements beginning with the usage of hearing protection moving to audiometric testing of exposed workers with job reassignment or reduced exposure times for those showing signs of hearing loss (Sanders and McCormick, 1993).

The problem at the worker's level can be detected after receiving different complaints from different workers in the same working environment. Once too many complaints are received different measurement should be taken such as audiometric tests and sound level measurements to check the validity of the high noise levels assumption and to take preventive actions. However, it is almost impossible to eliminate the total noise generated in an industrial work place, so an attempt to reduce this high noise level to a minimum threshold level would make an excellent, effective and efficient reduction plan. The criteria of accepting such levels are determined by different global organizations such as the occupational health and safety administration (OSHA).

In industrial atmospheres, hearing protection devices (HPDs) are used to protect workers from noise exposure. However, when workers sometimes remove their HPD's while exposed to high noise the effectiveness of this practice can be compromised.

2.6 Noise reduction

2.6.1 Reduction at the source

A very efficient noise reduction is the isolation of vibrating parts from other machine parts or structures by use of resilient materials such as rubber or elastomers reduces the number, and hence the surface are, of vibrating sources. In this technique the noise reduction is accomplished by isolating the machine from the floor by resilient pads. Adding damping materials to machine parts to increase their stiffness or mass can reduce the amplitude of vibrations as well (Sanders and McCormick, 1993).

So in order to reduce noise at the source it is very important to locate the exact parts of the noise that are emitting this high noise level. After determining the noisy parts of the source appropriate noise control measurement should be considered. Those measurements can sometimes be as simple as maintenance, or the substitution of some steel part by others made of strong durable plastic and the substation of different mechanical systems by less noise ones such as replacing the normal mechanical valves by electronic pneumatic valves etc.

2.6.2 Reduction along the path

Among the different noise reduction technic at the path level the most popular one is the reduction by barrier. When a noise barrier is located between a noise source and a receiver the sound attenuation occurs behind the barrier. In the case of high-frequency noise and to obtain extra sound attenuation in low frequency using barrier is a great active method for noise reduction (Han and Qiu, 2007).In that matter (Sanders and McCormick, 1993) states that high frequency noise is more directional that low frequency noise and is more easily contained and deflected by barrier. Acoustic linings and materials can reduce noise. An important consideration is to be kept in mind when designing full enclosures is the maintenance of the enclosed equipment. Although the noise from the machine has been drastically reduced by enclosing it in an acoustically lined, sealed, double vault, but, maintenance has not been considered and it is very hard for the maintenance person to get inside to change the fan belt. In addition, it is not necessary to include full enclosure for every single machine, a single wall, shield, or barrier placed between the source and the receiver will deflect much of this noise. Low-frequency noise, however, will not be reduced at all by such barriers, because such noise will easily go over or around the barrier. Another way to reduce noise is by moving the noise source farther away, which will increase the length of the path from the source to the receiver. This technique only works within the previously defined free-field area, where doubling the distance from the source will result in a 6 dB reduction in the noise level. Due to indoor space limitation this technique is usually not applied. Also, a poor described technique is the addition of sound absorption materials to the walls, ceiling, and floors of a room to reduce the noise of the equipment.

2.6.3 Reduction at the receiver

In most industrial cases the receiver is the worker in the plant. Controlling noise at the receiver involves primarily the use of hearing protection. OSHA for example, has different regulations regarding excessive noise to protect workers. One of them is that employers should provide employees with hearing protection devices where noise doses exceeds 50 percent (TWA= 85 dBA), and they should oblige them to wear them if their noise dose is above 100 percent (TWA = 90dBA).

There are several types of hearing protection devices (HPD); some are worn externally such as sound-isolating helmets and muffs or they can be placed into the ear canal like the plugs. Insert type can be premolded or custom-molded, can be made of an expandable foam or plastic, or can be a simple fiber plug. Muff types can be liquid-filled, of foam-filled and are mounted on the headband or helmet. As for their effectiveness, it varies widely from one type to another and even between brands within a specific type (Sanders and McCormick, 1993).

In addition, an inappropriate initial fit, loosening of the device during activity, and, of course, failure to wear the equipment reduces its effectiveness. One of its disadvantages is that hearing protection devices are not permeable to speech intensity which will make communication harder and nonverbal signals, such as warning sounds or sounds of machinery, are also affected by the wearing of am HPD.

After facing these permeability problems new types of HPD where produced:

<u>Passive HPD:</u>The old structure of hearing protecting devices consisted of making sounds pass through material that absorbs, dissipates, or otherwise impedes energy flow. These conventional HPDs can be highly efficient when properly selected and correctly worn. In an ambient noise of above 80 dBA, as mentioned before they have problems regarding speech delivery and machinery alerts. In fact, most of passive devices are designed to attenuate high-frequency sound more than low-frequency sound, thereby reducing the power of consonants and distorting speech.

<u>Active HPD:</u>New HPD designs incorporate electronics to improve communication and the reception of signals by the wearer. These active devices can provide diminished attenuation in low-level noise and increased protection during loud periods. They can reduce noise by destructive interference at selected frequency band. Also, they let pass or boost desired critical bands, especially those needed for speech and transmit desired signals, such as those for speech, warnings, or music, via built-in loud speakers (Kroemer, 2001).

So for a better result regarding the efficiency of sound reduction at the level of the receiver and as per cost, the use of both types the passive and active are preferable.

Chapter 3

METHODOLOGY

The European Union has provided in recent years (and is going to update) several tools to harmonize noise mapping methodologies through directives and guidelines. Unfortunately the same efforts have not been put in the harmonization of approaches for noise action plans, the effective instruments to manage noise impacts. As a consequence, each European Member State at national or even at local level defined its own methodology, usually considerably different one from the others (D'Alessandro and Schiavoni, 2015).

3.1 Selection of noise measurement site

The site chosen is a plastic recycling plant where expected high noise is generated. Ezzeddine Group s.a.r.l is a medium sized plastic company where second hand plastic bags, material and tubes are being recycled and reused as a second hand raw material. The plant is located in north Lebanon, Anfeh. The area is classified as an industrial area where no population is near. The plant is surrounded by olive trees from the back, the sides, and the main road from the front. The temperature was ranging between 27^{o}C and 29^{o}C during the six measurement days and the humidity was found to be 71% RH. Mainly the noise generated from the plant was inside the factory due to small spaces and sometimes old machinery. No noise was coming from the outside and therefore deflecting the measurements being done. Since, Lebanon has some electrical disruption the plant works on both generators and the government electricity. When the governmental electric power goes off the generators are turned on. The plant's generators are all placed outside the factory however; their noise is barely hearable due to the usage of complete isolation on each one of them.

3.1.1 Process description

The machinery in the plant consist of two giants crushing machines, one washing line, four thermal dryers, a centrifuge , one blending machine, two extruders, two dewatering machines and two granulating machines.

First, the plastic bags or sheets covered with dirt are being separated based on quality and color. Afterward, each type is treated alone. The process starts with throwing the plastic products in the plasticcrushing machines. After transforming the big sheets into small parts, a spiral stainless steel conveyor carries theminto the washing line.Using different motors and steel blades the small plastic pieces are being well washed cleaned and transmitted to the thermal dryers using a rubber conveyor belt. After, the first stage of drying through the thermal dryers the small plastic pieces passes through a second dewatering process into the centrifuge.After finishing from the centrifuge, to insure a complete dewatering of our product, the plastic pieces are put in a blending machine with heated walls. The final product is transmitted into an extruder where using high temperature help melting and remodeling the recycled plastic. As a final stage, the melted plastic passes through a pelletizing machine where granular product of same form and thickness are obtained.

3.2 Method used

1. Employee surveys where first distributed to the workers
2. Sound level measurements were conducted using both a sound level meter and different smart phone applications.
3. Characteristics of the non-respondents were known.

3.2.1 Questionnaire

Audiometric testing being considered as part of health surveillance can sometimes be a very costly exercise. A cheaper substitute isthe distribution of a questionnaire targeting the specific aims of the study and investigating whether a worker suffersfrom hearing loss or no and thus eliminating the need to perform audiometry in such cases (Rosso*et al.*, 2011). In this case, a comprehensive questionnaire was developed in both English and Arabic to investigate the desired information among workers. The questionnaire is divided into two main parts, the first part is composed of20 multiple-choice questions and 3descriptivequestions and the second part had 9 multiple-choice questions (Khameneh, 2011). The first part of the finding was designated to describe:

- The basic characteristic of the workers being studied
- The working condition in the plant
- The various hazards from exposure to high noise level in workplace
- Analyzing the awareness of the importance of wearing personnel protective equipment
- Analyzing the awareness of ergonomic and safety

In the first section of the first part, general descriptive information was gathered about age, gender, education level and work experience. The question related to ageis classified into five levelsforms:less than 20 to above 50 and each option between those two ages is a 10 year category. The other question is about the gender of the worker whether male or female. The question related to education level was categorized based on the education system in Lebanon. The work experience question was divided into 5 levels based on the company's past hiring and firing history.

