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EVALUATION OF NOISE POLLUTION BY UTILIZING NOISE MAPPING: A CASE STUDY FOR ASSESSING EFFECTS OF NOISE ON OCCUPATIONAL HEALTH AND SAFETY AT CONTAINER TERMINALS

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EVALUATION OF NOISE POLLUTION BY UTILIZING NOISE MAPPING: A CASE STUDY FOR ASSESSING EFFECTS OF NOISE ON OCCUPATIONAL HEALTH AND SAFETY AT CONTAINER TERMINALS

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“One day people will have to fight noise just as relentlessly as they fight cholera and plague.”

Dr. Robert Koch-1910

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ABBREVIATIONS

AGV	Automated Guided Vehicle
CCOHS	Canadian Centre for Occupational Health and Safety
CFS	Container Freight Station
CRS	Container Reach Stacker
dB	Decibel
dB(A)	A-weighted Decibel
ECS	Empty Container Stacker
END	Environmental Noise Directive
EU	European Union
FCS	Full Container Stacker
FEU	Forty Equivalent Unit
FLT	Forklift
HSE	Health and Safety Executive
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
L_0	Statistical Noise Level Indicators 0%
L_{10}	Statistical Noise Level Indicators 10%
L_{100}	Statistical Noise Level Indicators 100%
L_{90}	Statistical Noise Level Indicators %90
L_{Aeq}	A-weighted Equivalent Noise Level Indicator
L_{day}	Noise Level Indicator for the 07:00-19:00 period
L_{den}	Day, Evening, Night Noise Level Indicator
L_{eq}	Equivalent Noise Level Indicator
$L_{evening}$	Noise Level Indicator for the 19:00-23:00 period
$L_{EX,8h}$	Noise Exposure Level Indicator for a Nominal 8h Working Day
L_I	Sound Intensity Level
L_{max}	Maximum Noise Level Indicator
L_{min}	Minimum Noise Level Indicator
L_{night}	Noise Level Indicator for the 23:00-07:00 period
LOA	Length Over All
L_P	Sound Pressure Level
L_W	Sound Power Level
MESP	Management of Environmental Sustainability of Port Areas project
MHC	Mobile Harbor Crane
MTS	Multi Trailer System
NIHL	Noise-Induced Hearing Loss
NIOSH	The National Institute for Occupational Safety and Health
NoMEPort	Noise Management in European Ports project
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
REL	Recommended Exposure Limit
RMS	Root Mean Square
RTG	Rubber Tyred Gantry Crane
SC	Straddle Carrier
SIL	Sound Intensity Level
SILENV	Ships Oriented Innovative Solutions to Reduce Noise and Vibration project
SLM	Sound Level Meter

SPL	Sound Pressure Level
SSG	Ship to Shore Gantry Crane
TEU	Twenty Equivalent Unit
UN	United Nations
WHO	World Health Organization
YTT	Yard Towing Truck

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ABSTRACT

EVALUATION OF NOISE POLLUTION BY UTILIZING NOISE MAPPING: A CASE STUDY FOR ASSESSING EFFECTS OF NOISE ON OCCUPATIONAL HEALTH AND SAFETY AT CONTAINER TERMINALS

In every kind of workplace, depending on the on-going processes, sound is an integral part of the job being done. People occupying the area are directly exposed to a variety of sounds. Irrespective of their content, when the level reaches unwanted degrees it then becomes noise. Environmental noise, as it may have physical and physiological adverse effects on human health, has always been a social and occupational concern for people. Hence, identifying the amount of exposure to noise becomes a necessity in frequently used work places. In maritime field, there are a vast range of sources that could create unwanted noise levels in work places. Especially during port operations, either continuous or intermittent, noise sources may cause occupational health problems. Main assumption of this research bases on the fact that container terminal environment by nature involves a variety of shore-based noise sources which are someway harmful to human health. This assumption can only be proved by firstly making area-specific noise measurements, then analyzing the data obtained through this effort and finally by comparing the results to the standards set by national and international organizations. With this perspective on mind, this study firstly reviews the existing data on noise related problems and then discusses the methods for assessing and evaluating noise levels and then puts forward the international standards on the issue. Using a quantitative approach, the study utilizes *full day measurement method* as per ISO 9612:2009 Acoustics – Determination of occupational noise exposure – Engineering method at a container port to measure and evaluate operational noise levels at a running container terminal. The measurements are taken with intervals of 2 or 10 minutes in selected 30 points in the areas of the loading/discharging docks. For taking measurements a Sound Level Meter (Brüel & Kjaer 2260) was used and evaluation was performed through 7815 Noise Explorer software. Then, a thorough noise map of the workplaces concerned was generated. Research findings have revealed that the *equivalent sound pressure levels* in all workplaces where measurements are taken were around 76 dB which, though not drastically high, still falls under the harmful band of the noise. As one of the major assumptions of the study suggests, the results have shown that technological advances in port equipment and procedures does not always positively contribute to noise issue at container port terminals during cargo operations. However, the results of the study still make an attempt to contribute to enhancing environmental noise awareness as well as promoting efforts of researchers for further works in the field.

Key Words: Environmental noise, Noise mapping, Sound Pressure Level, Container Terminals, Occupational Health

ÖZET

KONTEYNER TERMİNALLERİNDE İŞ VE İŞÇİ SAĞLIĞI VE GÜVENLİĞİNE GÜRÜLTÜ KİRLİLİĞİ ETKİLERİNİN GÜRÜLTÜ HARİTASI ÇIKARILARAK DEĞERLENDİRİLMESİ

Çevresel gürültü, insan sağlığı üzerinde fiziksel ve fizyolojik olumsuz etkileri olabileceğinden, insanlar için her zaman sosyal ve mesleki bir endişe kaynağı olmuştur. İşyerlerinde ses yapılan işin ayrılmaz bir parçasıdır ve çalışanlar doğrudan çeşitli seslere maruz kalmaktadır. Bu nedenle, iş yerlerinde gürültünün ve çalışanların ne oranda buna maruz kaldıklarının belirlenmesi bir zorunluluk haline gelmiştir. Denizcilik sektöründeki çalışma ortamlarında istenmeyen gürültü seviyeleri yaratabilen çok çeşitli kaynaklar vardır. Özellikle limanlarda operasyon sırasında sürekli veya aralıklı gürültü kaynakları iş sağlığı sorunlarına neden olabilir. Bu araştırmanın ana hipotezi, konteyner terminal ortamının doğası gereği, insan sağlığına zarar veren çeşitli gürültü kaynakları içerdiği gerçeğine dayanmaktadır. Dolayısı ile bu çalışma belirlenen bir konteyner limanında gürültü ölçümleri yaptıktan sonra elde edilen verileri analiz ederek ve sonuçları ulusal ve uluslararası kuruluşlar tarafından belirlenen standartlarla karşılaştırmayı amaçlamıştır. Bu bakış açısına göre, öncelikle gürültü ile ilgili problemler hakkındaki mevcut verileri gözden geçirilmiş ve gürültü seviyelerini değerlendirme yöntemleri belirlenmiştir. Ardından konuyla ilgili uluslararası standartları ortaya koymuştur. Bu çalışma nicel bir yaklaşım ile ISO 9612: 2009 standardında önerilen ölçüm yöntemini kullanmaktadır. Ölçümler, belirlenen limanın seçilen 30 noktasında 2 ve 10 dakikalık ölçüm sürelerince gerçekleştirilmiştir. Ölçüm almak için Tip 1 Ses Seviyesi Ölçer (Brüel ve Kjaer 2260) kullanılmış ve 7815 Noise Explorer yazılımı ile alınan ölçümler analiz edilmiştir. Ardından, limanın kapsamlı bir gürültü haritası oluşturulmuştur. Araştırma bulguları, ölçümlerin yapıldığı noktalarda eşdeğer ses basıncı seviyelerinin 76 dB civarında olduğunu ortaya koymuştur. Bu gürültü seviyesi, standartların üzerinde olmasa da belirlenmiş limitlere yaklaşmakta olup zararları tespit edilmiştir. Çalışmanın diğer bir hipotezinin belirttiği üzere, sonuçlar da göstermiştir ki liman ekipmanlarındaki teknolojik ilerlemeler, konteyner terminallerindeki gürültü sorununa her zaman olumlu bir şekilde katkıda bulunmadığını göstermiştir. Sonuçlar, liman ekipmanı ve prosedürlerindeki teknolojik ilerlemelerin, kargo operasyonları sırasında konteyner liman terminallerinde gürültü sorununa her zaman olumlu bir şekilde katkıda bulunmadığını göstermiştir. Bununla birlikte, çalışmanın sonuçları hala çevresel gürültü bilincinin artırılmasına katkıda bulunmaya çalışmanın yanı sıra, araştırmacıları bu alanda daha fazla çalışması için teşvik etmeye çalışmaktadır.

Anahtar Kelimeler: Çevresel gürültü, Gürültü Haritası, Konteyner Terminalleri, İş ve İşçi Sağlığı

1. INTRODUCTION

One of the environmental problems arising from industrialization and the development of modern technology is noise pollution. The characteristics of the noise have changed throughout the years but it has always remained to be a problem. Even it was always seen as an inevitable fact of life, it is a growing environmental concern arising from a variety of sources. Recent studies have shown that noise have various adverse effects on human health. When human health is concerned, the noise problem should be considered not only an element of nuisance but also a serious health threat.

Noise, by definition already calls a negative term in which the sound reaches the level that poses harmful effects to health of human and other living creatures. Second term we need to focus on is the word pollution. Things that may affect natural flow of life to cause adverse effects on life forms are called pollutants and the process is called pollution. When the amount of the unwanted sounds becomes irritating, from environmental point of view, it is referred as noise pollution. In order to understand the nature of this specific pollution, firstly the term noise needs to be clearly defined. Very briefly noise also can be defined as unwanted sound or sound that is “out of place”. Derived from the Latin word “nausea”, the word besides meaning unwanted sound, also involves loud, unpleasant or unexpected sound (Singh & Davar, 2004). Hence, noise from transport and industry become prominent input of the environmental noise pollution (Stansfeld & Matheson, 2003). From this perspective, more precisely, the common features of noise can be briefly expressed to include three keywords: loud, unpleasant and disturbing (Oxford English Dictionary, 2014).

The term environmental noise, on the other hand, can be identified as being unwanted sound arising from human activities which is harmful to human health and quality of life (OSHA, 2019). Making a concrete definition of the term environmental noise surely requires input of international and national organizations’ approaches. In this context, WHO (World Health Organization) as the major international body operating under the UN specifically defines environmental noise as “noise emitted from all sources except industrial workplaces” (WHO, 2011). However, the EU, as the major regional organization which regulates 28 countries across Europe, by issuing directives on the matter has contributed to defining the environmental noise. The European Environmental Noise Directive (Directive 2002/49/EC, also known as END) defines environmental noise to include also industrial sites.

Although, in the last two decades both national and international institutions have made clear-cut definitions pertaining to noise related problems, somehow environmental noise has not always gathered sufficient attention. The reason behind can be explained by the fact that people tend to see environmental noise as an unavoidable fact of life and hence it has not adequately been pointed out or controlled. Murphy & King (2014) have referred environmental noise as the *forgotten pollutant,* they have also added that this issue has fairly recently been recognized as a public health issue. Singh & Davar (2004) also stated that environmental noise is becoming omnipresent, yet there is not enough awareness on the issue. So, as environmental noise has adverse effects on human health, it is a latent danger that shouldn't be disregarded.

1.1. Literature Review

In today's working environment overexposure to noise is considered as one of the most common occupational hazards (Kurt, McKenna, Gunbeyaz, & Turan, 2017). As far as excessive noise exposure and its health effects are concerned, basic causes of this kind of disturbance seems to source basically from urbanization, economic growth and motorized transport (WHO, 2011). Prolonged and/or high-level exposures to noise may cause serious health problems by affecting endocrine and brain functions, which in turn may affect the cognitive and physical conditions that consequently decrease the overall performance that can lead to be more vulnerable to external factors (Singh & Davar, 2004; Nelson et.al., 2005, WHO, 2004). Exposure at high levels and for prolonged times to such noises may cause physiological and psychological effects (Stansfeld & Matheson, 2003; Babisch, 2002). Annoyance, distraction, insomnia, mental health problems, high-blood pressure, cardiovascular diseases, tinnitus, and loss of hearing can be listed among these effects (Gerevandi et.al., 2015). Eventually, due to a decrease in overall performance of people who are exposed to noise, accidents may occur as a secondary effect of the pollution. To support this idea ergonomics theory proposes that when environmental noise level exceeds certain level, the operational efficiency of people in the area will sharply decline. Therefore, this decrease will probably cause errors in the way things operate, unexpected safety incidents as well as violations of safety rules in the working environment (Ning & Kuzhu, 2009). Hence, controlling and reducing environmental noise is beneficial to human health, eliminating potential hazards as well as promoting safety of working area. Looking from this perspective, it becomes obvious that these adverse effects of noise on human health are the fundamental reasons why environmental noise should be considered as a pollutant that needs to be avoided and controlled (OSHA, 2019). As a collective effort to control the environmental noise and its adverse effects on human health standards have been set for ameliorating environmental noise pollution.

When standardizing comes into play there needs to be certain prerequisites to be met. The word standard requires the subject matter to be recognized or implemented in the same manner with the majority. Hence, with the noise issue the standards are mostly set by international organizations such as United Nations and European Union. Within the UN WHO is the primary agent that deals with the environmental noise. Their contribution to standardization generally realized by issuing documents in form of guidelines and directives. The European Environmental Noise Directive (END) establishes the basis for noise management in the Member States. It also sets the basis for the how to create of Strategic Noise Maps which actually can be used as the main tool to fight against environmental noise. The END by setting concrete criteria, makes the guidelines for the production of noise maps uniform as well as presenting a list for noise maps to be produced across the union (END, 2002). WHO, on the other hand, issued Environmental Noise Guidelines for the European Region providing a guidance on protecting of human health from harmful exposure to environmental noise. The Environmental Noise Guidelines of WHO aim to support and serve as the basis for policy-making processes on local, national and international level. However, there are also national standards set by various countries to deal with noise related issues. In which these national based standards are also available across the world to complement the international standards. For example, Occupational Safety and Health Administration (OSHA) as a part of the United States Department of Labor, assures safe and healthful working conditions. Also, OSHA sets and enforces standards and provides education, training and assistance. The standards of OSHA on noise are to hearing conservation while explaining exposure to noise and setting engineering and administrative control methods (OSHA, 2019). Besides, as a part of the U.S. Centers for Disease Control and Prevention, in the U.S. Department of Health and Human Services, The National Institute for Occupational Safety and Health (NIOSH) was established to act as a researching body focused on safer, healthier workers and workplaces. On the issue of noise, it has publications on noise and hearing loss prevention [URL5]. Like OSHA, Health and Safety Executive (HSE) in UK, plays a regulatory role within the country. HSE when necessary, conducts research, lays statistics and enforce the law according to the regulations which were already shaped and reviewed by this organization. And it issued regulations on the matter to protect people against the risk to their health and safety arising from exposure to noise at work [URL6]. Canadian Centre for Occupational Health and Safety (CCOHS), on the other hand, is formed and operated by representatives of governmental bodies, employers and employees. This organization mainly aims to physical, psychosocial and mental well-being of the people in all workplaces across the country. Through their studies CCOHS institute contributed to the matter by introducing noise problem recognition guidelines which aims to control the noise and avoid its adverse effects [URL1]. One major non-governmental standard setting organization is ISO. And it provided ISO 9612:2009 Acoustics — Determination of occupational noise exposure — Engineering method which determines some methods to measure noise exposure of workers in their working environment (ISO, 2009).

