NOISE ASSESSMENT OF SHIPYARD WORKERS

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ABSTRACT

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Noise is one of the most important health risks in workplaces worldwide and NIOSH identified noise as one of the 10 important occupational problems. In OSHA's hearing conservation amendment it is stated that in U.S., more than 5 million workers are exposed to potentially hazardous levels of noise in manufacturing and utilities. In 1981 OSHA estimated that, at least one million workers in industry had undergone occupational hearing loss. Ship building has been one of the most promising and rapidly growing industries in Turkey in the recent years. It comprises many production techniques and activities, requires qualified personnel and compliance with several class institutions making the job interesting for the enthusiastic engineers and workers. However shipyard workers are subject to high levels of noise besides other health risks. The aim of this study is to figure out the effect of noise on shipyard workers. For this purpose 2 factories, namely Factory 1 and Factory 2 in a shipyard were chosen and two methods were adopted. The first method was the subjective evaluation of the workers through questionnaires distributed to them, whereas the second method involved the noise level measurement during their work hours. At all the points in Factory 1 where noise level measurements have been done, higher A-weighted values of noise than the limits stated in the legal regulations were found. In Factory 2, noise levels were all below the action value of 85 dBA .Dose measurements of the workers displayed the extremely variable acoustical conditions that the workers encountered. According to the “Noise Regulation” of Ministry of Labour and Social Security and “The European Noise Directive”, the employer seems to be obliged to measure periodically and to assess the level of noise exposure of workers in Factory 1 and take immediately the necessary precautions. Ear plug performance and speech interference conditions were also examined.

Key words: questionnaire, noise level measurements, dose level measurements, EU directives, ISO standards, ear plug.

ÖZ

TERSANE İŞÇİLERİNİN MARUZ KALDIĞI GÜRÜLTÜNÜN DEĞERLENDİRİLMESİ

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Gürültü, tüm dünyadaki işyerlerinde en önemli sağlık risklerinden biri olup, NIOSH tarafından en önemli 10 mesleki sağlık tehdidinden biri olarak tanımlanmıştır. OSHA'nın işitme sağlığı ile ilgili ekinde, Amerika Birleşik Devletlerinde 5 milyondan fazla işçinin çalıştıkları tesis ve imalathanelerde potansiyel olarak sağlığa tehlikeli seviyelerde gürültüye maruz kaldığı belirtilmiştir. 1981 yılında OSHA, endüstride çalışan en az 1 milyon işçinin mesleki kaynaklı işitme kaybına uğradığını açıklamıştır. Gemi inşa sanayi son yıllarda Türkiye'nin en hızlı gelişen ve gelecek vadeden endüstriyel sektörlerden biridir. Bir çok üretim teknik ve etkinliğini içermesi, nitelikli işgücü ve birçok klas kuruluşuna uygunluk gerektirmesi nedeniyle bu sektör, mühendis ve işçiler için ilginç bir iş kolu niteliğini kazanmıştır. Ancak tersane işçileri, sağlıklarını tehdit eden bir çok unsura ilaveten yüksek seviyelerde gürültüye de maruz kalmaktadır. Bu çalışmanın amacı gürültünün tersane işçileri üzerindeki etkisini ortaya çıkarmaktır. Bu amaçla bir tersanedeki Fabrika 1 ve Fabrika 2 olarak adlandırılan iki fabrika seçilmiş ve iki yöntem uygulanmıştır. Birinci yöntem işçilerin, kendilerine dağıtılan anketler aracılığı ile öznel olarak değerlendirilmesi iken ikinci yöntem mesai saatleri içinde gürültü seviyesi ölçümlerinin icra edilmesi olmuştur. Fabrika 1 içindeki tüm noktalarda gürültü seviyesi yönetmeliklerde belirtilen limit değerleri aşmıştır. Fabrika 2 içinde ise gürültü seviyelerinin 85 dBA değerinden düşük olduğu görülmüştür. Doz ölçümleri ise işçilerin karşı karşıya kaldığı çok yüksek derecelerde değişken akustik şartları göz önüne sermiştir. Çalışma ve Sosyal Güvenlik Bakanlığı ile Avrupa Birliği'nin gürültü yönetmeliklerine göre, tersane yönetiminin Fabrika 1 de periyodik olarak gürültü ölçümü ve değerlendirmesi yaparak, sonuçlara göre gerekli tedbirleri alması gerekmektedir. Bu çalışma esnasında, kulak koruyucuların performansı ve konuşma interferansı da ayrıca incelenmiştir.

Anahtar Kelimeler: anket, gürültü seviyesi ölçümleri, doz seviyesi ölçümleri, Avrupa Birliği yönetmelikleri, ISO standartları, kulak koruyucu.

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CHAPTER I

INTRODUCTION

Noise is one of the most important health risks in workplaces worldwide [1]. NIOSH identified noise as one of the 10 important occupational problems in the conference of "Proposed National Strategies for the Prevention of Leading Work-Related Diseases and Injuries". In OSHA's hearing conservation amendment it is stated that more than 5 million workers are exposed to potentially hazardous levels of noise in manufacturing and utilities. In 1981 OSHA estimated that, at least one million workers in industry had undergone occupational hearing loss, greater than 25 dB at the averaged audiometric frequencies of 1000, 2000, and 3000 Hz.

Ear is a very sensitive organ [2]. We can tell apart 400 000 different sounds with our ears and we can hear sounds as low as ones causing the ear drum vibrating with a magnitude of less than 1/80 000 000 of an inch. Sensitivity however changes from individual to individual, depending on many factors like age, noise exposure, smoking and other health factors.

Ear is a three stage organ:

1. Outer Ear (Pinna, External Auditory Canal)
2. Middle Ear (Ear Drum, Bones)
3. Inner Ear (Cochlea, Nerve Endings)

By definition sound is the pressure fluctuation in air and principally hearing is sensing these pressure changes using the mechanism explained below:

Sound waves are collected in the outer ear and directed to inner ear via the external auditory canal. Vibration of the eardrum moves the small bones and vibration is transferred to sensory hair cells in cochlea transforming the vibrations to nerve pulses, which eventually stimulate the relevant part of the brain. Hearing loss occurs due to the damaged hair cells not being able to send pulses to the brain. The primary effects of excessive noise exposure may include [3]:

(i) Acoustic trauma: a temporary or permanent hearing loss due to a sudden, intense, acoustic or noise event, such as an explosion.

(ii)Tinnitus: the condition of "ringing in the ears”. Individuals often describe the sound as a hum, buzz, roar, ring, or whistle. The inner ear or neural system produces the actual sound. The predominant cause of tinnitus is long-term exposure to high sound levels, though it can also be caused by short-term exposure to very high sound levels, such as gunshots. Non-acoustic events, such as a blow to the head, dietary issues, stress, jaw joint disorders, debris on the eardrum, or prolonged use of aspirin may also cause tinnitus. Many people experience tinnitus during their lives. Most of the time the sensation is only temporary, however, it can be permanent and debilitating. Diagnosis and treatment of tinnitus can be difficult because it is a subjective measurement.

A noise-induced temporary threshold shift (NITTS) is a temporary loss in hearing sensitivity. NITTS may be the result of the acoustic reflex of the stapedial muscle, short-term exposure to noise or the fatigue of the inner ear. With NITTS, hearing sensitivity will return to the pre-exposed level in a matter of hours or days, assuming that there is not continued exposure to excessive noise.

A noise-induced permanent threshold shift (NIPTS) is a permanent loss in hearing sensitivity due to the destruction of sensory cells in the inner ear. This damage can be caused by: long-term exposure to noise and acoustic trauma.

Noise-induced hearing loss like other neurological deficits, degrades, even destroys the quality of life [1]. Hearing impairment not only decreases the ability to hear music and the sounds of nature, but, more importantly, it prevents human relations and communication, especially in groups or in noisy backgrounds. The handicap of hearing impairment eventually leads to loneliness, isolation, depression, and lowered self-esteem as a result of keeping away from social interactions.

Apart from causing damage to the ear noise can cause stress on the individual [4]. Ising et al. [5] also points out the non auditive health effects of noise independent of the level. According to his study, noise not only results in stress reactions in the body like changes in peripheral blood circulation and galvanic skin resistance which can not be classified as pathologic, but also serum concentration of cholesterol and triglyceride and high blood pressure. Friesen et al. [6] found a statistically significant relevance between noise exposure and myocardial infarctions. In Rylander's study [7] the reactions of human body when exposed to noise are explained which are warning/alert reflexes; "orienting response" which is for pointing the head and eyes towards the source of the noise, "startle reflex" which is eye blinking, contraction of middle ear, limbs and other muscles, "defence/flight reaction" which is the extension of the previously mentioned reactions and aims readiness for fleeing or fighting for life. All these reactions cause increase in skeletal muscle tension and pulse rate, slower breathing and thus result in increase in blood pressure and heart rate, decrease in salivary and gastric secretion. All these indicate a disruption of the equilibrium of body physical functions initiating stress reactions in the central nervous system that may induce annoyance and high blood pressure.

According to Kempen et al. [8] noise exposure is associated with a number of health effects. We can distinguish psychosocial responses such as annoyance, sleep disturbance, disturbance of daily activities and performance and physical responses such as hearing loss, hypertension and ischemic heart disease. Currently there is much discussion about how noise can affect human health and well being. Stress is supposed to play an important role and can be seen as a coping reaction of the body using physiologic reflexes; fight and flight. In her study she concludes that a statistically significant increase in blood pressure level was evident in occupational noise exposure and the association between occupational noise exposure and hypertension is statistically significant.

Noise exposure is not a fatal problem; however, it is a work safety concern as high levels of noise and the resulting hearing losses contribute to industrial accidents [1]. Additionally hearing protection devices, which are worn to prevent noise-induced hearing loss, may actually jeopardise work safety under certain conditions. Adverse effects of noise exposure is not limited to hearing problems, it also adversely affects general health, and the cardiovascular system in particular, which directly affects mortality.

Arezes et al. [9] mentions the relation between work safety and noise levels. In his study he states that there are obvious advantages, beyond hearing preservation in reducing occupational noise exposure like reduction in absenteeism and accidents.

Ship Construction has been one of the most promising and rapidly growing industries in Turkey in the recent years. It comprises many production techniques and activities, requires qualified personnel and compliance with several class institutions making the job interesting for the enthusiastic engineers and workers. However it is also a branch of industry where a number of safety and health risks should be taken into account such as emissions of gases, working on high altitudes, heat and noise exposure. A number of academical studies have been conducted to investigate the aforementioned health risks but researches on shipyard workers are limited.

The aim of this study is to figure out the effect of noise on shipyard workers. For this purpose two factories in shipyard are selected. Major activity of one of the factories is ship hull production comprising mainly metal sheet cutting, grinding and welding while the other factory is the workshop for the production of various pieces of the ship machinery where a variety of work benches are present. Ship hull factory will be referred to as Factory 1, and machinery factory will be referred to as Factory 2 in the rest of this study.

In order to find out the effect of noise on the workers two methods were adopted [10]. The first method was the subjective evaluation of the workers through questionnaires distributed to them, whereas the second method involved the noise level measurement during their work hours. The total number of the workers in the two afore-mentioned factories was 94. General outlines of these two methods are given in the following chapters.

CHAPTER II

QUESTIONNAIRE SURVEY ON WORKERS

2.1. Preparation of Questionnaire

It is commonly believed that if the objective is to find the impact of noise on the person, it would be best to start with how that individual feels and thinks on what he is subjected to. Based on this belief a questionnaire consisting of 41 questions was prepared. Questions were organised under five headings; “Personal Information” such as age, sex, height and education, “Tasks Performed by the Workers” : type of tasks, working times, expertise, working tools, benches, extra work and shifts , working habits (his posture in working time, usage of protective devices, how much and how long he works, vacation), “Rating of Perceived Noise and its Effects”: perception level of noise in the factory, its effect on job productivity and other activities of workers, “Rating of Conservation of Hearing”: ear-plug usage, “Health Information”: hearing and ear problems, cholesterol, smoking and blood pressure.

According to Fields et al. [11] a noise reaction survey has to:

1. Permit valid international and national comparisons.
2. Show high quality and reliable measures of reactions.
3. Display clear results for the authorities who will make use of them.
4. Yield equally spaced response answers.
5. be internationally adoptable.

Questionnaire of Preis et al. [12] was regarded generally as the one that satisfied the criteria stated above and is taken as basis in this study while preparing the questionnaire. In the afore mentioned article questions related to the perceived noise level and its effect on job productivity (efficiency) consist of a 5-point verbal scale (not at all, a little, rather, substantially, extremely) and a 0 - 10 point numeric scale responses as recommended by “Community Response to Noise Team” of “The International Commission on the Biological Effects of Noise (ICBEN)”. Thus it is aimed to create internationally comparable noise reaction questions. In this study, 5 point verbal scale adopted was “extremely high”, “high”, “moderate”, “low” and “very low”. Turkish version of this scale was “çok fazla”, “fazla”, “orta”, “az”, “çok az”.

In order to prepare a suitable set of questions, a draft questionnaire was prepared and the opinion of an experienced worker was asked before it took its final form (APPENDIX-A). The worker stated that the questionnaire was ok in general and he had no contribution to the questionnaire.

Some questions were repeated in different forms to check the consistency of the answers. Questionnaires were distributed at the beginning of the work time, approximately between 07:30 and 08:00 in two factories, i.e., Factory 1 and Factory 2, and were collected generally after approximately four hours, so that the workers could comfortably think and answer during the period allowed to them.

On the day the questionnaires were distributed to the workers noise measurements were also taken. Results of these measurements are presented in the “Measurement Chapter”.

2.2. Evaluation of the Questionnaires

2.2.1. Personal Information

As seen in figure 2.1 and figure 2.2, people of factory 1 seem to be younger than those of factory 2. 81 % of workers in factory 1 are between 25 and 45 years while the corresponding percentage for factory 2 is 68%. 19% of Factory1 is above 45 years old and 32% of factory 2 is above that age. 81 % of the workers in factory 1 and 87% of workers in factory 2 are graduates of technical high school (meslek lisesi, sanat okulu). This leads to their good comprehension of the questions and to increase of the reliability of the responses received.

Based on the declaration of workers, 88% of Factory 1 workers are working in hull manufacturing (others were dressers, bench operators, mounting workers), 41% express that they perform tasks like cutting, grinding, drilling, welding, hammering and brazing with hand tools. Factory 1 workers therefore can be identified as multi-task workers.

In Factory 2 14 % declare their task type as miller, 28 % as dresser and 26 % as lathe bench operator. 24 % declare their main activity as cutting, drilling and surface applications on their working benches

Workers in Factory 1 perform their jobs having different postures; 14% out of 44 workers define their posture as a combination of standing on feet, standing on scaffolding and lying, 7% of them define their posture as a combination of standing on feet and on scaffolding. The percentage of these working postures are actually higher (almost 100% in total) because they can be found in different combined answers, that is to say, answers having different combinations of postures comprising standing, laying, sitting etc. In factory 2 they work mainly standing by the workbench

(30%), the rest standing on their feet (8%).86 % of factory 1 and 78 % of factory 2 have always worked in the same factory. The ones who haven't, worked in other work shops mostly for short periods of time.

In Factory 2, 16% of workers have worked for less than 5 years, 22% have worked 6-10 years and 20% have worked for 11-15 years. So, most of the workers in Factory 2 has worked in that factory for at least 5 years. However in Factory 1, 12 persons out of 44 have worked in that factory for one year and 44% of workers have worked ≤ five years, as seen in figures 2.3 and 2.4. Workers of factory 2 have worked in the same place for 16 years on the average and whereas for factory 1 it was 12 years, which is sufficient to perform a survey in a workplace [10]. As well as being younger, Factory 1 workers have spent less time until that time, in their factory.

Furthermore, 79% of factory 1 and 90 % of factory 2 workers has spent more than 50 % of their working time inside the factory, as illustrated in figure 2.5 and figure 2.6. Since the percentage of workers who spent ≥ 75% of their time in their factories are high (54% in Factory 1, 57% in Factory 2) the answers given to the questions in the questionnaire can be regarded as typical for the factory considered.

98 % of Factory 1 lead a daily working routine of 08:00 to 17:30 with a lunch brake of 1 hour and two tea brakes between 10:00-10:15 and15:00-15:15. Most of them (98 %) do not stay for extra working times and 49 % work for shift periods of 8 hours with a brake of 30 minutes. The remaining 51 % do not work at all in shifts. All of the workers in Factory 2 work from 08:00 to 17:30 just like the ones in Factory 1, 98% without extra working times and 95% without shifts.

Figure 2.7 shows that 98 % of factory 1 workers have to lift heavy weights at work, and figure 2.8 shows that in factory 2, percentage for the same condition is 88%. From figures 2.9 and 2.10 it can be deduced that while 34% of the workers in Factory 1 lift heavy weights in their leisure time, the percentage becomes 26 % in Factory 2.

2.2.2. Rating of Perceived Noise and Its Perceived Effects

Figures 2.11 and 2.12 display the verbal answers for the question about the perception of noise in the factories. 97 % of factory 1 stated that they would define the level of noise in their factory as high (extremely high + high). Only 3 % marked the level as “moderate”. However factory 2 showed a different behaviour and relatively less people defined the noise level, as “extremely high” and “high” (66 %). In factory 2, 34% thought that noise level was “moderate”.

The second question concerning the same issue demanded the workers to mark the level of noise in a scale from 0 to 10 (extremely high = 10, very low = 0). The answers are displayed in figure 2.13 and 2.14; 77 % marked levels 8 and above, 94% marked levels 7 and above and 6 % between 1 and 6 in factory 1, while percentages were 39 %, 56 % and 44% in factory 2. As stated above, this situation arises from two causes; workers in factory 1 are subject to higher levels of noise and they are relatively younger and new in the workplace, even under the same acoustical environment they would have sensed more noise.

Workers were also asked to express how their job productivity was affected by the noise level in their workplace. In factory 1, 75 % of the people thought that their productivity was highly effected (extremely highly + highly) as seen in figure 2.15. 25 % thought it was affected in moderate, low or very low level. Figure 2.16 reveals that the percentage of workers in factory 2 whose job productivity was affected in high levels (extremely high + high) make only 35 % of the labour population. The rest are affected below moderate. On the 10 degree scale 69 % of factory 1 workers marked levels 7 and above and 59 % marked levels 8 and above (Figure 2.17) . Corresponding percentages are illustrated in figure 2.18 for factory 2 as 39 % and 32 %.

After determining the effect of the noise level on the workers in general, it was necessary to further investigate the specific fields of their abilities which were affected. They were asked to rate the level of the effect of noise level on 6 specific fields namely; “Attention”, “Working Rate”, “Understanding Speech”, “Perception of Warning Signals”, “Communication with Others”, “Quality and Productivity of Work”. According to figures 2.19, 2.20, 2.21, 2.22, 2.23, 2.24, 2.25, 2.26, 2.27, 2.28, 2.29, 2.30; in factory 1 outstanding fields (percentages being summation of “extremely high” and “high” levels) were “Understanding Speech” (78%) and “Communication with Others” (69%) which are both concerning understanding speech . “Attention” (68 %) and “Perception of Warning Signals” (65%) were the fields concerning mainly psychology, perception and thus work quality and safety. Psychological effect is worth mentioning because many noise related health effects appear to be mediated through people’s emotional response to the noise [13]. In factory 2 corresponding percentages were 39%, 37%, 35%, 39%. In factory 2 answers are almost uniformly distributed to the fields while in factory 1 there is concentration on the above mentioned fields. It was interesting to see that “quality and productivity of work” was the least mentioned. It was probably the psychological attitude of the workers implying even under adverse conditions workers kept their quality and productivity standards.

The survey performed by Strasser et al. [14], on the members of a design department in a medium sized company having complaints about acoustic situation in their new offices, pointed out that the person on the other end of the line having a telephone conversation with the one in the design department, had problems following the conversation when noise level in the design department was 65 dB (A). Roughly 40% were unaffected by the noise level, half considered the situation unacceptable and 10% rated the situation with maximum noise perception level. Answers to another question proved that the current situation causes considerable general adverse effects on communication and understanding speech . Many employees (approximately 70%) felt that the acoustic situation negatively affected their mood. It is remarkable that in the answers to the question about possible effects on the ability to concentrate, about ¾ of all persons that were questioned, felt that their concentration suffers due to the acoustic situation. People also stated “irritation” and “increased error rate”. Even though this article is about a totally different working environment the effect of noise on workers’ mood and results are similar. It can be summarized that some difficulties associated with perception, understanding speech and communication should be expected in case of high level of occupational noise.

2.2.3. Rating of Conservation of Hearing

The percentage of ear plug usage among workers in factory 1 is 97% as seen in Figure 2.31 which is quiet a high level, however it drops to 18 % in factory 2 as can be seen in Figure 2.32. 54 % of workers in factory 1 believe that ear plugs decrease the noise moderately, 31% believe that the decrease is at high levels .15% believe that they decrease the noise only a little (Figure 2.33). 10 % of Factory 1 uses the ear plugs continuously. Others use them in intervals. Among the small portion of workers who use ear plugs in Factory 2, 72% believe ear plugs decrease noise level in moderate levels and 9 % believe that the decrease of noise is low (Figure 2.34).

2.2.4. Health Information

2.2.4.1. Auditory Health Effects

Figures 2.35 and 2.36 display the answers to the questions in the questionnaire, with regard to the general state of health of the workers. 18% of the Factory 1 workers declared that they had tinnitus and 17% declared they had both tinnitus and tubal dysfunction in addition to other minor problems. 15% revealed communication problems and 26% expressed that they had communication problems together with other health effects. The communication problem expressed here confirms the high level of the effect of noise on “understanding speech” mentioned above. Results obtained from Factory 2 were quite interesting. Although the noise level in this factory was much lower, percentage of workers having auditory problems were higher than Factory 1; tubal dysfunction: 9%, tinnitus: 30%, tinnitus and tubal dysfunction together with other problems: 9%, communication problems: 15%, communication problems together with other minor effects: 29%.

49 % of the labour force in factory 1 declared hearing loss. It is interesting to note that the level of hearing loss declaration in factory 2 is not much lower, approximately the same level (37%) as Factory 1. This information is displayed in figures 2.37 and 2.38. Only 2 % of Factory 1 and 4 % of Factory 2 have family members with hearing losses at young

ages so the hearing loss problem is not expected to be inherited. Even though ear effusion among workers was not of significant importance, 15% of the workers in Factory 1 and 18% in Factory 2 had claimed that they had such a problem.

According to Pyykkö et al. [15] among several susceptibility factors smoking and cholesterol are independently but causally related to Noise Induced Hearing Loss, NIHL, and may cause the subject to be more susceptible to the adverse effects of noise exposure. Aging further confounds some of these factors. Pyykkö's study was carried out on paper mill workers, miners, metal factory workers, shipyard workers and forestry workers so its results can be used in this study for comparison purposes. Cholesterol is a minor problem among workers being 13% in factory 1, 6 % in factory 2. As seen in figure 2.39 and 2.40 54 % of factory 1 and 44% of factory 2 are smokers with different durations and periods of smoking

2.2.4.2. Non-Auditory Health Effects

Babisch [16] states that even ear safe noise levels can cause nonauditory health effects if they chronically interfere with recreational activities such as sleep and relaxation and also if they disturb communication and understanding speech or if they interfere with mental tasks that require a high degree of attention and concentration. Among other nonauditory health end points, short term changes in circulation (including blood pressure, heart rate, cardiac output and vaso-constriction) as well as in levels of stress hormones (including epinephrine, norepinephrine and corticosteroids) in many experimental settings for many years can be termed. From this, the hypothesis emerged that persistent noise stress increases the risk of cardiovascular disorders including high blood pressure and ischemic heart disease. According to Lusk et al. [10]; male workers with noise induced hearing loss (NIHL) (i.e. an indicator of noise exposure) had higher blood pressures than subjects with normal hearing.

Noise is a psychosocial stressor that activates the sympathetic and endocrine systems. Acute noise effects do not occur only at high noise levels in occupational settings, but also at relatively low environmental noise levels when, more importantly, certain activities such as concentration, relaxation or sleep are disturbed. Many noise related health effects appear to be mediated through people's emotional response to the noise [13].

Question on the high blood pressure gives out an interesting result. Although both factories do not display very high rates, difference between them is outstanding. Percentage of people having high blood pressure is 21% in factory 1 and 6% in factory 2 (Figures 2.41, 2.42). The effects of noise on various cardiovascular parameters were investigated in Tomei et al. [17]. As his survey was performed on 52 workers who were employed in bed frame factory and were chronically exposed to noise and had poor hearing, it can be somehow representative for shipyard workers. The findings of his study suggested that:

"a. work performed by bed frame workers had some effects on the cardiovascular system,

b. noise is a cardiovascular risk factor,

c. cardiovascular effects are relative to intensity and type of exposure"

Willich et al. [4] point out that noise exposure may lead to increase in blood pressure by adversely affecting the psychological condition of subjects. Such effects may be further increased by other factors such as smoking.

Workers who declared hypertension were between 38 and 50 years old while two were 26 and 32 years old.

Body circulation system malfunctions is not widespread too (0 in Factory 1 and 4% in Factory 2).Only 3% of factory1 and 4 % of factory 2 had experienced automobile or motorbike accidents. In factory 1 25 % of workers use painkillers whereas 30% of workers use painkillers in factory 2.

In the study performed by Wild et al. [18], 30 long term smoker participants and a control group of 58 non smokers, both of which exposed to occupational noise, were examined and it was found that smokers had a higher percentage of hearing loss problems.

Ferrite et al. [19] stated that smoking, noise and age are associated with hearing loss. Age has the largest effect while noise and smoking have minor effects.

A cross-sectional study was carried out by Pouryaghoub et al. [20] on smoker and non smoker workers in a food factory where workers were exposed to occupational noise. The results showed that smoker workers had a higher percentage of hearing loss than the non-smokers.

However a statistical analysis was needed to support the comments made on the graphics.