Four questions where included in the second section of the questionnaire which is associated to the working position and the actual state of workers in their working place.Sitting/standing position of workers is investigated in the first question. The next question targets the shift of the worker and is divided into three categories. The following two questions address the contact of the worker with a specific machine(s) and the duration of working with the designated machine(s) which is categorized in five choices ranging from 1 hour to more than 9 hours.

Common occupational symptoms and worker's illness that may result from continuous exposure to high noise level are investigated in the third section of the questionnaire. Nine questions where chosen for this part. The first two questions were yes/no nominal scales to ask if worker has a high blood pressure or any other medical problems. The medical condition of the worker is shown in the third question which is a descriptive question. The following four questions targeted the usually observed symptoms of being subjected to continuous high noise level such as the frequency of disturbance by noise, headache while working, speech interference and stress. Those questions where categorized into five levels ranging from always to never. The following question is yes/no nominal scale question about the regular usage of earplugs to hear music. The final question was a yes/no question to check the knowledge of the workers about high noise levels (Khameneh, 2011).

The awareness of noise and hearing protective equipment among workers was investigated in the fourth section of the questionnaire. This part tried to show the workers exact knowledge about the benefits of using ear protection equipment with a yes/no direct question. The other question which is also a yes/no question investigated if the manager forces the workers to wear ear protective equipment. The next question where categorized into five levels to see how long workers uses the ear protective equipment during working hours. Then, a descriptive question was asked to check why in some cases workers do not wear ear protection. The final two questions of this section were asked to check if the workers had any training about safety and ergonomics starting with a yes/no question, followed by a descriptive question in case the answer was yes (Khameneh, 2011).

As for the second part of the questionnaire is was intended to find out the actual knowledge among the workers for both noise exposure and hearing protection.

As for part two in the questionnaire, in the first section the level of agreement with each statement among the workers concerning knowledge of noise was anticipated through four designed questions.

Questions include multiple questions assessing the knowledge of workers regarding exposure to high noise levels and if it can cause temporary loss of hearing, if hearing can be affected permanently by high noise levels, ifthere is a possible solution to reduce noise in the plant and if noise in the work place is not considered dangerous.

Section two of part two of the questionnaire targets worker's knowledge of hearing protection using five designed questions where each responder is supposed to express his level of agreement with each statement.

The questioned asked where to assess the knowledge of worker regarding if the same protection level is offered by all hearing protectors, the duration of daily usage of ear protection can determine the amount of human hearing preventions, if there is no need for the usage of ear protection equipment in the ambient working area,if thereexists multiple types of hearing protective equipment, and if each worker avoid himself from being exposed to high noise levels. Responses were categorized into five different levels ranging from strongly agree to strongly disagree (Khameneh, 2011).

The questionnaire was developed base on Health and Safety Executive (HSE) of United Kingdom (Health and Safety Executive UK, 2002) with consideration of OSHA standards and criteria (USDOL-OSHA, 2004-2011) and after reviewing questionnaires from previous studies (Arezes& Miguel, 2008) ; (Singh,*et al*,2009) ; Penafiel, 2007).

Questionnaires were used strictly to collect data. The questionnaire was distributed to workers in Arabic language as most of the workers do not know foreign language. A brief explanation about the study and the confidential nature of data collected was presented by the manager along with the distribution of the questionnaire to the workers. Most of the data collected was checked with the manager to insure higher accuracy.

3.2.2 Sound Level Measurement

Noise level measurements were accompanied after two days from the questionnaire distribution. The purpose of the study and the way measurement were conducted was explained to the workers under the supervision of the head of workers and the manager. Workers didn't show any curiosity toward numbers obtained but toward the general noise level obtained and whether it is harmful or harmless. The workers were asked to carry on their normal working routine without being distracted by noise measurements.

3.2.3 Sound Level Meter

The noise exposure level was evaluated using DAWE sound level meter model type: D-1405E (2/03819608 serial No.), and the device was calibrated with DAWE calibrator model type : D-1411E (3/06022628). As the user manual states the device satisfy the requirements of the international and national IEC 651 Type 2, BS 5969 Type 2, and ANSI S1.4 Type 2A standards for both free field and random incidence sound level meters. The instrument provides a clear and unambiguous digital indication of the A-weighted sound level on an easily read display. It feature the standard fast and slow time weightings, and can measure sound levels between 30 dB(A) and 130 dB(A) in two ranges, at frequencies between 10 Hz and 25KHz.

The sound level meter only measures the A-weight level and it was adjusted to the low range between 30 and 100 dB(A) in the slow response position throughout all measurements on each machine. The instrument was calibrated to 114 db at 1 kHz in all measurements as described in the user manual.

The average temperature and humidity in Anfeh, Lebanon which is mentioned before did not affect the noise measurement of this survey, since the device met IEC 651, BS 5969 Type 2, and ANSI S1.4 standards and according to user manual, the device can work from -10°C to +40 °C and 20 to 95 % RH. There was no need to use a windshield as the measurements were all conducted indoors area.

3.2.4 Different Measuring Technics

To insure a proper measurement of noise another technic was used. Different sound applications were downloaded on an iPhone 5. The first application used is called Sound Meter – Noise Dosimeter which measures the sound in decibels with a range from 0 to 100 dB(A). A slight disadvantage of this application is the non-digital display which makes it harder to read the collected level. The second application used is called Decibel Meter which measures noise within a range of 0 to 110 dB(A). This application presents an extra advantage on the previous one; it records the maximum attainable noise level. Again the disadvantage of this application is the hard reading from the non-digital screen. The third application is called Digital Sound Meter where it combines all the advantages of the previously mentioned applications. With a range between 0 and 100 dB(A) this application collect the maximum obtained value of the reading and shows on a digital display the collected measurements.

To insure a proper collection of the sound measurements the old microphone in the iPhone was substituted with a new one before starting the procedure.

3.2.5 Procedure of Measuring and Noise Layout

The measuring procedure was as follows: each machine was measured alone and then Leq of the whole plant was measured. The workers were asked to carry on their working habits as usual and the Sound Level Meter was placed at arm extent in order to minimize the reflection of the sound by the human body and thus have more error in the sound level collected. The sound level meter was positioned near the operator’s ear in cases where the worker was present on the machine as shown in figure 1.

Figure 1: Sound measuring technic

In case the worker was not there during measurements, the sound level was recorded from the source directly having 1 meter space between the sound level meter and the source.Measurements were taken from different machines 5 times a day for 6 succeeding days. Also, at each time the environmental noise level inside the factory was recorded. The sound level meter in this particular case was placed at the center of the plant.

In parallel, the applications previously mentioned where used as well to insure that the sound measurements being collected are credible. To omit body deflection of sound, the iPhone 5 was placed on a selfie-stick which was pointed near the ear of the worker in case he was available. In other cases where the worker is not there, the measurements were taken one meter away from the source. And at the end of each machine measurements, the total sound generated by the plant was recorded at its center.

The duration of measurement was considered 2-minute for each machine and 10 minute for measurement conducted at the middle of the factory. Measurements were carried out at other timing between 2 and 15 min as a pretest to insure that the measurements are correct. The difference was found to be minor of 0.5 to 1 dB(A) which will not affect the results of this study and there for the timing of 2 minute was adopted.

As mentioned in previous sections, adjustment of sound level meter was done before and after each testing.

The results obtained from the sound level meter and the iPhone applications were close to each other with a difference of 2 to 3 dB(A) and therefore for the analysis in the upcoming sections will be based om the sound levels collected by the sound level meter instead of those recorded with a smart phone application.

3.2.6 Method of Data Analysis

After transferring all data collected from questionnaires and from recorded measurements an electronic spreadsheet was done using the Statistical Package for Social Scientists (SPSS) version 20 and Microsoft Excel 2010 program for analysis. Different statistical tests were performed in order to evaluate for any meaningful and statistically significant relationship between variables. This analysis was done on a Hp Pavilion dv6 notebook PC with and intel core i5-2410M CPU @ 2.30GHz with an installed memory (RAM) of 6.00 GB and a 64-bit operating system.

The analysis of the variables was done sequentially according to the categorization which was discussed in 3.2.1. First of all descriptive statistics were calculated to understand the differences in the data collected from different responses. In some cases, charts where used to present a better explanation of the data distribution.

Correlation analysis was performed to find out the relationship among the collected data from the questionnaire distributed.

A hypothesis testing was used to analyses the data collected from machines. A two factor-factorial analysis was done to confirm the results and show the impact of high noise levels on workers.

Discriminant analysis was conducted to determine which independent variables contribute in the annoyance of workers being subjected to high noise levels.