Having covered the general aspects of noise and noise-related terms and international and national standards, this study intends to focus more on occupational impact of noise pollution in the workplaces. In this regard, looking at many major cities noise pollution is found to be originating mainly from traffic related sources such as airports, road and rail traffic as well as industrial areas.

In this context, the study conducted in İstanbul Atatürk Airport area sets a good example to this approach. Sari, Ozkurt, Akdag, Kutukoglu, & Gurarslan (2014) determined the noise levels at the İstanbul Atatürk Airport which includes a variety of noise sources. As the airport is close to a densely populated residential area, they collected short-term and long-term measurement data according to the END and aimed to find the contribution of the airport activities to background noises. Besides, through a comparison of short and long-term noise level measurements, they developed a model that can be used forecasting tool for future land use and operations. Ozkurt, Sari, Akdag, Kutukoglu, & Gurarslan (2014) calculated the level of noise exposure due to aircrafts around İstanbul Atatürk Airport according to the END. Their study was covered 25 km radius and showed that a considerable number of people are exposed to excessive noise. Ozkurt, Hamamci, & Sari (2015) calculated the noise levels for the day, evening and night time around İzmir Adnan Menderes Airport and prepared noise maps. Their results showed that at the north side of the airport, where İzmir's city center is located, people are more affected than other sides. So they suggested optimization of flight procedures, quitter aircraft and new routes in order to reduce impacts of airport noise on residential area in the vicinity. Vogiatzis (2012) conducted a research on Larnaka International Airport in Cyprus where he generated a Strategic Noise Map and evaluated the results in regards to residential exposure to the environmental noise. Then, he introduced a Noise Action Plan which suggests a new land use management scheme for the future Larnaka city land use plan. Licitra, Gagliardi, Fredianelli, & Simonetti (2014) studied on noise mitigation action plan for Galileo Galilei Airport which is a civil and a military airport that is very much close to central Pisa. Therefore, assuming the public health possibly be affected significantly from noise sourced from the airport, they evaluated population exposed to it by using Integrated Noise Model. Noise Maps showed that they were right about their hypothesis and they simulated them for present and future scenarios to suggest noise reduction measures.

Apart from the studies on noise pollution sourced from airports, road traffic noise is also a great concern for human health. Murphy, King, & Rice, (2009) determined environmental noise exposure levels in residential areas environmental noise exposure caused by road traffic in central Dublin, Ireland by using Harmonoise calculation method. And also, they used Strategic Noise Maps of the area in order to have an overview of noise levels in the selected area. After collecting all the necessary data and with the traffic management analysis it has been revealed that it is actually possible to reduce the number of people exposed to noise sourced from road traffic especially during night time. Seong et al. (2011) focused on modeling noise caused by road transport and analyzing exposure in Fulton

Country, Georgia, United States. Their study showed that a great number of people are affected from excessive noise levels of road traffic. By the noise level simulation and maps of the spatial patterns of noise exposure, they determined where to start noise management. The noise issue is also widely covered in construction sector as seen in the literature.

Fernández, Quintana, Chavarría, & Ballesteros (2009) investigated the noise levels of 7 construction sites with a sound level meter and also took measurements with a dosimeter from 40 workers to assess their exposure. Then, they analyzed those data and compared with the set rules and limits of various current regulations. With the drastic results they obtained, they raised a remarkable awareness on the issue and recommended several ways to control noise and avoid adverse effects by the usage personal hearing devices. Ballesteros, Fernández, Quintana, Ballesteros, & González (2010) stated a measuring method that is convenient for evaluating noise in construction sites by using this method to assess noise levels of the construction of a housing block of 26 flats. Their results showed that suggested method is reliable and specific to construction sector and it is needed. Li, Song, Wang, Zheng, & Ning (2016) calculated occupational noise exposure level according to ISO 9612:2009 in building projects in Beijing. They assess health impacts and made recommendations to improve health, safety and environment. However, Ali (2011) evaluated health impacts of industrial noise levels on 683 workers in 15 Egyptian sites of industry, ranging from food to metal industry. While determining how much the noise levels exceeded the permissible levels, he also looked into how the workers respond to the noise and he concluded that it makes them more vulnerable and the possibility of an incident to occur was increased.

While in the cities' main sources can be classified as above, when it comes to port cities the picture becomes more complicated which requires a different typology involving shipping traffic and harbor activities (Badino, Borelli, Gaggero, Rizzuto, & Schenone, 2016). There are many examples on noise pollution in maritime sector in literature such as noise in ports, ship recycling yards and on-board ships. For example, Murphy & King (2014) studied on residential night time exposure sourced from Dublin Port, Ireland noise levels. Their results showed that the levels exceeded the night time limits of WHO. In Lebanon, Kamali, El Moghrabi & Wahab (2015), investigated environmental noise in Tripoli port within the

MESP (Management of Environmental Sustainability of Port Areas" project. They focused on noise related activities in port and searched for noise level reduction measures especially for port vehicles. Within the NoMEPorts (Noise Management in European Ports) project Morretta, Iacoponi, & Dolinich (2008) emphasizes the importance of noise mapping for port planning and environmental management. They showed the results of Livorno port noise maps and reports on action plans proposed as a reference. The Livorno example was from NoMEPort project which carried out the analysis of the port's noise levels according to END. One other port noise study is done by Bakogiannis, Argyropoulos, Dagres, Fotiou, & Cambourakis (2015) in Piraeus, Greece. As the noise levels of the Piraeus port is excessive, they made an evaluation of each noise source at port and its vicinity. The results of the study showed that residents are exposed to high noise levels mainly because of traffic noise but at nights port activities contribute too and cause great annoyance. As an example, to the noise studies on board ships, Kurt, Khalid, Turan, Houben, Bos, & Helvacioglu (2016) represents the results of SILENV (Ships Oriented Innovative Solutions to Reduce Noise and Vibrations) project. The project looked into the noise levels that crew are exposed to. They also developed human response models to noise levels and by using them they proposed "SILENV Green Label noise standards". Borelli, Gaggero, Rizzuto & Schenone (2015) executed an all-out noise level measurement on a ferry during her navigation and manoeuvres. They aimed to determine the acoustical situation of the vessel and the results showed that certain operations on board are significantly higher. Also, Badino, Borelli, Gaggero, Rizzuto & Schenone (2012) underlined that ships are affecting a wide range of people while at sea or at port such as crew, passengers, people on the coastal areas and even marine fauna. So, they analyzed the standards in these various fields and suggested a general approach. Another example on noise and its effects in maritime sector is done by Kurt, McKenna, Gunbeyaz & Turan (2017) in a ship recycling yard. As it is known that the ship recycling yards have noisy environment, they made a quantitative explaining of the health and safety impacts of noise due to yard operations. They identified noise sources by SLM, conducted an exposure measurement by dosimeter to the workers who are most at risk and made recommendations regarding the results.

1.2. Hypotheses

As seen in the literature review presented above, work places are the primary environment for people to be exposed to noise-related pollution. While some working sectors are more affected, some others depending on the content of the work may be less affected. Maritime sector, in this sense, is very much affected by the nature of the heavy-duty processes, mostly in port areas. As ports are heterogeneous, considering their specialty of being hub and complex structures, they are significant noise sources for port workers (stevedores) as well as residential areas. Due to complexity of ground operations and variety of noise sources, much noise is produced in port areas. Within this aspect, container terminals pose a considerable problem of noise which is mostly generated by the ships, straddle carriers, cranes, forklifts and trucks. Although effects of noise pollution sourcing from ports may have negative impact on residential areas, due to focus and limits of this study, the core approach of the study will be kept within the port ground working area and the people working in this environment. In this aspect, two hypotheses are formulated:

- In container terminals, environmental noise sourcing from the port operations are high enough to make adverse effects on the port workers (stevedores).

- Effects of inevitable noises sourcing from loading/discharging operations are not directly related to technological improvement/advancement of terminal equipment.

The first hypothesis suggests that container terminals by default contains noise that is harmful to human health. This hypothesis will be proved by systematic field noise measurements by Sound Level Meter in operational part of MARPORT container terminal.

For proving the second hypothesis, a comparison will be made to assess noise differences between technologically diverse equipment. To further investigate record of events in the field will be corresponded to SLM recordings.

1.3. Scope of the Thesis

Owing to many noise sources in container ports, monitoring and evaluation of noise pollution through noise maps will contribute much to health and safety of the land-based crew. Besides, as Turkey is a developing country, port operations are more labor intensive here, compared to developed countries which makes even more necessary to evaluate noise in Turkish ports. So, the research questions for this research are formulated as follows:

- How much environmental noise sourcing from terminal equipment are the container terminal workers exposed to while performing loading and discharging duties?

- Can technological improvement/advancement of terminal equipment contribute to diminishing the environmental noise levels in container terminals?

In this regard, this study aims to monitor and evaluate noise levels in a container port, through noise maps that is going to be generated. For ease of field study, the selected container port is divided into regions according to sources of noise and places where the port workers (stevedores) are actively present. These are; cargo handling areas, storage areas, truck roads, facilities and common places. Measurements will be taken with sound level meter in the designated areas. With the data gathered, a noise map can be created to evaluate. An assessment is going to be done to see whether the noise level in the area exceeds the relevant noise regulation.

As noise is already known to have negative effects on cognitive states of an individual, noise in the working environment can be considered as an invisible cause of occupational accidents. Therefore, this study, taking the obtained results into account, will make recommendations to achieve a high level of occupational health and safety quality in environmental managements of ports. Also, it aims to raise awareness on environmental noise pollution considering its adverse effects on health and to draw attention on the issue as it directly affects the quality of life.

2. THEORETICAL AND CONCEPTUAL FRAMEWORK

In the theoretical and conceptual framework of this thesis, sound (noise) related terminology is one of the most important issue that should be considered. It is not possible to evaluate the results obtained without understanding this part. While discussing the sound (noise) related terminology, the study investigated from the sound theory to noise measurements as well as noise mapping.

The effects of environmental noise on human health constitute the second sub-title of the theoretical and conceptual framework in order to further examine the adverse effects of environmental noise sourcing from the port operations on stevedores, which is one of the hypotheses of this study. As the negative effects of noise on human beings have been proved in many studies, a lot of standards have been established on this subject. So, in the third part these standards will be mentioned.

Finally, in the last part of this chapter, terminal equipment will be introduced by a general description of the container terminals in order to determine the noise sources which affects container port workers (stevedores). Then the organization of port workers in a container port will be discussed in detail to determine the parameters while examining the noise exposure of the stevedores.

2.1. Sound (Noise) Related Terminology

First, we need to understand how sound is formed and to understand when it becomes noise. Basic sound terminology as frequency, wavelength, period and amplitude are explained below. Then, sound parameters as in sound power, sound intensity and sound pressure are discussed. Also, in order to evaluate noise, sound levels, dB, perception of dB, frequency weighting and noise indicators are defined. Then, how many different types of noise and how they are measured are examined along with noise mapping.

2.1.1. Sound Theory

Sound is briefly explained as what we hear whereas *noise* is simply an unwanted sound. The difference between the two varies according to the listener and/or the situation. For example, rock music can be a nice sound for someone, whereas for someone else it can be irritating. In either case, if the sound is too loud and exposure time is long enough, it can be damaging to hearing.

When objects vibrate, they create sound. These vibrations travel as waves in the air and reach the listeners ear. When a sound occurs with vibration, there is a small change in air pressure. As a result of these pressure changes, waves travel through air and sound is created. For example, imagine playing drums. When you hit a drum, its surface starts to vibrate back and forth. The forward vibration period of the surface creates a compression in the air by pushing it. Thus, it creates positive (higher) pressure. When the drum moves in the other direction right after, it decompresses the air and creates negative (lower) pressure. When the drum vibrates really fast, it creates higher and lower air pressure in succession. As a result, these pressures travel as sound waves as shown in Figure 2.1.

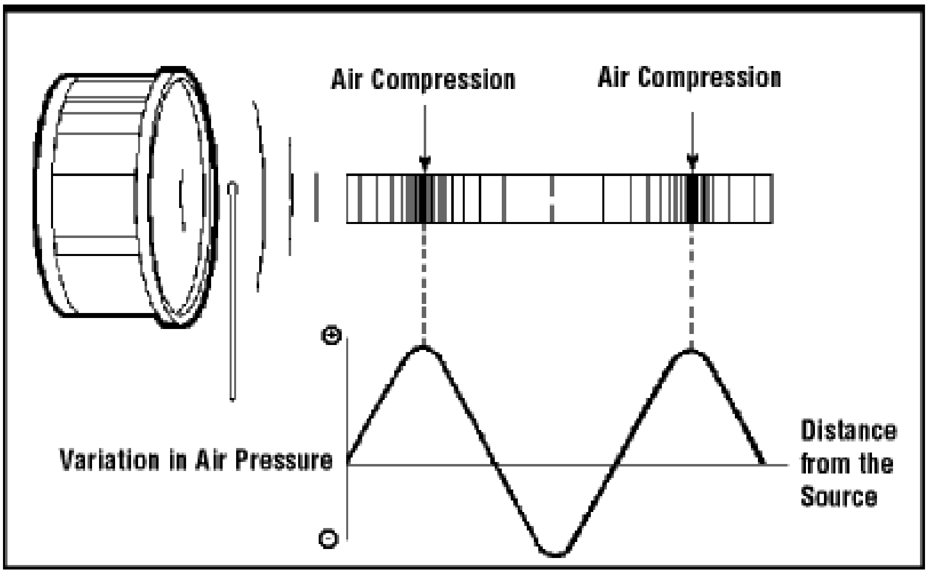


Figure 2.1. Generation of Sound Waves [URL1]

The pressure change that the ear collects is called sound. When the ear collects a sound wave, it converts the wave into an information which is then redirected to the brain. This information is then perceived as a sound in the brain. The atmospheric pressure is so high, even a really loud sound is considered very small (1 in 10,000) compared to it. But the ear is so sensitive so, it detects even small pressure waves. It is also tender, which is why loud sounds (noise) considered mostly to be damaging.

The science of sound is called ACOUSTICS, and this discipline covers all areas related to the production, dissemination and perception of sound. In order to be able to properly assess the noise, reliable sound measurements are required. But before starting the noise measurements, it is needed to have an idea about the basic principles of the relevant terminology and sound measurement.

Sound is a product of pressure changes or oscillations that occur from vibrating surfaces in an elastic environment such as air, water, solids. Sound disseminates as longitudinal waves that contains succession of compressions in the elastic environment (air, water and solids). In Figure 2.2. wavelengths in air presented in reference to frequency.