2.3. Statistical Analysis

In addition to examining and assessing the data outcome of questionnaires statistical analysis was carried out between different important variables. Results are tabulated below:

Table 2.1 Correlation between age/years of work and NPL/EJP (α = 0.05) FACTORY 1

	Noise Perception Level, NPL	Effect on Job Productivity, EJP
Age	"Univariate Analysis of Variance" k=0.438 **No Significant Correlation**	"Univariate Analysis of Variance" K=0.812 **No Significant Correlation**
Years of Work	"Univariate Analysis of Variance" k=0.239 **No Significant Correlation**	"Univariate Analysis of Variance" k=0.892 **No Significant Correlation**

Table 2.2 Correlation between age/years of work and HL/Hypertension (α = 0.05) FACTORY 1

	Hearing Loss, HL	Hypertension
Age	"Pearson Correlation" k=0.532 **Significant Correlation Exists**	"Pearson Correlation" k=0.291 **No Significant Correlation Exists**
Years of Work	"Pearson Correlation" k=0.519 **Significant Correlation Exists**	"Pearson Correlation" k=0.407 **Significant Correlation Exists**

Table 2.3 Correlation between age/years of work and Attention/Understanding Speech (α = 0.05) FACTORY 1

	Attention	Understanding Speech
Age	"Pearson Correlation" k=-0.018 **No Significant Correlation**	"Pearson Correlation" k=-0.12 **No Significant Correlation**
Years of Work	"Pearson Correlation" k=-0.004 **No Significant Correlation**	"Pearson Correlation" k=-0.112 **No Significant Correlation**

Table 2.4 Correlation between age/years of work and WR/PWS (α = 0.05) FACTORY 1

	Working Rate, WR	Perception of Warning Signals, PWS
Age	"Pearson Correlation" k=0.294 **No Significant Correlation**	"Pearson Correlation" k=-0.223 **No Significant Correlation**
Years of Work	"Pearson Correlation" k=0.29 **No Significant Correlation**	"Pearson Correlation" k=-0.225 **No Significant Correlation**

Table 2.5 Correlation between age/years of work and CWO/QPW (α = 0.05) FACTORY 1

	Communication with Others, CWO	Quality and Productivity of Work, QPW
Age	"Pearson Correlation" k=0.111 **No Significant Correlation**	"Pearson Correlation" k=0.331 **No Significant Correlation Exists**
Years of Work	"Pearson Correlation" k=0.158 **No Significant Correlation**	"Pearson Correlation" k=0.328 **No Significant Correlation Exists**

Table 2.6 Correlation between HL and hypertension/smoking (α = 0.05) FACTORY 1

	Hypertension	Smoking
Hearing Loss, HL	"Pearson Correlation" k=0.258 **No Significant Correlation**	"Chi-Square Method" **No Significant Correlation**

Table 2.7 Correlation between HL and age/years in factory (α = 0.05) FACTORY 1

	Age	Years in the Factory
Hearing Loss, HL	“Pearson Correlation” k=0.532 **Significant Correlation Exists**	“Pearson Correlation” k=0.519 **Significant Correlation Exists**

Table 2.8 Correlation between age/years of work and NPL/EJP (α = 0.05) FACTORY 2

	Noise Perception Level , NPL	Efficiency of Job Productivity ,EJP
Age	“Univariate Analysis of Variance” k=0.178 **No Significant Correlation**	“Univariate Analysis of Variance” k=0.029 **Significant Correlation Exists**
Years of Work	“Univariate Analysis of Variance” k=0.100 **No Significant Correlation**	“Univariate Analysis of Variance” k=0.060 **No Significant Correlation**

Table 2.9 Correlation between age/years of work and HL/HT (α = 0.05) FACTORY 2

	Hearing Loss, HL	Hypertension, HT
Age	“Pearson Correlation” k=0.298 **Significant Correlation Exists**	Very Low Number of Workers in Factory 2
Years of Work	“Pearson Correlation” k= 0.169 **No Significant Correlation**	Very Low Number of Workers in Factory 2

Table 2.10 Correlation between age/years of work and attention/US (α=0.05) FACTORY 2

	Attention	Understanding Speech , US
Age	“Pearson Correlation” k=-0.153 **No Significant Correlation**	“Pearson Correlation” k=-0.25 **No Significant Correlation**
Years of Work	“Pearson Correlation” k=-0.217 **No Significant Correlation**	“Pearson Correlation” k=-0.350 **Significant Negative Correlation Exists**

Table 2.11 Correlation between age/years of work and WR/PWS (α = 0.05) FACTORY 2

	Working Rate, WR	Perception of Warning Signals, PWS
Age	“Pearson Correlation” k=-0.291 **No Significant Correlation**	“Pearson Correlation” k= -0.228 **No Significant Correlation**
Years of Work	“Pearson Correlation” k=0.340 **Significant Correlation Exists**	“Pearson Correlation” k=-0.314 **No Significant Correlation**

Table 2.12 Correlation between age/years of work and CWO/QPW (α = 0.05) FACTORY 2

	Communication with Others, CWO	Quality and Productivity of Work, QPW
Age	“Pearson Correlation” k=-0.226 **No Significant Correlation**	“Pearson Correlation” k=-0.203 **No Significant Correlation**
Years of Work	“Pearson Correlation” k=-0.320 **Significant Negative Correlation Exists**	“Pearson Correlation” k=-0.320 **Significant Negative Correlation Exists**

Table 2.13 Correlation between HL and HT/smoking (α = 0.05) FACTORY 2

	Hypertension, HT	Smoking
Hearing Loss, HL	"Chi-square Method" **No Significant Correlation**	"Chi-square Method" **No Significant Correlation**

Table 2.14 Correlation between HL and age/YIF (α = 0.05) FACTORY 2

	Age	Years in the Factory, YIF
Hearing Loss, HL	"Pearson Correlation" k=0.298 **Significant Correlation Exists**	"Pearson Correlation" k=0.169 **Significant Correlation Exists**

A brief examination of the statistical analysis showed that; in Factory 1 there was significant correlation between ("age" and "hearing loss"), ("years in the factory" and "hearing loss"),("years in the factory" and "hypertension").

In Factory 2 there was significant correlation between ("age" and "effect on job productivity"), ("age" and "hearing loss"), ("years of work " and "Working Rate"), ("years of work" and "hearing loss").

Besides there was a negative correlation between ("years of work" and "understanding speech"), ("years of work" and "communication with others"), ("years of work" and " Quality and productivity of work").

2.4. Audiometric Test Results

Maltepe Occupational Illnesses Hospital in Istanbul was visited to examine the audiometric records of Factory 1 workers. Audiometric tests had not been practised in periodical basis but rather, they were applied in case of an auditorial complaint. All complaints recorded were about tinnitus (“kulağımda uğultulu çınlamalar oluyor”).

Audiometric test results of 73 of Factory 1 workers with tinnitus complaint revealed information about two issues; hearing threshold and acoustic trauma. Hearing thresholds were calculated by taking the arithmetical average of threshold values at 500 Hz, 1000 Hz. and 2000 Hz. for both ears. Threshold values of right and left ears were averaged one more time to get a single threshold value for one person. Results were assessed according to the criteria: 0-20 dB: normal, 20-40 dB: low, 40-60 dB: moderate, 60-80 dB: moderately severe, 80-90 dB: severe, 90-100 dB: extremely severe, >100 dB: total loss.

The audiometric curve of a healthy person should decline smoothly as the frequency increases. A dent (a sudden fall and then rise) after 2000 Hz. indicates an acoustic trauma.

Results of the audiometric tests are summarised in APPENDIX-B.

A statistical analysis was also done on the data extracted from the hospital but no significant correlation was observed between parameters age, years in factory, hearing threshold and acoustic trauma. Actually audiometric records obtained from the aforementioned hospital did not make a healthy domain for statistical analysis as it was impossible to match these records with the questionnaires and they belonged only to workers who allegedly had tinnitus.

2.5. Figures

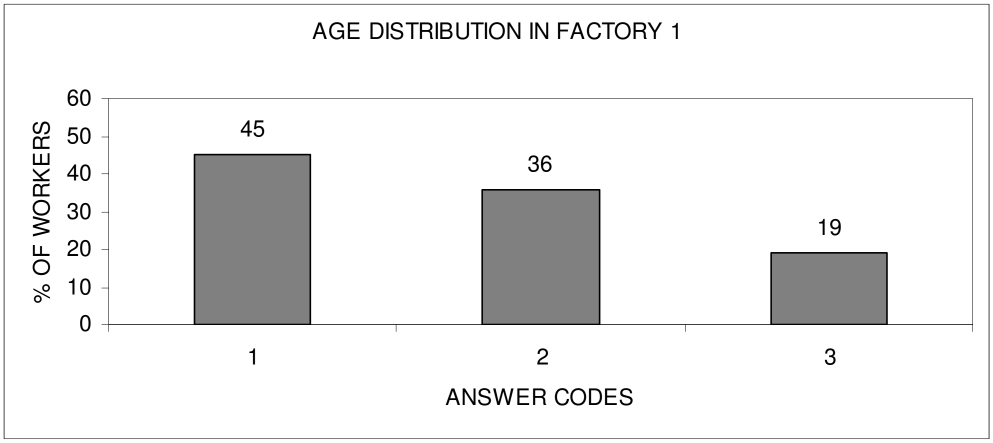


Figure 2.1 Age Distribution in Factory 1 (No. of Respondents: 44)

Answer Codes 1:25-35 years old, 2:36-45 years old, 3:46-55 years old

Figure 2.2 Age distribution in factory 2 (No. of Respondents: 50)

Answer Codes 1:25-35 years old, 2:36-45 years old, 3:46-55 years old

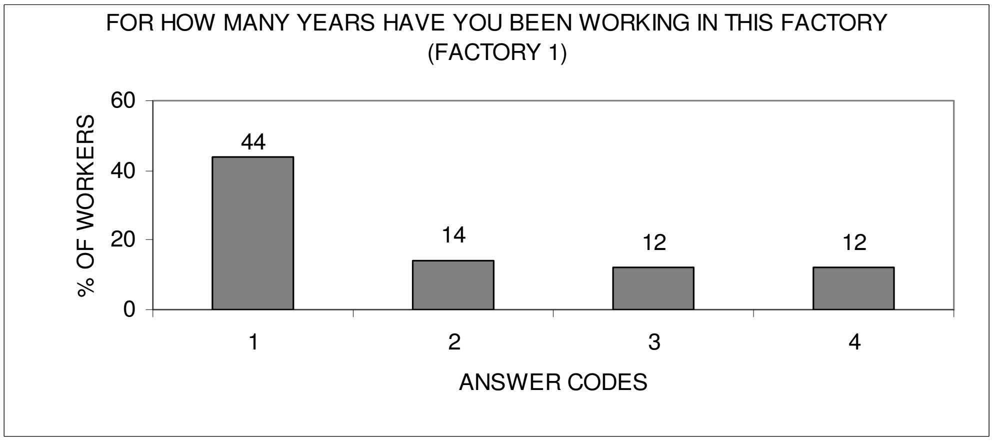


Figure 2.3 Work history of factory 1 workers (No. of Respondents: 43) Answer Codes 1:0-5 years, 2:6-10 years, 3:11-15 years, 4:16-20 years, 5:21-25 years, 6:26-30 years, 7:31-35 years.

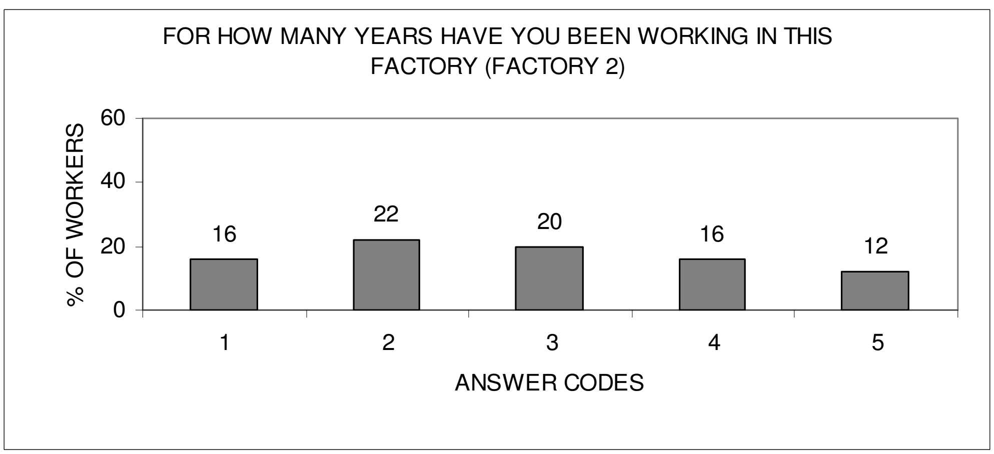


Figure 2.4 Work history of factory 2 workers (No. of Respondents: 49) Answer Codes 1:0-5 years, 2:6-10 years, 3:11-15 years, 4:16-20 years, 5:21-25 years, 6:26-30 years, 7:31-35 years.

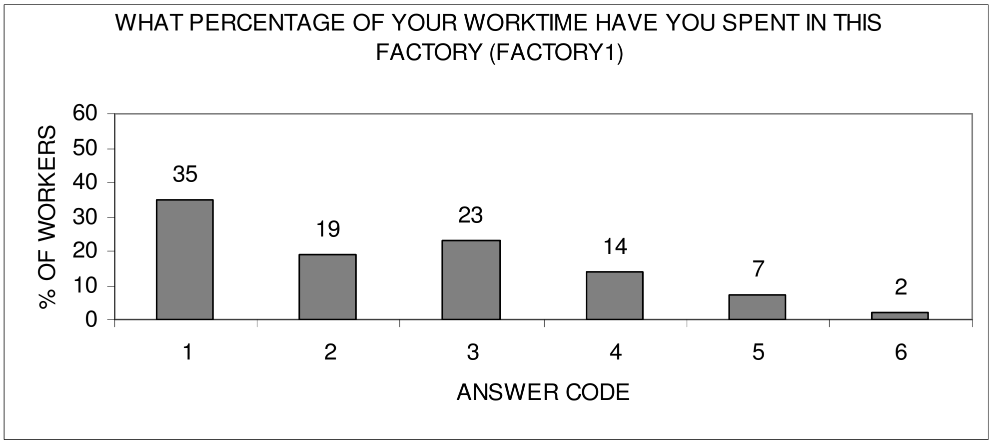


Figure 2.5 Working time in factory 1 (No. of Respondents: 43)

Answer Codes 1:90%, 2:75%, 3:50%, 4: 25%, 5:10%, 6:100%

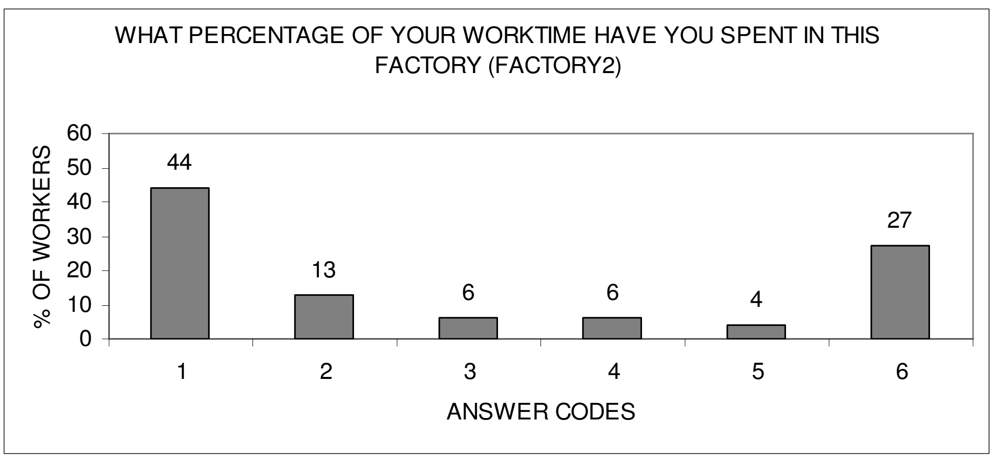


Figure 2.6 Working time in factory 2 (No. of Respondents: 48)

Answer Codes 1:90%, 2:75%, 3:50%, 4: 25%, 5:10%, 6:100%

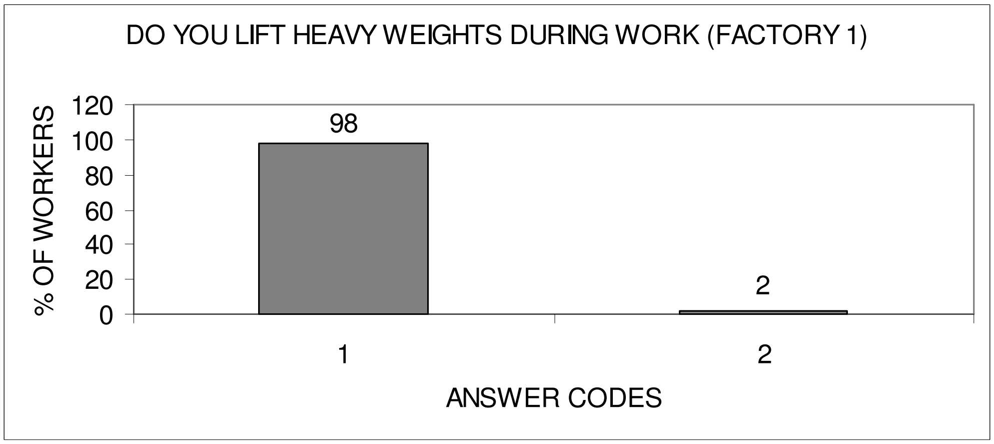


Figure 2.7 Do you lift heavy weights? (Factory 1)(No. of Respondents: 42)
Answer Codes 1: yes, 2: no.

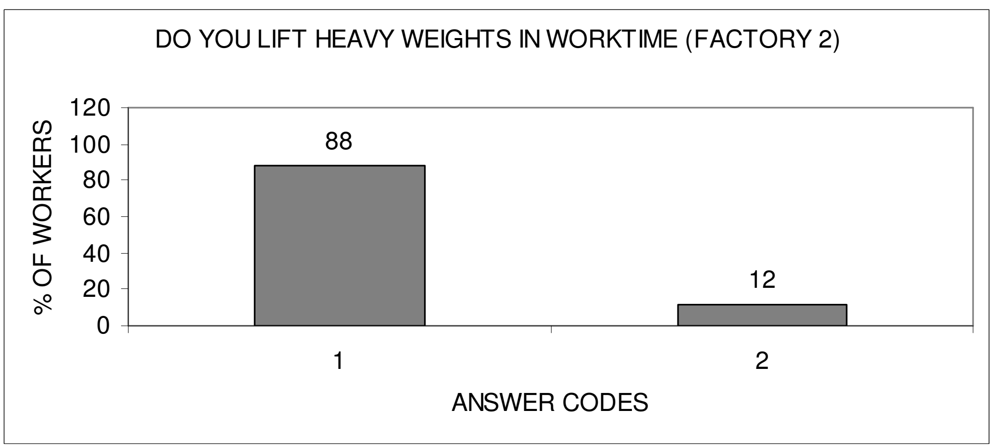


Figure2.8.Do you lift heavy weights? (Factory 2)(No. of Respondents: 50)
Answer Codes 1: yes, 2: no

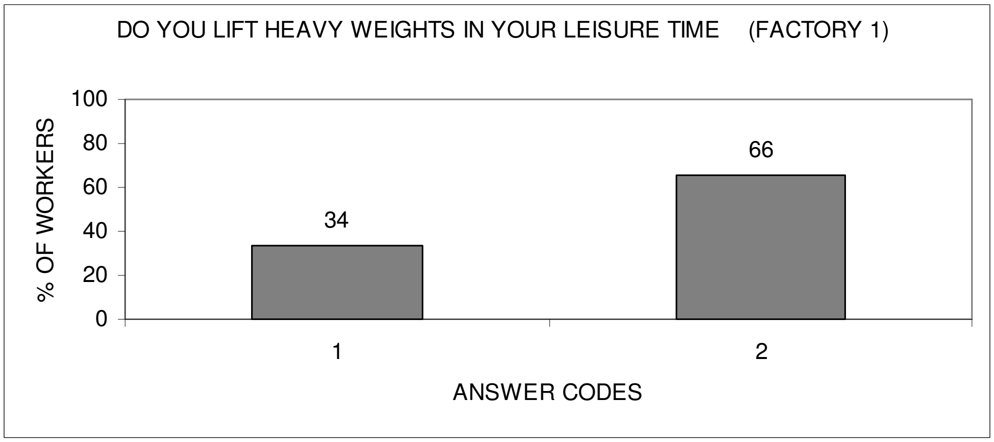


Figure 2.9 Do you lift heavy weight in your leisure time?

(No. of Respondents: 41) Answer Codes 1: yes, 2: no.

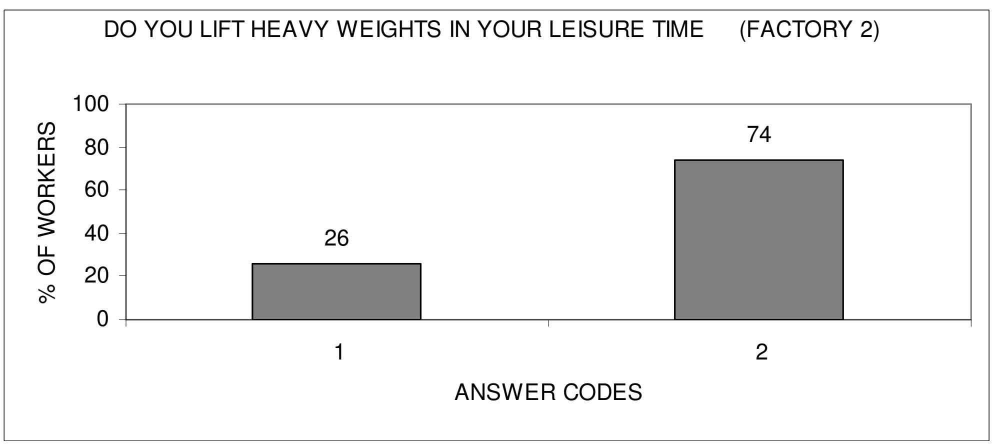


Figure 2.10 Do you lift heavy weight in your leisure time?

(No. of Respondents: 47) Answer Codes 1: yes, 2: no.

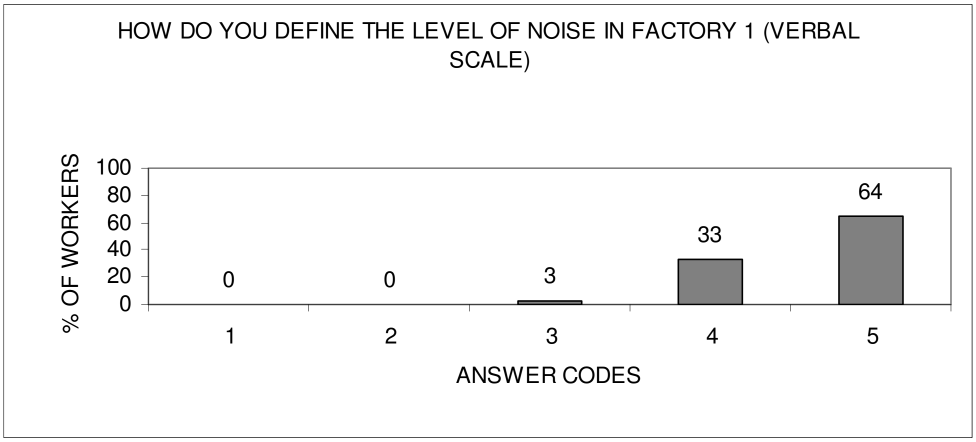


Figure 2.11 Noise level ratings (Factory 1) (No. of Respondents: 43)

Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high.