3.3 Case study on the factory

3.3.1 Noise dose measure at each machine

In this section a brief presentation of each machine will be done accordingly the average noise value will be presented and compared with the regulations imposed by OSHA.

At age 60, workers who have been exposed to a daily average of 80 dBA for more than 10 years have a risk of hearing loss of 1.3% greater than unexposed persons. At 85 dBA, the excess risk estimate increases to 6.7%, and at 90 dBA, the excess risk estimate increases substantially to 24.7% (Prince et al., 1997). OSHA has established permissible noise exposures for persons working on jobs in industry

(OSHA,1983).The permissible levels depend on the duration of exposure and are shown in the table below.

Table 1:Permissible noise exposures according to OSHA

Sound level, dBA	Permissible time, h
80	32
85	16
90	8
95	4
100	2
105	1
110	0.5
115	0.25
120*	0.125*
125*	0.063*
130*	0.031*

First of all, the shifts in the plant are divided into 12 hours shift twice a day. The workers have Sunday as their off day.

Starting with the crushing machines the average noise level collected for each one is around 90 dB(A). As it is shown in table 2 the permissible noise exposure for 90 dB(A) according to OSHA is 8 hours however, workers spend around 10 to 11 hours from their 12 hour shift near the machines. The wasted 1 or 2 hours are for maintenance purposes (changing blades, adding oil to the joints, cleaning, etc.) and lunch break.

Moving along the recycling process, the next stage is the washing line. Having simple mechanical structure and mounted by small motors desired to move the blades and clean small plastic pieces, the average noise level was found to be around 81.5 dB(A) which according to OSHA standards is acceptable.

The next stage is the four thermal dryers. The obtained average for the noise generated by this machine is around 93 dB(A) which according to OSHA the worker should be placed as maximum 4 to 6 hours and not 12 in front of this machine. Here the actual time is almost the double of the acceptable time which may causes severe consequences to the worker as discussed in section 2.3.

After measuring the thermal dryers, the centrifuge has been measured with an average of 90 dB(A) for a 10 to 11 working hours and not as OSHA states 8 hours.

Afterward, the pelletizing machines were tested. The average sound level obtained was around 93 dB(A). Same as explained in the thermal dryers' part, the worker should be placed somewhat between 4 and 6 hours. Unfortunately, workers are placed for almost 10 hours in such high noise level. The wasted two hours varies between lunch time and the time needed for the machine to reach the desired temperature to help melting and transforming the plastic films into pellets.

3.3.2 Proposing appropriate precautions & protection

As discussed in section 2.5. The control and precautions of noise can be done under 3 forms:

- Control at the source
- Control along the path
- Control at the receiver

3.3.2.1 Solutions at the source

Now in this section a presentation of the possible solutions for each machine will be given and in the next section the economical liability of the noise reduction solution proposed will be studied.

Starting with the crushing machines Hansen and Bies (1995) present a solution that emphasize the decrease of the raw material dropping heights by using an adjustable height conveyor and by inserting rubber flats inside the crushing machine as shown in figure 2.

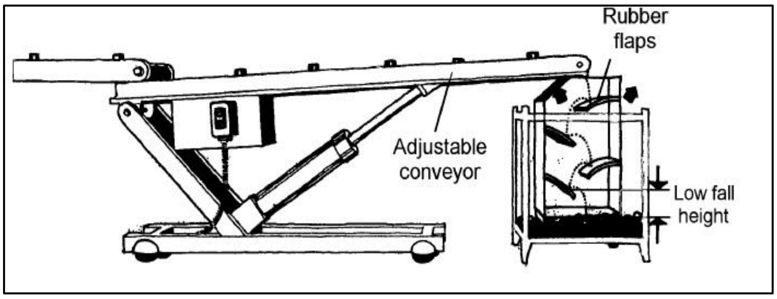

Figure 2: Adjustable height conveyor including rubber flaps

The decrease of the fall height of objects helps reducing the noise generated by their impact when hitting the bottom of the machine. In addition, the presence of rubber flaps makes it much easier to reduce this impact.

Another proposed solution by Hansen and Bies (1995) is coating a hopper with an impact absorbing and stiflinglayer. Figure 3 presents clearly how this lining can help reduce the impact of the thrown raw materials inside the hopper.

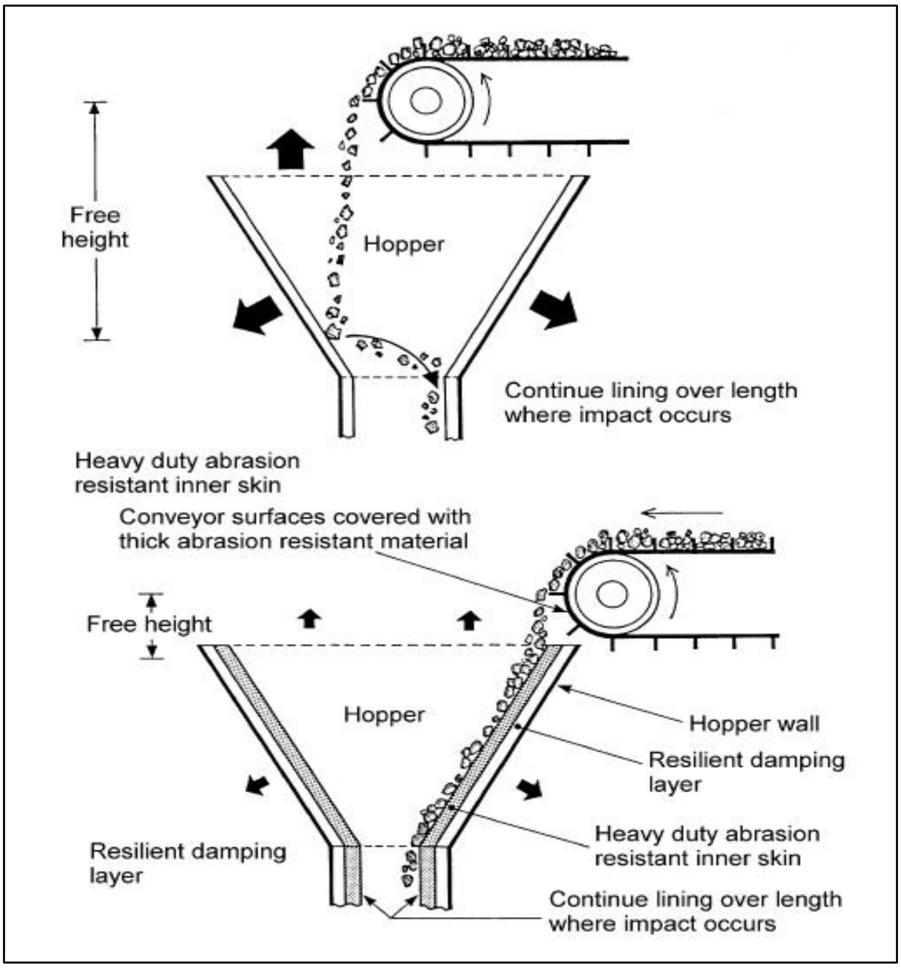

Figure 3: Coating a hopper with an impact absorbing and damping layer

The next stage is the washing line; though this machine is considered the least to generate noise in the plant. However, many solutions can be applied to even make it less noisy. Since the mechanical part of this machine consist mainly of different motors, ASF(1977), proposed the usage of narrower belts than a large one as shown in figure 4.

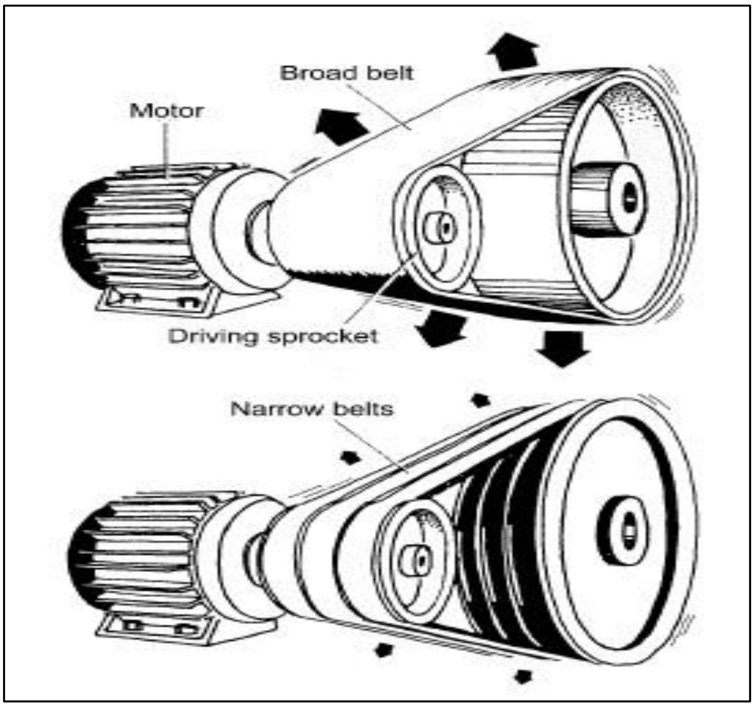

Figure 4: Presentation of different belt usage (ASF, 1977)

Belle(1982) also talks about another form of noise reduction for electric motors and that is by using a silencer or better defined a muffler that covers the noisy part of the electric motor. Figure 3.4 clarify the usage of a muffler on an electric motor.