The moment a sound wave disseminates in the air; the vibrations are either below or above the atmospheric pressure. The characteristics of sound waves composed of pure tone only are as follows:

- **the wavelength** (m), is the distance that a pressure wave travels throughout one cycle;
- **the frequency** (f), is basically the number of variations in pressure per second and its unit is Hertz (Hz). A noise is generally comprised of various frequencies. In Figure 2.3 the relation between wavelength and frequency is shown.
- **the period** (T), is the time that is required for a wave to complete its one cycle. The relation between period and frequency can be shown as: $T = 1/f$

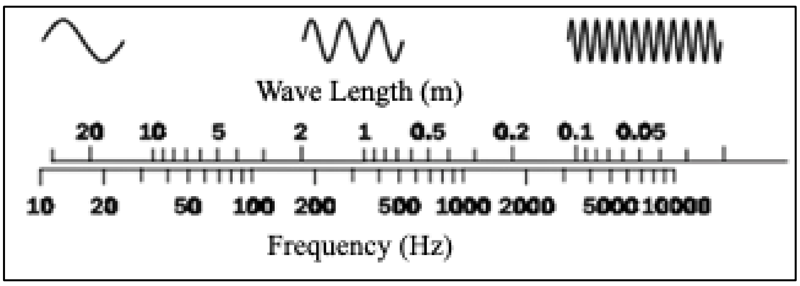


Figure 2.2. Wavelength in Air Compared to Frequency [URL2]

2.1.1.1. Sound Parameters

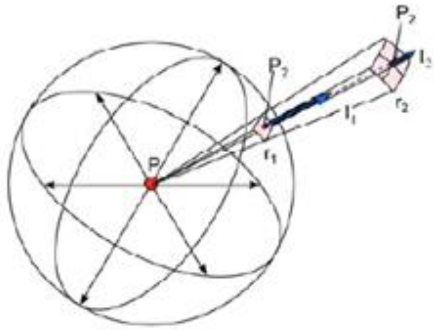


Figure 2.3. Basic Sound Parameters (Brüel & Kjær, 1998)

When a sound power is generated by a sound source such as P, an energy flow through the source to surrounding air molecules occurs. In this way, energy is spread to the environment in a manner similar to that of waves in the lake. The amount of this energy that passes through the unit area in a given direction in a certain direction is called the sound intensity. Spreading energy causes sound pressure at every point it passes (Figure 2.3.).

The formula that links the three basic parameters is given below.

$$I = (P / 4\pi r2) = p2 / \rho c \tag{2.1}$$

Where, r: Distance to source

ρ: Density of air

c: Sound speed

Sound intensity and sound pressure can be measured using appropriate instruments. Sound power on the other hand, can be calculated by use of sound pressure or sound intensity values that are measured.

The sound power is used to rank the machines according to the noise they produce but the sound intensity values are for detecting the noise sources. Sound pressure is however the most important parameter that must be followed for the damage and bad effects of noise sources.

Herein, it is crucial to make a clear difference between sound pressure level (L_P), sound power level (L_W) and sound intensity level (L_I). Sound pressure level is the level of sound according to the hearing limits of humans specified in decibels. Sound power, on the other hand, is the acoustic energy produced by a sound source and it is an element of the sound source alone which is expressed in Watts (W). And, the term sound intensity defines the rate of flow of an acoustic energy considering the unit area in a specific direction. So, if a sound power (W) passes uninterrupted from an area (S), the formula for sound intensity is as follows:

$$I = W / S \ (W/m^2) \tag{2.2}$$

When a point source is considered disseminating in open air; it can be stated that its energy spreads out in a spherical shape and its size will improve further as the sound disseminates. So, as the surface area of a sphere is $A= 4\pi r^2$, the radius (r) can be considered as the distance from the source in this case. This means that the sound intensity of a source in open air can be calculated as follows:

$$I = W / 4\pi r^2 \tag{2.3}$$

Sound pressure and sound power are often confused in acoustics. Take, for example, a vacuum cleaner switched on and laced on a chair in the center of a room. This will approximate a relatively constant broadband noise source. If with a sound level meter, the sound level is measured directly in front of the vacuum cleaner, 2 m from the side of the vacuum cleaner and 3 m behind the vacuum cleaner, the measured results will be quite different. This is because what have just measured is the sound pressure level and it is dependent on a variety of external conditions such as the orientation of the microphone, its distance from the source, reflections from the room walls, floors and ceilings. It should be noted though that the radiated sound energy from the vacuum cleaner does not change.

Sound power is an element of a noise source alone and it is usually used to compare the sound levels of different equipment types. In environmental noise studies the sound source is generally referred to in terms of a sound power level; it is the sound pressure level that is measured at different distances from the source.

- **Sound Power Level**

The sound energy transmitted from a noise source per second to the air is called sound power. A source of noise, has a constant sound power that does not changed even it is placed a different environment. Watt (W) is the unit that is used for power.

Such as sound pressure, sound power is also stated as sound power levels in dB. Sound power level calculation example is as follows; [URL1]

The formula to calculate sound power levels (Lw) is : (2.4)

$$Lw = 10 \log (\text{Sound Power Level} / \text{Reference Power Level})$$

The reference power level stated in the formula is accepted as one trillionth of a watt (0.000000000001 W). Therefore; (2.5)

$$Lw = 10 \log (\text{Sound Power Level} / 0.000000000001)$$

Thus, if a sound source has a sound power of 0.0000001 W, its sound power level (SPL) is calculated as; (2.6)

$$Lw = 10 \log (0.0000001 / 0.000000000001) = 50 \text{ dB}$$

Figure 2.4. demonstrates sound power level in decibels and sound power in watts. While the range of the sound power in watts goes from one trillionth of a watt to one hundred thousand, the sound power levels goes from 0 to 170 dB. For this reason, sound power levels in other words decibels are more manageable statements.

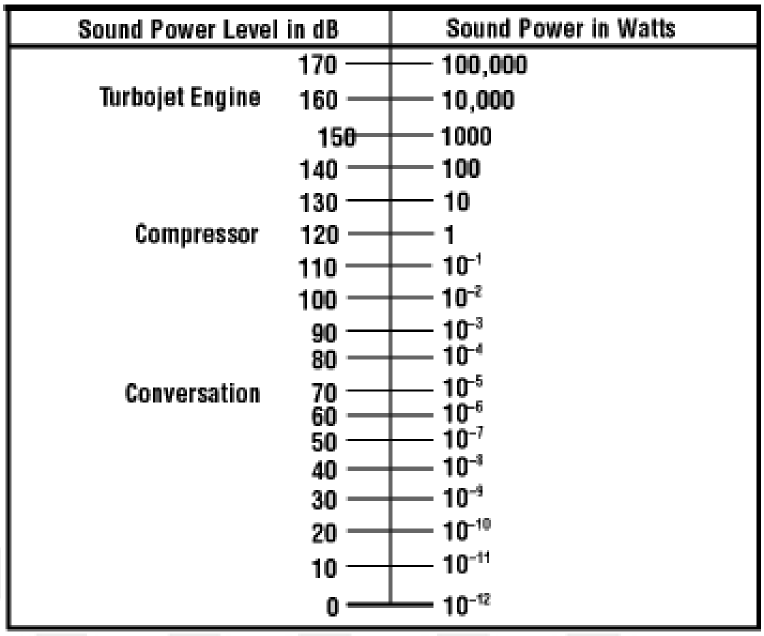


Figure 2.4. Comparison of Sound Power Level and Sound Power [URL1]

- **Sound Intensity Level**

Sound Intensity is the sound power per unit area and its unit is Watts/m^2. An average person can perceive sound intensities in a range of 0.000000000001 Watt/m^2 and 20 Watts/m^2 which is a very wide scale. So, if decibel is used with a conversion formula given below, the range can be compressed into manageable numbers as in Sound Intensity Levels. Also, in Table 2.1. there are some common sound sources with their sound intensity and SIL (dB).

(2.7)

$$\text{Sound Intensity Level (SIL)} = 10 \log(I/Io) \text{ dB re 1 pW/m}^2$$

$$0 \text{ dB} = 0.000000000001 \text{ W/m2} = 10^{-12} \text{ W/m2} = \text{reference level Io*}$$

$$\text{Reference Sound Intensity (Io)} = 1 \text{ pW/m2} = 1 \times 10^{-12} \text{ W/m2} \equiv 0\text{dB}$$

Table 2.1. Sound Intensity and Sound Intensity Levels of Sound Sources (Brüel & Kjær, 1998)

Source	Sound Intensity Level (dB)	Intensity (W/m^2)
Nearby jet airplane	150	1000
Machine gun	130	10
Siren, rock concert (Threshold of Pain)	120	1
Subway, power mower	100	1×10^{-2}
Busy traffic	80	1×10^{-4}
Vacuum	70	1×10^{-5}
Normal conversation	50	1×10^{-7}
Mosquito buzzing	40	1×10^{-8}
Whisper	30	1×10^{-9}
Rustling leaves	10	1×10^{-11}
Threshold of hearing	0	1×10^{-12}

- **Sound Pressure Level**

When a sound source vibrates, it brings changes in air pressure around it. These pressure changes in the air can be identified with the waves formed by a stone thrown into the lake. The waves begin to disseminate from the point where the stone enters the water. This example is similar to the sound. The stone corresponds to the sound source and the lake is like the air. So, the resulting waves on the water surface correspond to sound waves.

The amount of air pressure fluctuation that a noise source creates is called sound pressure. Sound pressure is perceived as volume of that sound. Sound pressure is often stated in units called pascals (Pa).

A young and healthy person can perceive sound pressures as low as 20 μPa. It is considered to be the lowest sound level that an average person can hear. So, it is called the sensation threshold. Sound pressure of a normal conversation is 0.02 Pa. Therefore, 100Pa is a very high level which causes pain and called the pain threshold.

The ratio of these two levels to each other is more than one million. Therefore, a linear scale in Pa, which will be used, will cause the measurement results to vary widely in a very wide range (Fig. 2.5.).

In addition, our ears are not linear but sensitive to logarithmic increases. For these reasons, the decibel (dB) scale, which is the logarithm of the measured value to a reference level, is used to determine the acoustic parameters.

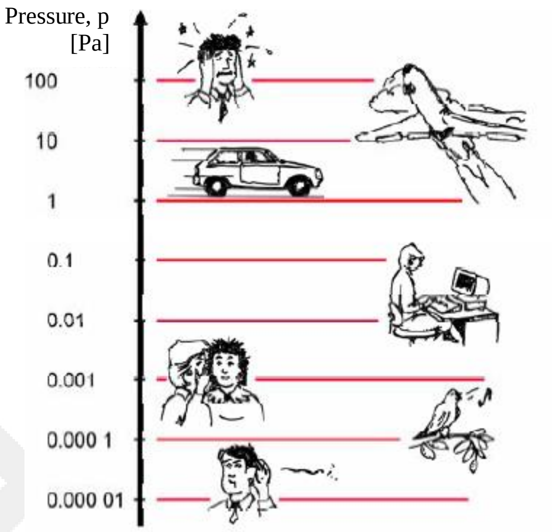


Figure 2.5. Range of Sound Pressure Change

2.1.1.2. Decibel (dB)

As is challenging to work with sounds pressures (20 μPa - 20 Pa) as it is a wide range scale, a logarithmic scale (decibel; tenth (deci) of a Bel) is being used to deal with this difficulty. The logarithmic scale helps to narrow down the wide range in a manageable range.

The word *decibel* is given after Alexander Graham Bell, who took dealt with the problems of deaf people other than his well-known great achievements [URL1].

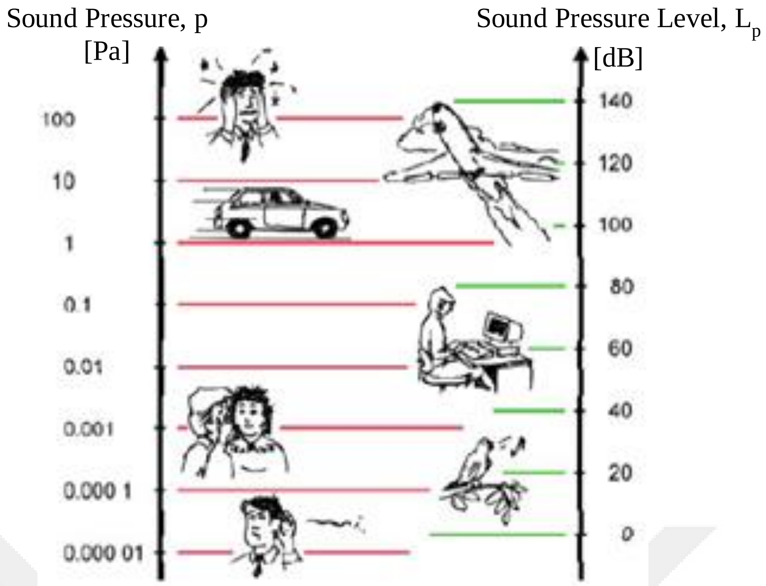


Figure 2.6. Range of Sound Pressure Change in Pa versus dB (Brüel & Kjær, 1998)

The linear scale, which has very large numbers and a wide range, is transformed into a simpler scale, which starts at the hearing threshold (0dB) and ends at the pain threshold (140dB) as seen in the Figure 2.6.

$$L_p = 20 \log \frac{p}{p_0} \text{ dB re } 20\ \mu\text{Pa} \tag{2.8}$$

where $p_0 = 20\ \mu\text{Pa} = 20 \times 10^{-6}$ Pa.

The decibel scale represents sound pressures converted to sound pressure levels. The symbol for the sound pressure level is Lp.

The sound pressure level in decibels is calculated as follows:

$$Lp = 20 \log (p / p0) \tag{2.9}$$

In this equation, p is the measured sound level (in Pa), and p0 is the reference sound level (20µPa), which is accepted as the standard.

2.1.1.3. Perception of dB

Table 2.2 representing the sound level perceived when there is a change in dB while the table 2.3 represents how sound energy evolves when there is a change in dB.

Table 2.2. Perceiving of Sound Levels [URL1]

Change in dB	Change in perceived sound level
3	Barely perceptible
5	Significant change
10	Doubled
15	Quite different
20	Quadrupled

Table 2.3. Decibel (dB) Basics [URL1]

Change in dB	Change in sound energy
3 dB increase	Sound energy doubled
3 dB decrease	Sound energy halved
10 dB increase	Sound energy increased by factor of 10
10 dB decrease	Sound energy decreased by factor of 10
20 dB increase	Sound energy increased by factor of 100
20 dB decrease	Sound energy decreased by factor of 100

A change in pressure of 3 decibels can only be felt while a change of 10 decibels perceived as doubled sound level. Therefore, there is no linear correlation between the level of sound perceived by humans and the specified level in dB.

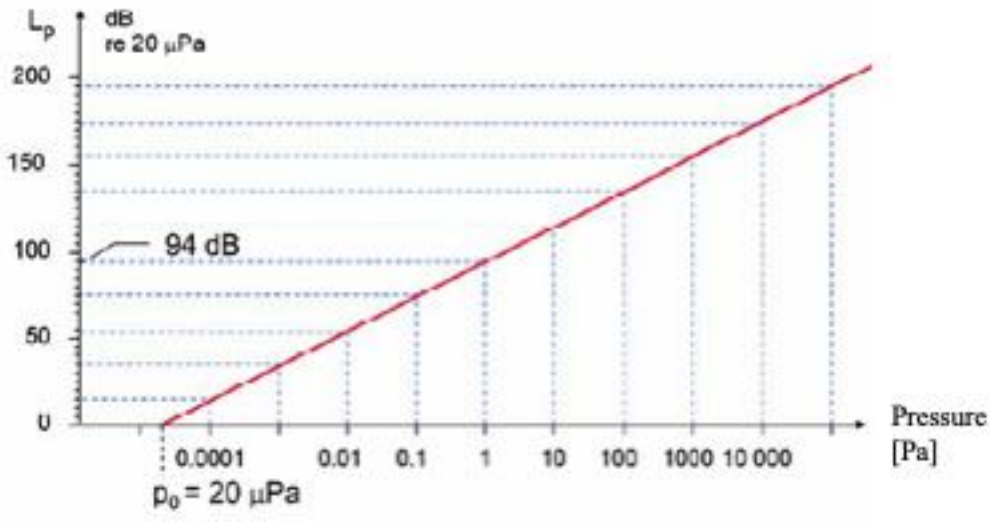


Figure 2.7. Sound Pressure (Pa) to Sound Pressure Level (dB) with a graphic (Brüel & Kjær, 1998)

Instead of using the conversion formula, a simple graph a simple graph can also be used to convert pressure values to each other (dB-Pa). The figure 2.7 shows the dB values prepared with reference to 20μPa. The values marked with a dashed line indicate how 1Pa corresponds to 94dB.