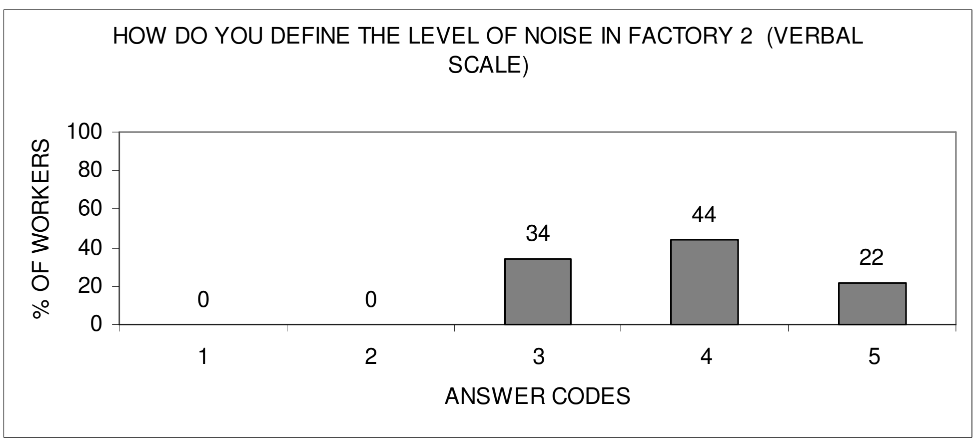


Figure 2.12 Noise level ratings (Factory2) – verbal scale

(No. of Respondents: 49)

Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

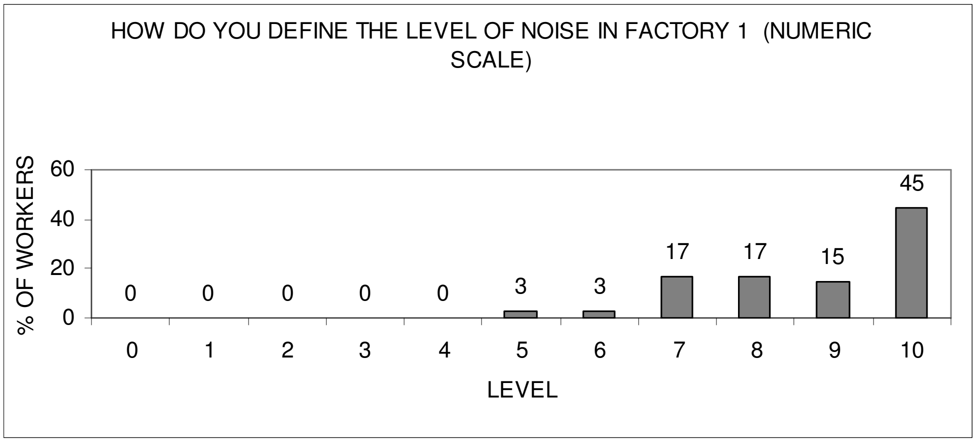


Figure 2.13 Rating of noise levels (Factory 1) – Numerical scale

(No. of Respondents: 43)(Extremely high = 10…very low = 1)

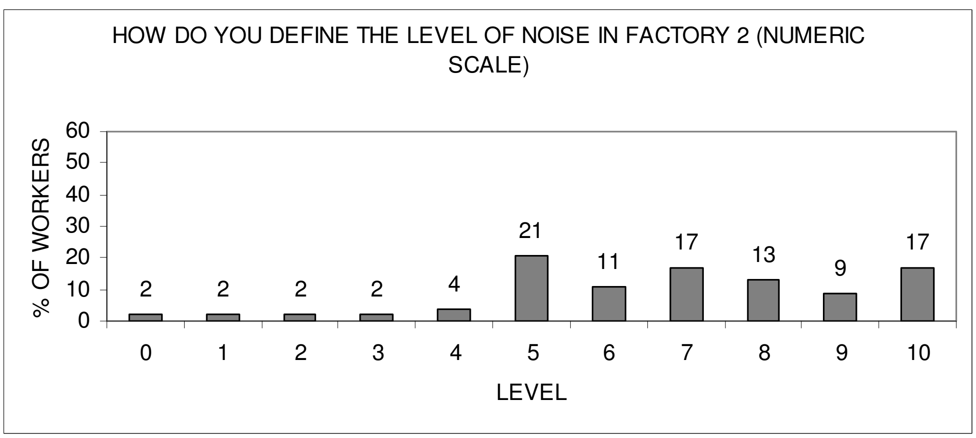


Figure 2.14 Rating of noise levels (Factory2) – Numerical scale

(No. of Respondents: 46)

(Extremely high = 10…very low = 1)

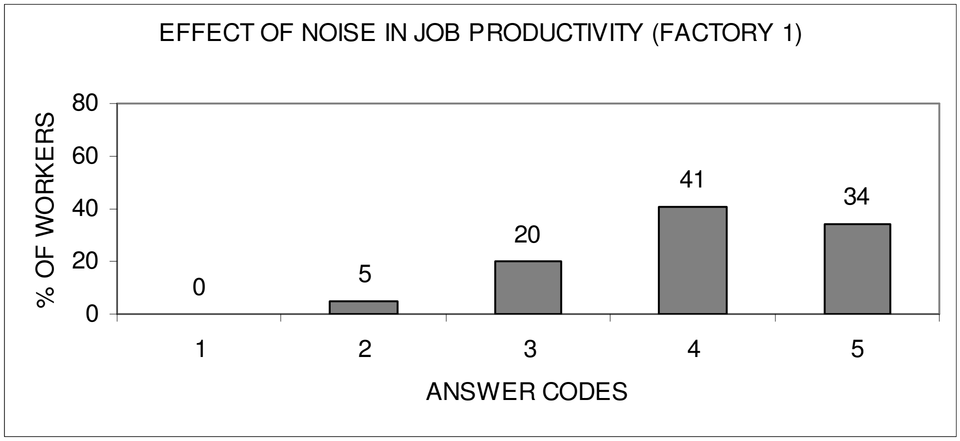


Figure 2.15 Effect of noise on job productivity-verbal scale (Factory 1)
(No. of Respondents: 43)
Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high.

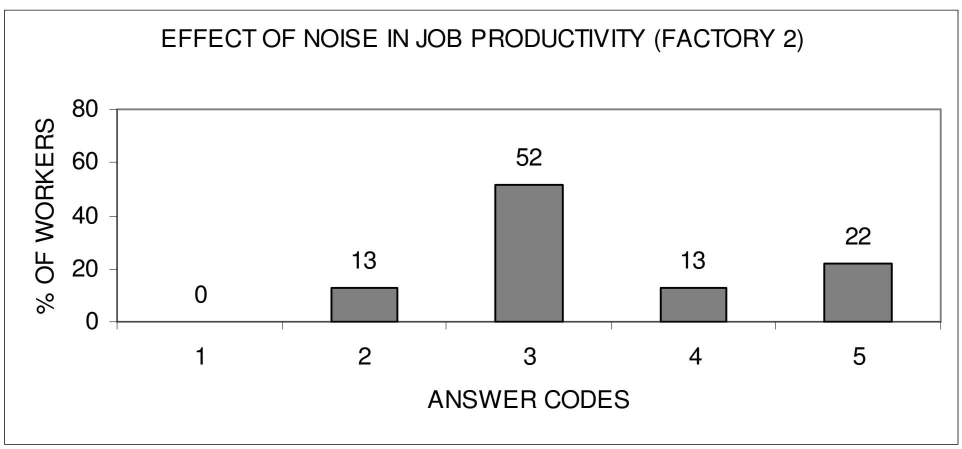


Figure 2.16 Effect of noise on job productivity-verbal scale (Factory 2)
(No. of Respondents: 50)
Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

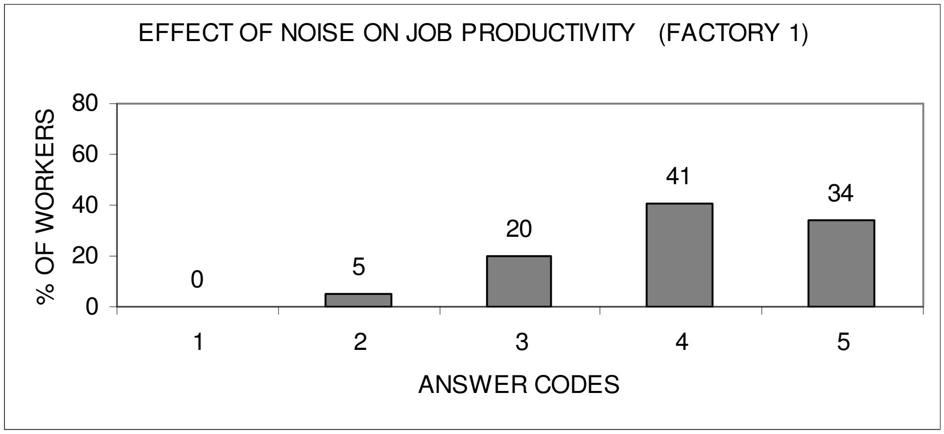


Figure 2.17 Effect of noise on job productivity-numerical scale (Factory 1) (No. of Respondents: 41) (Extremely high = 10…very low = 1)

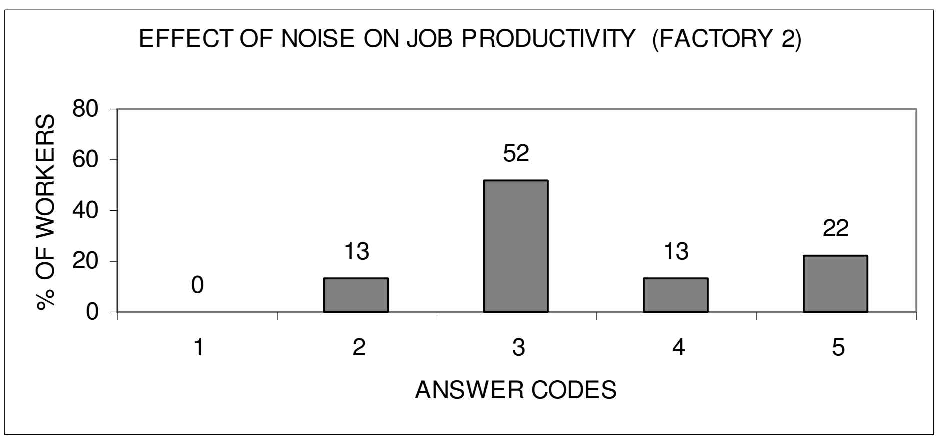


Figure 2.18 Effect of noise on job productivity-numerical scale (Factory 2) (No. of Respondents: 46) (Extremely high = 10…very low = 1)

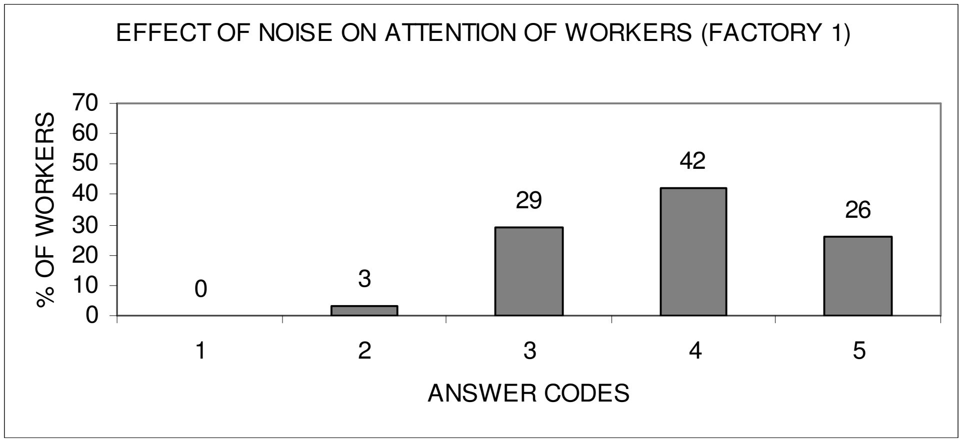


Figure 2.19 Effect of noise on the attention of workers (Factory1)

(No. of Respondents: 38)

Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

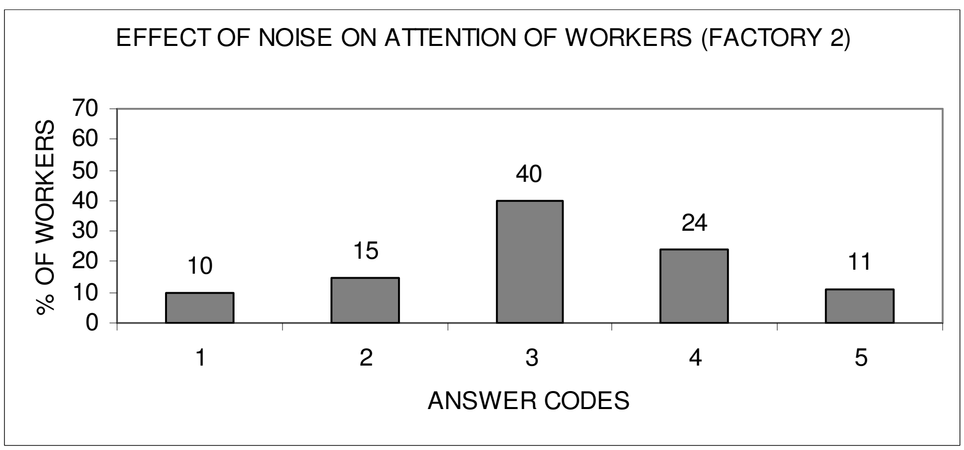


Figure 2.20 Effect of noise on the attention of workers (Factory 2)

(No. of Respondents: 45)

Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

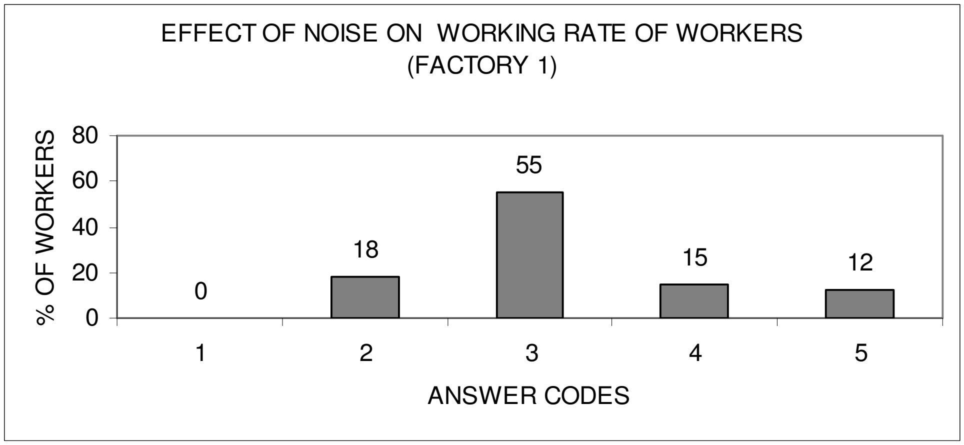


Figure 2.21 Effect of noise on the working rate of workers (Factory 1)
(No. of Respondents: 33)
Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

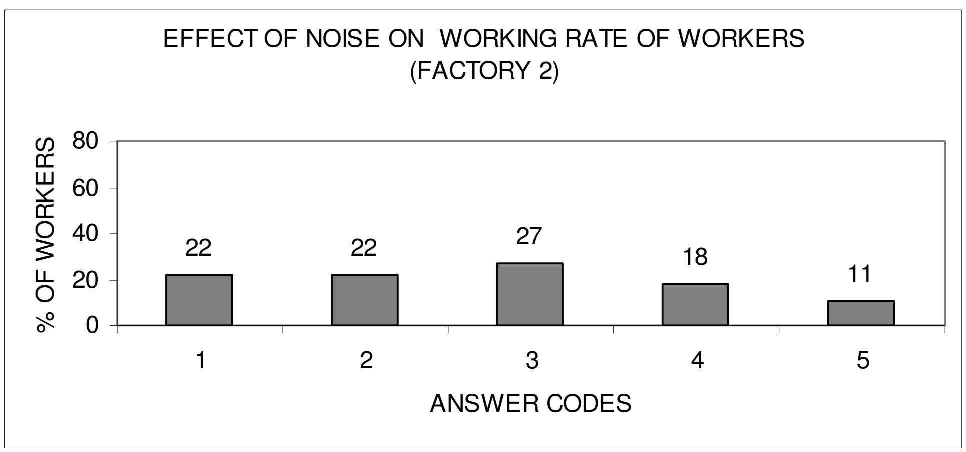


Figure 2.22 Effect of noise on working rate of workers (Factory 2)
(No. of Respondents: 37)
Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

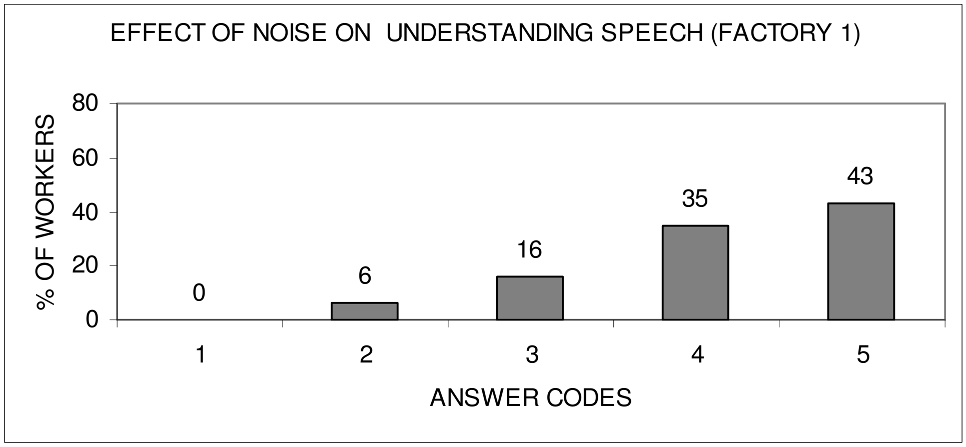


Figure 2.23 Effect of noise on" understanding speech" (Factory 1)

(No. of Respondents: 37)

Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

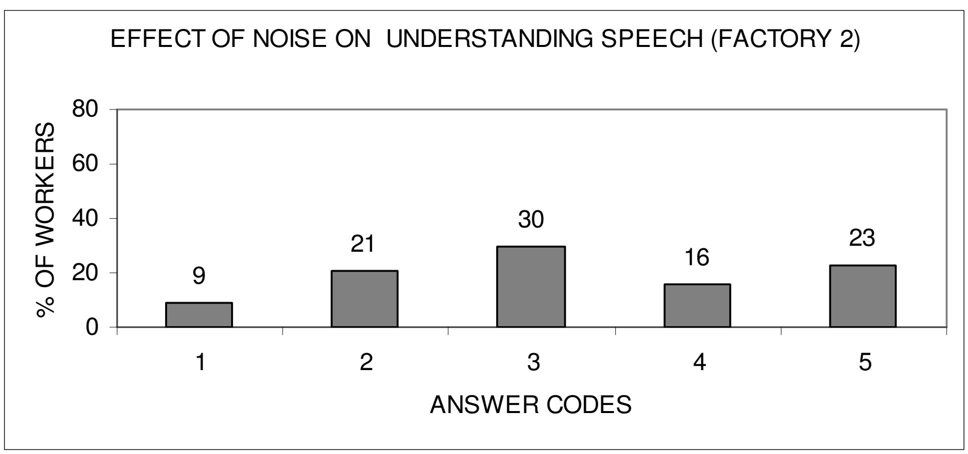


Figure 2.24 Effect of noise on "understanding speech " (Factory 2)

(No. of Respondents: 43)

Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

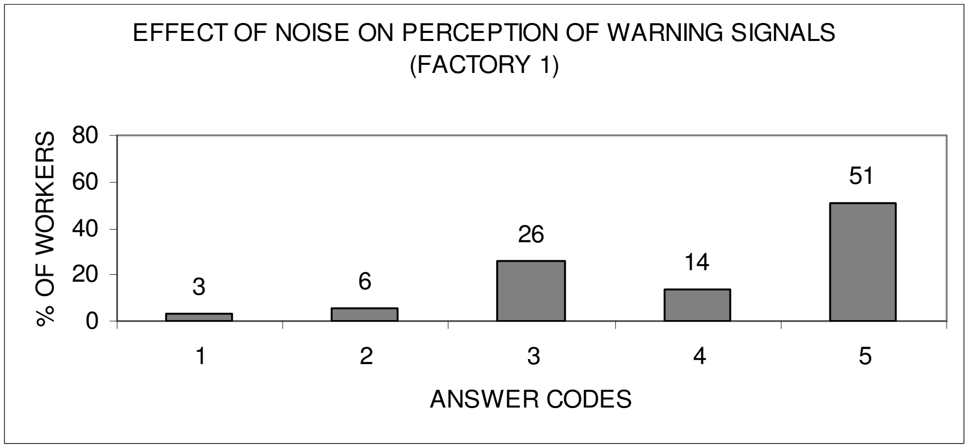


Figure 2.25 Effect of noise on the perception of warning signals
(Factory 1) (No. of Respondents: 35)
Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

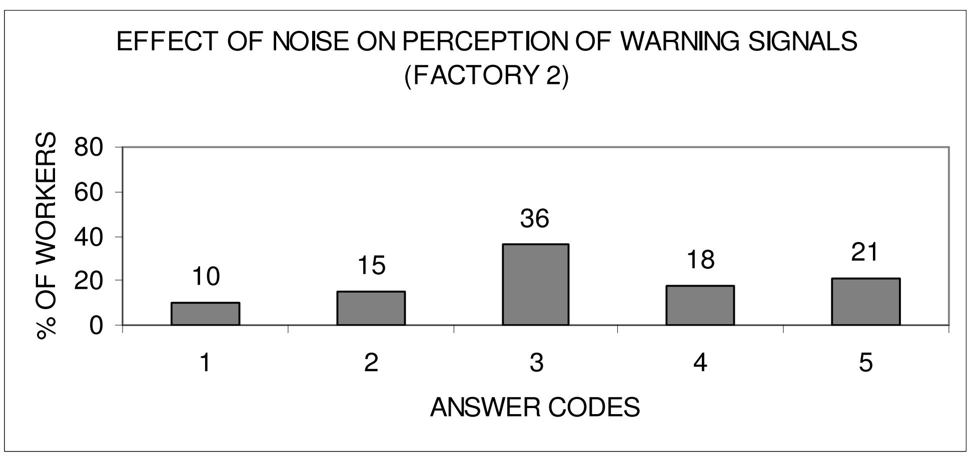


Figure 2.26 Effect of noise on the perception of warning signals
(Factory 2) (No. of Respondents: 39)
Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

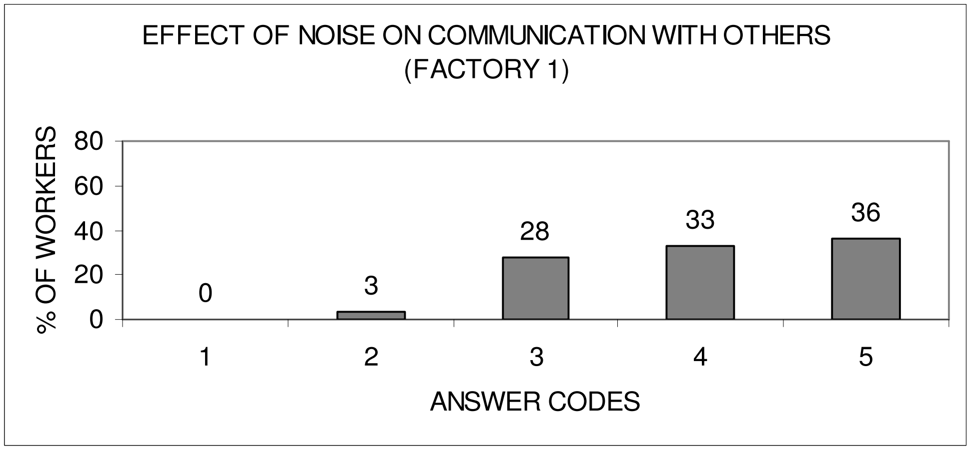


Figure 2.27 Effect of noise on “communication with others” (Factory 1)
(No. of Respondents: 34)
Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

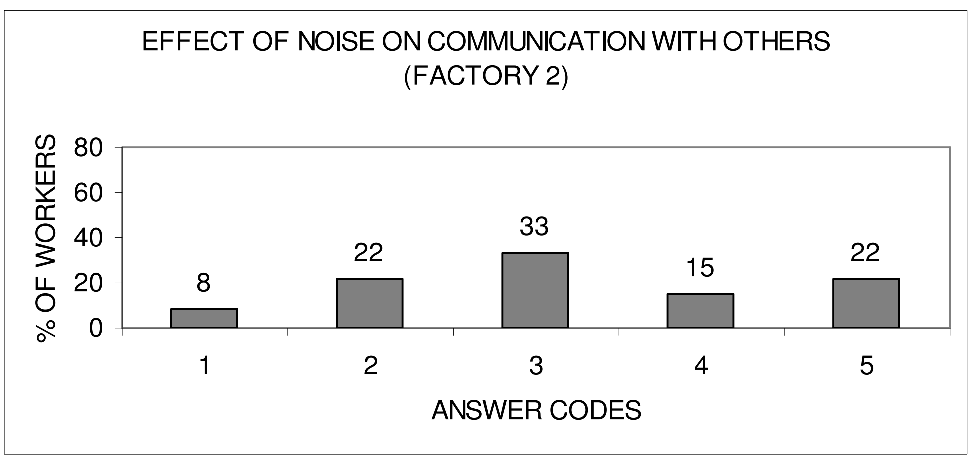


Figure 2.28 Effect of noise on “communication with others” (Factory 2)
(No. of Respondents: 40)
Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

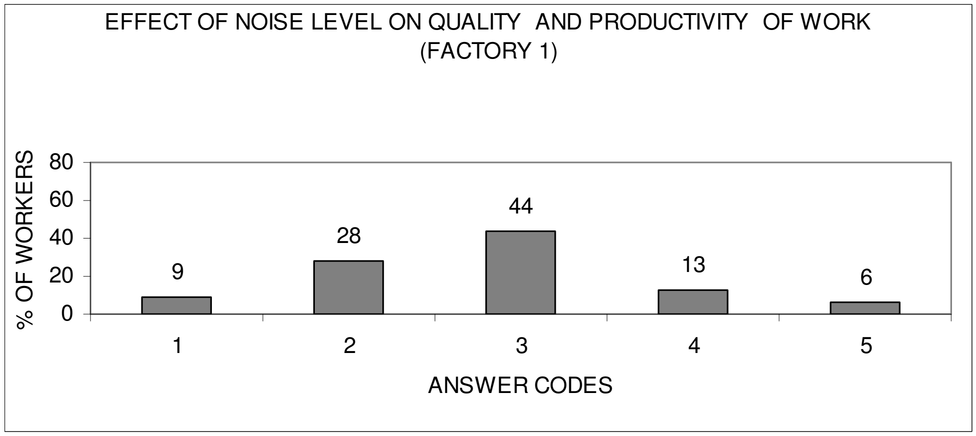


Figure 2.29 Effect of noise on "quality and productivity of work"
(Factory 1)(No. of Respondents: 32)
Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

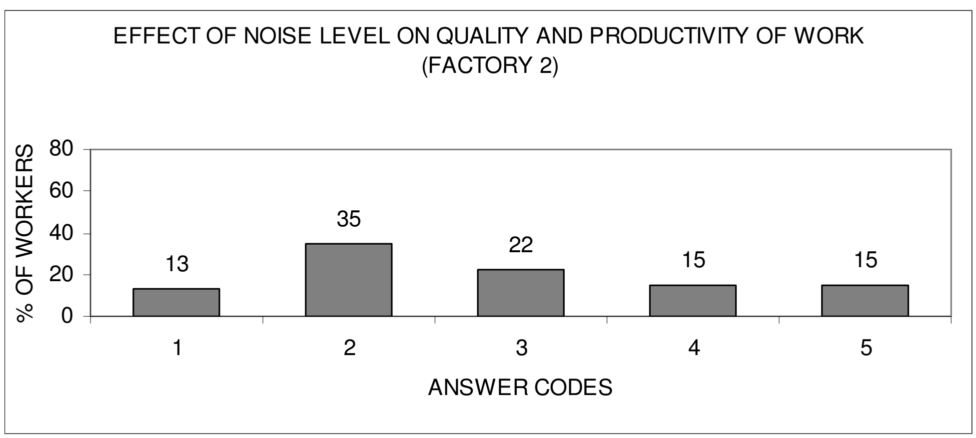


Figure 2.30 Effect of noise on "quality and productivity of work"
(Factory 2) (No. of Respondents: 39)
Answer Codes 1: very low, 2: low, 3: moderate, 4: high, 5: extremely high

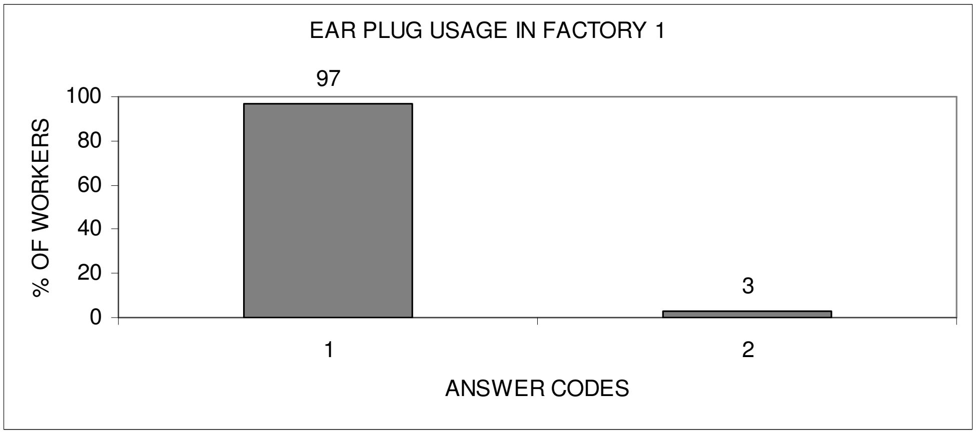


Figure 2.31 Ear plug usage (Factory 1) (No. of Respondents: 40)
Answer Codes 1: yes, 2: no

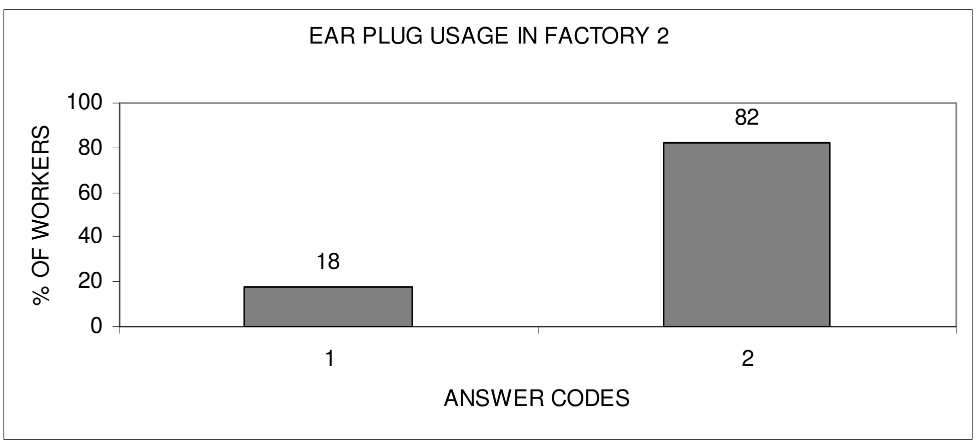


Figure 2.32 Ear plug usage (Factory 2) (No. of Respondents: 44)
Answer Codes 1: yes, 2: no.