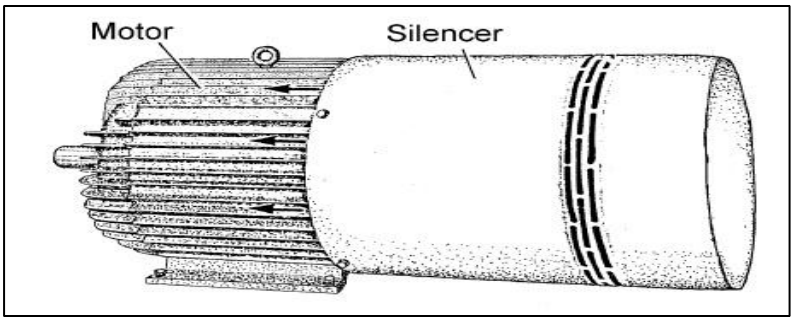

Figure 5: Electric motor with dissipative muffler (Bell, 1982)

For the thermal dryer one can use a quiet nozzle for air stream venting (ASF, 1977). As it is shown in figure 5 the quiet nozzle with its perforated surface and its filled structure help in the attenuation of the air stream by transforming the single entering air stream into multiple outgoing streams and therefore less noise will be generated.

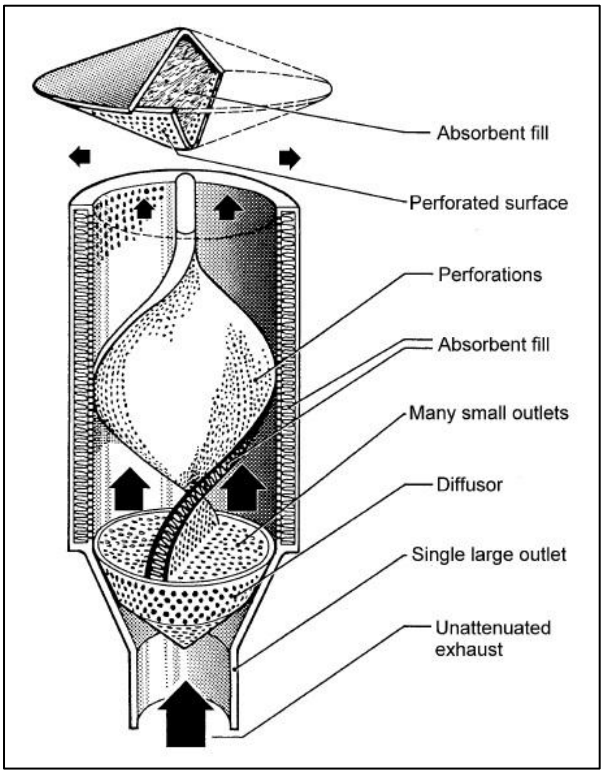

Figure 5: Quiet nozzle technic (ASF, 1977)

After passing through the thermal dryer, the products proceed to the centrifuge. The centrifuge is a machine with a rapidly rotating container that applies centrifugal force to its contents, typically to separate fluids of different densities or liquids from solids. The centrifuge is a very delicate mechanically structured machine meaning one cannot adjust any of its mechanical structure. A proposed solution for this machine is the usage of support that can absorb the mechanical movements and vibration better than steel. The support is shown in figure 6.

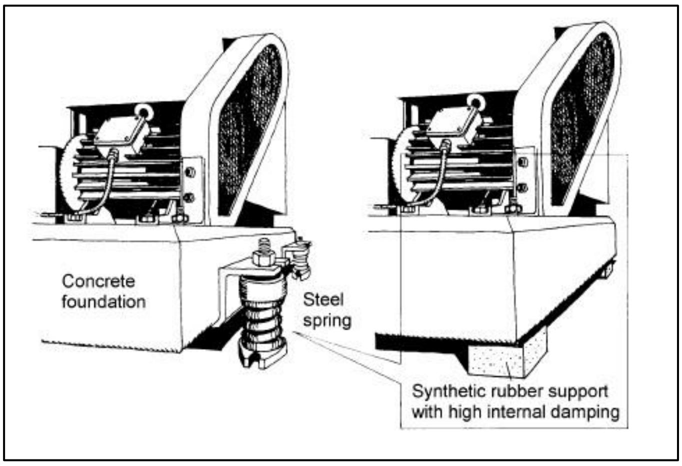

Figure 6: Steel vs rubber isolators (ASF, 1977)

The last machine to be checked is the pelletizing machine. This machine has a hopper where products are being feed to the machine. So, the same approach used in the crushing machine can be applied.

3.3.2.2Solution along the path

One of the best solutions to reduce noise is the reduction by barrier as suggested by Kurze(1973). The reduction by barrier is a technic where separation between worker and the machine is being done using some kind of barrier whether it is plastic, glass or any other material type. The barrier shown in figure 7 the deflection of the noise generated by the machine and how it helps preventing worker from being subjected to such high noise levels.

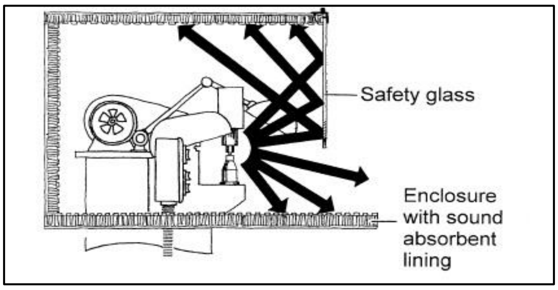

Figure 7: Example of barrier usage

3.3.2.3Solution at the receiver

One of the best solutions is the hearing protective equipment weather the advanced mufflers or the simple ear plugs. Ear protecting equipment helps protecting the worker from surrounding noise. Unfortunately, workers tend to remove this type of protection most of the time.

Figure 8: Ear protection equipment

3.3.3 Economical appraisal of the protection

When applying some type of protection on any of the 3 previously mentioned sections; it is very important to consider the economical factor. Not to forget many other important factors such as the durability and the efficiency of this protection, the financial potentials of the factory and the time needed to apply such a preventive action.

To effectively decide and apply any of the technics mentioned in section 3.3.2 first it is important to check the prices of the machines and the cost of applying each technic. Table 2 shows the price range of each machine depending on the size of the motors installed and the extra features like LCD touch screens or normal buttons etc.

The prices shown it table 2 are based on the price list offered by the supplier: **AkmaMakina**, one of the leading companies producing plastic recycling machines in Turkey.

Table 2: Machinery Price List

Machine	Range in $
PE crusher	$8000 - $10000
PE washing line	$5900 - $8300
Thermal Dryer	$3900 - $9000
PE centrifuge	$15800 - $18000
PE palletizing machine	$80000 - $120000

Now after having the machinery price list, a consideration of the price of each protection technic will be shown in table 3.

Table 3: Estimated prices for each protection technic

Technic number	Technic name	Estimated price
1	Adjustable height conveyor	\$500 - \$1200
2	Heavy duty abrasion resistant inner skin	\$50 - \$200
3	Usage of smaller belts	\$2 - \$3.3
4	Electric motor muffler	\$75 / motor
5	Quiet nozzle for steam	\$178
6	Synthetic rubber support	\$1 - \$50
7	Plexiglas sound barrier	\$200
8	Ear protection	\$0.5 - \$5

Note that prices presented in table 3were offered by different companies depending on the type of protection used. For instance, the adjustable height conveyor price was offered by "AKMAmakina", the applied heavy duty abrasion resistant inner skin for the hoppers in the plant and the synthetic rubber support prices were offered by " La Libaniase du Caoutchoucs.a.r.l" ; the smaller belts , electric motor muffler and quiet nozzle for stream prices were given by " JahedRidanni and Sons group". The Plexiglas installation price was estimated by " PlexiJammal" and the ear protection prices were given by " S.I.S sal".

3.3.3.1 Protection technic favored for each machine

After showing the original prices of the machines and the possible applicable protection technics and their cost, a suggestion will be made for each machine to reduce sound as possible.