2.1.1.4. Frequency

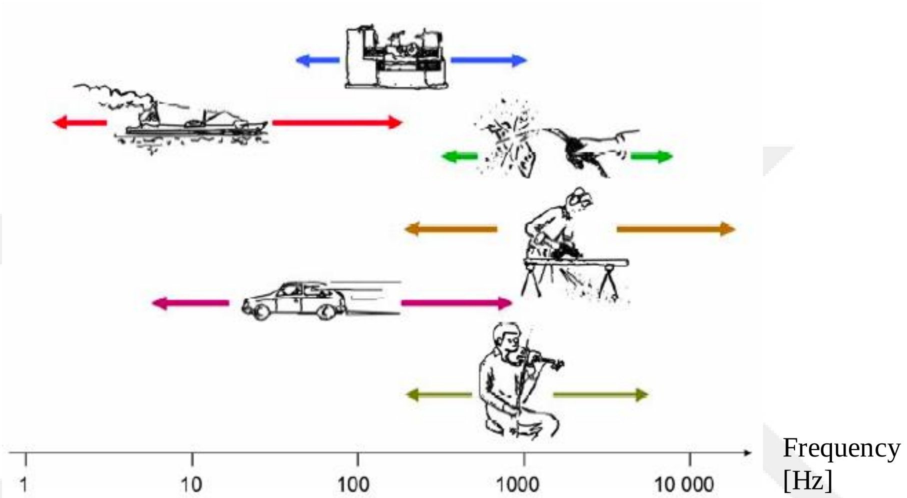


Figure 2.8. Frequency range of various sound sources (Brüel & Kjær, 1998)

The frequency ranges of the sound sources that we can hear in daily life vary considerably as represented in Figure 2.8. However, the figure does not cover the entire audible frequency range.

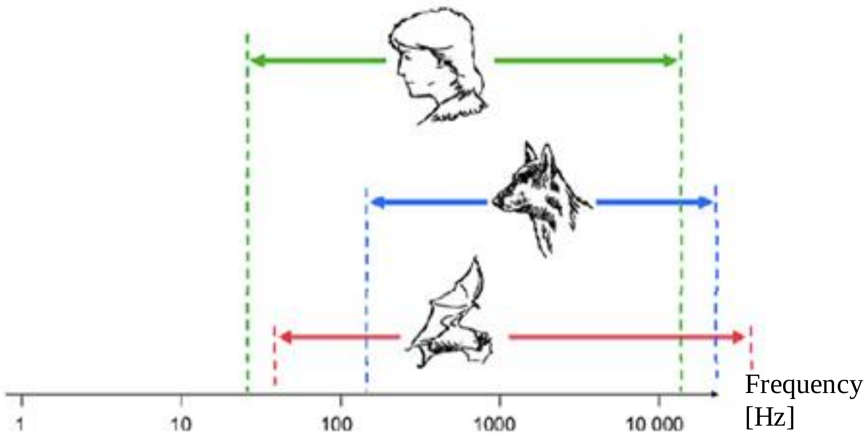


Figure 2.9. Audible sound ranges (Brüel & Kjær, 1998)

As can be seen in the above figure 2.9., the sounds that a healthy and young person can hear are in the range of 20 to 20000 Hz. As they get older, people's ability to hear high frequency sounds is reduced. When exposed to excessive noise, our auditory organ may be damaged in such a way that low-level sounds may be more difficult to hear. Sometimes the extent of this damage may be limited to the specific frequency range. In addition, between 1 to 20 Hz infrasound and 20000 to 40000 Hz ultrasound is perceived by other senses and causes discomfort (Figure 2.10.).

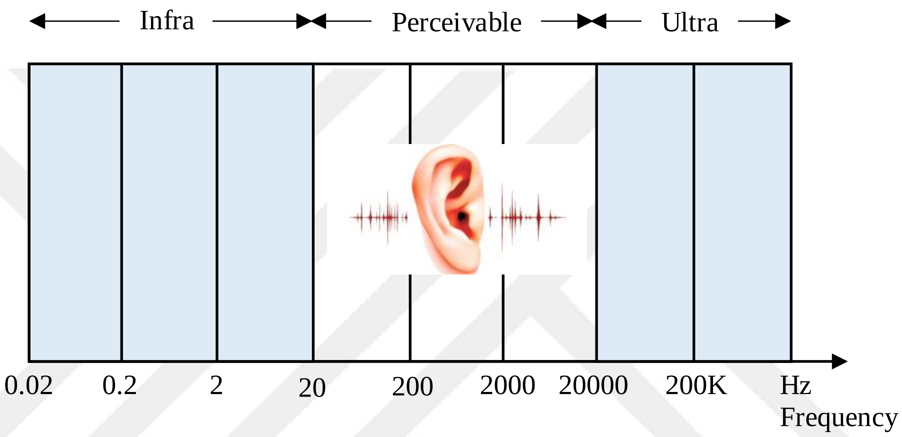


Figure 2.10. Sound Frequency Range (Brüel & Kjær, 1998)

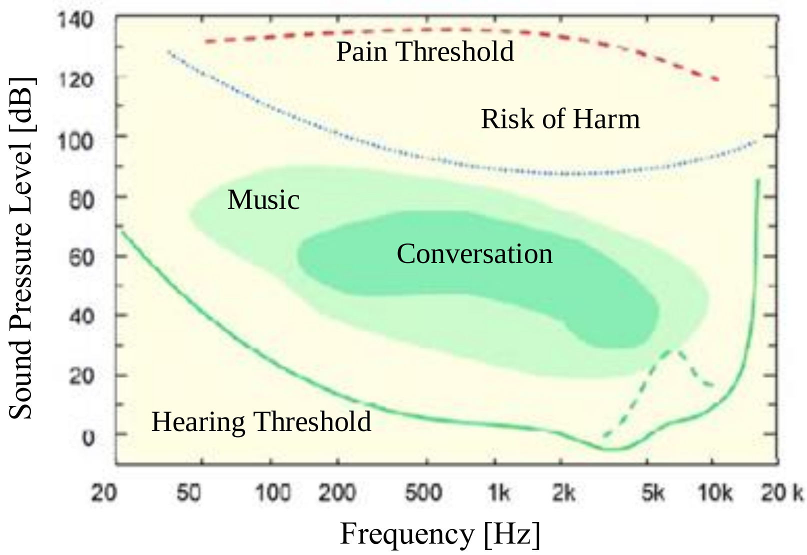


Figure 2.11. Hearing limits (Brüel & Kjær, 1998)

The above figure 2.11 shows the limits of the sound a person can hear.

The lower limit indicated by the straight line corresponds to the lowest level at which the bee sound starts to be heard. The dashed lines above indicate the pain threshold. Permanent hearing loss may occur if there is a certain period of time over the line of risk of harm. These losses occur especially in the high frequency region and cause the hearing threshold to increase at these frequencies, such as the dashed lines shown at the lower right. The limits for normal speech and music are also indicated.

2.1.1.5. Frequency Weighting

The human ear cannot perceive various sound frequencies equally. In order to evaluate thoroughly the noise exposure of people during the measurements this sensitivity difference must be considered. To achieve this, frequency weighting networks (or filters) have been created.

These networks take different frequencies and weight them to the overall sound pressure level. Therefore, before being combined to give a general sound level of that measurement level, sound levels are given specific to the frequencies existed in the sound.

There are two standard weighting networks commonly used and they are A weighting and C weighting. These weighting networks developed in regards to the frequency detection of an average person's ear for various sound pressure levels.

- **A-Weighting**

The human ears sensitivity to sound depends on the frequency of the sound. Some people perceive different frequencies better than others. If someone perceives two different sounds in different frequencies but in the same sound pressure level, one of the them might seem louder than the other. The reason for this is that the human ear is more sensitive to high-frequency sounds.

The noise measurements can be done regarding this human hearing features stated above. An A-weighted filter placed inside the sound level meter holds down low frequencies. The values measured using a sound level meter equipped with this filter is called dB (A). Considering all these, legislation on workplace noise uses dB (A) for exposure limits. In table 2.4. typical noise levels presented in dB (A).

Table 2.4. Typical Noise Levels [URL1]

Noise Source	dB (A)
pneumatic chipper at 1 meter	115
hand-held circular saw at 1 meter	115
textile loom	103
newspaper press	95
power lawn mower at 1 meter	92
diesel truck 50 km per hour at 20 meters	85
passenger car 60 km per hour at 20 meters	65
conversation at 1 meter	55
quiet room	40

There are two important aspects of A-weighting:

-It counts sound levels of all frequencies resulting in a single noise level.

-It presents a range of noise level as it is perceived by the human ear.

- **C-weighting**

The other weighting is called C-weighting (dB(C)), which is usually used for specifying peak noise levels, like gunfire.

2.1.1.6. Noise Indicators

- **Equivalent noise level L_{eq}**

L_{eq} is one of the most important parameters used to identify variable noise.

(2.10)

$$L_{eq} = 10 \log_{10} \frac{1}{T} \int_{U}^{T} \left(\frac{p(t)}{p_0}\right)^2 dt$$

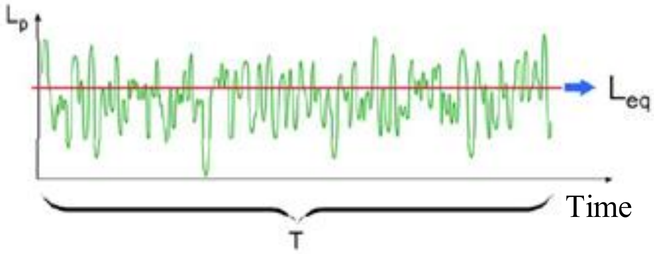


Figure 2.12. Demonstration of Equivalent Sound Level L_{eq} (Brüel & Kjær, 1998)

Equivalent continuous sound level is the electronically calculated average Root Mean Square (RMS) level obtained by dividing the total acoustic energy contained in the instantaneous sound pressure values measured in a given time interval T by the measurement time (Figure 2.12.).

The formula used for mathematical calculation of equivalent continuous sound level is given above where:

T: total measurement time
p (t): instantaneous sound pressure
p0: is the reference sound pressure (20 μPa).

Generally, the magnitude of the L_{eq} value is expressed in dB (A) because the instantaneous sound pressure is passed through the A-weighted frequency filter.

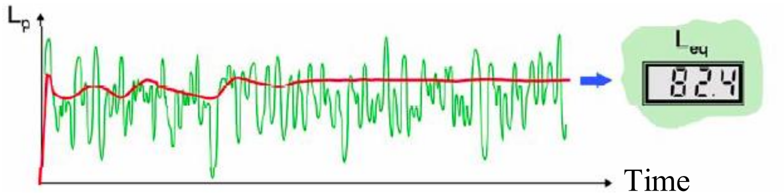


Figure 2.13. Measurement of Equivalent Sound Level L_{eq} (Brüel & Kjær, 1998)

At the start of the measurement, the L_{eq} value is zero and starts to follow the actual signal by rising rapidly. Because it calculates the average over the entire measurement period, it is less and less variable.

As seen in the figure 2.13., the initial fluctuations in L_{eq} value are gradually decreasing over time. A L_{eq} value that is very close to a constant state is an indication of the adequacy of the measurement. There is no need to continue the measurement after this point.

- **Statistical Indicators L_{10}, L_{90}, etc.**

Statistical parameters are other parameters that help to identify varying noise, such as traffic noise. The noise dose describes the noise impact that an employee is exposed to during his / her daily work.

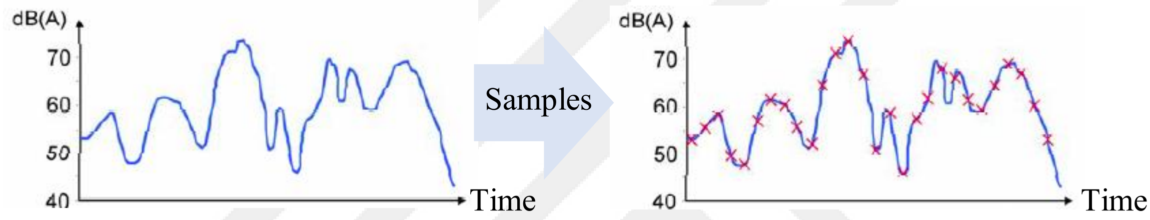


Figure 2.14. SLM's Signal Sampling (Brüel & Kjær, 1998)

Modern digital sound meters operate by sampling the actual noise signal at a specified frequency (e.g. 100 samples per second) as shown in Figure 2.14. These sound level values taken by sampling can also be used to calculate the statistical data.

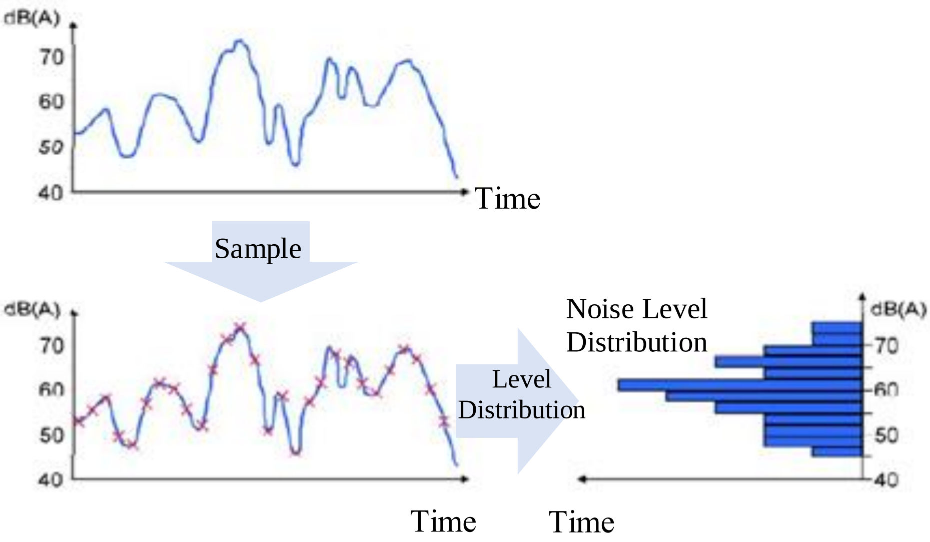


Figure 2.15. Noise Level Distribution (Brüel & Kjær, 1998)

After performing the sampling process, we can divide our dynamic measurement range into smaller ranges that we can characterize as class. If each new sample is taken by the sound meter, we determine which class belongs to this sample, and if we increase the counter for that class, then we divide the number of samples belonging to that class by the total number of samples and we obtain the level distribution in% of the noise.

When we look at the Noise Level Distribution graph in the figure 2.15., we can observe that the dynamic measurement range (40 - 75dB) is divided into 2.5dB classes and most of the samples taken are between 60 - 62.5dB. In addition, there are no measurement records below 45dB and above 75dB.