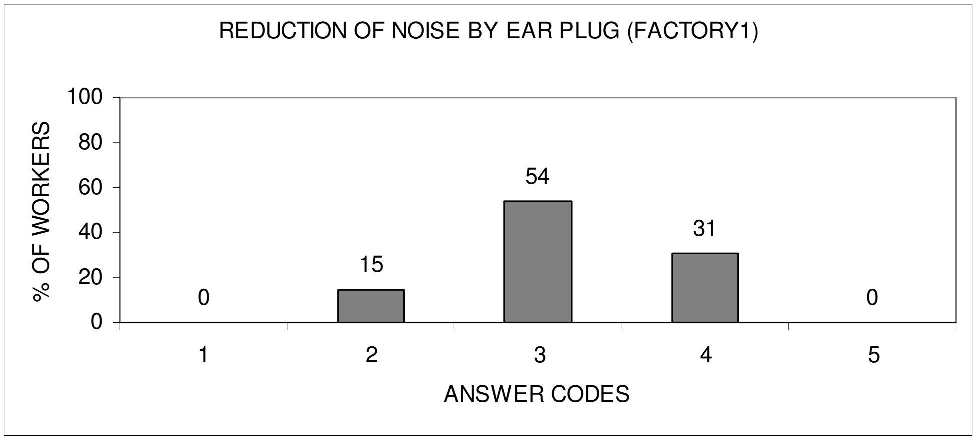


Figure 2.33 Rating of noise reduction due to ear plug (Factory 1)

(No. of Respondents: 42)

Answer Codes

5: completely, 4: Highly, 3: Moderately, 2: A little, 1: Not at all

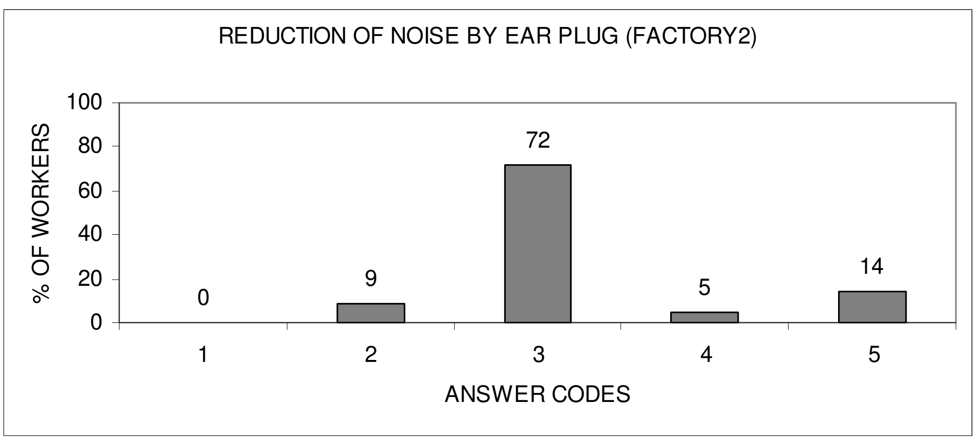


Figure 2.34 Rating of noise reduction due to ear plug (Factory2)

(No. of Respondents: 45)

Answer Codes

5: completely, 4: Highly, 3: Moderately, 2: A little, 1: Not at all

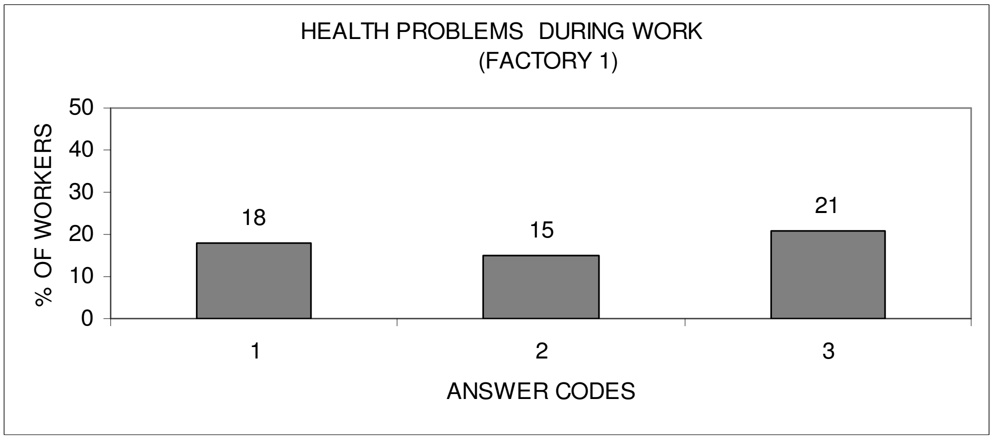


Figure 2.35 Health complaints (Factory 1) (No. of Respondents: 39)

Answer Codes

1: have tinnitus, 2: Sometimes I don’t understand what is said to me, 3:1+2.

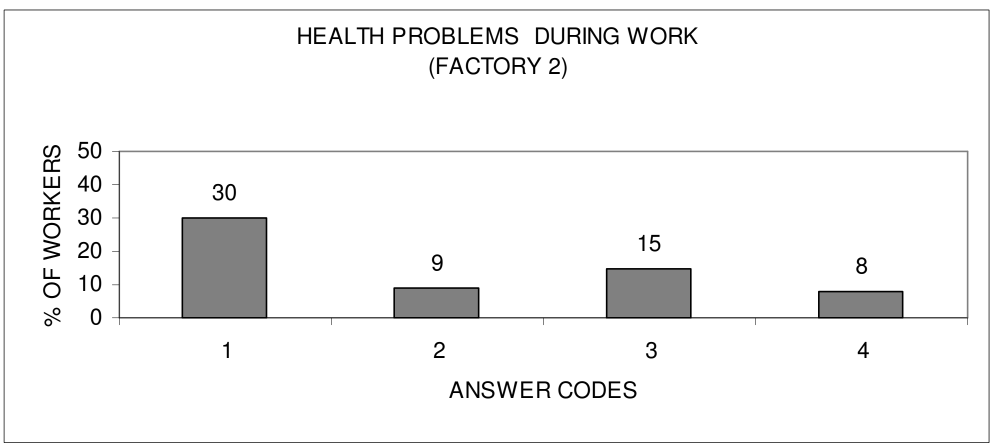


Figure 2.36 Health complaints (Factory 2) (No. of Respondents: 40)

Answer Codes

1:I have tinnitus, 2:I have tubal dysfunction, 3:Sometimes I don’t understand what is said to me, 4: My head aches.

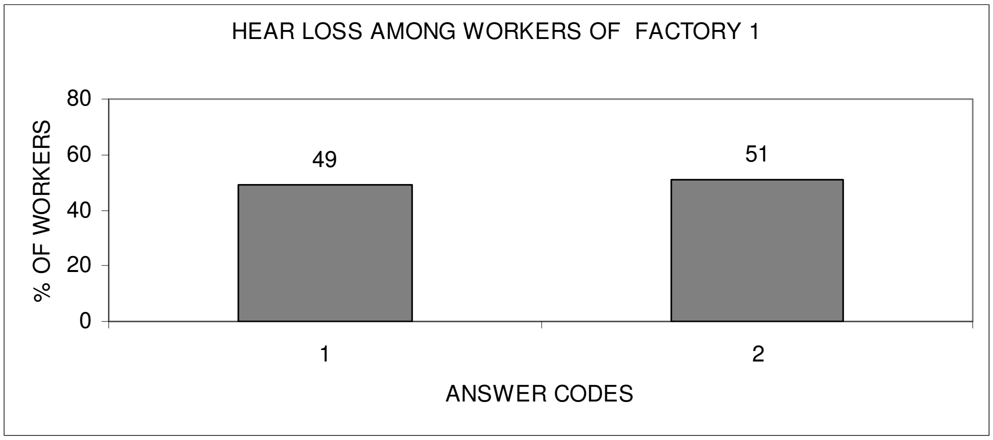


Figure 2.37 Do you have Hearing Loss? (Factory 1)
(No. of Respondents: 41)
Answer Codes 1: yes, 2: no

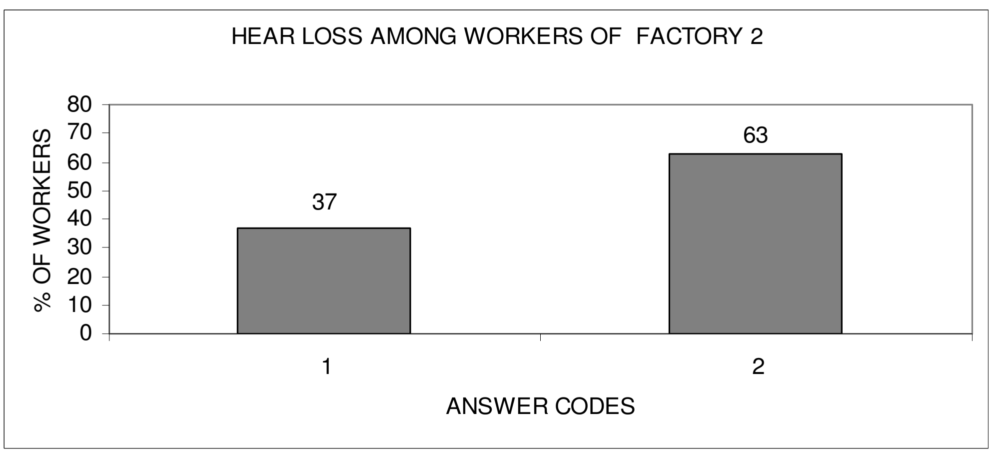


Figure 2.38 Do you have Hearing Loss? (Factory2)
(No. of Respondents: 49)
Answer Codes 1: yes, 2: no.

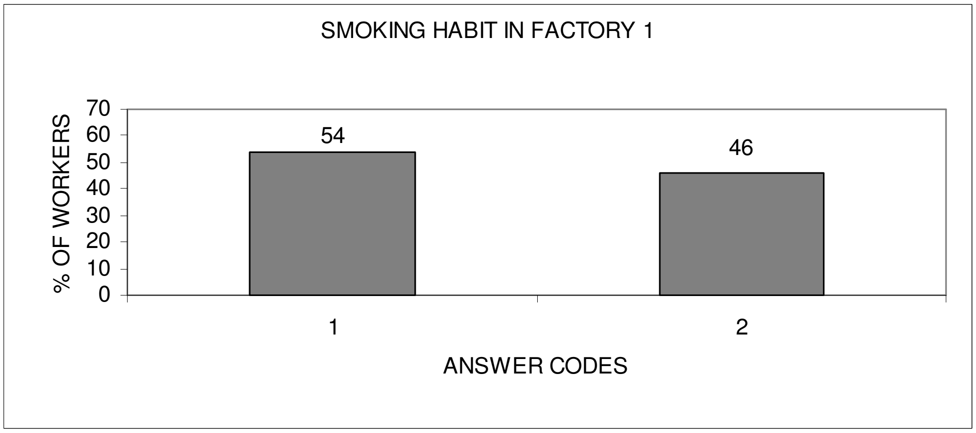


Figure 2.39 Do you smoke? (Factory 1)

(No. of Respondents: 41)

Answer Codes 1: yes, 2: no

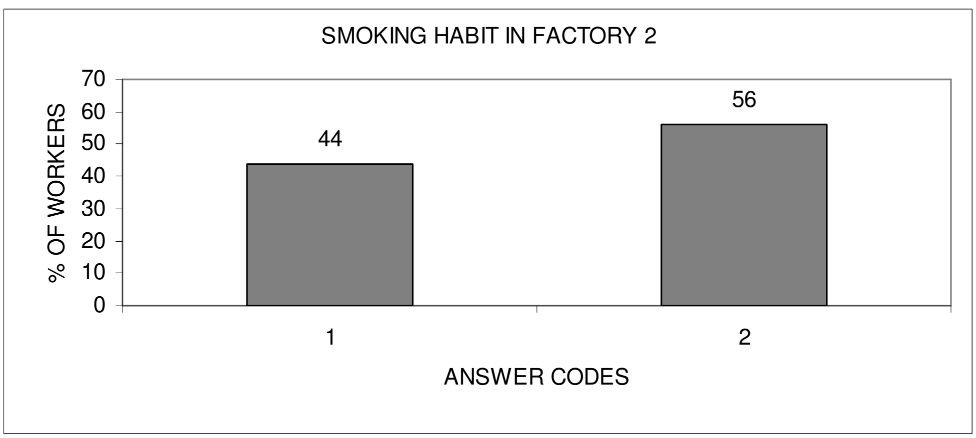


Figure 2.40 Do you smoke? (Factory 2)

(No. of Respondents: 50)

Answer Codes 1: yes, 2: no.

Figure 2.41 Do you have hypertension? (Factory 1)
(No. of Respondents: 42) Answer Codes 1: yes, 2: no

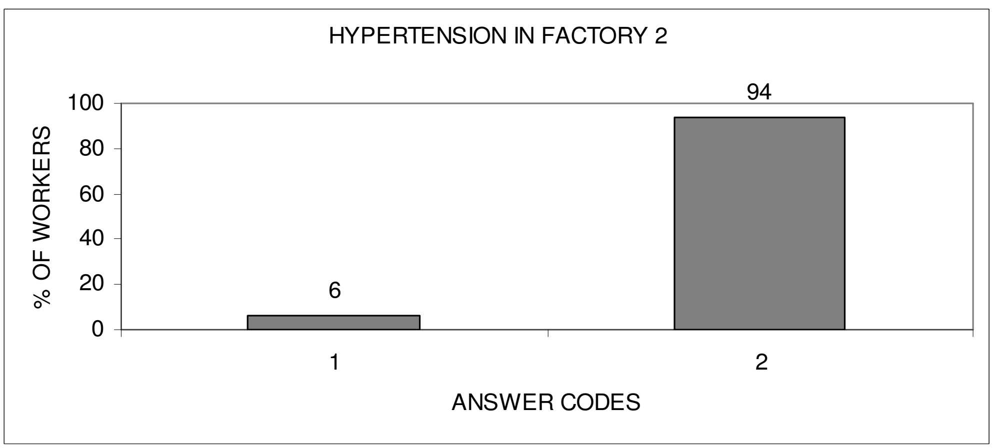


Figure 2.42 Do you have hypertension? (Factory 2)
(No. of Respondents: 49) Answer Codes 1: yes, 2: no.

CHAPTER III

NOISE MEASUREMENT AND ASSESSMENT METHODOLOGY

International Standard ISO 9612 was taken as basis for the measurement method of this study [21]. This standard provides general guidance for the types of measurements and the measurement positions required for the evaluation of the noise with respect to its effects on the worker in order to monitor compliance with established documents and in order to indicate the need for reducing noise by appropriate measures. It describes the acoustical quantities to be measured, especially the type and locations of sound pressure level measurements to be conducted, the time sampling and frequency analysis required and the special characteristics of the noise to be considered. The purpose is to allow an assessment of the noise in the working environment with respect to its various effects on the worker as a result of daily habitual exposure.

The preferred basic measurement quantity is A-weighted sound pressure level L_{Aeq} during a time interval of 8 hours.

In this study 16-8000Hz**.** frequency band was taken. At least three discreet positions are advised by ISO 1996-2: 2007 (E) [22] for indoors measurements. More microphone positions are advised for places with volumes > 300 m^3. In our case, following a pilot study the number of measurement points was decided to be 15 in Factory 1 and 10 in Factory 2. Measurement points have to be chosen so that they were evenly distributed in the areas of the room and at places where affected persons spend more time. If dominant low frequency (i.e., 16Hz<f<200 Hz) is suspected, one of the three positions has to be in a corner. The corner position has to be at least 0.5 m away from all boundary surfaces in a corner with the heaviest walls and without any wall openings nearer than 0.5m. When the distance between microphone positions are regarded as the distance between the measurement points the distance between neighbouring measurement points has to be least 0.7m. In our measurements this was at least 3 m. In addition the microphone location preferably shall be the position of the head of the person occupying the working place under consideration without the person. This was also not possible so the measuring device was hold by the measurer at the ear level of the exposed person. In the above mentioned standard it is stated that in such cases the microphone should be located approximately 0,1m from the entrance of the external canal of the ear receiving the higher value of the equivalent continuous A-weighted sound pressure level. This point was also kept in consideration.

For measurement positions at a specific location, the reference direction of the microphone was directed in a way to point the direction of sight of the person occupying the working place.

In ISO 9612 the normalizing/reference time interval is the time representing the duration of one work shift, which in our case is 8 hours. Most of the time, workers work 2 hours in the morning then have a tea brake for 15 minutes and then work again for 2 hours until lunch brake which lasts 1 hour. The afternoon session composed of 2 hours of work, 15 minutes of rest and 2 hours of work sub sessions. Therefore in order to see the noise exposure range of the workers in the longest sub session, A-weighted sound pressure level for two hours was also taken.

According to ISO 9612 the measurement time interval should be chosen so that all significant variations of noise levels at the workplace are measured and included. Further the measurement time intervals should be such that the measurement result is consistent with respect to repetitive measurements. During the measurement time interval, care should be taken so that noise which is characteristic of the specific working place is existent. Two procedures may be used to acquire the characteristic noise exposure: If the measurement time interval is extended over the normalizing/reference time interval, the total exposure to noise of the work shift to be rated may be determined directly. If a measurement time interval is less than the normalizing/reference time interval, the characteristic noise exposure being measured may be selected by experience. In the latter case the measurement time interval sample must be chosen such that the noise exposure determined represents the spatial and time variations of the working place noise. In this study the second method was utilized; workers and managers of the two factories were briefly interviewed about the noisiest periods and about the periods which they thought didn't represent the usual noise level. Information was also gathered about the periods when extraordinary numbers of workers were out in other workplaces. Measurements were then done in the noisy and normal periods and in the presence of the highest number of workers.

In ISO 9612 it is stated that the selected measurement duration shall depend on the fluctuations of the noise. It shall be sufficiently long for the resulting noise exposure to be representative of the activities performed by the employee. The duration should be either the entire length of an activity or a portion of it or several repetitions of the activity, as required to stabilize the readings of the sound exposure level or the equivalent continuous A-weighted sound pressure level within 0.5 dB. The minimum duration should be 15 seconds. 15 seconds was too short to be representative of the factory's noise characteristic so Pykkö et.al.'s [15] choice of 10 minutes was tested and seen to be sufficient also for this study.

In order to assess the impulsive characteristic of the noise within the specified time interval, ISO 1996-2 suggests a comparison with the impulsive sound sources given in ISO 1996-2.In ISO 1996-2:1987/Amd.1:1998(E) metal hammering, which is a dominant activity in Factory 1, is identified as “highly impulsive sound”. When impulsive sounds can not be separately measured as a single event (which is the case in Factory 1), the rating level, $(L_{Ar,T})_i$ for each reference time interval is advised to be calculated from:

$(L_{Ar,Tr})_i=(L_{Aeq,Tr})_i+K_{Ti}+K_{Ii}$

Where

T_r = duration of the reference time interval

K_{Ti} =tone adjustment

K_{Ii} =Impulse adjustment

ISO 9612-2:1997(E) does not recommend the total analysis of indoor noise due to the modal behaviour of tones in the enclosed spaces. One another method is stated in Annex-B of the above mentioned standard, which proposes the measurement of the difference between $L_{AIeq,\,T}$ and $L_{Aeq,\,T}$ as K_I over the measured time interval.

While rating the noise level in Factory 1 in this study, K_{Ti} is ignored and K_{Ii} is taken to be 5 (as recommended in Amd.1:1998(E) of ISO 1996-2:1987) because impulsiveness is a predominant characteristic of the noise in this factory . The difference between $L_{AIeq,\,T\,=\,10\,mins}$ and $L_{Aeq,\,T=10\,mins}$ was also measured in both factories.

The results of the questionnaire survey show that the approximately 69% of the workers of Factory 1 had claimed that communication with others were highly affected by the noise level existent in Factory 1. Perception of warning signals was also highly affected in this factory. This effect of noise on understanding speech was evaluated referring to TS 2726 [23]. In this standard sufficient perception of speech refers to minimum of 95% and a speech index of 0.4. Speech interference level of noise is the arithmetical average of the sound pressure levels at octave bands of 500, 1000, 2000, 4000 Hz and is applicable to cases where reverberation and echoing levels are ignorable and there exists a continuous spectrum with steady state noise caused by speeches at high or normal levels. Sound pressure levels should be measured at fast time weighting at listener's head height.

The quality of speech communication was tested in accordance to TS EN ISO 9921 [24]. This standard specifies the requirements for the performance of speech communication for verbal alert and danger signals, information messages and speech communication. Assessment of speech communication includes speech interference and vocal effort.

Interference is tested by both subjective and objective methods. Subjective methods were not used in this study. Commonly used objective methods are Speech Interference level (SIL), Speech Transmission Index (STI) and Speech Intelligibility Index (SII).

The level of the speech signal depends on the vocal effort of the speaker. The vocal effort is expressed by the equivalent continuous A-weighted sound pressure level of speech measured at a distance of 1m in front of the mouth of the speaker. Ambient noise above a certain level influences the vocal effort (Lombard effect). The quality of loud speech above the level of 75 dB (A) is substantially reduced making it more difficult to understand in comparison with speech produced at lower vocal effort. STI method is based on the calculation of the effective signal to noise ratio in seven relevant frequency bands using a test signal. This method was not utilised. The speech interference level offers a simple method to predict or to assess the speech interference in cases of direct communication in a noisy environment. The speech interference level of noise is calculated as the arithmetic mean of sound pressure levels of the ambient noise in four octave bands with central frequencies 500, 1000, 2000 and 4000 Hz. The level of the speech signal is determined by the vocal effort of the speaker. Speech Interference is given by the difference between the speech level and speech interference level of noise. Fair communication quality is ensured if the difference is more than 10 dB.

The noise attenuation due to utilization of ear plugs was evaluated according to TS EN ISO 4869/2 [25]. Three methods can be used depending on the circumstances. They are HML Method, SNR method and an alternative octave band method. HML method like the SNR method is designed for estimating the effective A-weighted sound pressure levels from the measured C and A weighted sound pressure levels when ear protectors are used. Octave band method is a short cut method which is concerned about the attenuation of ear protectors. Although all three methods have close accuracies in high and low frequencies HML and octave band methods might yield advantageous results.

These methods can be applied to sound pressure levels or equivalent sound pressure levels. They are basically applicable to steady state noise environments; however they can also be used for environments that contain impulsive noises.

Octave band method firstly requires the calculation of protection value of an ear protector and then using it together with octave band pressure levels to obtain Effective A-weighted sound pressure level.

HML method requires C and A weighted sound pressure levels and H, M, L values. H, M, L values depend on (L_C - L_A) and protection value of the ear protector.

SNR method requires the C weighted sound pressure values and it is calculated based on the pink noise spectrum values and assumed protection value of the ear protector.

According to the standard; all three methods yield results with close accuracies. SNR method was used in this study.