Starting with the crushing machinesthe conveyors belt are designed for the exact heights of each of them and therefore no need for adjustable conveyor belt. But, one can apply the heavy duty abrasion resistant inner skin and minimize the impact sound of the product when hitting the inner walls of the machine. The estimated meters needed to coat the inner walls of the crusher hopper are around 4 for each crusher. With an average price of $100, the final cost will be 100 × 4(walls of hopper) × 2 (2crushers) = $800.

As for the washing line, it is one of the least noisy machines in the plant however, to minimize the overall sound in the factory one can apply motor silencer. Having 3 motors the overall cost will be 75 × 3 = $225.

Going to the thermal dryers, the quiet nozzle is a great way to reduce the incoming large air stream into smaller ones. Unfortunately, this technic cannot be applicable here because the small plastic part will be stuck in the nozzle and the process will be stopped to clean the jammed plastic parts. Thus, the best protection to be used here is the usage of ear protection equipment which will cost around $5 × 2 (number of workers)×2 (number of shifts) = $10.

The next machine is the centrifuge which practically the best solution for this machine's noise is the usage of ear protection equipment and the cost will be $5 × 2 (number of workers)×2 (number of shifts) = $10.

Finally, the pelletizing machines where applying Plexiglas sound barrier is a great way to reduce the noise generated by this machine. By using this technic workers can carry on their normal working routine and the estimated cost is \$200 × 2 (number of machines)= \$400.

In addition, one can use the synthetic rubber support for each machine. In this factory we will need 8 support for the crushing machines, 6 for the washing line, 4×4=16 for the thermal dryers , 4 for the centrifuge and 8×2= 16 for the pelletizing machines which makes it a total of 50 synthetic rubber support at the cost of 50×\$25 = \$1250.

The total cost of noise suggested noise reduction technics for the 7 machine will be:

Crushers + washing line + thermal dryers + centrifuge + pelletizing machines+ support =

\$800 + \$225 + \$10 + \$10 + \$400 + \$1250 = \$2695.

This plan proposed is taking into consideration the durability of the protection applied, the efficiency and the cost. One can distribute ear protection equipment to the workers and this will be the cheapest protective plan, but most of them will stop using them after a while. That is why a permanent solution is proposed.

Chapter 4

ANALYSIS

4.1 Analysis of the questionnaire

The statistical data of the questionnaire allocated into the different classifications which was explained in the previous chapter section 3.2.1. are being analyzed in this part. A response rate of 93.8 % was obtained (30 out of 32 questionnaires), the high percentage was obtained because the surveys where distributed by the CEO himself so most of the workers returned them.

4.1.1 Basic Characteristic of Workers

The first part of the questionnaire shows the different basic characteristic of the workers being subjected to the noise exposure study.

Table 4: Age distribution

		Frequency	Valid Percent
Valid	less than 20	1	3.3
	20-30	10	33.3
	30-40	11	36.7
	40-50	5	16.7
	50-60	3	10.0
	Total	30	100.0
Mean = 2.9667 Std. Error of Mean = 0.18866 Std. Deviation =1.03335			

Tables4show the age of workers and the dispersal of the worker's age in each category. Based on the numbers obtained using average of the mean, the age average of the workers was found to be between 20 and 40.

Table 5 shows the gender distribution of this plant. There was no feminine interference in this factory. This result was expected due to the roughness of the work and sever working environment.

Table 5: Gender distribution percentage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	30	100%	100%	100%
	Female	0	0%	0%	0%

Table 6 shows the highest education level for the 30 study participant. 36.7% of the participant had a high school level of education, following by an equal amount of 26.7 % having a junior high school level and a technical school level of education. 10% completed elementary school level and none of the participants reached university.

Table 6: Distribution of different educational Levels

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Elementary school	3	10.0	10.0	10.0
	Junior high school	8	26.7	26.7	36.7
	High school	11	36.7	36.7	73.3
	Technical school	8	26.7	26.7	100.0
	University	0	0	0	100.0
	Total	30	100.0	100.0	

Table 7 shows the distribution of work experience in each group, the majority of the workers are new in this field and they have been working for one month (30 %). Here it might be very useful to consider the noise reduction plans proposed in section 3.3.2. Maybe noise reduction will lead to more stability in workers commitment to working in this plant. Meaning that noise could be one of the major reasons why workers do not stay for too long in this factory and there for an endless search for new workers is always taking place and therefore more wasted product, time and higher cost on teaching new worker the adopted working routine.

Table 7: Distribution of work experience

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 month	9	30.0	30.0	30.0
	1-6 month	8	26.7	26.7	56.7
	6-12 month	5	16.7	16.7	73.3
	1-3 years	4	13.3	13.3	86.7
	more than 3 years	4	13.3	13.3	100.0
	Total	30	100.0	100.0	

To check if there is a relation between age and education level a one way analysis of variance (ANOVA) was done. As shown in table 8the F_0 ratio is found to be less than $F_{0.05,3,26}$ = 2.98. Therefore, H_0 failed to reject mean equality between age and education.

Table 8: Analysis of variance between age and education

		Sum of Squares	df	Mean Square	F	Sig.
age * education	Between Groups	1.308	3	.436	.382	.767
	Within Groups	29.659	26	1.141		
	Total	30.967	29			

4.1.2 Basic Working Conditions

Table 9 shows the position of employees in their working place. 100% of workers responded standing. As previously explained the recycling industry is a tough industry where high mobility is needed from the worker. That is why all the workers are working in a standing position. It was noted that in some machine’s worker can sit while waiting the machine’s cycle to be done. However, employer did not offer any chairs for workers and when asked about this issue, he cleared that workers tend to lose a lot of time when having a chair and therefore much less productivity will be obtained.

Table 9: Sitting and standing position representation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Standing	30	100.0	100.0	100.0
	Sitting	0	0	0	100.0

Table 10 presents the daily shifts of the workers. All the workers have a fixed shift which is more than 8 hours per day. This plant works with a 12 hours two shift per day system.

Table 10: Daily shifts representation

		Frequency	Percent	Valid Percent	Cumulative Percent
	Less than 6 hr	0	0	0	0
	6 to 8 hr	0	0	0	0
Valid	more than 8 hr	30	100.0	100.0	100.0

Table 11 shows the distribution of workers operating a machine in the work place. 76.7% of the workers are operating a machine while 23.4% are doing multiple jobs during their working hours.

Table 11: Workers operating machines

		Frequency	Percent	Valid Percent	Cumulative Percent
	YES	23	76.7	76.7	76.7
Valid	NO	7	23.3	23.3	100.0
	Total	30	100.0	100.0	

Table 12 shows the daily duration of operating a machine for the workers that answered the previous question with a "YES". 23 out of 30 workers answered this question with a 7 to 9 operating hours per day. The remaining lost hours are due to maintenance and to lunch break for the workers. The remaining 7 workers did not answer this question since they are not operating a machine.

Table 12: Machine operating duration

		Frequency	Percent	Valid Percent	Cumulative Percent
	no answer	7	23.3	23.3	23.3
Valid	7-9 hour	23	76.7	76.7	100.0
	Total	30	100.0	100.0	

4.1.3 Analyzing Common Noise Symptoms

Table 13 present the number of workers suffering from a high blood pressure. 43.4% of the workers were diagnosed with high blood pressure while 56.7% of the workers had no high blood pressure.

Table 13: Blood Pressure among workers

		Frequency	Percent	Valid Percent	Cumulative Percent
	YES	13	43.3	43.3	43.3
Valid	NO	17	56.7	56.7	100.0
	Total	30	100.0	100.0	

Table 14 represents a comparison of variance (ANOVA) between the age and having a blood pressure. Note that F_0ratio is higher than $F_{0.05,1,28}$ = 4.20. Therefore F_0 is rejected and mean of having a high blood pressure and different age categories differ.

Table 14: ANOVA test for blood pressure vs age

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.618	1	5.618	6.206	.019
Within Groups	25.348	28	.905		
Total	30.967	29			

70% of the workers are found to be subjected to other medical problems while only 30% do not have any medical problems (table 15).

Table 15: Medical problems among workers

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	21	70.0	70.0	70.0
	NO	9	30.0	30.0	100.0
	Total	30	100.0	100.0	

The pie chart below represents the different types of medical problems among workers where reported having other medical conditions. As shown in figure 9, 28% of the workers suffer from allergy, 29.05% from peripheral vascular disease, 14.29% from diabetes, 14.29% from and disc back pain and 23.81% from other medical problems.