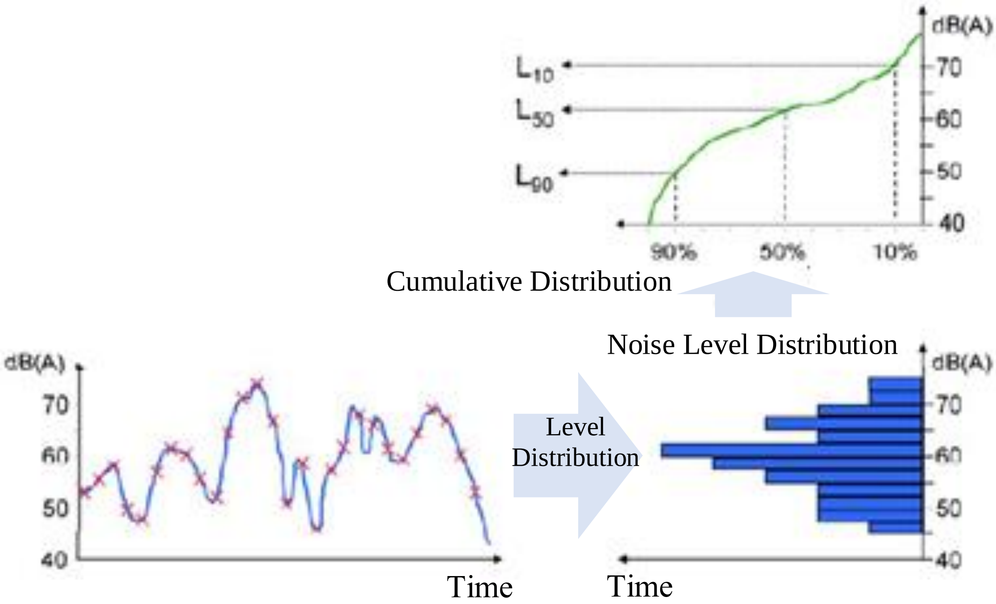


Figure 2.16. Cumulative Distribution (Brüel & Kjær, 1998)

The information obtained from the distribution of the level (in%) is collected from the high noise level and the new graphical cumulative distribution is obtained as seen in figure 2.16.

It is possible to read the L_N parameters that we can define as percentage values on the new graph that we have created. This parameter specifies the noise level exceeded in the % N section (N, 0 to 100) of the measurement time.

In the figure 2.16., the time during which the noise is 70dB and above is 10% of the total measurement time. In the same graph we can see that 50% of the measurement time is over 60dB and over 90% is over 50dB.

As a final example, we can say that the L0 value is the highest measured value and the L_{100} value will show the lowest sound pressure level value. Because L_0 is defined as the definition of sound pressure level which exceeds 0% of the measurement time, which is not exceeded, this is the highest level, in the same way the L_{100} is the level exceeded in 100% or all of the measurement time, which has to be the lowest measured sound level.

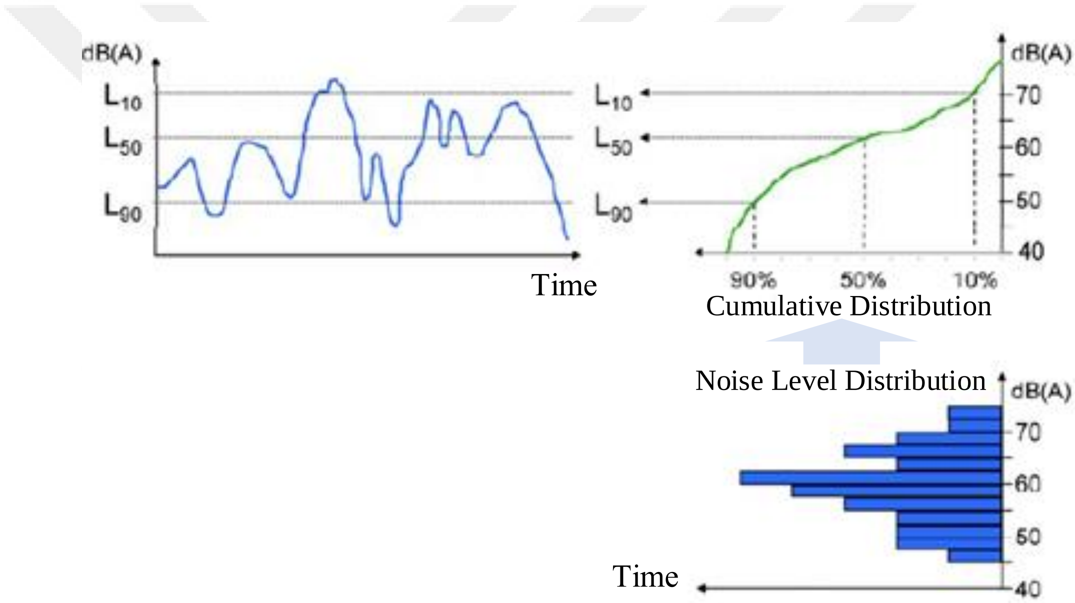


Figure 2.17. Percentage Values (Brüel & Kjær, 1998)

The percentage values are a parameter that describes how the noise level changes over the measurement period (Figure 2.17.). This parameter is taken into account in various applications such as traffic or stretch noise. The most commonly used are L_{10}, L_{90} and L_{95} (Figure 2.18.).

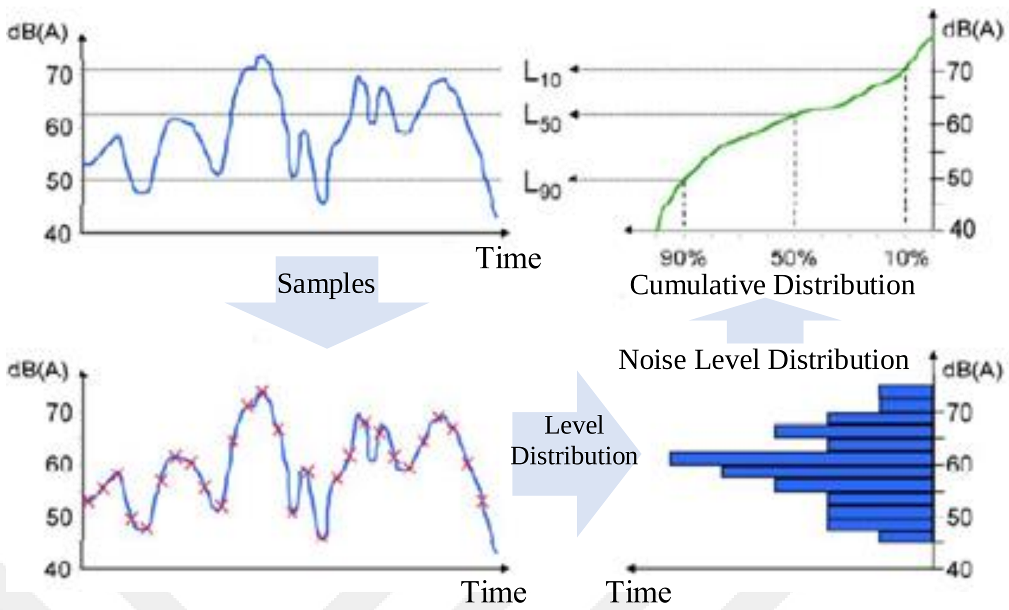


Figure 2.18. Statistical Analysis of Noise Levels (Brüel & Kjær, 1998)

- **EU Noise Indicators L_{den} and L_{night}**

There are two noise indicators that can be used while a strategic noise map is generated. These are developed by the EU Directive 2002/49/EC and they are L_{den} and L_{night}. These two developed indicators are derived from the L_{eq} indicator. L_{den} is composed of the day, evening and night noise indicators and is calculated as follows:

(2.11)

$$L_{den}=10 \log_{10}(1/24)\ (12.10^{L_{day}/10}+4.10^{(L_{evening}+5)/10}+8.10^{(L_{night}+10)/10})\ [dB(A)]$$

- L_{day} : Average of noise levels measured between 07:00 and 19:00 throughout a year.
- $L_{evening}$: Average of noise levels measured between 19:00 and 23:00 throughout a year.
- L_{night} : Average of noise levels measured between 23:00 and 07:00 throughout a year.

L_{den} is a value used to detect general discomfort, while L_{night} is used for the detection of sleep disturbance. So, L_{den} and L_{nigh}t are quite beneficial indicators in terms of using for planning purposes.

- **Maximum and Minimum levels L_{max} and L_{min}**

The indicators L_{max} and L_{min} are very simple. They are basically the highest (maximum) and the lowest (minimum) values that are recorded by a sound level meter during the measurement period of time.

2.1.1.7. How to Add Noise Levels

The sound pressure levels in decibels (dB) are calculated with a logarithmic scale so, it means that these values cannot be directly added or subtracted. When a sound level meter measures 75 dB and a second SLM is placed next to it, the combined level will not be 150 dB, it will be 78 dB. Below, in Table 2.5, a basic way for adding noise levels is demonstrated.

Table 2.5. Addition of Decibels [URL1]

Numerical difference between two noise levels [dB(A)]	Amount to be added to the higher of the two noise levels [dB or dB(A)]
0	3.0
0.1 - 0.9	2.5
1.0 - 2.4	2.0
2.4 - 4.0	1.5
4.1 - 6.0	1.0
6.1 - 10	0.5
10	0.0

The case of two sound level meters both measuring 90 dB is explained step by step below in order to understand the usage of the above table.

Step 1: The difference between two measurement is 0 dB so, the first row of the table will be used.

Step 2: After selecting the row that will be used, to see the amount to be added from the right-hand column which in this case the value to be added is 3.

Step 3: The value that is found from the table will be added to the highest level. In this case 3 will be added to 90 dB. Therefore, the noise in an environment that has two 90 dB noise source will be 93 dB.

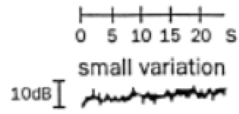
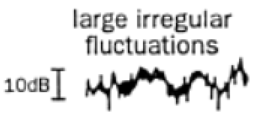
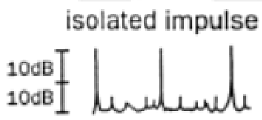
If there are two noise sources which the difference between is 10 dB(A) or more, the value to be added is 0 according to the table. Because, in such a case, the adjustment factor is not necessary, since the addition of a sound source at a lower level than the total noise level does not make a difference in human hearing or measurement. For example, if the noise level in one area is 95 dB (A) and an 80 dB (A) noise source is added, the noise level in this zone will still be 95dB (A).

2.1.2. Different Types of Noise

According to the changes in sound pressure level, noise can be divided into five categories: Steady, fluctuating, tonal, intermittent and impulsive.

The various types of noise are illustrated in the following Table 2.6.

Table 2.6. Noise types and their measurement (Hansen, 2001)

<table>
<tr><th></th><th>Characteristics</th><th>Type of Source</th></tr>
<tr><td></td><td>Constant continuous sound</td><td>Pumps, electric motors, gearboxes, conveyers</td></tr>
<tr><td></td><td>Constant but intermittent sound</td><td>Air compressor, automatic machinery during a work cycle</td></tr>
<tr><td></td><td>Periodically fluctuating sound</td><td>Mass production, surface grinding</td></tr>
<tr><td></td><td>Fluctuating non-periodic sound</td><td>Manual work, grinding, welding, component assembly</td></tr>
<tr><td></td><td>Repeated impulses</td><td>Automatic press, pneumatic drill, riveting</td></tr>
<tr><td></td><td>Single impulse</td><td>Hammer blow, material handling, punch press, gunshot, artillery fire</td></tr>
</table>

Steady noise is identified as noise with negligible changes of sound pressure level in a period of time. If sound pressure levels change considerably in a period of time, the noise becomes non-steady. Non-steady noise can be separated as intermittent and fluctuating.

Fluctuating noise is identified as noise with continuous, considerable changes in sound pressure level in a period of time.

Tonal noise is identified by one or two single frequencies and can be either steady or fluctuating. This type of noise is more irritating than broadband noise which has the same sound pressure level because broadband noise is present over a wide range of frequencies unlike tonal noise.

Characteristics of noise are identified depending on the way they change in time. When a noise remains within the range of 5dB for a long period of time, it is called constant noise. Intermittent noise is a constant noise that starts and stops. Fluctuating noise has a steady long-term average but has notable variances. A noise that lasts less than a second is called impulsive noise.

Intermittent noise is identified as a noise which the level drops several times to the ambient noise level during the observation period. The time at which the level remains at a constant value other than the background noise should be equal or more than one second.

Its characteristics are determined by;

- Level of background noise
- Level of intermittent noise
- Average time of the on and off period

Mostly, both sound pressure levels of intermittent and fluctuating noise vary with time and their intermittence rate is dynamic. Because of this, it can generally be similar to fluctuating noise.

Impulsive noise involves several bursts of sound energy which lasts less than a second. These are generally identified as type A or type B. Type A is described as gunshot type of impulses, whereas Type B is usually found in industry. Attributes of these impulses are the peak pressure value, the duration of the peak and the rise time. These different types of noises are measured with different instruments as seen in Table 2.7.

Table 2.7. Instrument Types for Different Types of Measurements (Hansen, 2001)

Type of measurement	Type of Instrument	Remarks
Direct reading of A-weighted value	Sound level meter	Octave or 1/3 octave analysis if noise is excessive
dB value exposure time or L_{Aeq}	Sound level meter, Integrating sound level meter	Octave or 1/3 octave analysis if noise is excessive
dB value, L_{Aeq} or noise exposure	Sound level meter, Integrating sound level meter	Octave or 1/3 octave analysis if noise is excessive
L_{Aeq} or noise exposure Statistical analysis	Noise exposure meter, Integrating sound level meter	Long term measurement usually required
L_{Aeq} or noise exposure & Check "Peak" value	Integrating sound level meter with "Peak" hold and "C-weighting"	Difficult to assess. More harmful to hearing than it sounds
L_{Aeq} and "Peak" value	Integrating sound level meter with "Peak" hold and "C-weighting"	Difficult to assess. Very harmful to hearing

2.1.3. Noise Measurements

This part of the study will introduce the practices behind environmental noise measurements. Depending on the purpose, the methods used may change. Whichever method is used, it is subject to follow a national or international standard. Moreover, most national agencies have their own directives that have to be followed.

The methodology used for the measurement always depends on the purpose of the noise measurement. The intention of the measurement has to be clear beforehand in order to determine measurement method. It is important to choose what method will be used because some parameters differ method to method such as the time when it will take place and the duration of the measurement(s), position, height, and equipment type, etc.

The instrument that is used for recording the sound level and for analyses on sound to transform the data to usable information is called Sound Level Meter (SLM).

It is important to calibrate the sound meter before starting the measurements. This process is not only a control of the operation of the device, it also ensures the correct results with high precision and the compatibility with previous measurements. Therefore, calibration should be done before and after the measurements.

The ISO 1996 international standard contains guidance on the location of the microphone during sound measurements made indoors and outdoors. Although the position of the microphone may vary depending on the purpose of the measurement, as a general rule, both the indoor and outdoor measurements should be 1.2 to 1.5 meters above the ground.

For the measurements to be made in the interior, it is recommended to keep the microphone at a distance of 1 meter from the reflective surfaces such as walls or furniture and 1.5 meters from the windows. For measurements to be made outdoors on the other hand, it is recommended that the microphone should be 3.5 meters away from the nearest reflective surface in order to minimize the effect of possible reflections.

During the measurements the sound level meter should be held by hand or placed on the tripod should be placed. The ISO 1996 standard contains information on how to minimize the impact of reflections from the user.