A selection guide for ear protectors is given in TS EN 458 [26]. An ear protector is selected considering the factors below:

- CE mark
- Noise Attenuation
- User Comfort
- Environment and Activity
- Medical Problems
- Compatibility with other safety protectors used by the workers

It was declared by the authorities of both factories that, ear protectors used by the workers had been selected in accordance with above mentioned factors.

CHAPTER IV

NOISE MEASUREMENTS

It was essential to support the subjective assessments of the workers by objective noise measurements to obtain a complete view of the situation in the two factories. Therefore several measurements were taken in different circumstances and settings. Each measuring activity was performed with the permission and under the guidance of the factory administrations to maintain the best achievable conditions for valid measurements. Measurement days and hours were taken so that they would have represented the usual working conditions and activities. For instance; days when the factory employed less people than usual, due to duties on ships, were avoided. Unfortunately field activities of this study expanded from May to August, mostly in July, when a considerable number of workers (in all cases less than half) were at vacation. This unavoidable situation therefore renders it very difficult to find representative time periods of the works done in the factories.

4.1. Choice of the Factory Where the Noise Level Measurements have to be done

There are over 20 factories in the shipyard in different scales and having different worker populations. First, a sound walk was carried out in the shipyard, observing the noise levels of factories and than 4 factories were decided to be worth for noise measurements. They were: 1.hull construction factory, 2.machinery factory, 3.thin sheet applications workshop and 4.hydraulics factory. Measurement points were chosen to be the noisiest places of the factory at that time. Measurement settings for the device used, which was B&K 2233, and results are presented below:

Polar Voltage: 0V
Sound Incidence: Frontal
Time Weighting: Fast
Range: 40-110 dB
External Filter: Out
Display: Maximum Hold

Table 4.1 Sound Pressure Level, SPL, values in Factory 1 (Friday)

Sound Pressure Level (Linear) (dB)	Sound Pressure Level(A-weighted) (dB(A))	Notes about the locations and the activities
99.2	91	Hammering and grinding
84	82.9	Grinding and lathe machine working, no hammering
90.3	102	Hammering, crane working
109.1	107	Hammering and grinding
103.7	97	Hammering
86.3	92.5	Factory Chief's room
92.6	82.3	Group Managers room
86	-	Tea Brake
89.5	81	Tea Brake

Table 4.2 Sound Pressure Level, SPL, values in Factory 2 (Friday)

Sound Pressure Level (Linear) (dB)	Sound Pressure Level (A-weighted) (dB(A))	Notes about the locations and the activities * BGN = Back Ground Noise
76.9	70	
80.8	75.7	*BGN:78.6 dBL / 71.9 dBA (teatime) light hammering
81	74.7	BGN:81.2 dBL / 72.2 dBA (teatime) workbenches running
78.4	73	BGN:77.7 dBL /63.7 dBA (teatime) workbenches running
82.6	76.1	BGN:77.5 dBL /68.5 dBA (teatime) workbenches running
96.5	84.2	Factory gate. 15 m away a generator is running.
67.5	51.4	Factory Manager's room. Door shut
68.6	60	Planning Office
72.3	52	Factory Chief's room. Door shut
82.6	65.7	Computer Aided Design Room. Door open
76.7	65.1	Warehouse. Door shut
69.9	51.1	Hand Tools Warehouse. One window open

Table 4.3 Sound Pressure Level, SPL, values in Factory 3 (Friday)

Sound Pressure Level (Linear) (dB)	Sound Pressure Level (A-weighted) (dB(A))	Notes about the locations and the activities
113	110	Beam cutting
118	119	Hammering and grinding
113	105	Hammering and grinding

Table 4.4 Sound Pressure Level, SPL, values in Factory 4 (Friday)

Sound Pressure Level (Linear) (dB)	Sound Pressure Level (A-weighted) (dB(A))	Notes about the locations and the activities
88	85	Valve cleaning with high pressure air

Table 4.5 Comparison of factories

SPL	Min. dBL	Max. dBL	Mean dBL	Min. dBA	Max. dBA	Mean dBA
Factory 1	84	109.1	93.3	81	107	92
Factory 2	67.5	96.5	77.8	51.1	84.2	66.6
Factory 3	113	118	114.7	105	119	111.3
Factory 4			88			85

A comparison of these results, as shown in the table above, reveals that the study should have been carried out in Factory 3 having the highest sound pressure level and Factory 2 as the one having the lowest sound pressure level. However Factory 1 was chosen instead of Factory 3 because, Factory 3 had only a total number of 35 workers and it was not possible to perform a proper questionnaire survey and then carry out a statistical analysis on such a small population.

4.2. Decision for the Number and Location of Measurement Points

Measurement points selected in the two factories were determined by taking sound pressure level measurements from several points as shown below and identifying the groups of points that would represent an area showing a common acoustical behaviour. Preliminary points are given in Figure 4.1 and measurement results are tabulated in Table 4.6:

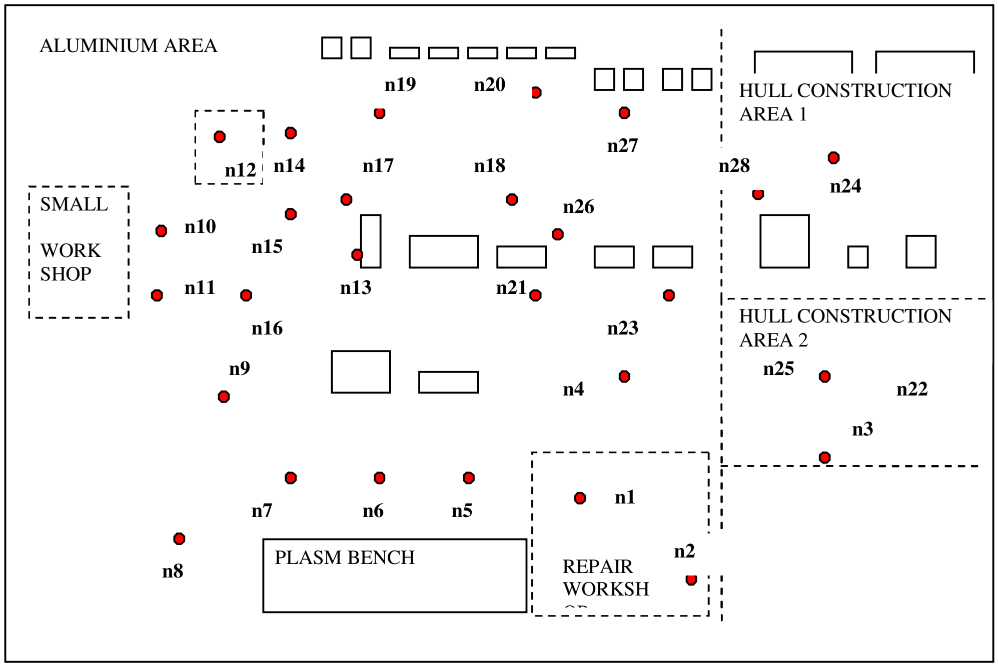


Figure 4.1 Preliminary measurement locations (Factory 1).

Table 4.6 L_{eq} (dBA) values measured in Factory 1 (duration= 15 seconds)

	Wed.	Mon.	Wed.	Thu.	
Point No.	1.Set	2. Set	3. Set	4. Set	Mean
1	100	79	80	93	88
2	103	80	87	94	91
3	104	110	95	76	96
4	104	98	84	85	93
5	104	103	85	91	96
6	101	106	85	89	95

Table 4.6 L_{eq} (dBA) values measured in Factory 1 (duration= 15 seconds) (continued)

	Wed.	Mon.	Wed.	Thu.	
Point No.	1.Set	2. Set	3. Set	4. Set	Mean
7	104	100	93	90	97
8	100	81	90	82	88
9	98	100	85	80	91
10	99	105	83	83	93
11	99	98	90	85	93
12	102	97	88	87	94
13	98	93	95	82	92
14	96	89	99	86	93
15	94	95	85	88	91
16	90	91	89	85	89
17	108	83	91	82	91
18	93	97	84	85	90
19	91	88	86	83	87
20	96	96	85	85	91
21	92	96	81	88	89
22	89	100	102	90	95
23	82	99	100	83	91
24	88	98	97	84	92
25	88	96	97	94	94
26	93	95	86	81	89
27	96	103	86	82	92
28	88	86	86	85	86

Observation of the mean values of the 4 set of measurements enables the regrouping of the twenty eight points as shown in Table 4.7.

Table 4.7. Final Set of Measurement Points (Factory 1)

Prelimenary Points	No of the measurement Points
10 , 11	n1
12 , 14, 15 ,	n2
8 , 9 , 16	n3
17 , 19 , 13	n4
5 , 6 , 7	n5
18 , 20 , 21 , 26	n6
23 , 4 , 27	n7
1 , 2	n8
24 , 28	n9
22 , 25 , 3	n10

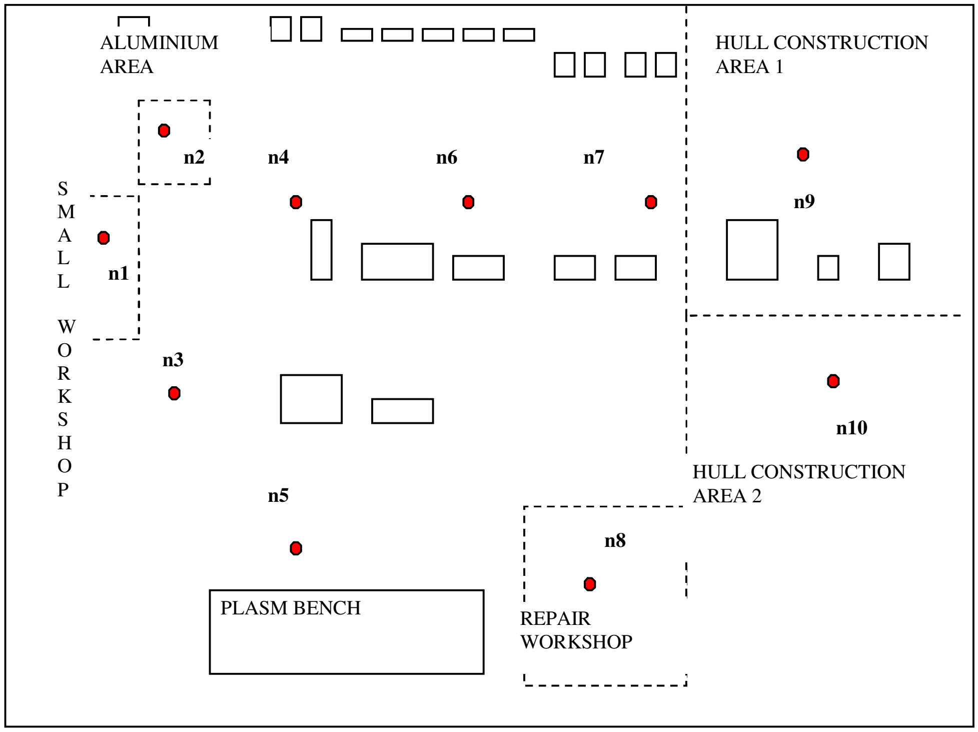


Figure 4.2 Measurement points in Factory 1.

Due to the managerial inconvenience of Factory 2, separate measurements for decision about points could not be performed. Preliminary measurement points, given in Figure 4.3., for Factory 2 were determined according to the “range level” measurements given below in section 4.3.

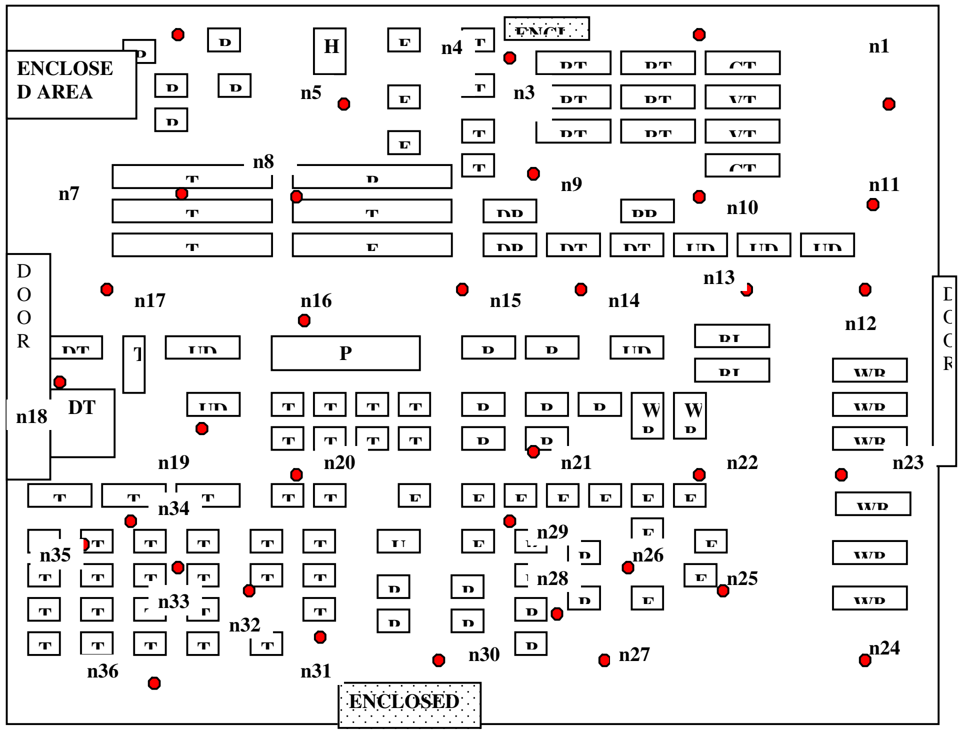


Figure 4.3 Preliminary measurement locations for the determination of measurement points for Factory 2.

Table 4.8 Final Set of Measurement Points (Factory 2)

Preliminary Points	Measurement Point
5 , 6	n1
3 , 4	n2
1 , 2	n3
7 , 8	n4
9 , 10	n5
11	n6

Table 4.8 Final Set of Measurement Points (Factory 2) (continued)

16 , 17	n7
14 , 15	n8
12 , 13	n9
18 , 19 , 20 ,21	n10
22 , 23	n11
32 , 33 , 34 , 35 , 36	n12
29 , 30 ,31	n13
26 , 27 , 28	n14
24 , 25	n15

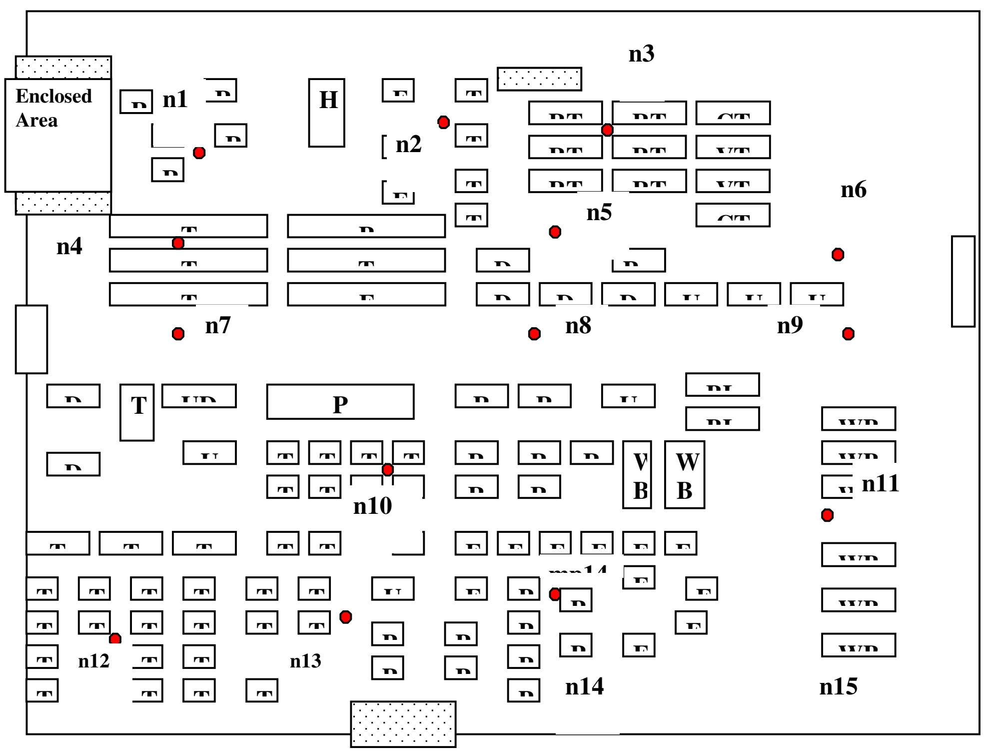


Figure 4.4. Measurement points in Factory 2.

4.3. Decision of Noise Level Range

Next step was to determine the correct amplitude range setting that would be selected in the measuring device (B&K 2260 Investigator).

Noisiest parts of the factory were chosen and sound pressure level was measured for 15 seconds in 0.5-80.5, 10.9-90.5, 20.5-100.5, 30.5-110.5, 40.5-120.5 dB ranges for A weighted spectrum and 30.5-110.5, 40.5-120.5, 50.5-130.5 dB ranges for L weighted spectrum and overload condition was observed. In case of overload next higher level range interval was checked.

Settings and results for Factory 1 are given below:

<u>Setting 1</u>

Time Weighting: fast

Broadband Meas.: A&C

Broadband Stat.: A

Spectrum: A

<u>Setting 2</u>

Time Weighting: fast

Broadband Meas.: A&L

Broadband Stat.: L

Spectrum: L

Table 4.9.Range interval for Factory 1 (Wednesday)
(Measurement Duration: 2 seconds)

Meas. Point	Range Used dB(A)	Overload Condition	Range Used dB	Overload Condition
1	0.5-80.5 (setting 1)	overload	30.5-110.5 (setting 2)	No overload
1	10.9-90.5 (setting 1)	overload	30.5-110.5 (setting 2)	No overload
1	20.5-100.5 (setting1)	No overload	30.5-110.5 (setting 2)	No overload
2	20.5-100.5 (setting 1)	No overload	30.5-110.5 (setting 2)	No overload
22	20.5-100.5 (setting 1)	No overload	30.5-110.5 (setting 2)	No overload
23	20.5-100.5 (setting 1)	No overload	30.5-110.5 (setting 2)	No overload
28	20.5-100.5 (setting 1)	No overload	30.5-110.5 (setting 2)	No overload
28	20.5-100.5 (setting 1)	No overload	30.5-110.5 (setting 2)	No overload

Settings and results for Factory 2 are given below

<u>Setting</u>

Time Weighting: fast

Broadband Meas.: A&C

Broadband Stat.: A

Spectrum: A

Table 4.10 Range interval for Factory 2 (Wednesday)
(Measurement Duration: 2 seconds)

Point	Range Used dB(A)	Overload Condition	Point	Range Used dB(A)	Overload Condition
1	10.5-90.5	No overload	19	10.5-90.5	No overload
2	10.5-90.5	overload	20	10.5-90.5	No overload
3	10.5-90.5	No overload	21	10.5-90.5	No overload
4	10.5-90.5	No overload	22	10.5-90.5	No overload
5	10.5-90.5	No overload	23	10.5-90.5	No overload
6	10.5-90.5	No overload	24	10.5-90.5	No overload
7	10.5-90.5	No overload	25	10.5-90.5	No overload
8	10.5-90.5	No overload	26	10.5-90.5	No overload
9	10.5-90.5	No overload	27	10.5-90.5	No overload
10	10.5-90.5	overload	28	10.5-90.5	No overload
11	10.5-90.5	No overload	29	10.5-90.5	No overload
12	10.5-90.5	No overload	30	10.5-90.5	No overload
13	10.5-90.5	No overload	31	10.5-90.5	No overload

Table 4.10 Range interval for Factory 2 (Wednesday)
(Measurement Duration: 2 seconds) (continued)

Point	Range Used dB(A)	Overload Condition	Point	Range Used dB(A)	Overload Condition
14	10.5-90.5	No overload	32	10.5-90.5	No overload
15	10.5-90.5	No overload	33	10.5-90.5	No overload
16	10.5-90.5	overload	34	20.5-100.5	overload
17	10.5-90.5	No overload	35	20.5-100.5	No overload
18	10.5-90.5	overload	36	20.5-100.5	No overload

Based on these studies “20.5-100.5 dB” and “30.5-110.5 dB (A)” ranges were chosen for Factory 1 and “20.5-100.5 dB (A)” range was chosen for Factory 2.

4.4 Decision for the Duration of Measurements

Last step before the real measurements was to determine the measurement duration by taking recordings for 10, 15, 20, 30 minutes and inspect the changes in L_{eq} values.

Factory 1 (point 25):

10 minutes (L_{eq}): 80.9 dB (A), 80.2 dB (L)

15 minutes (L_{eq}): 82.8 dB (A), 85.4 dB (L)

15 minutes (L_{eq}): 79 dB (A)

20 minutes (L_{eq}): 77.9 dB (A)

30 minutes (L_{eq}): 78.6 dB (A)

Factory 2 (point 23):

10 minutes (L_{eq}): 77.1 dB (A), 75.3 dB (L)

15 minutes (L_{eq}): 74.9 dB (A), 76.3 dB (L)

10 minutes (L_{eq}): 74.9 dB (A)

15 minutes (L_{eq}): 77.7 dB (A)

20 minutes (L_{eq}): 74.8 dB (A)

The difference between 10 minutes, 15 minutes and 20 minutes measurements was less than 5 dB for both factories so 10 minutes was considered to be appropriate for the actual measurements.

4.5 Noise Measurements

Noise measurements which would be the basis for various analyses, were taken at the determined points, for the level range and the duration stated above. Noise levels given for a factory do not necessarily belong to the same day. Measurements were taken on July 2007 in Factory 1 and Factory 2 and additional measurements were performed in April 2008 in Factory 1, to investigate the impulsive content of the factory noise.

The work load at the factory in 2008, was a bit higher than the one in 2007 but still not at its paramount level because all the major projects at the factory were about to be finished and workers were working on some minor scale ship construction projects. In 2008, of the 223 workers of Factory 1, 136 were working outside the factory mainly at dry dock repairement activities.

In addition, reports of “İşçi Sağlığı ve Güvenliği Genel Müdürlüğü “ (İSGÜM) on the acoustical situation of factories were utilised for this study. İSGÜM’s measurements, given in APPENDIX-C, were taken on November of 2007 so they represent a noisier period of the factory compared to the measurement period of this study.

4.5.1. Noise Level Assessment

Several noise limit values are recommended in several noise exposure standards around the world, many of them being close to each other. For instance Safety, Health and Environment Division of Department of Industry and Resources in South Australia proposes 85 dB(A) and 140 dB(C), Canadian Federal Labour Operations, Human Resources Development imposes 87 dB(A) and 120 dB max, China imposes 70-90 dB(A) depending on industry and 115 dB(A) max. and Israel 85 dB (A), 115 dB (A) max, 140 dB(C) peak.

In this study noise levels in both factories were assessed according to the “European Noise Directive 2003/10/EC” [27] and “Noise Regulation” of Ministry of Labour and Social Security” [28]. The exposure limit value is 87 dBA where as upper exposure action value is 85 dBA and lower exposure action value is 80 dBA. Peak values are 140 dB(C), 137 dB(C) and 135 dB(C) respectively. Ear protector effect will be taken in to consideration in the “Ear Plug Performance” section.

4.5.1.1. Factory 1

4.5.1.1.1. A-weighted Noise Level

The major activities in this factory were observed to be metal grinding, cutting, bending, welding and hammering. Big size metal pieces were processed in hydraulic machines where small size pieces and some special activities were handled by hand devices. These special activities comprise grinding of manufactured parts and hammering of the thin sheet shell of ship blocks while fitting them to their places.

Results differed from time to time in different measurements in this factory and this is something to be expected because ship construction factories have varying work loads and work characteristics. Even within the same day noise levels vary considerably and it is not possible to have a single value to represent the noise level of a particular point.

Therefore assessment of the A-weighted noise levels was carried out considering the maximum values of several measurements.

Table 4.11 A-weighted noise level assessment of Factory 1

Measurement Point	L A eq	Rating According to Noise Regulations
n1	88	Above the Exposure Limit
n2	88	Above the Exposure Limit
n3	83	Above the Lower Exposure Action .Limit
n4	80	The Lower Exposure Action Limit
n5	87	The Exposure Limit
n6	90	Above the Exposure Limit
n7	93	Above the Exposure Limit
n8	99	Above the Exposure Limit
n9	102	Above the Exposure Limit
n10	103	Above the Exposure Limit

Even though the criterion levels are exceeded at 8 points it should be noted that the workload and thus the noise level of the factory was relatively low during the measurements compared to the high season of the factory. This was partly a result of the condition of the projects in the Shipyard. At the time of the measurements big projects had been almost completed and the small jobs at hand were proceeding at a slow rate due to managerial reasons. Approximately 136 out of 223 workers were working outside the factory (ships, dry docks etc.) in April 2008.

In 2007 measurements, taken in July, approximately 1/3 of the workers were on vacation. So higher levels should be expected in high work periods of the factory i.e., winter time, big projects, heavy workload and big labour force working in the factory.

Workers' Compensation Board of Columbia [29] reveals the general noise exposure levels in shipbuilding industry as; 91-100 dBA for welders and 94-100 dBA for shipwrights. This verifies the relative low level of noise in Factory 1 at the time of measurements.

Points 7,8,9 and 10 in Factory 1 generally seem to have the highest levels due to intensive metal hammering, grinding and cutting activities around these points, while points 1,2,5,6 were observed to be noisy too from time to time. It should be noted that first measurements of 2007 display a somewhat different picture. Points 9 and 10 displayed noise levels very much below the limit while other points are above the limit. This is supposed to be an exception.