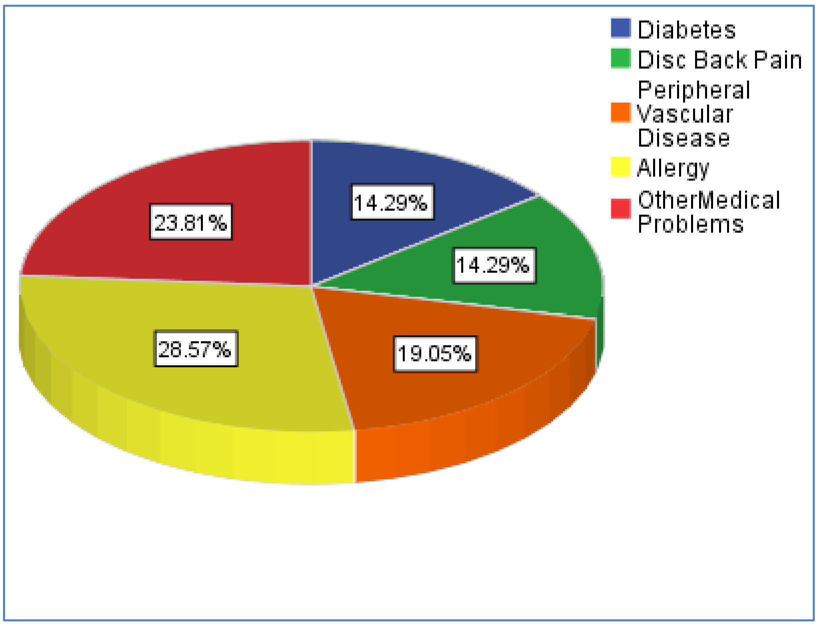

Figure 9: Distribution of medical problems among workers

Table 16shows the frequency of noise annoyance along with the previously mentioned symptoms of being subject to a continuous high noise level such as headache, speech interference, and stress. It has been noticed that the majority of workers reported being disturbed from the high noise level with a 30% to an always answer, 36.7% to often and 23.3% to sometimes. It was noticed that very few workers did not report being disturbed with a 6.7% to a never answer and 3.3% to seldom. The same high percentage continue to appear when asked about headache while or after working in a noisy environment; 13.3% answered always, 40% answered often, 36.7 % answered sometimes. While only 6.7% reported seldom and 3.3% never. Almost, the same results were obtained when asked about speech interference with a high noise level. 9 workers out of 30 (30%) confirmed always having speech interference, 10 out of 30 (33.3%) reported they are often subjected to it, while 7 out of 30 (23.3%) answered sometimes, 3 out of 30 (10%) for seldom and 1 out of 30 (3.3%) for never. Finally, the workers were asked about whether they feel stressed while or after working in a noisy area. The majority answered with an often choice with 36% and sometimes with 33.3% while the other answers were distributed as follows: 20% always, 16.7% seldom and 3.3% never.

Table 16: Frequency of noise annoyance, headache, speech interference and stress in a noisy environment

		Valid					
		Always	Often	Sometime	Seldom	Never	Total
Annoyed or disturbed by high noise level	Frequency Valid percent	9 30	11 36.7	7 23.3	1 3.3	2 6.7	30 100.0
Headache while or after due to high noise level	Frequency Valid percent	4 13.3	12 40.0	11 36.7	2 6.7	1 3.3	30 100.0
Speech interference with high noise level	Frequency Valid percent	9 30.0	10 33.3	7 23.3	3 10.0	1 3.3	30 100.0
Feel stressful while or after working in noisy area	Frequency Valid percent	3 10.0	11 36.7	10 33.3	5 16.7	1 3.3	30 100.0

The majority of the worker's answers were centered mainly on both often and sometimes category shown in figure 4.2 which shows the existence of a noise problem in this factory.

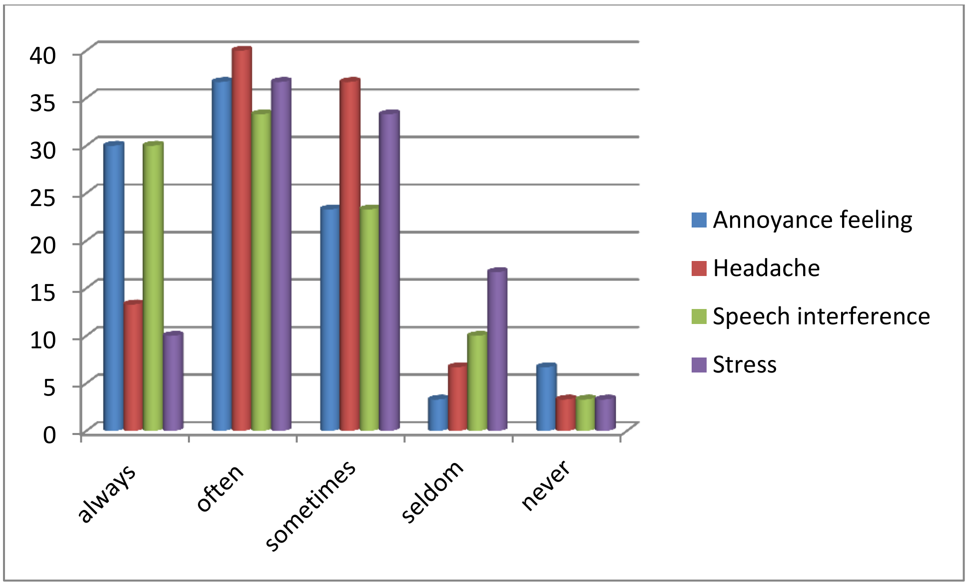

Figure 10: Distribution of noise annoyance and symptoms (in %)

The majority of workers (60%) do not listen to music using earplugs while only 40% of them use them.

Table 17: Number of workers using earplugs to hear music

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	12	40.0	40.0	40.0
	NO	18	60.0	60.0	100.0
	Total	30	100.0	100.0	

Table 18 shows the ANOVA test to check if there is a relation between listening to music and feeling annoyed. The F_0 ratio obtained was found to be less than $F_{0.05,1,28}$ =4.20. Thus, H0 failed to reject and mean of workers annoyance and listening to music does not differ.

Table 18: ANOVA test between workers annoyance and listening to music

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.939	1	2.939	2.430	.130
Within Groups	33.861	28	1.209		
Total	36.800	29			

4.1.4 Analyzing Awareness of The Importance of Ergonomic

Table 19 shows the knowledge of the workers about high noise levels, the benefits of using ear protection, weather the manager force them to use ear protection or not, if personally they use ear protection equipment and if the workers received any training concerning safety and ergonomics.

70% of the workers do not know about the hazardous effect of high noise levels. 66.7% of them are not aware of the benefits of using ear protection equipment as well. All the workers confirmed that they are not forced by the manager to wear ear protection equipment, that they do not use them and that they did not receive any training concerning safety and ergonomics.

Table 19: Representation of plant's state regarding high noise protection

		YES	NO	Total
Information about hazardous effect of high noise levels	Frequency	8	22	30
	Valid percent	26.7	73.3	100.0
Awareness of the benefit of using ear protective equipment	Frequency	10	20	30
	Valid percent	33.3	66.7	100.0
Workers forced by manager to use ear protection equipment	Frequency	0	30	30
	Valid percent	0	100.0	100.0
Usage of ear protection equipment	Frequency	0	30	30
	Valid percent	0	100.0	100.0
Training about safety and ergonomics	Frequency	0	30	30
	Valid percent	0	100.0	100.0

4.1.5 Analyzing Attentivenessto Noise and Hearing Protection Equipment

In table 20 it was noted that 40% of the workers agree that exposure to high noise levels can cause temporary hearing loss. However, most of them (40%) had no opinion if high noise levels can permanently affect hearing. 50% of them have no opinion as well is all hearing protectors offer the same protection and 56.7% had no opinion if the duration of wearing ear protection can contribute in the protection against high noise levels. Finally, 60% of the workers also showed lack of knowledge on whether there are different types of hearing protection equipment or not.

Table 20: Representation of worker's knowledge of hearing loss and ear protection equipment

		Valid					
		Strongly agree	Agree	No option	Disagree	Strongly disagree	Total
Temporary Hearing loss can be caused by high noise exposure	Frequency Valid percent	7 23.3	12 40.0	9 30.0	1 3.3	1 3.3	30 100.0
High noise levels can permanently affect hearing	Frequency Valid percent	4 13.3	11 36.7	12 40.0	3 10.0	0 0	30 100.0
All hearing protectors offer the same protection	Frequency Valid percent	1 30.0	7 23.3	15 50.0	6 20.0	1 3.3	30 100.0
Protection of hearing depends on the duration of ear protection equipment used	Frequency Valid percent	1 3.3	8 26.7	17 56.7	3 10.0	1 3.3	30 100.0
There are several types of hearing protection equipment	Frequency Valid percent	3 10.0	6 20.0	18 60.0	2 6.7	1 3.3	30 100.0

4.1.6 Analyzing Awareness of the Working Environment Risks

30% of the workers agreed that there is no need to use ear protection equipment in the work place while 33.3% had no opinion about it. In addition, 40% has no opinion is the noise in the work place is dangerous or not. Some of the workers try to avoid being exposed to high noise levels (30%) whereas 33.3% had no opinion if they are avoiding this high noise level or not. Finally, concerning the general state of the noise in the plant, 40% of the workers had no opinion if noise can be reduced in their working area and 26.7% agreed that the noise reduction can be applied to this plant.