If you are holding the device in your hand, try to keep your arm as wide as possible (about 1 meter) away from you and try to minimize the reflections that may arise from you. In cases where the device is placed on a tripod, it is recommended that the user be at least 0.5 meters behind the microphone (Figure 2.19.).

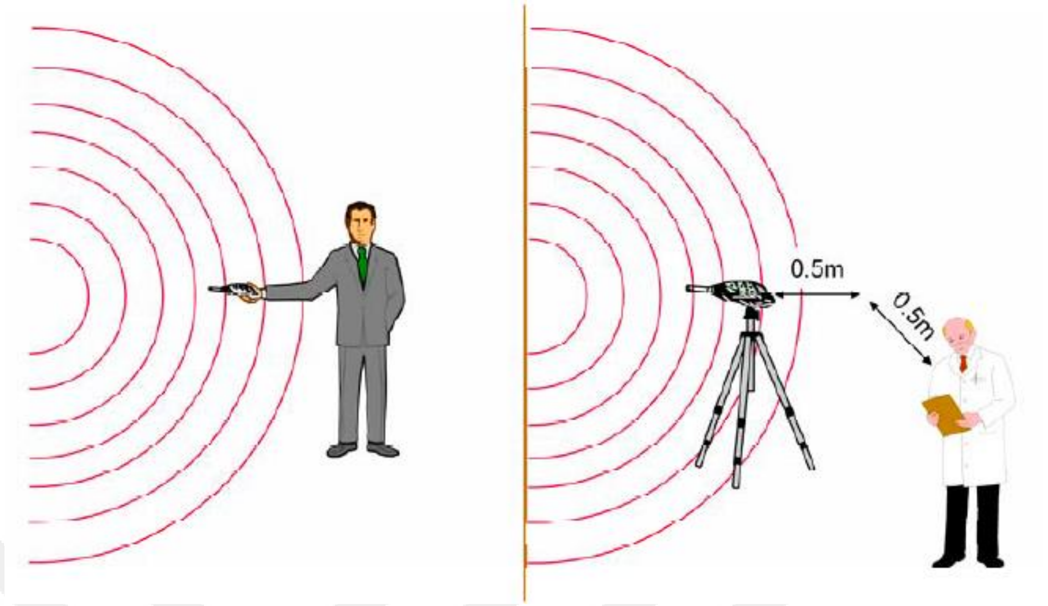


Figure 2.19. Users Positioning When Using SLM (Brüel & Kjær, 1998)

Since the sound meter itself also disrupts the actual sound field, it affects the measurement in some way. As this effect is less than 1dB, the Type 1 sound metering device is within tolerances (according to IEC 651 and IEC 804).

The four sensitivity levels are separated from each other due to differences in tolerances. The tolerance range increases as the type number increases. Different sensitivity levels target different measurements:

- Type 0: Laboratory standard and has the narrowest tolerance ranges.
- Type 1: It is intended for both laboratory and field measurements with great accuracy and accuracy. In many countries' standards or regulations, it is stated that the device must meet at least Type 1 requirements in order for the measurement to be official.
- Type 2: For general purpose use. It is intended for use in the field. It is preferable for any measurements that do not require any reporting.
- Type 3: Although it is designed for control measurements, this type of devices is no longer available in the market because of the wide progress and tolerance limits in the electronics sector.

2.1.4. Noise Mapping

Noise mapping is a technic to represent graphically the noise levels of a designated area for a reference time interval. The evaluation of sound levels in the long or short term can be done through noise maps. Preliminary action plans can be deduced from a noise map and by estimating people's exposure to noise control measures can be appointed (Asensio, Recuero and Ruiz, 2011). Therefore, for environmental noise research, mapping is an extremely important part of the process of quantifying and visualizing noise pollution levels (de Klujiver and Stoter, 2003).

Even though there were some efforts to generate noise maps in the mid-1990s (de Vos and Licitra, 2013), the introduction of the *strategic noise mapping* application came up with the European Noise Directive (END) came into force by the EU. Basically, noise mapping is a simple way to present the measured noise levels on a specific geographic area in a representative manner (Murphy and King, 2010). The noise mapping in the END is defined as noise data indicating any exceeding exposure value, the number of housing and/or people affected from it and data presentation of the current or predicted noise situation. Thus, within the scope of END, noise maps are considered to be multidimensional, because they contain not only the measured noise levels for a designated area, but also information about the potential violations of determined limit values as well as the number people and/or housings exposed to the environmental noise.

Within the scope of END, "strategic noise mapping" is defined differently from "noise mapping". A strategic noise map is defined as a map of a designed area generated for the assessment of the exposure to noise due to different noise sources, or for making broader estimations for that area. That is to say, noise mapping primarily concentrates on the demonstration of noise data, while strategic noise mapping primarily focuses on the evaluation of noise and exposure to it.

2.2. Noise and Human Health

One of the most common occupational hazards in the world is definitely exposure to excessive noise (Kurt, McKenna, Gunbeyaz &Turan, 2017). Adverse effects of noise on human health is the most fundamental reason why environmental noise is considered a pollutant that needs to be avoided and controlled. Therefore, noise management is a factor that directly affects the quality of life, as noise has a long-term impact on health. Due to its effects on human health, standards have been set for ameliorating environmental noise pollution and/or reducing environmental noise impacts on human health. These adverse effects of noise and standards on the subject will be presented in the following part of this study.

2.2.1. Effects of Environmental Noise on Human Health

Hearing deterioration caused by noise is directly related to over amplitude of sound received by the inner ear section. However, apart from industrial noise, different levels of environmental noise usually have lower amplitudes and have effect mostly on the health outside the audible range. This is why adverse effects cannot directly be explained as outcome of sound energy as a whole. Hence, consequences of noise on human health are explained taking characteristics of sound into account. From this perspective, complexity, duration, frequency as well as intensity of noise should are the basic parameters used for determining the consequences of exposure.

There is a large amount of scientific literature evaluating the effects of environmental noise on human health. In sum, the health effects caused by environmental noise pollution are as follows: loss of hearing, nervous breakdown, mental disorder, heart troubles, high blood pressure, dizziness, insomnia and a general reduction in the quality of life (Stansfeld & Mathesob, 2003; Nassiri et.al., 2014; Geravandi et.al., 2015; Nelson, Nelson, Concha-Barrientos & Fingerhut, 2005).

OSHA (Occupational Safety and Health Administration) (OSHA, 2019) states that impacts of loud noise may vary across a wide range of effects which include, negative effects on communication and concentration, reduce performance and productivity, create disturbance and stress hence, can cause workplace injuries as well as accidents. (OSHA, 2019) also underlines that "*the effects of noise induced hearing loss can limit your ability to hear high frequency sounds, understand speech, and seriously damage your ability to communicate*".

When exposed to loud noise for a short period of time, symptoms like tinnitus which actually means a ringing in the ears may linger for a period of time varying from few minutes to few hours. On the other hand, if the exposure to loud noise is continuously repeated over a period of time, the loud noise may cause permanent hearing loss or ringing in the ear. The worst result of exposure to high levels of noise is permanent hearing loss and most of the time it cannot be corrected. For example, exposure to noise pollution exceeding 85 decibels for more than eight hours daily for a long period of time can cause loss of hearing (Concha-Barrientos, Campbell-Lendrum & Steenland, 2004). Hence, when the amplitude of the noise and the time frame of exposure are increased in a proportional manner the threat posed by noise to human beings also increases.

In figure 2.20., sound pressure levels of common environmental sounds are shown in dBA. As for in figure 2.21., health effects of noise can be seen regarding the number of people effected in general.

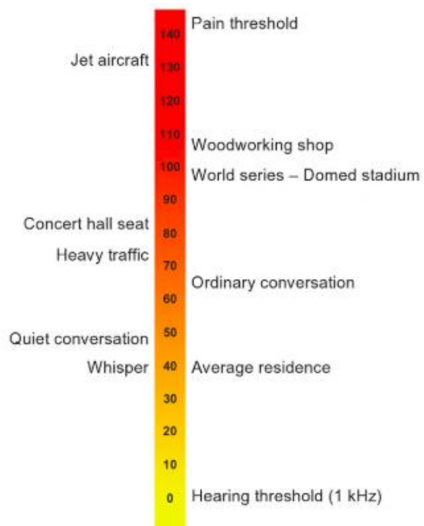


Figure 2.20. Typical sound pressure levels of noise sources (Murphy &King, 2014).

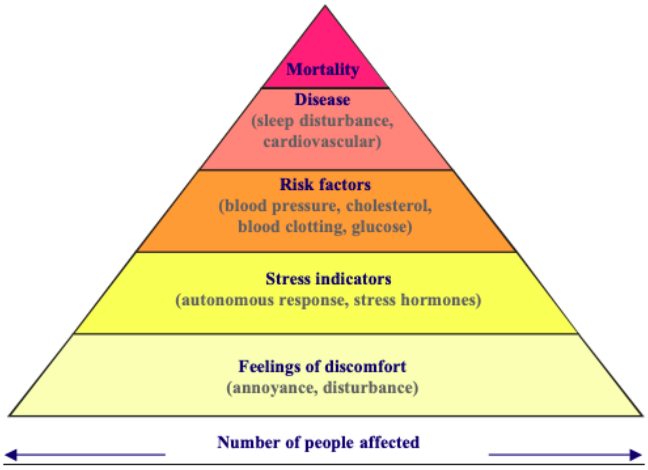


Figure 2.21. Severity of health effects of noise and number of people affected (WHO, 2011).

Then again, in figure 2.22. exposure to noise pollution effects can be seen with the division of auditory and non-auditory noise effect reactions.

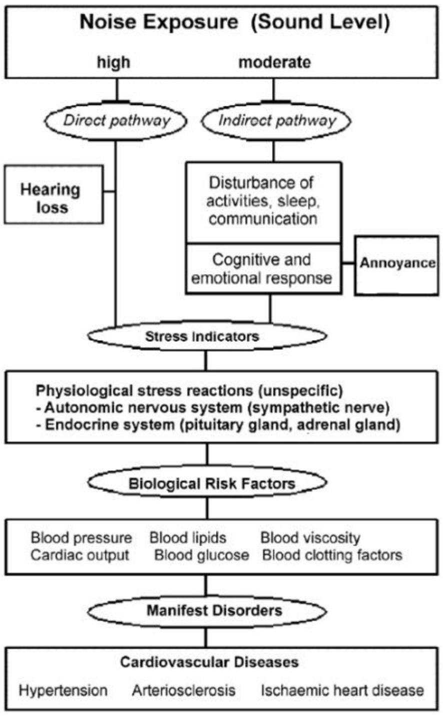


Figure 2.22. Noise effects reaction schema (Babisch, 2002).

Excessive noise is an occupational health hazard with significant impacts as well as noise-induced hearing loss (NIHL) (Nelson, Nelson, Concha-Barrientos & Fingerhut, 2005). Occupations in manufacturing, construction and maritime sectors such as ports, shipyards and ship recycling yards are at highest risk for NIHL. The workers in these sectors exposed to continuous noise of 85–90 dBA and some equipment even exceeds 90-95dBA. In this regard, environmental noise sources that port workers (stevedores) exposed to are ships, trucks, cranes and forklifts. Especially in container terminals these sources cause even more pollution during loading/discharging operations. The consequences of environmental noise pollution that stevedores are in danger of include communication interruption with coworkers and decreased ability to monitor the work environment such as warning signals which increases the injury risk.

2.2.2. International Standards on Noise

In addition to above, whether national and international regulations on noise pollution are available and which ones of them is covering ports is going to be examined. It is also going to be investigated that if Turkey is a signatory country to the existing international regulation(s) or not. At the same time, it going to be looked up on what extent the selected port takes precautions.

In order to ameliorate environmental noise pollution, standards have been set as in noise limits, measurement and assessment methods. The emphasis in this part of the study is on international standards related to the environmental noise management. These standards set limits, specify measurement and assessment methods and define strategic actions to take. Apart from international standards on the matter there are also many country-specific and numerous European norms too.

Guidance for protection of human health from harmful exposure to environmental noise are set by the WHO. The organization gives a brief summary of recent developments and changes concerning the effects of noise on health, and establishes primary recommendations for handling environmental noise. From this perspective, noise matters started to be included in assessment of environmental effects both in transport infrastructures and in industry. Noise regulations are being created and continuously updated and the noise mapping is being considered as a useful tool to manage this problem in many cities.

EU (European Union) on the other hand, took the subject in the year 2002 by producing the European Environmental Noise Directive (Directive 2002/49/EC, also known as END). This document establishes the basis for noise management in the Member States. It also sets the basis for the how to create of Strategic Noise Maps which actually can be used as the main tool to fight against environmental noise. The END by setting concrete criteria, makes the guidelines for the production of noise maps uniform as well as presenting a list for noise maps to be produced across the union (END, 2002; Asensio, C., Recuero, M., & Ruiz, M., 2011).

To begin with, ISO 9612:2009 Acoustics — Determination of occupational noise exposure — Engineering method specifies “an engineering method for measuring workers’ exposure to noise in a working environment and calculating the noise exposure level” (ISO, 2009). It is useful when determining the occupational noise exposure via noise level measurements. It provides three different strategies for measurements which are task-based measurement, job-based measurement and full-day measurement. These strategies lead for choosing an appropriate measurement strategy for the purpose of the research.

In the United States, NIOSH (The National Institute for Occupational Safety and Health) and OSHA set occupational regulations and standards to protect workers from the environmental noise exposure consequences. NIOSH establishes REL (Recommended Exposure Limits) for noise at 85 decibels, using the A-weighting frequency over an 8-hour average. It is considered as hazardous to expose at or above this level. OSHA, on the other hand, sets PEL (Permissible Exposure Limit) to 90 dBA for all workers for an 8-hour day. In table 2.8. it can be seen the decibel levels which a person can safely be exposed for its corresponding time without risk of NIHL according to NIOSH and OSHA (NIOSH,2019; OSHA 2019).

Table 2.8. Permissible noise exposures (NIOSH,2019; OSHA 2019)

Time to reach 100% noise dose	Exposure level per NIOSH REL	Exposure level per OSHA PEL
8 hours	85 dBA	90 dBA
4 hours	88 dBA	95 dBA
2 hours	91 dBA	100 dBA
1 hour	94 dBA	105 dBA
30 minutes	97 dBA	110 dBA
15 minutes	100 dBA	115 dBA

These standards have been extremely efficient in the protection of the environment and people. In the long term, it was aimed to create a tendency for continuous and gradual reduction of environmental noise levels. In this process, noise mapping is playing an important role in informing the policy maker, the public and stakeholders about noise issues.

The recommendation of END is to create noise maps which are graphical representations of the sound levels for assessing and evaluating noise. They can be used to assess sound levels in the long or short term. When determining action plans, noise control measures, noise maps are useful in the preliminary assessment. They can also be a beneficial tool when predicting people's noise exposure (END, 2002).

According to WHO, the most accurate assessments of noise impacts on human health are received through local exposure data, since population exposure distributions can vary country to country. The most common method to assess health impacts are area surveys, dosimetry and engineering surveys. In area surveys noise levels are measured in different parts of that area. With dosimetry, cumulative exposure to noise of a person can be measured over a period of time. And in engineering surveys, noise is measured using a range of instruments (WHO, 2004).