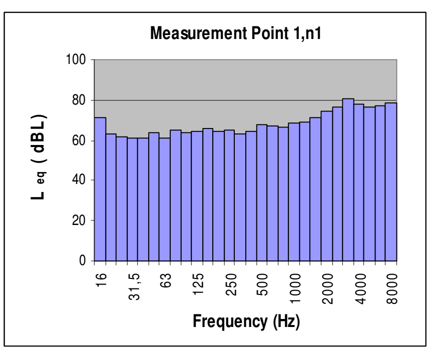
Metal hammering was frequently observed at almost all regions in the factory. For this case ISO 1996-2:1987/Amd.1:1998 (E) recommends an adjustment. According to this standard if impulsiveness is a predominant characteristic of the sound within a specified time interval an adjustment should be applied for this time interval, to the measured equivalent continuous A-weighted sound pressure level. In the case when the impulsive sounds can not be separately measured as single events, which is the situation for Factory 1, adjustment value is 5 dB. ISO 9612:1997(E) also recommends an adjustment value between 3 dB and 6 dB when the impact value, $K_I = L_{Im} - L_{A\,eq}$ exceeds 2 dB. Mean K_I for factory 1 was 4 dB, and 5 dB seems to be an appropriate correction value.

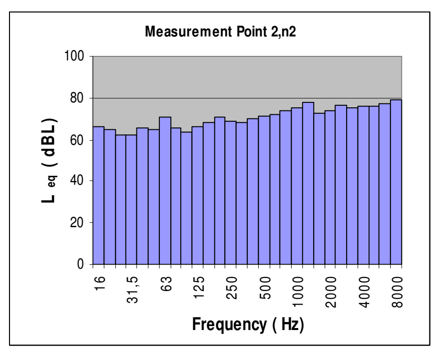
Table 4.12 Corrected $L_{A\,eq}$ values due to Impulsive content

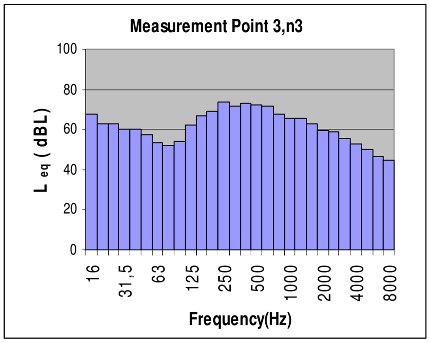
Measurement Point	Corrected L A eq	Rating According to Noise Regulations
n1	93	Above the Exposure Limit
n2	93	Above the Exposure Limit
n3	88	Above the Exposure Limit
n4	85	The Upper Action Limit
n5	92	Above the Exposure Limit
n6	95	Above the Exposure Limit
n7	98	Above the Exposure Limit
n8	104	Above the Exposure Limit
n9	107	Above the Exposure Limit
n10	108	Above the Exposure Limit

4.5.1.1.2 Noise Spectra

Factory 1







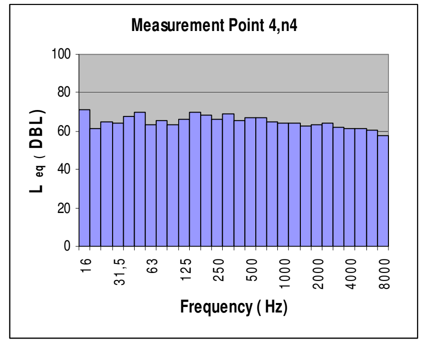
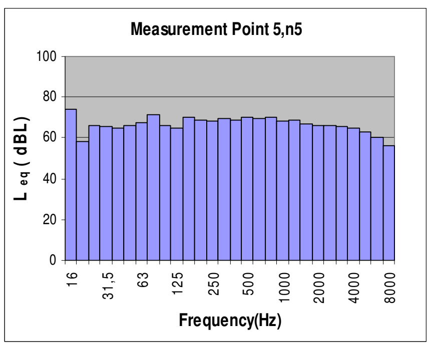
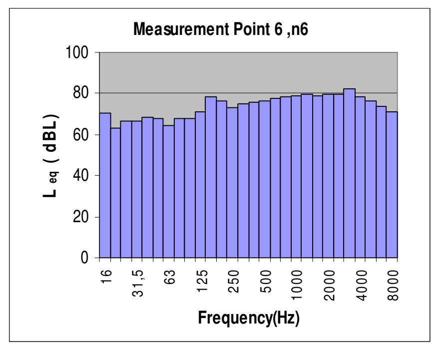
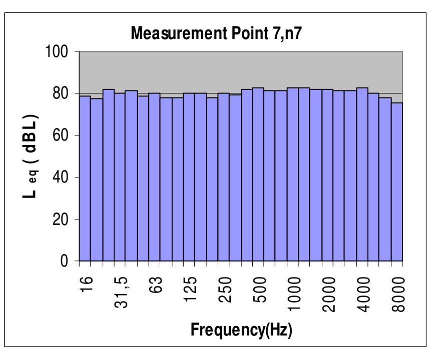
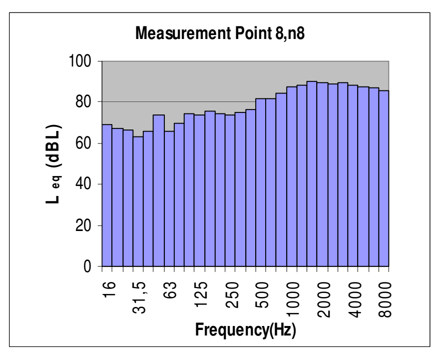


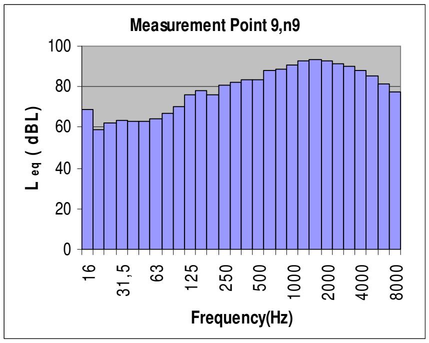
Figure 4.5 Noise spectra for points n1-n4 (Factory 1)











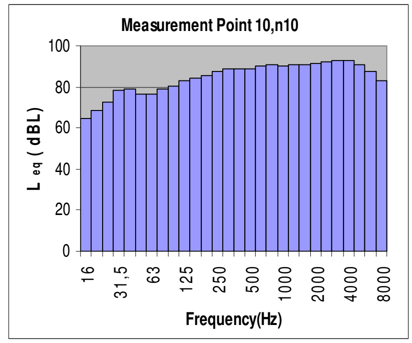
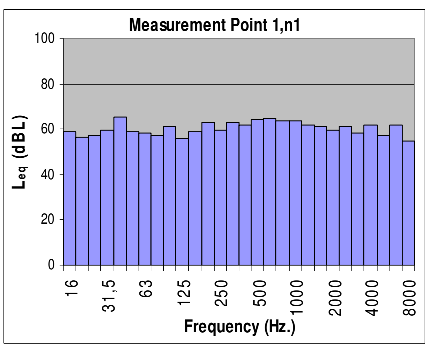
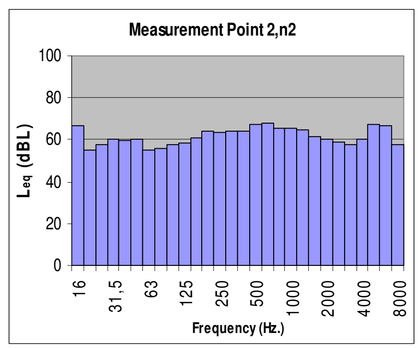
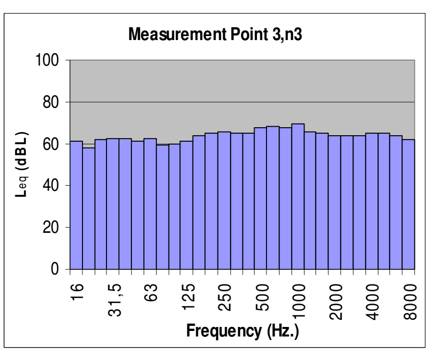


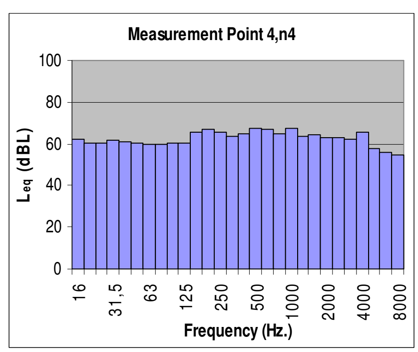
Figure 4.6 Noise spectra for points n5-n10 (Factory 1)

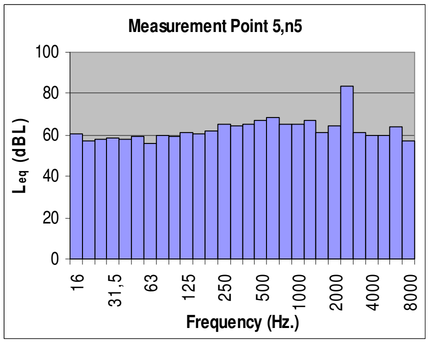
Factory 2











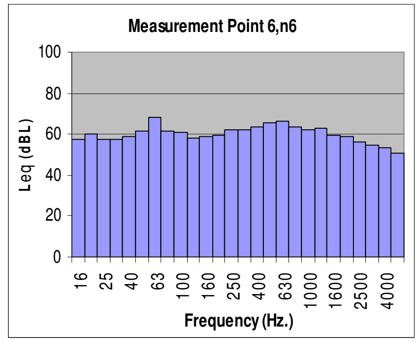
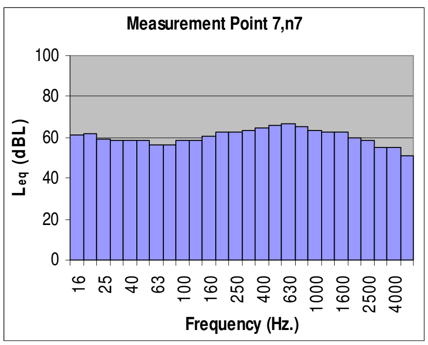
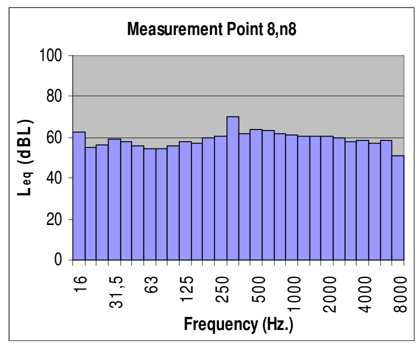
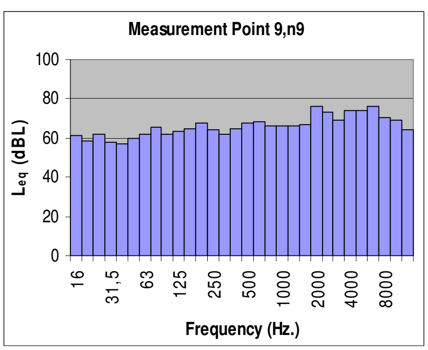
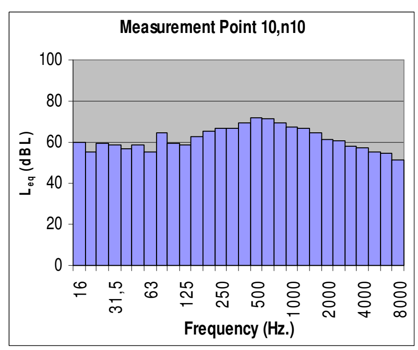


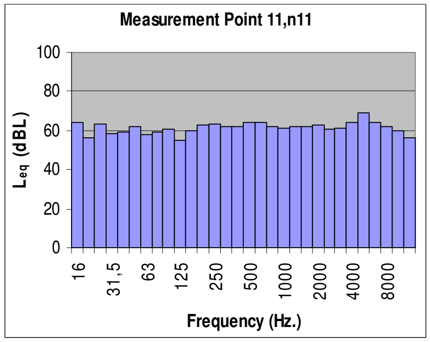
Figure 4.7 Noise spectra for points n1-n6 (Factory 2)











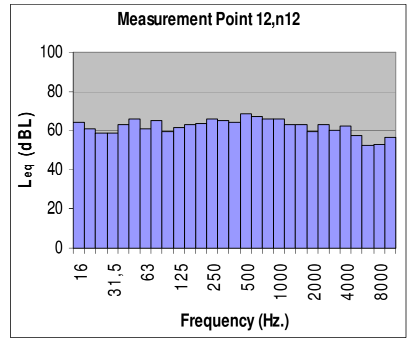
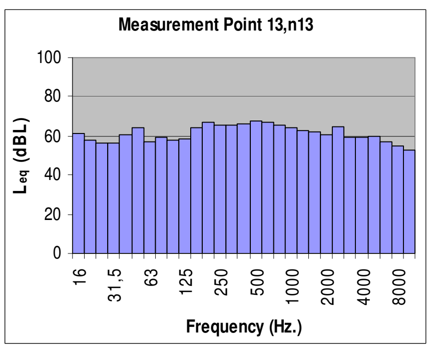
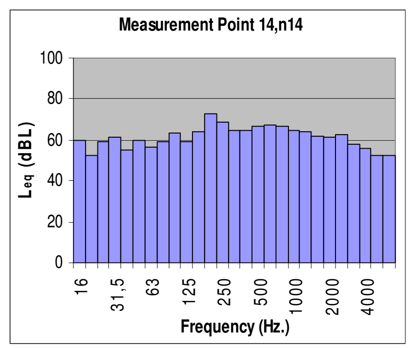


Figure 4.8 Noise spectra for points n7-n12 (Factory 2)





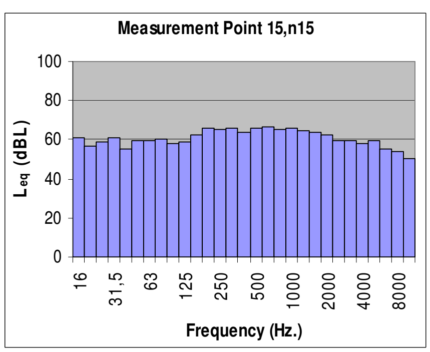


Figure 4.9 Noise spectra for points n13-n15 (Factory 2)

4.5.1.1.3. Dosimeter Measurements

Another way of expressing noise exposure of the workers is to predict the noise dose by dosimeters. Noise dose is measured in units called Pascal squared hours abbreviated as Pa^2h. It can also be used as a percentage of an "acceptable" or "criterion" noise dose. In several resources, a noise exposure of 85 dB (A) is equal to 1 Pa^2h or 100%. However for the dosimeter used in this study, 1 Pa^2h or 100% equals to
90 dB (A). The measured values below should therefore be assessed accordingly.

WORKER-1
DATE: 07.04.2008 MONDAY
LOCATION: REPAIREMENT WORKSHOP (n8)
TASK: MANUFACTURING FOUNDATION FOR MINIMAX TUBES
CUTTING, GRINDING, HAMMERING

Table 4.13 Dosimeter values for worker 1.

10:00		11:40		15:10		16:55	
LEP:	88.2	LEP:	90.3	LEP:	90.8	LEP:	92.5
DOSE:	65	DOSE:	105	DOSE:	119	DOSE:	176
Pa^2h:	2.080	Pa^2h:	3.36	Pa^2h:	3.808	Pa^2h:	5.632

WORKER-2
DATE: 08.04.2008 TUESDAY
LOCATION: SHIP CONSTRUCTION AREA (n9)
TASK: POINT WELDING

Table 4.14 Dosimeter values for worker 2.

10:30		11:35		16:30	
LEP:	83.7	LEP:	84.5	LEP:	88.4
DOSE:	23	DOSE:	28	DOSE:	68
Pa^2h:	0.736	Pa^2h:	0.896	Pa^2h:	2.176

WORKER-3

DATE: 09.04.2008 WEDNESDAY

LOCATION: SMALL WORKSHOP (n1)

TASK: SHEET CUTTING, BENDING AND ASSEMBLAGE

Table 4.15 Dosimeter values for worker 3

10:00		11:30		16:00		17:00	
LEP:	82	LEP:	83.9	LEP:	85.7	LEP:	86.4
DOSE:	15	DOSE:	24	DOSE:	37	DOSE:	43
Pa^2h:	0.480	Pa^2h:	0.768	Pa^2h:	1.184	Pa^2h:	1.376

WORKER-4

DATE: 10.04.2008 THURSDAY

LOCATION: SMALL WORKSHOP (n8)

TASK: METAL HAMMERING

Table 4.16 Dosimeter values for worker 4

10:30		11:30		14:30		17:00	
LEP:	98.8	LEP:	99.5	LEP:	99.9	LEP:	100.9
DOSE:	750	DOSE:	892	DOSE:	979	DOSE:	1204
Pa^2h:	24	Pa^2h:	28.54	Pa^2h:	31.32	Pa^2h:	38.52

4.5.1.1.4. C-weighted Peak Levels

Table 4.17 C-weighted noise level assessment of Factory 1.

Measurement Point	C-weighted Peak values	Rating According to Noise Regulations
n1	114	Below the Lower Exposure Action Limit
n2	125	Below the Lower Exposure Action Limit
n3	120	Below the Lower Exposure Action Limit
n4	115	Below the Lower Exposure Action Limit
n5	132	Below the Lower Exposure Action Limit
n6	131	Below the Lower Exposure Action Limit
n7	134	Below the Lower Exposure Action Limit
n8	128	Below the Lower Exposure Action Limit
n9	127	Below the Lower Exposure Action Limit
n10	132	Below the Lower Exposure Action Limit

In Factory 1 it was easily observed that, impulsive noise, mostly due to metal hammering, was quiet outstanding. However C weighted noise levels were below the limits at all points. It should be again noted that all the measurements in 2007 and 2008 were unfortunately taken at relatively quiet periods of the factory. Higher levels should be expected at usual times.

4.5.1..2. Factory 2

In this factory the general characteristic of the job is different from Factory 1. Here workers mostly work on machines like lathe, planing and drilling machines, which create a lower level of steady noise. This will be better observed in impulse content section of this study. Still, higher levels should be expected at usual (busy) times of the factory, because nearly ¼ of total 170 workers of Factory 2 were at vacation at the time of measurements.

The average impact value, $K_I = L_{Im} - L_{Aeq}$ found in the measurements of Factory 2 was 3, and this implied a need to apply an impulse adjustment.

Table 4.18 A-weighted noise level assessment of Factory 2

Measurement Point	LA eq	Rating According to Noise Regulations
n1	78	Below the Lower Exposure Action Limit
n2	76	Below the Lower Exposure Action Limit
n3	78	Below the Lower Exposure Action Limit
n4	76	Below the Lower Exposure Action Limit
n5	85	Upper Exposure Action Limit
n6	75	Below the Lower Exposure Action Limit
n7	73	Below the Lower Exposure Action Limit
n8	74	Below the Lower Exposure Action Limit
n9	84	Above the Lower Exposure Action Limit
n10	77	Below the Lower Exposure Action Limit
n11	75	Below the Lower Exposure Action Limit
n12	76	Below the Lower Exposure Action Limit
n13	75	Below the Lower Exposure Action Limit
n14	75	Below the Lower Exposure Action Limit
n15	74	Below the Lower Exposure Action Limit

Exposure noise limit is approached at points 5 and 9 in this factory. This is due to the mobile compressor outside and so called “Revolver Lathe Machines”. Besides being old, these machines were used to work on long metal mills which created considerable noise and vibration because of the turning an unbalanced long piece of mill.

Table 4.19 Corrected. A-weighted noise level assessment of Factory 2

Measurement Point	LA eq	Rating According to Noise Regulations
n1	83	Above the Lower Exposure Action Limit
n2	81	Above the Lower Exposure Action Limit
n3	83	Above the Lower Exposure Action Limit
n4	81	Above the Lower Exposure Action Limit
n5	90	Above the Exposure Limit
n6	80	The Lower Exposure Action Limit
n7	78	Below the Lower Exposure Action Limit
n8	79	Below the Lower Exposure Action Limit
n9	89	Above the Exposure Limit
n10	72	Below the Lower Exposure Action Limit
n11	80	The Lower Exposure Action Limit
n12	81	Above the Lower Exposure Action Limit
n13	80	The Lower Exposure Action Limit
n14	80	The Lower Exposure Action Limit
n15	79	Below the Lower Exposure Action Limit

The correction of +5dB for impulsive character brings points 5 and 9 noise levels above the exposure level limit, but point 5 was quite close to the door of the factory which opens directly to the docks. A mobile compressor was actively working during the measurements. So the high level of noise at point 5 was due to the outside noise. High noise level at point 9 was due to revolver lathe machines.

4.5.2. Noise Maps

Noise maps were created for both factories to display the regions having the same characteristic noise levels. Results, as stated before, differ from time to time but still one can get an idea about the situation.

4.5.2.1.Noise Map of Factory 1

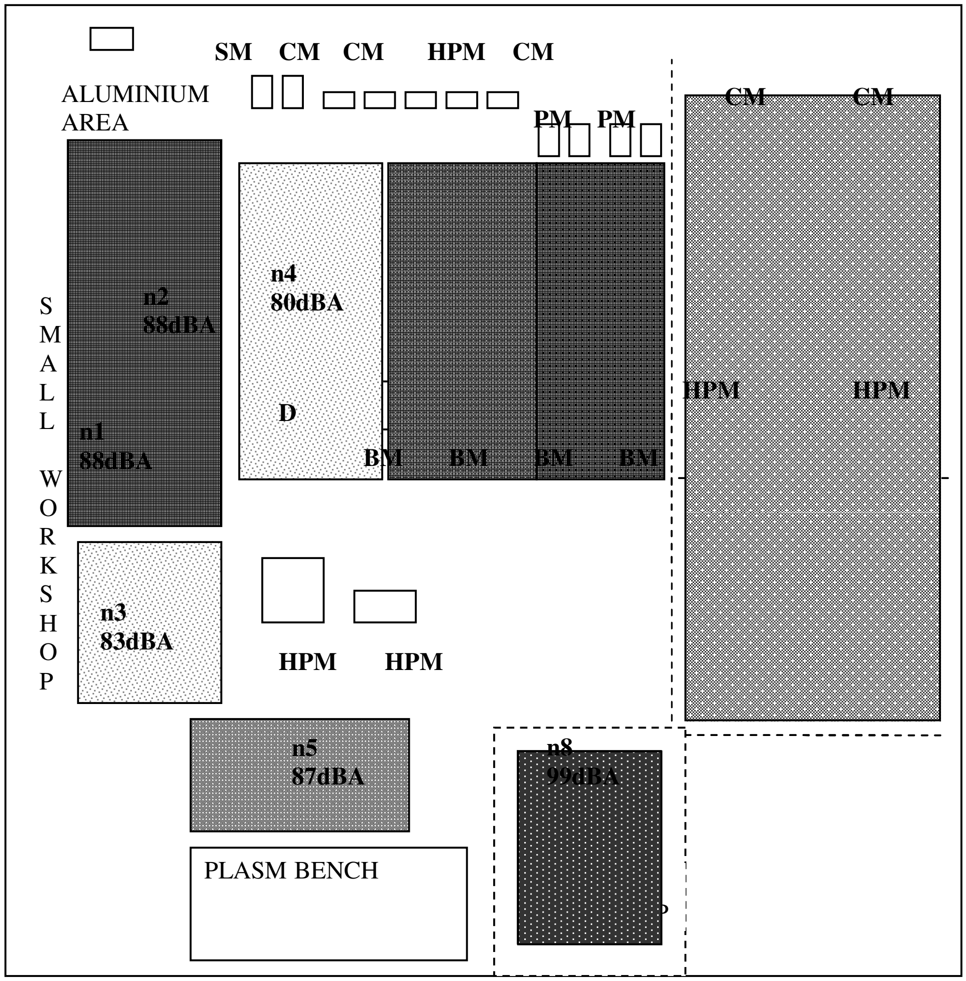


Figure 4.10 Noise map of Factory 1 for A-weighted noise levels

Legends for Figure 4.10

	80, 81, 82, 83 dBA		92, 93, 94, 95 dBA
	84, 85, 86, 87 dBA		96, 97, 98, 99 dBA
	88, 89, 90, 91 dBA		100, 101, 102, 103 dBA

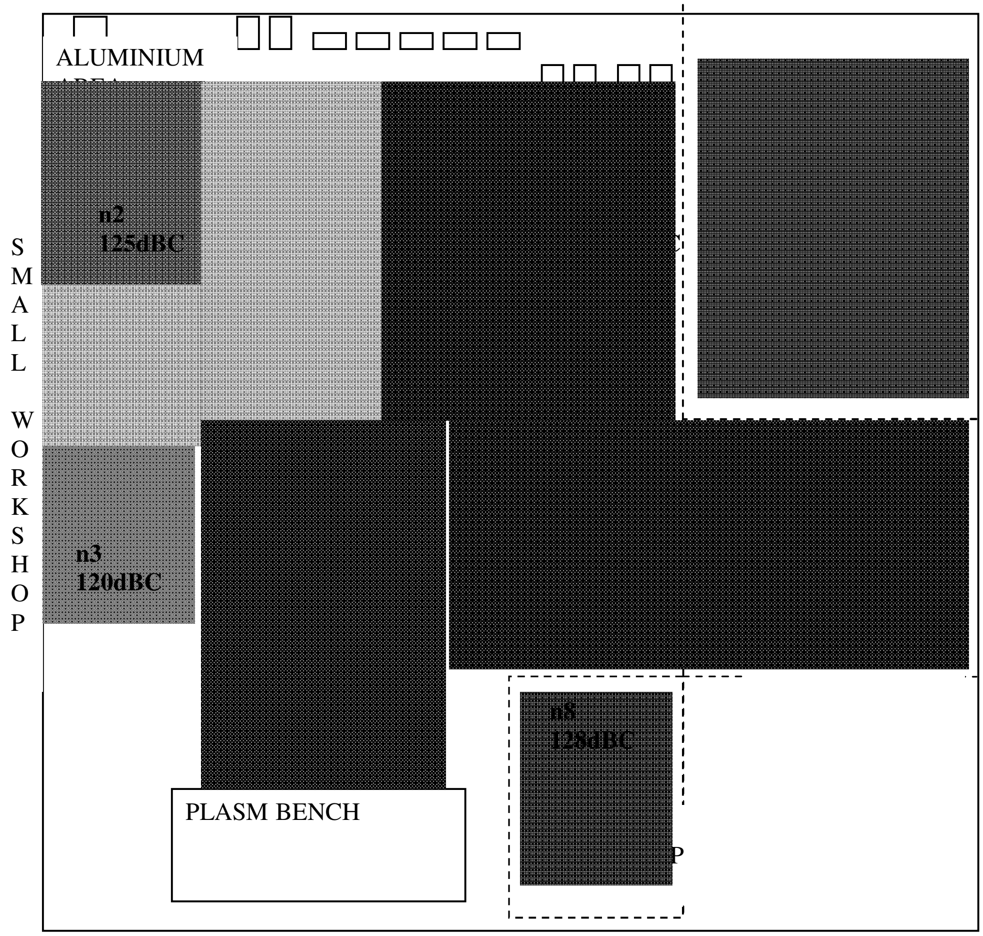
In repair workshop small and medium scale metal parts brought from ships are repaired and this is a high noise job almost all the time. In aluminium area; aluminium parts are cut and grinded by hand devices. Both locations are major sources of noise in the factory.