Table 21: Representation of worker's knowledge of the hazards of his working environment

		Valid					
		Strongly agree	Agree	No option	Disagree	Strongly disagree	Total
In my work place ear protection is not necessary	Frequency Valid percent	3 10.0	9 30.0	10 33.3	6 20.0	2 6.7	30 100.0
Noise is not dangerous in my work place	Frequency Valid percent	2 6.7	5 16.7	12 40.0	8 26.7	3 10.0	30 100.0
I avoid being exposed to high noise levels	Frequency Valid percent	2 6.7	9 30	10 33.3	4 13.3	5 16.2	30 100.0
It is possible to reduce noise level in my work place	Frequency Valid percent	6 20.0	8 26.7	12 40.0	3 10.0	1 3.3	30 100.0

4.2 Correlation Analysis

To find out the relationships among the collected data by the distributed questionnaire correlation analysis was used. By definition, the correlation strength is within the interval between 0 and 1 (M. Li *et al*., 2002). In the case of positive linear relationship, the correlation is +1 and in the case of perfect decreasing linear relationship the correlation is -1 and the values between +1 and -1 indicate the degree of linear dependence between variables. The closer the coefficient is to either -1 or +1 the stronger the relationship between variables exists. Twenty two variables in the questionnaire were tested to check the correlation among them (age, education level, how long the worker has been doing the job, if he is operating a machine, duration of operation, the existence of high blood pressure, the existence of other medical problems, having a headache, having speech interference, having stress, listening to music through earplugs, knowledge of noise effect, knowledge of ear protection importance, avoid noise exposure, relation between high noise and hearing loss, knowledge of different types of hearing protectors, if protection depend on duration, knowledge of noise in the workplace, importance of ear protection in the workplace, knowledge of different types of hearing protection, if worker avoid himself from noise, possible noise reduction in the workplace).

The highly correlated variables in the questionnaire where the correlation coefficient is greater than r=0.5 are shown in table 4.18.

Table 22: Highly correlated variables in the questionnaire

Variable 1	Variable 2	Correlation coefficient
Noise reduction at the workplace	Education level	0.605*
The worker avoid himself from being subjected to noise	Having a high blood pressure	0.515*
Having stress	Having speech interference	0.517*

4.3 Linear discriminant analysis (LDA)

Fisher linear discriminant analysis (LDA) is a popular supervised subspace learning technique and has been widely used in computer vision, pattern recognition and machine learning. It looks for a linear transformation such that in the transformed subspace the between-class covariance relative to the within-class covariance is maximized (Zhao *et al*., 2012). LDA aims to seek a lower-dimensional subspace by maximizing the ratio of the between-class scatter to the within-class scatter, finally boiling down to solving a generalized eigenvalue problem (Chen *et al.*, 2012).

To predict the categorical variables and to find a linear combination of variables and different categorical independent classes LDA method was used.

LDA doesn't change the location but only tries to provide more class separation and draw a decision region between the given classes. This method also helps to better understand the distribution of the feature data (Balakrishnama and Ganapathiraju, 1998).

The dependent variable was chosen to be question 12 in the survey: "how often do you get annoyed or disturbed by the high noise level in your workplace? ".

This question is a 5 level categorical question.

The coefficients of the independent variables are presented in table 23.

The classification score follows the following general formula:

$$Y = \beta_0 + \beta_1 * X_1 + \beta_2 * X_2 + \ldots + \beta_n * X_n$$

Table 23: Linear discriminant function

	Function			
	1	2	3	4
Age	2,190	,091	,330	-,282
Education	-2,559	,411	,112	-,205
Working Duration	-,242	,378	,318	1,278
Op_Machine	-2,338	,362	,364	,694
Operating Machine	-1,134	-,441	,011	1,384
Medical Problems	2,384	-,372	-,100	,177
Headache	1,147	-,608	-,157	,735
Speech	-,485	-,635	,260	-1,261
Stress	,140	-,323	-,597	,402
Listen to music through earplugs	-2,713	,291	-,073	,512
Information about Noise effect	1,286	-,673	-,126	,000
Ear protection knowledge	3,721	,287	,260	-,297
Exposure to high noise	,928	,157	1,179	,477
Noise affect hearing	-3,652	-,072	-1,267	-,054
All hearing protection are the same	2,787	,568	-,041	-,885
Protection depend on duration	3,180	-,515	,855	-,063
No need for ear protection in my workplace	2,470	-,050	,649	,902
No noise danger in my workplace	1,264	,076	,464	,370
Knowledge of types of ear protection	3,015	1,171	-,045	,379
I avoid high noise	5,403	,188	,721	-1,351
Possibility of noise reduction in my workplace	1,954	,003	,199	-,015

4.4 Hypothesis Testing

The mean of sound generated by machines depending on days, time and different machines was represented in figure 11.

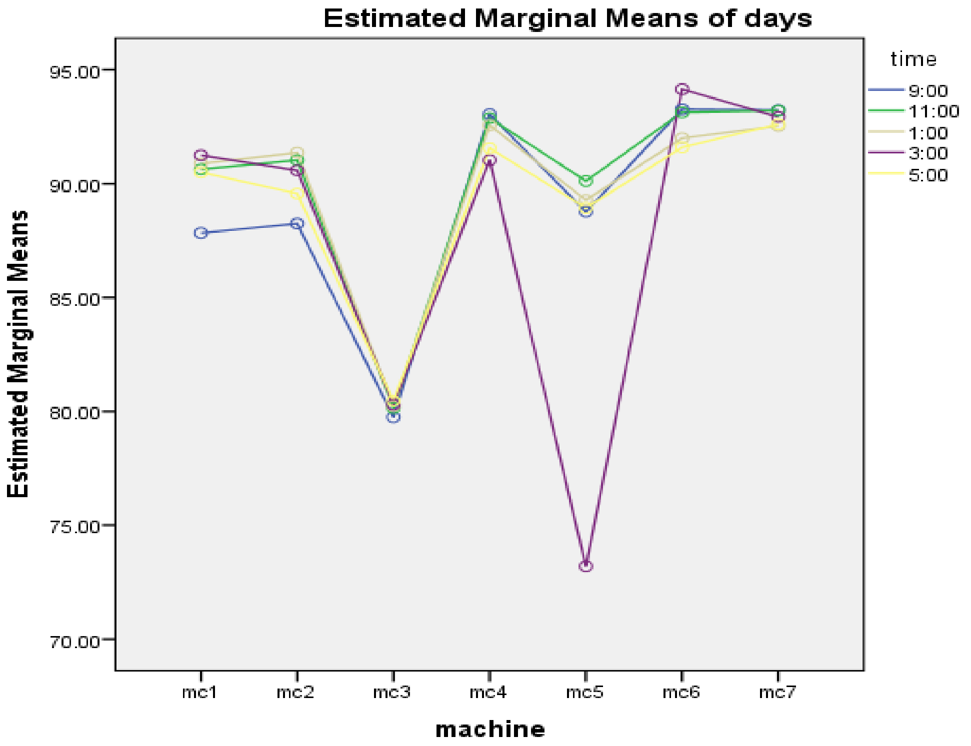

Figure 11: The estimated marginal means

The equivalent sound level (Leq) at the center of the plant was taken for the 6 measuring days and the mean and standard deviation where shown in table 24.

The mean obtained for 6 days and 5 repetition per day was 97.58 dB(A) with a standard deviation of 1.178. This high sound level shows a dramatic problem for a 12 hours daily shift.

Table 24: Equivalent sound level at the center of the plant

N	Valid	30
	Missing	0
Mean		97.5800
Std. Error of Mean		.21525
Std. Deviation		1.17895

To check the validity of this assumption a hypothesis testing was done.

The null hypothesis was suggested to be: mean noise generated does not differ among machines. Meaning that the worker is subjected to high noise level despite the machine he is standing in front of.

H0: μ1 = μ2 = μ3 = μ4 =μ5 = μ6 =μ7

H1: μ1 ≠ μ2 ≠ μ3 ≠ μ4 ≠μ5 ≠ μ6 ≠μ7

The Levene's test of equality of error variances was performed in table 25.

With a significance P-value less than 0.05 the null-hypothesis was rejected.

Table 25: Levene's Test of Equality of Error Variancesa

F	df1	df2	Sig.
5.593	34	175	.000

Table 26 shows the two factor factorial design of random effects. It was noticed that F_0 for time is less than $F_{0.05,\ 4,175}$ = 2.37. Hence, H_0 failed to reject and mean of time and noise measurements taken do not differ.