ISO 9612-2009 provides measurement strategies for the assessment of occupational exposure to noise. These measurements strategies are recommended as task-based, job-based and full-day (ISO, 2009). The task-based measurement strategy recommends performing noise measurements for tasks that causes a worker to expose to noise. This type of measurement is convenient when the task and noise source are well-defined. The job-based measurement is logical when tasks are not well defined or when it is impractical to realize a detailed work analysis. The full-day measurement strategy on the other hand, is advised when there is not a specified work pattern so that the exposed noise levels are varying (Kurt, McKenna, Gunbeyaz, & Turan, 2017).

ISO 1999:2013, on the other hand, provides "the basis for calculating hearing disability according to various formulae when the hearing threshold levels at commonly measured audiometric frequencies, or combinations of such frequencies, exceed a certain value". Also, it specifies various dangerous noise levels with durations when exposed. According to this standard, exposure to noise is measured with the noise exposure level normalized to a nominal 8 h working day ($L_{EX,8h}$) for a period of time. It is for a variety of noise sources such as steady, intermittent, fluctuating and irregular and applied for frequencies less than approximately 10 kHz (ISO, 2013).

2.3. Study Specific Container Terminal Terminology

As this study is investigating the environmental noise pollution at a container terminal and its adverse effects on port workers (stevedores), it is necessary to have an overview of container terminals' setup and workers' team organization as well as yard equipment used. Before analyzing the noise levels of the terminal, the noise sources should be determined. Therefore, yard equipment and their functions will be explained in this section. Also, crew organization will be explained in order to understand in which level they are exposed to the existing noise.

2.3.1. General Description of Container Terminal Setup

A container is an article of transport equipment which is;

- designed for repeated use;
- suitable for multiple transportation methods such as truck, rail, or ship;
- equipped with tools enabling its direct transfer from one mode of transport to another;

easy to load and discharge; (ISO, 1999)

Containers can be classified according to their size and the type of cargo they carry. According to their size, containers can be classified into two groups as 20’ and 40’. (ISO, 1999)

- The 20’ container is 20 feet (6,096 meters) long, 8 feet (2,438 meters) wide and 8 feet 6 inches (2,591 meters) height. This type of container is generally loaded between 15 tons and 20 tons and is called TEU (twenty equivalent unit) in general use.
- Another dimensioning is 40-feet containers which can be loaded up to 30 tons and they are called FEU (forty equivalent unit).
- There are several other types of containers out of the standards which are oversize, high cube, and over width containers.

According to the type of cargo they carry, there are basically flat racks, open-top, dry freight, reefer, and tank containers. (ISO, 1999)

- Flat racks are containers which do not have side walls and used to transport heavy machinery.
- Open-tops are containers that have no solid cover on top which enables them to be loaded from the top. They are for carrying heavy and/or tall materials.
- Dry freight containers are suitable for general-purpose transportation and they are completely enclosed.
- Reefer containers have an integral refrigeration unit in order to control temperature of the cargoes loaded.
- Tank containers are actually cylindrical shaped but according to ISO standards they have a rectangular framework that is in the same dimensions with other type of containers. These containers are used for the transportation of liquid cargoes.

The container terminal is where containers are transferred from the ships and transferred to land vehicles (trucks, trains). Therefore, it is the main node in the intermodal transport network.

Container terminals must have some structures, as is the case with all other terminals. Structures in typical container terminals; berths, aprons, storage areas, container freight station (CFS), waiting areas, inland port traffic lines, port management buildings and gate.

The berths are the structures that provide the connection between the land and sea vehicles which can be safely unloaded with the help of cargo handling systems at the port.

Apron is the area between the dock and the warehouse or the open storage areas to ensure safe and proper traffic of the cargo handling vehicles, load entry and exit, and cargo handling vehicles, with the temporary stacking of loading / unloading cargoes.

Storage Areas are areas where containers are safely stored for the next process.

Waiting Areas are the areas where road and rail vehicles wait in regular rows without entering the loading and unloading areas. These areas are important in terms of ensuring regular traffic flow and increasing port efficiency.

Inland Port Traffic Lines are roads that provide transportation between fields and docks or between other ports of the port. In order to ensure the regular and safe traffic flow within the port, it is necessary to plan the arrival of these roads in a good way.

The Container Freight Station (CFS) is where the container and container are handled when needed. It does not have to be in a container terminal.

The gate is the terminal structures where the entrance and exit of the incoming and outgoing containers are made.

The container terminal system can be defined as a dynamic integrity where the container flow is carried out by the human, field, handling vehicles, operation and management organization. Many interconnected operations are carried out at the container terminals. These operations vary according to the characteristics of the container terminal and the handling system used. So, container terminal system consists of two sub-systems as berth side and land side.

The berth side is the port area where loading / unloading services are provided to the ships. There are cranes for handling containers at the berth. Containers handled with these cranes from ships are transported to the storage area via port transport vehicles or vice versa. According to the characteristics of the container terminal, containers are sometimes stacked in the apron area behind the berth zone and then sent to the storage area.

Container site design may vary depending on the structure of the stacking device and the means of transport used in the terminal. However, there are some common features for all systems. Containers are stacked in groups in rectangular form but not in an irregular manner. In addition, there are narrow roads in the field terminal that provide access between the blocks that regulate traffic. These roads are designed so that the vehicles that will stack can be operated and maneuvered easily and the necessary gaps are formed accordingly.

2.3.2. Container Terminal Ground Equipment

Various handling tools are used in container terminals. These vehicles generally have stacking and / or transporting features. Most of them are equipped with a spreader and twist lock that locks in the corners of the container (lock slots). This equipment can be divided into three basic groups according to their location in container terminals. These can be classified as cranes used in the berths (ship side), in the storage areas and in port transportation vehicles.

The cranes used in the berths are used for unloading and loading the container. These cranes are divided in to two types as Mobile Harbor Crane (Mobile Harbor Crane-MHC) and Gantry Crane (Ship to Shore Gantry-SSG).

- Mobile Harbor Crane (MHC): The Mobile Harbor Crane is a movable harbor crane that is used for the loading and discharging of containers and general cargo types. They are rubber wheeled diesel vehicles. They have three-dimensional motion capability. Therefore, due to the fact that the load center of gravity is constantly changing and the loads are not standardized, the crane operator and the stevedore gang member who assist the operator must have a complete knowledge and adequate practice on the subjects. Otherwise, the operations are slowed down and the risk of accidents increases due to the operators and/or stevedores who do not have the qualifications required by the job. As an advantage of mobile harbor cranes, they can be used in loading and discharging of all kinds of heavy loads with a change of spreader in a port.

- Ship to Shore Gantry (SSG): SSGs are fixed berth cranes that works with electricity. These cranes are designed to move parallel to the pier on the rails laid along the quay (Figure 2.23.). Unlike mobile cranes, these cranes are designed to handle only containers which in return simplifies the handling process. Hence, they can load and discharge 30 containers per hour (30 vertical movements per hour).

Figure 2.23. Ship to Shore Gantry Crane (SSG) of Marport [URL3]

The cranes used in the storage areas are used to stack containers in the field. Some of this equipment is only for stacking purposes, while some of them are used for stacking and transporting containers in the field. The most widely used cranes in the container field; Ruber Tyred Gantry (RTG), Full Container Stacker, Empty Container Stacker and Forklift and Straddle Carrier.

- Rubber Tyred Gantry (RTG): RTGs are used for stacking of containers, handling containers from stacking areas to inland transportation vehicles (YTTs) or vice versa and/or used for displacement between storage areas (Figure 2.24.). With its ability to move on rubber tires, Rubber Tyred Gantry (RTG) is a crane with flexibility in its movements in a stacking area. RTGs are mainly used for vertical positioning of containers. For the horizontal transport of containers, a fleet of trucks is needed in the area. With RTG cranes, the container block can be stacked between 5 and 8 in width and 4 to 8 in height. The distance between the RTG blocks is approximately 300-400 mm. The stacking area layout of containers is arranged as in an average 500 TEU block per one RTG crane.

Figure 2.24. Rubber Tyred Gantry (RTG) Crane of Marport [URL3]

- Full Container Stacker (FCS) (or Container Reach Stacker (CRS)): Full Container Stacker is a versatile stacker used for picking up containers from rearward rows and for the transportation of full containers from one point to another within the field. It is generally used for displacement between storage areas of containers. They are powerful vehicles that can safely lift up to 45 tonnes of cargo.

- Empty Reach Stacker (ECS): Empty Container Stacker has similar properties to Full Container Stacker. They are used for empty containers transport. Lifting power is less than FCS. It is sufficient for ECS to hold container from two points for transport. It can only safely lift up to 4 tons.

- Forklift (FLT): Forklift is a kind of vehicle that is used to lift heavy loads up to 90 tons through its forks and in particular to load them in a vehicle. It is used for transportation of containers between storage areas at container terminals. The largest forklift available today can handle a 20 feet container with a certain load. 20 ft. containers have two rows of rectangular channels on its basis where the forks of the forklifts enter to lift them up. However, the 40-ft containers do not have these channels.

- Straddle Carrier (SC): The Straddle Carrier can be used for storing the container in the storage area or for transporting containers from the ship side to the storage area. Depending on the SC storage height, 2 or 3 rows of stacks can be stored. Because of its space efficiency and flexibility, it is popular among the terminal operation methods. SC is a machine that allows both horizontal transport and vertical bursting of containers. One of the advantages is the possibility to take containers from the heap and put them under the crane without having to wait for the movement of the crane.

Port transfer vehicles are used for container transfer between berths and storage areas and other points. The most widely used transport vehicles are Chassis, MTS, AGV and YTT.

- Chassis: A frame with wheels that is equipped with locking devices to ensure the container can be secured for road haulage. Chassis pulled by a tractor unit and enable containers to be moved.

- Multi Trailer System (MTS): In MTS, the trailers are tied together and pulled only by a tow truck, thus reducing the driver's need.

- Automated Guided Vehicle (AGV): Unmanned chassis running between the docks and storage area. It is remotely controlled from a central station and therefore has caused a lot of savings from manpower. It has also made safer and easier-to-operate operations.

- Yard Towing Truck (YTT): Yard Towing Trucks are used in internal transfer operations to transfer the containers from one point to another within the terminal. They are generally used for transporting containers from the stowage areas to the ship's side or from the ship side to the stowage areas at the terminal.

2.3.3. Terminal Shore-Based Crew Team Organization

Port workers which also known as stevedores or longshoremen, are responsible for loading and discharging cargo and/or administrative duties associated with the loading/discharging of cargo. They are in a physically heavy labor which requires teamwork. Transferring cargo from the ship to the stowage area safely and efficiently or vice versa, as well as securing ships are in the tasks of port workers. While they supervise cargo handling process, they also inspect the cargo for determine any damaged or lost items. Keeping track of cargo inventory and document any irregularities are also in their responsibilities. Ports are generally working 24/7, which means there should be port workers all the time. So, they work in shifts, 3 shifts each consisting of 8 hours in a day. The shifts are 00:00 to 08:00, 08:00 to 16:00 and 16:00 to 24:00.

Port operation employees and stevedoring gang operate in the terminal sections of the port, which are partially or completely closed to the access of other pedestrians, reserved for cargo handling and technical works. Their working environment is mostly open spaces.

Generally, in port operation fields, cargo handling operations are carried out through the coordination of tallyman, crane operator and gang members. In order to understand the port workers jobs, tasks, their working environment and how an operation is carried out, the structure of a stevedoring gang and their jobs are explained below in detail (Figure 2.25.).

- Stevedoring Gang: The working group that carries out cargo handling operations on board ships and port areas and which consists of 2 personnel for ship operation, 1 crane operator, 1 gang member and 1 tallyman.
- Personnel for Ship Operation: Personnel for ship operations who assembles the containers with the load slings, twistlocks according to their type.

- Crane Operator: Qualified personnel using cranes and who has a crane driving license.

- Gang Member: Qualified employee directing the machine operator with internationally recognized signs and who has a crane driving license.

- Tallyman: They serve as shift supervisors. They oversee the conduct of the operation in accordance with occupational health and safety, environmental and quality standards, international rules and work instructions. They are also qualified people who keep records of quantity of goods shipped or received and controls the operation in this process.

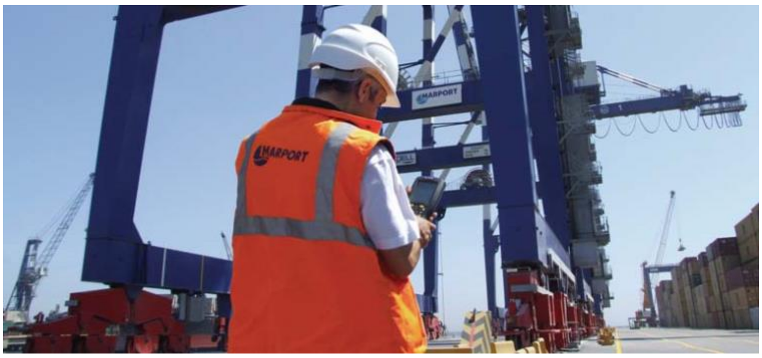


Figure 2.25. Stevedore member from MARPORT container terminal [URL3]

3. METHODOLOGY

3.1. Outline of The Conduct

First, the sound (noise) theory was investigated thoroughly and then the effects of noise on human health along with the standards on the issue have been examined. After all the research done, it was decided to build the method of the study on a quantitative basis.
Throughout the research much of the effort is made to prove the hypotheses put forward in the introduction section. The study followed quantitative method in which the noise measurements obtained from the field work are loaded to … software in order to produce audible frequency versus A-weighted equivalent noise level graphs along with cumulative graphs and to reach tangible conclusions about the noise levels in the selected port. Using the measurement results and the graphs the study made another step for creating a well-defined noise map of the port.

The port chosen for the research is a typical container port (Figure 3.1.). MARPORT authorities kindly made the research process possible by offering day time access to operational yards of the port. The main sources include Sirens of cranes while moving, hitting of containers while loading/unloading, ground vehicle movement to support loading/unloading of containers and noise from vessels. (Murphy & King, 2014)

Figure 3.1. Overview of the selected container port (MARPORT) [URL3]

Most of the recent noise studies in ports focus on determining the effects of port-based noises on the residential areas in the vicinity. However, this study aims to conduct an overall noise survey of the selected container port when fully operating. In contrast to other recent studies, this research does not bound itself with the adverse effects of noise sourcing from the ports onto residential area. Because firstly MARPORT is quite away from the nearest residential place, and secondly this remoteness of the port contributes to the precision of the measurements. This is due to the fact that the more the distance from residential areas the less interference to measurement from the local traffic. Looking from occupational health perspective, this case justifies itself because the noise in question will only include active shore-based equipment used during a loading/discharging operation.

During the field study, noise measurements were taken, following the standards set forth in ISO (9612-2009) Acoustics Determination of Occupational Noise Exposure: Engineering method as closely as possible. In the standards, the document suggests 3 different measurement strategy taking into account the amount of occupational exposure.

Task-based measurement is performed in a short time which assesses workers' exposure during completion of a task. On the other hand, *job-based measurement* is recommended when work patterns and task descriptions cannot clearly be defined and this method requires to take samples throughout the job execution time. However, *full-day measurement* is more suitable when the work patterns are not clearly defined and change according to the situation and also when noise levels involved are varying. This strategy is useful when all different noises in the work area needed to be measured as a whole. (ISO, 2009) Since in a container terminal, loading and discharging operations require a set of ground-based equipment which work with irregular periods and at times sporadic intervals, *full day measurement strategy* was utilized during the field work.

3.2. Details of Measurement Area in Marport

The layout of measurement area is presented in Figure 3.5. The measurements are performed in 7 different designated areas. Measurements covered a full working period of a ground team as in 8 hours.