Noise at point 5 was governed by the plasma cutting bench. There was no significant activity at point 3 so the noise level at that point is assumed to be effected from neighbouring areas. Noise at point 1 was the result of the activities of the small scale lathe and drilling machines, hammering and similar activities.

Noise Sources at Factory 1 are:

BM : Bending Machine	D : Driller
SM : Saw Machine	CM : Cutting Machine
SM : Saw Machine	CM : Cutting Machine
HPM : Hydraulic Press Machine	PPM: Punch Press Machine

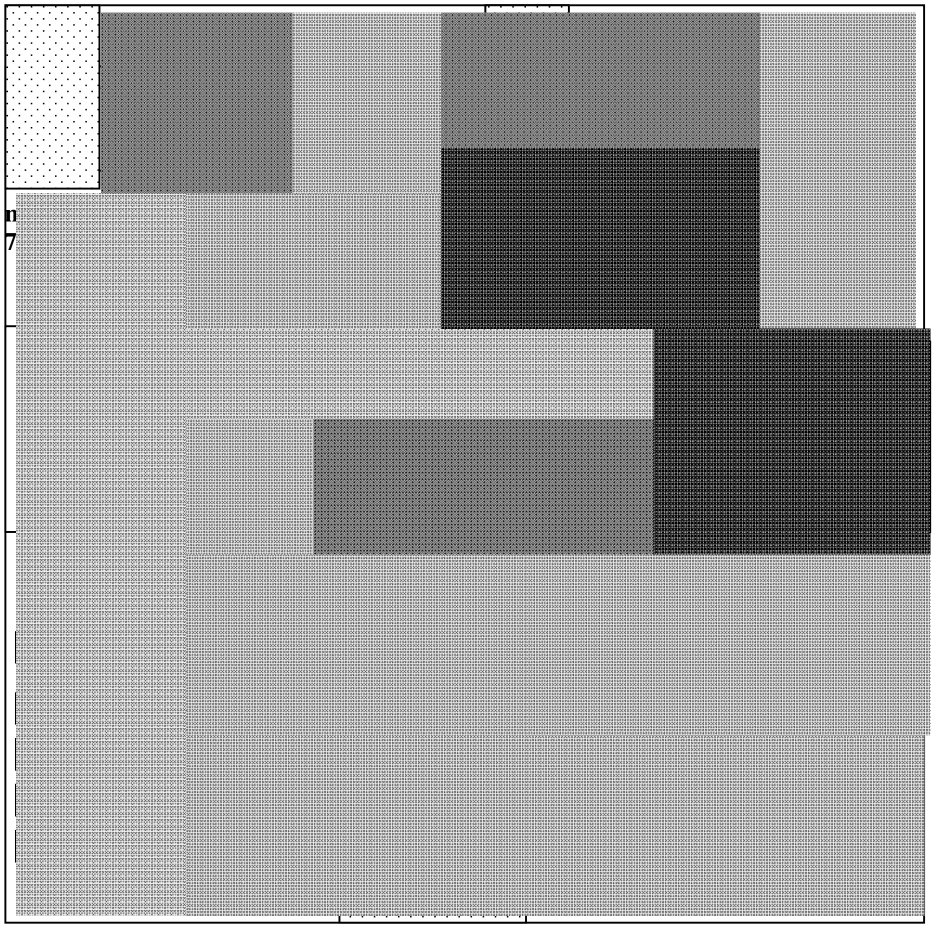
It should be noted that the major contribution to the noise level of Factory 1 does not come from these machines but hand tools used for cutting, grinding and hammering.



	114, 115, 116, 117 dBC
	118, 119, 120, 121 dBC
	122, 123, 124, 125 dBC
	126, 127, 128, 129 dBC
	130, 131, 132, 133 dBC

Figure 4.11 Noise map of Factory 1 for C-weighted peak noise levels

4.5.2.2. Noise Map of Factory 2



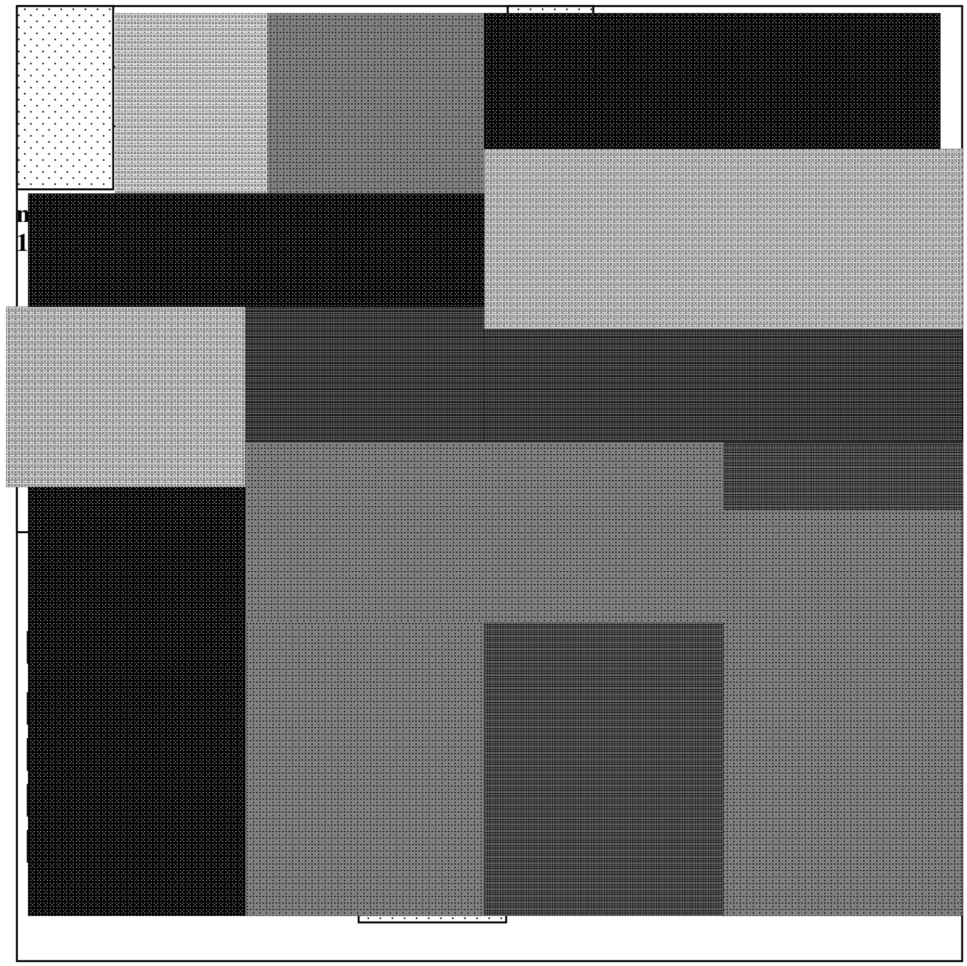
	73, 74, 75, 76 dBA
	77, 78, 79, 80 dBA
	81, 82, 83, 84 dBA

Figure 4.12 Noise map of Factory 2 for A-weighted peak noise levels

Factory 2 has 3 noise regions having close A-weighted noise levels. High noise level at point 9 is misleading because it belongs to the mobile compressor working some 15 m to the factory door. Relatively high levels at point 3 and 5 belong to the revolver lathe machines working on long mills.

Noise Sources at Factory 2 are:

R	: Grinder Machine	H	: Honing Machine
T	: Lathe Machine	P	: Plane Machine
DP	: Vertical Planing Machine	DT	: Vertical Lathe Machine
PRS:	Press Machine	F	: Milling Machine
T	: Lathe Machine	RT	: Revolver Lathe Machine
CT	: Nut Machine	VT	: Screw Machine
RM	: Radial Driller	BL	: Balancing Machine
UD	: Horizontal Lathe.		



	98, 99, 100, 101 dBC
	102, 103, 104, 105 dBC
	106, 107, 108, 109 dBC
	110, 111, 112, 113 dBC

Figure 4.13 Noise map of Factory 2 for C-weighted peak noise levels

4.5.3. Spectrum Characteristics

4.5.3.1. Frequency Content

Frequency content of the noise spectrums obtained from Factory 1 and Factory 2 was analyzed to find out whether low, middle or high frequency bands were dominant. Frequency bands are defined as follows [30]:

<500 Hz.(Octave Band): Low Frequency
500 Hz – 3000 Hz (Octave Band): Middle Frequency
>3000 Hz (Octave Band): High Frequency

Determining the spectrum characteristic of the noise measured in the factory involves checking the low, medium and high frequency content which was performed according to TS EN ISO 4869-2. Method given in this standard is to calculate the value L_C - L_A and check for the intervals given below:

$L_C - L_A < 2dB$: High Frequency Content
$2 < L_C - L_A < 10$: Medium Frequency Content
$10 < L_C - L_A$: Low Frequency Content

4.5.3.1.1. Factory 1

Table 4.20 Frequency content of Factory 1.

Measurement Point	L_{Ceq} - L_{Aeq}	Asessment
n1	0.3	High Freq. Content
n2	3.2	Medium Freq.Content
n3	2.8	Medium Freq. Content
n4	3.3	Medium Freq. Content
n5	2.8	Medium Freq. Content
n6	3.8	Medium Freq.Content
n7	1.4	High Freq.Content
n8	1	High Freq. Content
n9	2	High Freq. Content
n10	0.5	High Freq. Content

Frequency spectrum of Factory 1 is dominated by medium frequency at points 2, 3, 4, 5 and 6 while it is dominated by high frequency at points 1, 7, 8, 9 and 10.

Points 2,3,4,5,6 indicate a region on the left of the noise map, containing aluminium region, plasma bench and the part of the factory where cutting and bending presses are located.

High frequency content is dominant at the region of hull construction and repair workshop.

4.5.3.1.2. Factory 2

Table 4.21 Frequency content of Factory 2.

Measurement Point	L_{Ceq} - L_{Aeq}	Asessment
n1	2.1	Medium Frequency Content
n2	3	Medium Frequency Content
n3	2.9	Medium Frequency Content
n4	3.8	Medium Frequency Content
n5	2.2	Medium Frequency Content
n6	1.3	High Frequency Content
n7	3.1	Medium Frequency Content
n8	1.5	High Frequency Content
n9	-1.3	High Frequency Content
n10	1.6	High Frequency Content
n11	2.1	Medium Frequency Content
n12	1.8	High Frequency Content
n13	1.3	High Frequency Content
n14	3	Medium Frequency Content
n15	1.3	High Frequency Content

Just like Factory 1, Factory 2 was dominated by high/medium frequency content. Points 1, 2, 3, 4, 5, 7, 11 and 14 (mostly at the upper part of the factory except 11 and 14) having medium range frequencies and points 6, 8, 9, 10, 12, 13 and 15 (mostly at the lower part of the factory) having high frequencies. Upper part with medium frequency content primarily contains revolver lathe machines, planning machines while lower part with high frequency primarily contains lathe machines

4.5.3.2. Impulse Content

Second aspect of spectrum characteristics was the impulse content of spectrum. $L_{Im} - L_{Aeq}$ value is automatically given by the measurement device for evaluation.

4.5.3.2.1. Factory 1

Table 4.22 Impulse content of Factory 1

Measurement Point	$L_{Im} - L_{Aeq}$
n1	3
n2	6.1
n3	5.9
n4	3.4
n5	8.1
n6	3.1
n7	9.3
n8	6.4
n9	5
n10	6

Mean value of $L_{Im} - L_{Aeq}$ is 4

4.5.3.2.2. Factory 2

Table 4.23 Impulse content of Factory 2

Measurement Point	$L_{Im} - L_{Aeq}$
n1	6.1
n2	2.8
n3	3
n4	3.7
n5	1.4
n6	2
n7	2.4
n8	1.8
n9	3.3
n10	4.2
n11	3.7
n12	2.5
n13	2.6
n14	2.8
n15	1.7

Mean of $L_{Im} - L_{Aeq}$: 2.93

4.5.4. Performance Assessment of Ear Plugs

According to Workers' Compensation Board, WCB, of British Columbia [31], the goal of hearing protecting device, HPD, is to reduce the noise level reaching to ear canal, approximately to a level of 75-80 dB(A). This level of protection is called "optimal". At this level there is enough attenuation to protect the wearer's hearing as well as to allow the wearer to work safely and productively. If the noise level reaching the ear canal is less than 75-80 dB(A) then the wearer has too much attenuation. This is called overprotection and it is not desirable. The wearer may not be able to hear important safety information. If the noise level under the device is over 85 dB (A) then this is regarded as insufficient protection and treated as unacceptable. At this level, the wearer may sustain permanent hearing loss. Noise levels of 70-75 and 80-85 dB (A) under the device are called "acceptable". So, noise levels, under the hearing protector device, in the range of 70-85 dB (A) are all acceptable.

TS EN 458 gives a similar criteria for the evaluation of earplug performance. The effective level, L_{eff} above 87dBA is unacceptable, 87-82 dB(A) acceptable, 82-77 dB(A) good, 77-72 dB(A) acceptable and below 72 dB(A) unacceptable.

Ear plug performance is calculated according to TS EN 4869-2. Three methods are proposed in this standard as Octave band method, HML method and SNR method. SNR method reveals the following results for both factories (Technical data for ear plugs used in both factories is given in APPENDIX-D), and ear plug performance according to the technical data of the earplugs that used are given in APPENDIX-E).

4.5.4.1.Factory 1

Table 4.24 Ear plug performance in Factory 1

Measurement Point	L_{Ceq} (dB)	SNR (dB)	L_{eff} (dBA)	Rating According to WCB British Columbia	Rating According to TS EN 458
n1	82	22	60	Overprotect.	Overprotect.
n2	79	22	57	Overprotect.	Overprotect.
n3	81	22	59	Overprotect.	Overprotect.
n4	81	22	59	Overprotect.	Overprotect.
n5	82	22	60	Overprotect.	Overprotect.
n6	81	22	59	Overprotect.	Overprotect.
n7	86	22	64	Overprotect.	Overprotect.
n8	85	22	63	Overprotect.	Overprotect.
n9	83	22	61	Overprotect.	Overprotect.
n10	90	22	78	good	good

Table 4.25 Ear plug performance in Factory 1 with impulse adjustment

Measurement Point	L_{Ceq} (dB)	SNR (dB)	L_{eff} (dBA)	Rating According to WCB British Columbia	Rating According to TS EN 458
n1	82	22	65	Overprotect.	Overprotect.
n2	79	22	62	Overprotect.	Overprotect.
n3	81	22	64	Overprotect.	Overprotect.
n4	81	22	64	Overprotect.	Overprotect.
n5	82	22	65	Overprotect.	Overprotect.
n6	81	22	64	Overprotect.	Overprotect.
n7	86	22	69	Overprotect.	Overprotect.
n8	85	22	68	Overprotect.	Overprotect.
n9	83	22	66	Overprotect.	Overprotect.
n10	90	22	83	acceptable	acceptable

4.5.4.2 Factory 2

Table 4.26 Ear plug performance in Factory 2

Measurement Point	LCeq (dB)	SNR (dB)	L_{eff} (dBA)	Rating According to WCB British Columbia	Rating According to TS EN 458
n1	79	22	57	Overprotect.	Overprotect.
n2	78	22	56	Overprotect.	Overprotect.
n3	81	22	59	Overprotect.	Overprotect.
n4	77	22	55	Overprotect.	Overprotect.
n5	75	22	53	Overprotect.	Overprotect.
n6	76	22	54	Overprotect.	Overprotect.
n7	76	22	54	Overprotect.	Overprotect.
n8	76	22	54	Overprotect.	Overprotect.
n9	85	22	63	Overprotect.	Overprotect.
n10	78	22	56	Overprotect.	Overprotect.
n11	75	22	53	Overprotect.	Overprotect.
n12	77	22	55	Overprotect.	Overprotect.
n13	76	22	54	Overprotect.	Overprotect.
n14	78	22	56	Overprotect.	Overprotect.
n15	75	22	53	Overprotect.	Overprotect.

Table 4.27 Ear plug performance in Factory 2 with impulse adjustment

Measurement Point	L_{Ceq} (dB)	SNR (dB)	L_{eff} (dBA)	Rating According to WCB British Columbia	Rating According to TS EN 458
n1	79	22	62	Overprotect.	Overprotect.
n2	78	22	61	Overprotect.	Overprotect.
n3	81	22	64	Overprotect.	Overprotect.
n4	77	22	60	Overprotect.	Overprotect.
n5	75	22	58	Overprotect.	Overprotect.
n6	76	22	59	Overprotect.	Overprotect.
n7	76	22	59	Overprotect.	Overprotect.
n8	76	22	59	Overprotect.	Overprotect.
n9	85	22	68	Overprotect.	Overprotect.
n10	78	22	61	Overprotect.	Overprotect.
n11	75	22	58	Overprotect.	Overprotect.
n12	77	22	60	Overprotect.	Overprotect.
n13	76	22	59	Overprotect.	Overprotect.
n14	78	22	61	Overprotect.	Overprotect.
n15	75	22	58	Overprotect.	Overprotect.

Ear plugs are seldom used in Factory 2 and when they are used it results in overprotection as seen in the tables.

Ear plug performance assessment in İŞGÜM's report is given in APPENDIX-F

4.5.5. Speech Interference

Speech interference was evaluated according to TS EN ISO 9921 assuming very loud vocal effort in Factory 1 and loud vocal effort in Factory 2.

Speech Interference Level of Noise (SIL) was calculated as the arithmetic mean of the measured sound pressure levels in four octave bands with the central frequencies 500 Hz., 1000 Hz., 2000Hz. And 4000 Hz., designated as **(a)** in the tables below. This value was subtracted from the vocal effort of the speaker which is **(b)** and the result **(b-a)** reveals the Speech Interference.

4.5.5.1. Factory 1

Table 4.28 Speech Interference in Factory 1

Measurement Point	Speech Interference Level of Noise (SIL) **(a)**	Speech Signal (Vocal Effort) $L_{S,A,1m}$, dBA Very Loud **(b)**	Speech Interference (dB) **(b-a)**	Speech Int. Rating
n1	77	78	1	BAD
n2	79	78	-1	BAD
n3	76	78	2	BAD
n4	69	78	9	POOR
n5	80	78	-2	BAD

Table 4.28 Speech Interference in Factory 1 (continued)

Measurement Point	Speech Interference Level of Noise (SIL) **(a)**	Speech Signal (Vocal Effort) $L_{S,A,1m}$, dBA Very Loud **(b)**	Speech Interference (dB) **(b-a)**	Speech Int. Rating
n6	83	78	-5	BAD
n7	87	78	-9	BAD
n8	91	78	-3	BAD
n9	94	78	-16	BAD
n10	96	78	-18	BAD

4.5.5.2. Factory 2

Table 4.29 Speech Interference in Factory 2

Measurement Point	Speech Interference Level of Noise (SIL) **(a)**	Speech Signal (Vocal Effort) $L_{S,A,1m}$, dBA Loud **(b)**	Speech Interference (dB) **(b-a)**	Speech Int. Rating
n1	67	72	5	POOR
n2	69	72	3	POOR
n3	71	72	1	BAD

Table 4.29 Speech Interference in Factory 2 (continued)

Measurement Point	Speech Interference Level of Noise (SIL) **(a)**	Speech Signal (Vocal Effort) $L_{S,A,1m}$, dBA Loud **(b)**	Speech Interference (dB) **(b-a)**	Speech Int. Rating
n4	70	72	2	BAD
n5	73	72	-1	BAD
n6	65	72	7	POOR
n7	66	72	6	POOR
n8	66	72	6	POOR
n9	75	72	-3	BAD
n10	70	72	2	BAD
n11	68	72	4	POOR
n12	68	72	4	POOR
n13	68	72	4	POOR
n14	67	72	5	POOR
n15	68	72	4	POOR

CHAPTER V

DISCUSSION OF RESULTS AND CONCLUDING REMARKS

In Factory 1, corrected A-weighted Values (due to impulsive nature of noise)measured at points 1, 7, 8,9,10 in April 2008, exceeded the exposure limit value of 87 dB(A) given in the “The European Noise Directive” [27] “Noise Regulation” of Ministry of Labour and Social Security [28]. Whereas in the 2007 measurements it was observed that points 2,3,4,5,6 sometimes had high values too, occasionally even higher than 1,7,8,9,10. When moderate workload of the factory is taken into consideration, it wouldn’t be wrong to assume that all the points in Factory 1 have higher A-weighted values of noise than the exposure limits stated in the legal regulations. Dose measurements associated with the workers working at point 8:176% (above limit), point9: 68% (below limit) and point 1: 43% (below limit) underlines the extremely variable acoustical conditions that the workers encountered. It has to be noted that this situation is in parallel with the subjective assessment of the vast majority of Factory 1 workers, defining the noise level of Factory 1 as “high” or “extremely high”. C-weighted Peak values, without exception, were below the limits as displayed in the associated noise maps. The “Repair Workshop” and “Hull Construction Areas” sections seem to be noisier than the rest of the factory.

In Factory 2, except point 5 and 9 where a mobile compressor placed outside the factory and the revolver lathe machines were located, noise levels were all below the exposure limit of 87 dB(A). This is almost in accordance with the questionnaire results about the rating of noise level in the factory. Percentages of “high” or “extremely high” answers were lower in this factory compared to Factory 1 and a considerably large amount of workers define the noise level as “moderate”. Noise levels were more uniform in this factory when compared to the other factory because of its steady character.

According to the “The European Noise Directive” [27] the employer is obliged to measure and assess the level of noise exposure of workers and take the necessary precautions. These precautions may include:

a. Choosing alternative techniques of production with lower noise emission.
b. Choosing work equipment with lower noise levels.
c. Reconstruction of the workplace.
d. A training programme for the workers.
e. Using sound absorbing curtains, enclosures, etc. for the attenuation of airborne noise.
f. Using attenuation techniques for structural noise.
g. Suitable maintenance programmes for reducing the noise of the production equipment.
h. Reorganisation of the workers schedules
i. Elongation of the resting periods.
j. Marking and controlling the access to the regions which do not comply with the noise limits.

Realistically, in the short run only a training programme can be implemented by the factory among those precautions. Choosing alternative production techniques, maintenance programmes, work equipment and a reorganisation effort of the workers requires a change in the master plan of procurement and personnel and will probably be costly. Reconstruction of the workplace may be suitable for small scale factories but not for Factory 1 and Factory 2. Elongation of resting periods does not seem suitable either because, workers already have two periods of rest for 15 minutes both in the morning and in the afternoon in addition to the 1 hour lunch break. Workers have a tendency to leave working actively some 10 minutes before the official beginning of these resting periods and so a further elongation of these periods would reduce the productivity. Precautions like controlling the access to noisy areas, structural noise reduction techniques, sound absorption curtains and enclosures are not practically applicable too. It would be very difficult to get these done in an environment where a big scale production equipment and ship parts are located, produced and transported.

A training programme for the workers sounds reasonable however, though the workers had not attended to such a programme, further studies of the factory engineers and institutions like İŞGÜM will hopefully increase the awareness towards this subject.

According to the above mentioned regulations if the stated noise reduction measures are not applicable (which is the case for Factory 1 and Factory 2), then personal protection equipment has to be properly selected and provided to the workers. The employer is also responsible for the proper utilization of this protection equipment by the workers. Sufficient amount of earplugs are provided to the workers in both factories. In Factory 2 earplug usage was very low due to the low noise levels. In Factory 1, earplug usage of 97% indicates a certain level of awareness for the high noise level in this factory.

İŞGÜM results for Factory 1, presented in Appendix C, support this study. At point 1 A-weighted noise level is below the limit and at points 7, 8 and 10 it is above the limit. C-weighted noise levels are all below the limits. Factory 2 measurement results are also in accordance with this study. Except point 1, in which grinding produced a high noise level, all the points have acceptable levels.

"Noise Regulation" of Ministry of Labour and Social Security [28] also proposes audiometric checks for the workers who are exposed to noise above the criterion limits. Workers of factory 1 are sent to "Hospital of Labour Illnesses of Maltepe Başıbüyük" in İstanbul upon their complaints which is, almost always, tinnitus.

Apart from the noise level of both factories, frequency contents were also investigated as low frequency and high frequency noises have different effects on human health. Low frequency noise, LFN, (< 500 Hz.) was not observed in Factory 1 and Factory 2 so workers are not subject to LFN consequences. In Factory 1; high frequency (> 3000 Hz) noise is dominant at the region of two hull construction parts and repair workshop while rest of the factory is dominated by medium frequencies (500-3000 Hz.). In Factory 2 mostly medium (due to revolver lathe machines) and high frequency (due to planning machines) content noise was predicted. A detailed noise survey on machine basis may be suggested in order to exactly identify which workbenches emit high frequency noise and which ones emit medium frequency noise.

One another feature observed was the existence of considerable impulse content. Normally hull construction area of the factory should have the highest impulsive content in Factory 1 as these are the regions where metal sheet cover of the ship hull welded to the constructional elements is heavily hammered to fit to its place. However, as stated earlier, work load of the factory was not at its usual levels so other points sometimes had the leading impulse content. This character brings about a +5 dB (A) adjustment to the A-weighted noise levels.