Considering the machines now, it was noticed that F_0 is higher than $F_{0.05,\ 6,\ 175}$ = 2.10 and so H_0 was rejected and the mean of the machines and noise measurements taken differ.

Finally, the most important notice was the connection between the different times, the different machines and the noise measurement taken. It was noticed that F_0 is less than $F_{0.05, 24, 175} = 1.52$. Therefore, H_0 was failed to reject and the mean of sound measured does not differ from one machine to another according to different times.

Table 26: Two factor-factorial analysis

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5254.481[a]	34	154.544	3.966	.000
Intercept	1671840.054	1	1671840.054	42908.590	.000
Time	159.660	4	39.915	1.024	.396
Machine	3876.427	6	646.071	16.582	.000
time * machine	1218.394	24	50.766	1.303	.168
Error	6818.495	175	38.963		
Total	1683913.030	210			
Corrected Total	12072.976	209			

Chapter 5

DISCUSSION

The maximum OSHA exposure limit of 90 dBA was exceeded by this factory. This may cause different harmful effect on workers.

Shifts records have shown no stability for workers in such rough environment and therefore reasons why workers are quitting their jobs within a month was taken into consideration. Since the financial state and the minimum living standards were offered by the company, high noise was more likely to be of great contribution in worker's early quitting their jobs.

In this study 76.7% of workers were operating a machine. However, it was shown that the noise exposure is not only limited to machine operators but rather the sound levels measured at the center of the plant exceed OSHA standards as well.

In addition workers exceeded the OSHA standards for occupational exposure to high noise levels due to their long shifts. All the workers reported a more than 8 hours shift per day in such a noisy environment.

Different economical affordable approaches that can have an extreme effect on noise reduction were suggested in section 3.3.3. Even though such solutions may cost the employer some extra cost but they can save the high hiring-firing situation in this plant and therefore maintain a stable noise friendly process line.

5.1 Results Discussion

The statistical summary of the questionnaire distributed to 30 workers in Lebanon showed that the workers age was found to be between 20 and 40 years old. As for the gender all of the workers were males. As for the education level, it was ranging between junior high school, high school and technical school but university degrees. Also, age and education level showed a significant relation with each other.

The results obtained and showed in chapter 4 were consistent with the high noise symptoms showed in chapter 1. Workers subjected to high noise levels showed different symptoms such as speech interference, headaches, feeling stressed, feeling disturbed and sometimes high blood pressure. However, no significant relation was found between the different age categories and having a high blood pressure.

High correlation was found between the opinion of possible noise reduction in the workplace and the education level of the worker. Also, this relation was found between workers avoiding them self from being subjected to high noise level and having a high blood pressure and finally it was found between having stress during working or after working hours and having speech interference.

73.4% of workers lack the essential knowledge about hazardous effect of high noise level. Likewise, 66% are not aware of the benefits of using ear protective equipment. This absence of knowledge was linked to the fact that all the workers did not receive any training regarding safety and ergonomics.

All the workers did not use any ear protecting equipment because employers did not offered any and when asked about the reason, they clarified that they tried to introduce ear protection to the regular working routine but most of workers seems to ignore them or throw them away. Thus, when trying to apply the effective sound reduction proposed method it is very important to consider the ones on the source or the path before considering the receiver which is the worker in this case. This will provide a permanent more effective solution to the high noise level generated in the plant. In the case where machines are not ordered yet it is better to have some control at the design level and purchasing less noisy machinery than applying protective technics later on.In a developing country such as Lebanon it is very rare that we see effective application of health and safety programs and consideration of OSHA standards. Therefore, small short times trainings and seminars are very important for workers and can transmit the knowledge required to stay safe.

Workers by nature showed tendency to avoid noise even though most of them do not know about the impact of high noise levels on human body.

When asked about the possibility of noise reduction in the work place 60% of the workers seemed to have no opinion regarding this issue. So, an effective illustration of the importance of personal protective equipment could be very useful and could encourage workers to wear them.

The results obtained from the questionnaire were confirmed by the measurement taken from the machines showing that no matter where the working is standing in the plant, he is subjected to a high noise level exceeding the acceptable threshold imposed by OSHA standards.

This study showed the essential need for an effective and efficient application of the OSHA standards to protect workers in Lebanon.

Chapter 6

CONCLUSION

Attention to ergonomics is spreading broadly in recent years. Giving higher productivity and working conditions and thus ensuring satisfaction for both employers and employees. This growing knowledge in ergonomics has led to a significant development of different industries. One of the major hazards studied by ergonomics is noise. Noise is found to be one of the main threats in industries. High or continuous noise levels can cause permanent hearing loss. Industrial noise is mainly found in non-developed countries such as Lebanon, where no new technologies are introduced to the production process. However, in such a country having low minimum wages salaries, low investment prices and cheap raw material it is essential to apply strategic plans to insure development of industry and thus less suffering for the workers to get higher production. Therefore, it is very important to adopt noise reduction technics and different ergonomic approaches in those industries. Applying those principals to this factory, high noise levels where detected and so proper, cheap and efficient noise reduction solutions were proposed.

Unfortunately, countries such as Lebanon industry is still too far from applying effective noise reduction programs and educating workers about the high impact of noise and how avoiding noise can help them avoid the symptoms they are suffering from.

The chamber of commerce and industry in Lebanon should start applying different noise reduction programs and should try to educate both employer and employees. As a first step they can start with the importance of personal protective equipment since it is the cheapest alternative hence, all parties will accept it; workers once educated about their importance will start using them and supervisors will provide them.

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APPENDICES

Appendix A: Machines representation

Shredding machine

Washing line

Centrifuge

Thermal dryer

Plastic pelletizing machine

Appendix B: Questionnaire

This questionnaire is prepared to improve noise aspect on workers in this factory and others in Lebanon. This study is a part of a master thesis taking place in EMU. The information will remain confidential in case of format publication

1) How old are you?

Less than 20	20-30	30-40	40-50	Above 50

2) What is your gender?

Male	Female

3) What is your education level?

Elementary school	Junior high school	High school	Technical school	University

4) How long have you been doing this job ?

1 month	1-6 month	6-12 month	1-3 years	More than 3 years

5) Are you working in a standing or sitting position?

Standing	Sitting

6) How long is your shift?

Less than 6 hr	6-8 hr	More than 8 hr

7) Are you working with or operating a machine in your work place?

Yes	No

8) If your answer to question 7 was “YES” how long do you operate a machine during the day?

1 hr	1-3 hr	3-7 hr	7-9 hr	More than 9 hr

9) Do you have high blood pressure?

Yes	No

10) Do you have any other medical problems?

Yes	No

11) If the answer to question 10 was “YES” please specify the case :

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

12) How often do you get annoyed or disturbed by the high noise level in your workplace?

Always	Often	Sometime	Seldom	Never

13) How often do you have any headache while working or after working due to high noise level?

Always	Often	Sometime	Seldom	Never

14) How often do you have speech interference with high noise at your work place?

Always	Often	Sometime	Seldom	Never

15) How often do you feel stressful while working or after working in a noisy area ?

Always	Often	Sometime	Seldom	Never

16) Do you listen to music using earplugs?

Yes	No

17) Do you have information about the hazardous effect of high noise levels?

Yes	No

18) Are you aware of the benefit of using ear protection equipment ?

Yes	No

19) Does your manager or head of the factory force you to use ear protection when you are working in noisy area?

Yes	No

20) How long do you use ear protection equipment during your working hour?

Always	Often	Sometime	Seldom	Never

21) If you do not use ear protection what is the reason(s)?

……
……
…………………………………….

22) Did you have any training about safety and ergonomics?

Yes	No

23) If the answer is "YES", give a brief description?

……
……
……………….

Please (X) the most appropriate choice:

24) Exposure to high noise levels can cause temporary loss of hearing

Strongly agree	Agree	No opinion	Disagree	Strongly disagree

25) High noise levels can permanently affect hearing

Strongly agree	Agree	No opinion	Disagree	Strongly disagree

26) All hearing protectors offer the same protection

Strongly agree	Agree	No opinion	Disagree	Strongly disagree

27) Protection of hearing depends on the duration of ear protection equipment use in each day

Strongly agree	Agree	No opinion	Disagree	Strongly disagree

28) There is no need to use ear protection equipment in my work place

Strongly agree	Agree	No opinion	Disagree	Strongly disagree

29) Noise in my work place is not dangerous

Strongly agree	Agree	No opinion	Disagree	Strongly disagree

30) There are several types of hearing protection equipment

Strongly agree	Agree	No opinion	Disagree	Strongly disagree

31) I, avoid myself from being exposed to high noise level

Strongly agree	Agree	No opinion	Disagree	Strongly disagree

32) It is possible to reduce the noise level in my workplace

Strongly agree	Agree	No opinion	Disagree	Strongly disagree