Most of the precautions stated in "Noise Regulation" of Ministry of Labour and Social Security and "The European Noise Directive" were inapplicable so personal protection measures play the most important role for the health of workers. Ear muffs are not preferred at all because of the discomfort they present while working. Ear plugs of various types are used in both factories but efficiency of their performance remains a question. They are procured in large numbers and distributed to the workers randomly without taking into consideration the level of protection they provide and how proper those earplugs are for that specific factory. When TS EN 458 and WCB of British Columbia suggestions are considered it is seen at times of relatively low levels of noise, with the calculated SNR value, earplugs used are overprotective even with +5 dB correction.

When product technical data is used for the calculation of the attenuation levels workers are seen to be overprotected in extreme levels.

İŞGÜM Report (presented in Appendix F) concludes that at almost all the points in Factory 1 workers are overprotected which is something undesirable and it verifies the results of this study.

This supports also the subjective questionnaire survey results which display high communication and warning signal perception problems of the workers of Factory 1 and their low hearing loss.

Although the protection level in Factory 1 is overprotective 54% of the workers still think that the ear protectors they use reduce the noise only “moderately” and 31% claim that the attenuation is only “a little”. The reason of this contradiction probably lies in the frequency of ear plug usage. Only 10 % of the workers use continuously the ear plugs. Others use their protectors from time to time. To use hearing protectors less than 100% of the time diminishes the effectiveness of the protection. No matter how much protection is afforded by design, protection is reduced as percent of wearing time decreases. Wearers who remove an earplug or lift an ear muff to talk with fellow workers in noisy environments can severely reduce the amount of protection they receive.

Decrease in the effective protection with respect to the time of non-use during an 8 hour day increases as shown in the graphic below:

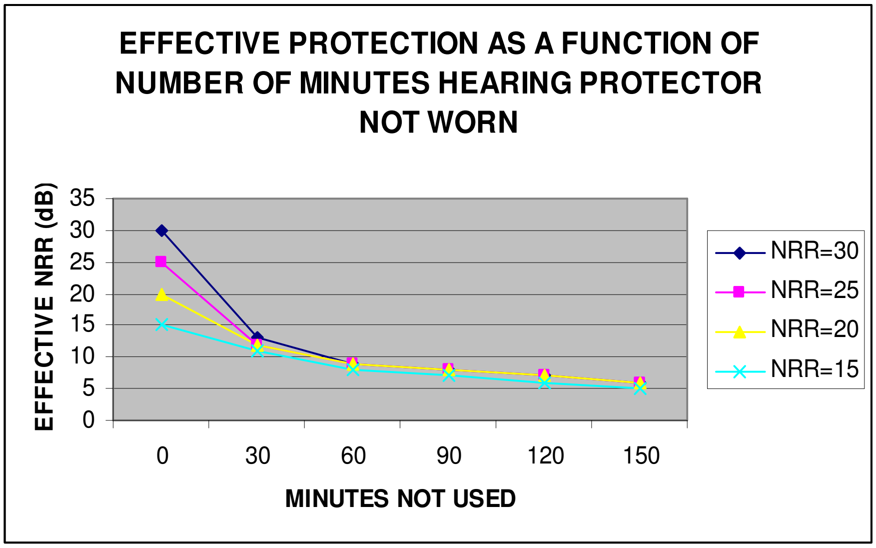


Figure 5.1 Ear plug performance as function of the plug usage

Time [32]

Workers did not declare “the minutes not used” in their answers to the questionnaire but as seen in the graph only a period of 30 minutes without the ear protector decreases effective noise reduction rate, NRR, from 30 to 13.

In Factory 2 hearing protection is also overprotective but earplugs are used very seldom anyway. Workers’ Compensation Board of British

Columbia Documents claim that high attenuation of protectors, especially when coupled with distortion effect of speech result in rejection and non-use by the worker [33]. So overprotection not only jeopardizes work safety but also decreases the chance of protector usage.

Workers in the factories have basic information on the usage of earplugs but there is no detailed and systematic training programme for the correct usage of hearing protectors. It would not be wrong to assume a high rate of protector misusage which will further decrease the efficiency of protectors.

Depending on the measurement point, understanding of speech is either bad or poor in both factories. This is verified by the answers to the questionnaires.

A Hearing Conservation Programme may consist of the following parts: [34]

(i). Noise Measurements

(ii). Education and Training

(iii). Noise Control

(iv). Hearing Protection

(v). Posting of Noise Hazard Areas

(vi). Hearing Tests

(vii). Programme Review

(i)Noise measurements should be taken periodically in the factories especially in Factory 1 in order to check whether or not the noise levels are within the acceptable limits. The interval between the measurements should be kept as short as possible since in ship building industry noise level changes very quickly depending on the workload and season. Annual measurements of İŞGÜM do not seem sufficient and the factory should assign the job of running a hearing conservation programme to one of its employees. As long as the A-weighted noise level is below 82 dB (A) there is no need for further action [35]. In the range of 82-85 dB(A), the worker should be informed of the results, of the minimal risk of hearing loss, and about the roles of hearing protection and audiometric testing. Above 85 dB(A), not only a noise survey is needed but attention should be paid to other requirements of the Noise regulation, like education of the workers about the effects of noise on hearing and training on the proper usage of hearing protectors. Other conditions and corresponding requirements can be summarised as follows:

Table 5.1 Recommendations [36]

L_{eq},8h dB(A)	dB(C), Peak	Comments	Recommendations
< 85	-		Make Ear plugs Available
> 85	-	Steady Noise for Long Periods	Noise Control
> 85	< 137		Hearing Conservation Programme/ Noise Control
> 85	< 137	Significant Impact Peaks	Hearing Conservation Programme/ Noise Control
> 85	> 137	Significant Impact Peaks	Hearing Conservation Programme/ Noise Control

The situation at Factory 1 fits to the "> 85 dB (A) and <137 dB(C)" part in the Table 5.1 which urges a Hearing Conservation Programme together with a Noise Control programme. Factory 2 which is in "<85 dB(A)" condition doesn't require a Noise Control or Hearing Conservation

Programme, making ear plugs available would suffice.

(ii) education and training

All newly employed workers should be informed about, the effects of noise on hearing, the usage and maintenance of hearing protection devices and updating of this information should be done on periodical basis.

(iii) Noise control

An acoustical engineering consultant should be hired for preparing a noise control plan or one of the employees should be provided with adequate training and certified on this subject. The best method of dealing with noise in the workplace is to reduce the noise at the source with engineering controls. Noise control includes; choosing quieter equipment when purchasing new equipment, retrofitting existing equipment or substituting quieter equipment. These precautions demand long term planning and budgetary allocations and do not have much chance of implementation in the short run.

Noise reductions of 25 dB are common with noise enclosures. The ceiling and walls of enclosure can be lined with material that absorbs sound to prevent reverberation in the enclosure and escape through small openings. This is not a good solution for Factory 1 since constructing such enclosures would be very difficult. Big pieces of ship blocks and the dimensions of the factory will render these precautions costly. Besides it is the hand tool activities that create most of the noise so there is no particular place to build an enclosure. Reduction of the length of exposure is not possible either because the workers already have two 15 minutes breaks in addition to a 1 hour lunch break. Further decreasing exposure times would probably decrease the productivity too. In the short run hearing protection devices seem to be the only possible means to decrease the adverse effects of noise on workers (iv)Ear plugs used in the Factories are overprotective so new earplugs should be selected for both factories which will reduce the noise level reaching the ear canal to approximately 75-80 dB which is the optimal level.

For different A-weighted occupational noise levels hearing protectors with the following SNR values should be selected:

Table 5.2.Ear plug selection [37]

Noise Level dB(A)	Proper Hearing Protector SNR Value
85-90	20 or less
90-95	20-30
95-100	25-30
100-105	30 or more

It should be noted that these are noise levels not the exposure levels.

Other alternative protectors can also be thought namely: Ear Muffs have the ability to control noise reduction and are hygienic. Most earmuffs have a lining inside the ear cup to absorb the sound that is transmitted through the shell of the ear cup in order to improve the attenuation above approximately 2000 Hz. One another example can be "Non-foam ear plugs" which are comfortable, inexpensive and useful in cases when a bit less sound reduction is needed. Ear Canal Caps can also be thought. They are Ideal for the workers moving continuously in and out of the noisy environment. Foam earplugs (high level of sound reduction) and Custom Moulded Earplugs (custom moulded to the shape of wearer's ear canal) can also be recommended.

Given the current situation non-foam ear plugs are suitable to prevent overprotection while ear muffs will serve to reduce high frequency sounds which are the characteristic of both factories.

(v) Posting of noise hazard areas

All areas with noise levels greater than 85 dB (A) should be posted with warning signs indicating hearing protection is required. Managers should check the condition of the signs and replace them whenever necessary.

(vi)hearing tests

Currently hearing tests are performed on the workers of Factory 1 but not on regular basis. They are sent to Labour Illnesses Hospital in Maltepe Başıbüyük upon their complaints. The audiometric tests should be performed on regular basis especially for those exposed to high noise levels.

(vii) Programme review

Results of audiometric tests and periodically done noise measurements should be kept in a data base and analysed to review the condition of the workers and alter the noise control and hearing protection measures.

Others factors like usage of other personal protective equipments, the effects of temperature and air pollution on the workers should also be taken into consideration.

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APPENDIX-A

QUESTIONNAIRE

1. Çalıştığınız fabrika :
2. Yaşınız :
3. Cinsiyetiniz :
4. Boyunuz :
5. Kilonuz :

6. Eğitim düzeyiniz aşağıdakilerden hangisine uyuyor?

Ilkokul
Ortaokul
Sanat Okulu
Meslek Lisesi
Üniversite
İlköğretim Okulu
Diğer

7. Mesleğiniz aşağıda sıralananlardan hangisine daha çok uyuyor?

ambarcı	marangoz
borucu	plancı
camcı	planyacı
çilingir	taşlamacı
döşemeci	tekneci
endazeci	tesviyeci
frezeci	tezgah operatörü

ince sac işçisi	tornacı
kalıpçı	yelkenci
kaynakçı	gemi montajı

8. Tezgah Operatörü İseniz Çalıştığınız tezgahın/tezgahların adları:
Sac makası
Kenet tezgahı
Silindir tezgahı
Matkap
Torna
Freze
Planya
Diğer

9. El aleti ile çalışıyorsanız (dekopaj, taşlama aleti, matkap, kaynak makinesi vs.) kullandığınız aletlerin adları:
Dekopaj
Taşlama aleti
Matkap
Kaynak makinesi
Çekiç
Breyz

10. İşinizi genellikle nasıl yapıyorsunuz?
Masa başında oturarak
Ayakta sabit olarak
Ayakta yürüyerek
Yüzükoyun yatarak
Çömelerek
İskele üzerinde ayakta durarak

İskele üzerinde çömelerek
Tezgah önünde ayakta durarak
Sırtüstü yatarak

11.Mesleğinizi icra ederken en çok hangi faaliyetleri yapıyorsunuz?
El aletleri ile malzeme kesme
El aletleri ile taşlama
El aletleri ile delme
Çekiçle dövme
Yapıştırma/izolasyon
Kimyasal toz ve sıvılarla temizleme
Kaynak/lehim yapma
Montaj
Tezgahta malzeme kesme
Tezgahta malzeme delme
Tezgahta malzeme bükme
Tezgahta malzeme dövme
Tezgahta malzeme yüzey işleme
Ölçüm ve test
Kreyn ve forklift operatörlüğü
Yazışma ve kayıt

12. Kaç yıldır bu işyerinde çalışıyorsunuz?

13. Bu iş yerinde hep aynı atelyede mi çalıştınız? Cevabınız hayır ise çalıştığınız atelyeleri (veya fabrikaları) süreleri ile birlikte sıralayınız.

14. Bu fabrikada çalıştığınız tüm yıllar boyunca, mesainizin yüzde kaçını fabrika içinde, yüzde kaçını fabrika dışında (gemide, limanda, havuzda, dış birliklerde vs.) geçirdiğinizi düşünüyorsunuz?

% 90 fabrika içinde, % 10 fabrika dışında

% 75 fabrika içinde, % 25 fabrika dışında

% 50 fabrika içinde, % 50 fabrika dışında

% 25 fabrika içinde, % 75 fabrika dışında

% 10 fabrika içinde, % 90 fabrika dışında

% 100 fabrikada

15.Bu iş yerinde haftada kaç gün çalışıyorsunuz ?

1 gün

2 gün

3 gün

4 gün

5 gün

6 gün

16. Çalışma süreleriniz nasıl ?

1. Molasız 4 saat sabah ,1 saat öğle tatili, molasız 4 saat öğleden sonra

2. sabah : 8-10 arası çalışma,15 dakika mola,10.15-12.00 arası çalışma, öğle tatili : 1 saat, öğleden sonra : 13-15 arası çalışma,15 dakika mola,15.15-17.30 arası çalışma

3. diğer

Fazla Mesaide

1. Fazla mesai yapmıyorum

2. 17.30 - 20.00 arası fazla mesai yapıyorum , toplam .... saat mola veriyorum

3. 17.30 - 24.00 arası fazla mesai yapıyorum,toplam .... saat mola veriyorum

4. normal mesaiden sonra 4 saat dinlenip .... saatleri arasında……………saat mola vererek.

5. diğer

Vardiyada

1. vardiyaya kalmıyorum

2. molasız devamlı 8 saat

3. Toplam 8 saat çalışıyorum.Çalışma süresi içinde mola süresi toplam yarım saat oluyor.

4. Diğer

17. Çalışma saatlerinizi lütfen ilgili kutuları işaretleyerek belirtiniz

Normal mesaide (Pazartesi – Cuma)

1. Sabah 8-12   öğleden sonra 13 -17 .30

2. Diğer

Fazla mesai yaptığımda

1. fazla mesai yapmıyorum

2. Çok nadir fazla mesai yapıyorum,fazla mesai yaptığımda ....saatleri arasında mesai yapıyorum.

3. Hergün .... saatleri arasında fazla mesai yapıyorum

4. ....günleri   .... saatleri arasında fazla mesai yapıyorum

5. Cumartesi günleri .... saatleri arasında fazla mesai yapıyorum

6. Cumartesi Pazar yedirme sistemi ile

Vardiyaya kaldığımda

1. vardiyaya kalmıyorum
2. 8-16 arasında
3. 16-24 arasında
4. 24-8 arasında
5. 8-17:30 arasında
6. 14:30-24 arasında
7. 24-8 arasında
8. Cumartesi günleri ....arasında (lütfen saatleri belirtiniz)

18. Haftada kaç saat fazla mesai yapıyorsunuz?

Fazla mesai yapmıyorum

1 saat

2 saat

3 saat

Çok nadir fazla mesai yapıyorum

19.Haftada kaç saat vardiyaya kalıyorsunuz?

Vardiyaya kalmıyorum

Çok nadir kalıyorum

20.İşiniz gereği sık sık ağır kaldırıyormusunuz?

Işte

Iş dışında

21.Yılda toplam kaç gün izin kullanıyorsunuz?

22. Fabrika içinde Devamlı çalıştığınız yerdeki “ses ” düzeyini nasıl tanımlarsınız ?

1 çok fazla
2 fazla
3 orta
4 az
5 çok az

23. Fabrika içinde Devamlı çalıştığınız yerdeki bu “ses ” düzeyi çalışma veriminizi etkiliyor mu?

1 çok fazla
2 fazla
3 orta
4 az
5 çok az

24.Fabrika içinde Devamlı çalıştığınız yerdeki “ses “ düzeyini bir de aşağıdaki cetvelde işaretler misiniz? Eğer çok fazla ise “on” u seçiniz, çok az ise “sıfır” ı seçiniz. Diğer düzeyleri belirtmek için se “sıfır” ile “on” arasında bir sayı seçiniz

25. Fabrika içinde Devamlı çalıştığınız yerdeki bu “ses” düzeyinin çalışma veriminizi ne kadar etkilediğini aşağıdaki cetvelde işaretliyiniz? Eğer çok fazla ise “on” u seçiniz, çok az ise “sıfır” ı seçiniz. Diğer düzeyleri belirtmek için se “sıfır” ile “on” arasında bir sayı seçiniz

26. Fabrika içinde Devamlı çalıştığınız yerdeki “ses “ düzeyi aktivitelerinizi nasıl etkiliyor ?

Çalışma hızımı

Yanımdakilerin söylediğini anlayabilmemi

Sesli ikaz ve Uyarı sinyallerini duyabilmemi

Yanımdakilere birşeyler söyleyebilmemi

Yaptığım İşin Kalitesini ve Verimliliğimi

1 çok fazla

2 fazla

3 orta

4 az

5 çok az

27. Çalışırken kulaklık kullanıyor musunuz?

28. Kulaklıkları ne kadar süre ile ve ne sıklıkta kullanıyorsunuz ?

29. Kulaklık çalıştığınız ortamdaki gürültü düzeyini ne kadar azaltıyor?

gürültüyü tamamiyle kesiyor

gürültüyü çok azaltıyor

gürültüyü orta derecede azaltıyor

gürültüyü hafifçe azaltıyor

gürültüyü azaltmakta hiç etkili olmuyor

kulaklık kullanmıyorum

30. Çalışmalarınız sırasında hangi durumlar ile karşılaştığınızı ilgili kareleri işaretleyerek cevaplayınız

Kulağımda kısa süreli ağrı veya sızılar oluyor

Kulağımda çınlamalar oluyor

Kulağımda tıkanma oluyor

Bana söylenenleri (heceleri)anlayamadığım zamanlar oluyor

Başım ağrıyor, migrenim var

Başım dönüyor

31. İşitme azlığınız var mı ?

32. Kulak akıntınız hiç oldu mu ?

33. Daha önceden kulağınızla ilgili bir şikayetiniz oldu mu?

34. Kolesterol probleminiz var mı?

35. Tansiyon probleminiz var mı ?

36. Ailenizde genç yaşta (30-40 yaşlarında) işitme kaybı olan var mı?

37. Tanısı konulan dolaşım bozukluğunuz var mı ?

38. Ağrı kesici kullanıyor musunuz ?

39. Otomobil veya motosiklet kazası geçirdiniz mi? Başınızdan yaralandınız mı?

40. sigara içiyor musunuz ?

41. Önerileriniz

APPENDIX-B

AUDIOMETRIC TEST RESULTS

Rating of Treshold Values

0-20 dB : normal
20-40 dB : slight
40-60 dB : moderate
60-80 dB : moderate severe
80-90 dB : severe
90-100 dB : extremely severe
100 + dB : total loss

Rating of Aoustic Trauma

0: no acoustic trauma
1: acoustic trauma in one ear
2: acoustic trauma in both ears

Test Results

Table B.1 Audiometric test results.(ac.tr.=acoustic trauma)

no	age	years in factory	average treshold (dB)	Average Rating	left ac.tr.	right ac.tr	total ac.tr.
1	37	15	23	slight	0	0	0
2	41	9	33	slight	0	0	0
3	54	34	20	normal	0	1	1
4	38	15	16	normal	1	1	2
5	50	30	15	normal	1	1	2
6	33	9	14	normal	0	1	1
7	43	14	43	moderate	1	1	2
8	47	31	15	normal	1	1	2
9	39	15	21	slight	1	1	2
10	45	17	8	normal	1	1	2
11	43	20	28	slight	1	1	2
12	40	17	23	slight	1	0	1
13	43	14	14	normal	1	0	1
14	46	29	41	moderate	0	0	0
15	30	1	12	normal	1	1	2
16	47	20	93	extreme severe	0	0	0
17	53	30	11	normal	1	1	2
18	49	28	19	normal	1	1	2
19	35	9	18	normal	1	1	2
20	39	14	27	slight	1	1	2

Table B.1 Audiometric test results.(continued)

21	41	20	32	slight	0	0	0
22	39	15	29	slight	1	1	2
23	44	19	17	normal	1	1	2
24	45	20	23	slight	1	1	2
25	37	16	16	normal	1	1	2
26	47	29	33	slight	1	0	1
27	48	31	33	slight	0	0	0
28	53	29	41	moderate	1	1	2
29	38	14	26	slight	0	1	1
30	38	8	67	moderate severe	1	1	2
31	53	33	33	slight	0	1	1
32	40	15	14	normal	1	1	2
33	38	15	46	moderate	0	0	0
34	26	1	17	normal	1	1	2
35	43	9	16	normal	1	1	2
36	34	9	18	normal	1	1	2
37	39	15	48	moderate	1	1	2
38	48	30	14	normal	1	0	1
39	51	29	30	slight	0	1	1
40	35	9	38	slight	1	1	2
41	43	15	74	moderate severe	0	1	1
42	44	20	36	slight	0	0	0
43	51	33	12	normal	1	1	2
44	28	1	16	normal	1	0	1
45	46	29	17	normal	1	1	2
46	53	33	23	slight	1	0	1

Table B.1 Audiometric test results.(continued)

47	47	20	23	slight	0	1	1
48	48	31	39	slight	1	1	2
49	51	32	27	slight	0	1	1
50	40	14	16	normal	1	1	2
51	44	20	18	normal	1	1	2
52	35	10	23	slight	1	0	1
53	47	34	33	slight	1	1	2
54	37	9	8	normal	1	1	2
55	38	15	17	normal	1	0	1
56	49	30	12	normal	1	1	2
57	35	10	10	normal	1	1	2
58	29	1	8	normal	1	0	1
59	50	33	14	normal	1	1	2
60	36	14	7	normal	1	1	2
61	43	14	65	moderate severe	0	0	0
62	38	14	28	slight	1	0	1
63	33	10	41	moderate	1	1	2
64	49	15	15	normal	1	0	1
65	44	13	26	slight	1	1	2
66	30	1	10	normal	1	1	2
67	47	29	15	normal	1	1	2
68	48	30	35	slight	0	0	0
69		31	37	slight	1	1	2
70	37	15	24	slight	0	0	0
71	42	14	33	slight	0	0	0
72	34	9	23	slight	1	1	2
73	34	1	17	normal	0	0	0

APPENDIX-C

İŞGÜM'S SURVEY ON NOISE LEVEL

Factory 1

A-weighted Noise Level

Table C.1 İŞGÜM A-weighted levels Factory 1

Point	İSGÜM Measurements L_{Aeq} (Average)	Rating According to Noise Regulations"
1	81	Below The Limit
2		
3		
4		
5		
6		
7	88	Above The Limit
8	101	Above The Limit
9		
10	97	Above The Limit

Weighted Peak Level

Table C.2 İŞGÜM C-weighted levels Factory 1

Measurement Point	İSGÜM Measurements L_{Cpk} (Average)	Rating According to Noise Regulations
1	107.8	Below The Limit
2	127.4	Below The Limit
3		
4		
5	115.8	Below The Limit
6		
7	119	Below The Limit
8	121.7	Below The Limit
9		
10	120.8	Below The Limit

Factory 2

A-weighted Noise Level

Table C.3 İŞGÜM A-weighted levels Factory 2

Point	İSGÜM Measurements L_{Aeq} (Average)	Rating According to Noise Regulations
1	93	Above the Limit
2	80	Below The Limit
3		
4	81	Below The Limit
5	76	Below The Limit
6	82	Below The Limit
7	78	Below The Limit
8		
9		
10	80	Below The Limit
11		
12	77	Below The Limit
13		
14	83	Below The Limit
15		

APPENDIX-D

TECHNICAL DATA OF EAR PLUGS USED

Factory 1

1. QUITE EAR PLUGS
   HOWARD S. LEIGHT & ASSOCIATES INC.
   (MOLDED)
   NRR=26

2. BILSOM 304L
   NRR=33

Factory 2

EAR EXPRESS POD PLUGS
NRR=25

APPENDIX-E

EAR PLUG PERFORMANCE USING EAR PLUG TECHNICAL DATA

Factory 1

Table E.1 Ear plug performance Factory 1

Point	L_{Ceq}	NRR (dB) (QUIET EARPLUGS)	L_{eff} dB(A)	Rating According to WCB British Columbia	Rating According to TS EN 458
n1	82	26	56	Overprotect.	Overprotect.
n2	79	26	53	Overprotect.	Overprotect.
n3	81	26	55	Overprotect.	Overprotect.
n4	81	26	55	Overprotect.	Overprotect.
n5	82	26	56	Overprotect.	Overprotect.
n6	81	26	55	Overprotect.	Overprotect.
n7	86	26	60	Overprotect.	Overprotect.
n8	85	26	59	Overprotect.	Overprotect.
n9	83	26	57	Overprotect.	Overprotect.
n10	90	26	64	Overprotect.	Overprotect.

Factory2

Table E.2 Ear plug performance Factory 2

Point	LCeq	NRR (dB) EAR EXPRESS	Leff dB(A)	Rating According to WCB British Columbia	Rating According to TS EN 458
n1	79	25	54	Overprotect.	Overprotect.
n2	78	25	53	Overprotect.	Overprotect.
n3	81	25	56	Overprotect.	Overprotect.
n4	77	25	52	Overprotect.	Overprotect.
n5	75	25	50	Overprotect.	Overprotect.
n6	76	25	51	Overprotect.	Overprotect.
n7	76	25	51	Overprotect.	Overprotect.
n8	76	25	51	Overprotect.	Overprotect.
n9	85	25	60	Overprotect.	Overprotect.
n10	78	25	53	Overprotect.	Overprotect.
n 11	75	25	50	Overprotect.	Overprotect.
n12	77	25	52	Overprotect.	Overprotect.
n13	76	25	51	Overprotect.	Overprotect.
n14	78	25	53	Overprotect.	Overprotect.
n15	75	25	50	Overprotect.	Overprotect.

APPENDIX-F

ASSESMENT OF EAR PLUG PERFORMANCE IN İŞGÜM'S REPORT

Factory 1

Table F.1 Ear plug performance Factory 1

Point	L_{Ceq} (Average)	SNR	L_{eff} dB(A)	Rating According to WCB British Columbia	Rating According to TS EN 458
n1	87.5	28	59.5	Overprotect.	Overprotect.
n2	104.5	28	76.7	acceptable	acceptable
n3		28			
n4		28			
n5	97.4	28	69.3	Overprotect.	Overprotect.
n6		28			
n7	98.3	28	70	Overprotect.	Overprotect.
n8	97.7	28	70	Overprotect.	Overprotect.
n9	91	28	63	Overprotect.	Overprotect.
n10	97	28	69	Overprotect.	Overprotect.