Marport container terminal is located on 530.000 m2 area with its 7 berths, storage areas and Container Freight Station (CFS). The quay length of the terminal is 1605 meters in total and maximum draft is 16.5 meters. The total storage capacity is 30.654 TEU, refrigerated container capacity 1.064 (380V) and the handling capacity is 2.300.000 TEU / Year. The total number of yard equipment is listed in Table 3.1.

Table 3.1. Marport Container Terminal Equipment [URL4]

Pier Cranes		Field Equipment	
Equipment Names	Quantity	Equipment Names	Quantity
Ship to Shore Gantry Crane (SSG)	10	Rubber Tyred Gantry Crane (RTG)	41
Mobile Harbor Crane (MHC)	5	Full Container Stacker (Side lifter)	8
		Empty Container Stacker (Top lifter)	10
		Yard Towing Truck (YTT)	102
		Forklift	16

MARPORT container terminal equipment can be classified under two categories as pier cranes and field equipment. Pier cranes moves containers from ship to yard towing trucks or vice versa. Various types of pier cranes were explained in the previous chapter. In the selected container terminal, MARPORT, there are 10 Ship to Shore Gantry Cranes (SSG) and 5 Mobile Harbor Cranes (MHC). These cranes are located at berths as seen in Figure … . where most of the measurements were taken. On the other hand, field equipment which are for moving containers from storage area to trucks or vice versa or to in another location in the yard as explained in the previous chapter. For these purposes, in MARPORT, there are 41 Rubber Tyred Gantry Cranes (RTG), 8 Full Container Stackers (FCS), 10 Empty Container Stackers (ECS), 102 Yard Towing Trucks (YTT) and 16 Forklifts. Only MHCs and YTTs are diesel powered and the rest of the terminal equipment are electric powered. The details of each berth are as follows:

- Berth 1 (designated area 7): There are 3 SSG cranes in Berth 1. The length of this berth is 355 m. During the measurements, the operation of a container ship in LOA 299.99 m and width 40 m was being held. Her container capacity was 6750 TEU. During her operation, the all 3 SSGs of this berth were working. A total of 4 measurements were taken in this designated area.

- Berth 2: There is no crane at berth number 2. According to the information received from the port employees, this place is not used because it is very open to the wind. Empty containers were stacked here. Since there is no sound source in this region and there are no port workers (stevedores) working in this region, no significant measurements were taken here.

- Berth 3 (designated area 6): There are 3 SSG cranes in Berth 3. The length of this berth is 307 m. During the measurements, the operation of a container ship in LOA 168.8 m and width 27.3 m was carried out. Her container capacity was 1119 TEU. During her operation, only 1 SSG of this berth out of 3 was working. A total of 2 measurements of 10 minutes were taken in this designated area.

- Berth 4: There is no crane at berth number 4. According to the information received from the port employees, this berth is not being used for ship operations and it is only used for stacking empty containers. Since there is no sound source in this region and there are no stevedores working in this region, no measurements were taken here.

- Berth 5 (designated area 4): The berth 5 and 6 are next to each other and on this quay, there are only MHCs used in lieu the SSGs. There are 3 MHCs in total in Berth 5 and 6. The length of this quay (Berth 5 and Berth 6) is 402 m. During the measurements, the operation of a container ship in LOA 166.15 m and width 25 m was carried out in Berth 5. Her container capacity was 1284 TEU. During her operation, only 1 MHC was working. A total of 4 measurements of 10 minutes were taken in this quay.

- Berth 6 (designated area 3): As stated above berths 5 and 6 are next to each other and on a 402 m in length quay where only MHCs used and there are 3 of them along the quay. During the measurements, the operation of a container ship in LOA 156 m and width 25 m was carried out in Berth 6. Her container capacity was 1221 TEU. During her operation, again, only 1 MHC was working. And, as previously mentioned 4 measurements of 10 minutes were taken in this quay.

- Berth 7 (designated area 1): There are 4 SSG cranes in Berth 7. The length of this berth is 396 m. During the measurements, the operation of a container ship in LOA 366.07 m and width 51.2 m was carried out. Her container capacity was 10000 TEU. During her operation, the all 4 SSGs of this berth were working. A total of 6 measurements of 10 minutes were taken in this designated area.

The designated areas 2 and 5 for the measurements are respectively storage area and truck road. Storage area behind Berth-7 is appointed as the designated area 2. A total of 7 measurements of 2 minutes were taken in this designated area with the necessary permits and security measures because normally the pedestrians are not allowed in storage areas. Designated area 5 was selected as the YTT road between the main terminal and the west terminal of the port. The road is also used by other port vehicles as forklifts, FCSs and ECSs other than YTTs. A total of 4 measurements of 2 minutes were taken along the road.

3.3. Conduct of Measurement Process

This survey was carried out using a Sound Level Meter (SLM) (Brüel & Kjaer 2260) shown in Figure 3.2. The SLM used was in full compliance with IEC 61672 – A Standard for Sound Level Meters Explained Type 1. It was also calibrated just before and after the measurements in accordance with ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories with using an acoustical calibrator (Brüel & Kjaer 4231) compliant with IEC 60942:2017 Electroacoustics - Sound calibrators shown in Figure 3.3. The calibration process of the device is also shown in Figure 3.4. Acoustic measurement range of the device was set at 40 dB (A) to 120 dB (A). Bandwidth of the device was chosen as 1/3 octave band as it allows a more detailed analysis than 1/1 octave band. During the measurements the device was kept at a height of 1.6 meters by the help of a tripod which was considered as an average hearing zone and a wind-shield was used to avoid the effect of the wind. The measurements were taken in approximately 5 to 10 meters away from the noise source due to safety precautions of the port.

Figure 3.2. Sound Level Meter (Brüel & Kjaer 2260)

Figure 3.3. Acoustical Calibrator (Brüel & Kjaer 4231)

Figure 3.4. Calibration of the Sound Level Meter

The day of measurement was chosen when the port is fully operating as in there were ship operation in each berth of the port. The measuring approach involved taking instantaneous noise measurements at various locations throughout the yard and 10-minute noise measurements along the berths near the SSGs and MHCs where it was foreseen that the stevedores most exposed to noise. Instantaneous measurements were about 2-minute measurements and that was enough time for the device to obtain accurate data. On the other hand, the 10-minute measurement were taken in order to at least involve one move of the crane which could be opening/closing a hatch cover or loading/unloading a container. After these data acquisitions, the obtained data were averaged automatically by the device (L_{Aeq}). The maximum and minimum values (L_{max} and L_{min}) were also collected during each measurement. With the L_{Aeq} values recorded a noise map of the port was generated. Through these noise maps the high-risk areas for port workers (stevedores) where they are most exposed to environmental source. And it will be determined if these noise levels are high enough to make adverse effects on the port workers (stevedores). Also, considering the noise sources and their intermittent nature due to the activity done through the terminal operations this study also interests in Lmax values in addition to L_{Aeq} values which are for investigate continuous noise sources as it is known that intermittent noises are harmful as continuous sources.

Along with the SLM Brüel & Kjaer 2260, a software named 7815 Noise Explorer was also supplied specific to the SLM. After the measurements are completed, the measurement results in the memory of the device are downloaded to the computer through this software. In addition to the L_{Aeq}, L_{max} and L_{min} data, a cumulative distribution of noise level graphic which gives statistical information and a frequency spectrum were also given for each measurement. To see if effects of noise sourcing from terminal operations are related to technological improvement/advancement of terminal equipment or not, a comparison will be made to assess noise differences between technologically diverse equipment. To further investigate a record of events and videos corresponded to SLM recordings during each measurement were also taken in the field measurements.

Figure 3.5. Marport Container Terminal Layout Plan

4. RESULTS AND DISCUSSION

The part container terminal where the measurements are taken included 5 of the berthing areas and a small portion of storage area resulting in 210.000 m^2. In parallel to the aims of the study within this area a total of 30 measurements are taken and processed. All the 7815 Noise Explorer program outputs for these measurement points are presented in Annex A. For analysis purposes, 11 of them are displayed in this chapter. The explanations include graphics of the chosen measurement points and descriptions of the graphs.

Below are four graphics derived from the assessment tool (7815 Noise Explorer). The first three graphics separately show processed measurement results in bar graphic format to display frequency (Hz) versus sound pressure level (dB). The red one displays the results of minimum (L_{min}) values measured in cumulative fashion (Figure 4.1). Likewise, the blue and green graphics display equivalent noise levels (L_{Aeq}) (Figure 4.2) and maximum noise levels (L_{max}) (Figure 4.3) respectively. The fourth one shows combined results of the measurements (Figure 4.4).

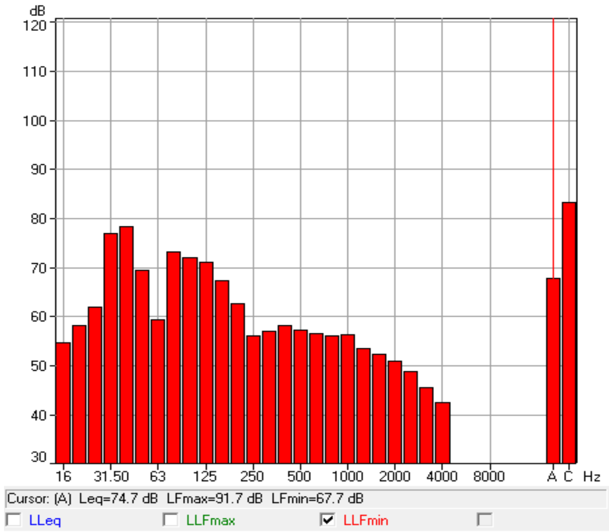


Figure 4.1. SPL versus Frequency Cumulative Graphic for Minimum Sound Levels

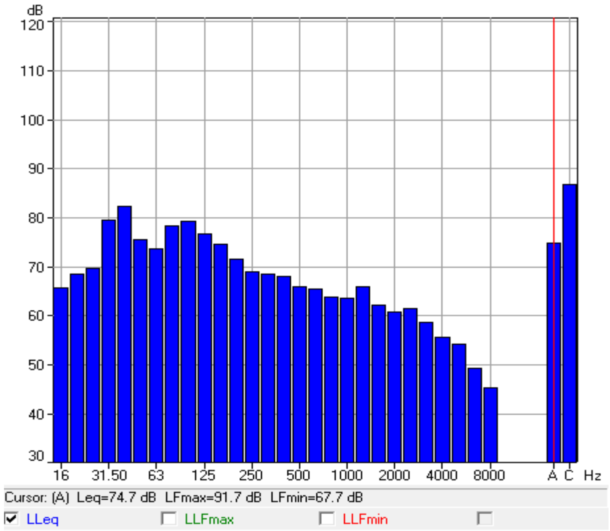


Figure 4.2. SPL versus Frequency Cumulative Graphic for Equivalent Sound Levels

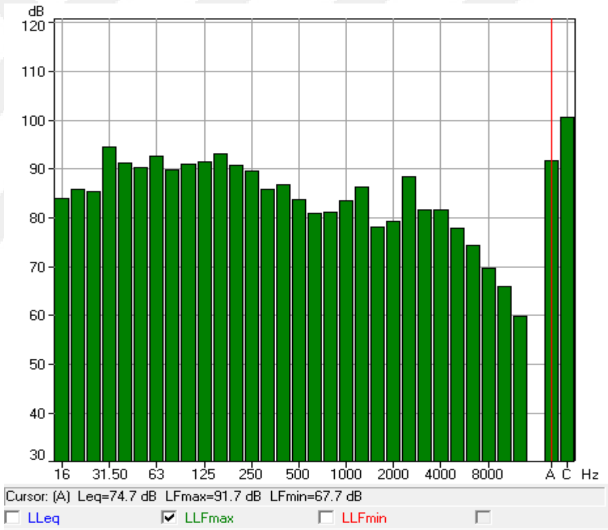


Figure 4.3. SPL versus Frequency Cumulative Graphic for Maximum Sound Levels

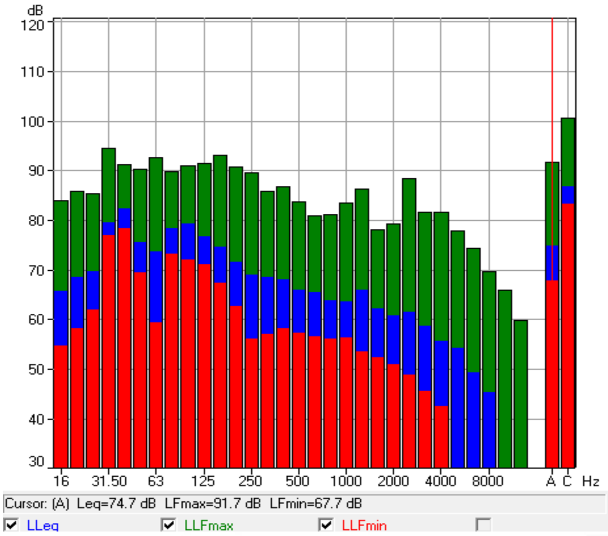


Figure 4.4. 3 level SPL versus Frequency Cumulative Graphic

This study preferred to use combined graphic for ease of use and understanding. The graph lists audible frequency (20Hz-20kHz) using 1/3 octave increments starting from 16 Hz on the X-axis where Y-axis displays sound pressure level (dB) using A-weighting. Using the above graphs, minimum, maximum and equivalent noise levels over a period of time can be actively selected per each class of frequency spectrum. On the graphs each step of 1/3 octave spectrum can separately be analyzed to see what minimum and maximum noise level existed in the testing area as well as their equivalent value through the measuring period of time. This is so because every sound and/or noise produced by any source includes a spectrum of frequency besides the main sound/noise frequency itself. So, when it comes to measuring the noise level, which is unwanted level of sound, all possible frequencies within the noise itself should be measured and evaluated. For this reason, on each graphic 30 bars starting from 16 Hz extending to 16 kHz indicate the noise levels in the audible frequency spectrum over the measurement time.

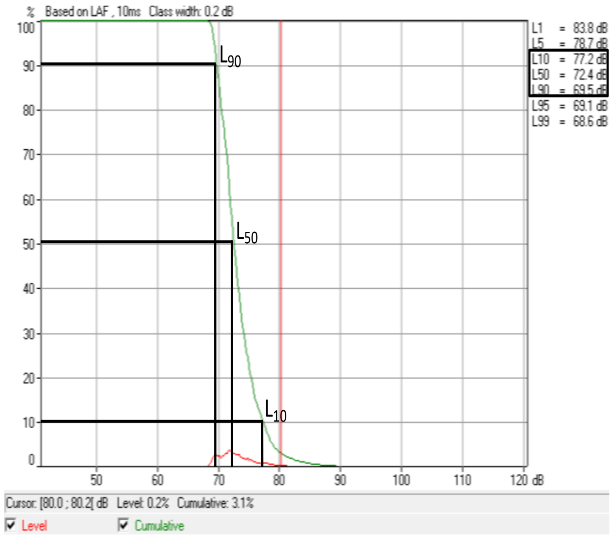


Figure 4.5. Percentage versus SPL Cumulative Graphic

In addition to bar graphic displaying L_{Aeq}, L_{min} and L_{max} figures, the figure 4.5. shows cumulative noise level basing on sound pressure level (dB) with versus percentage of measuring time.

Also, considering the noise sources and their intermittent nature due to the activity done through the terminal operations this study also interests in L_{max} values in addition to L_{Aeq} values which are for investigate continuous noise sources as it is known that intermittent noises are harmful as continuous sources.

The continuous effect of noise as stated in previous chapters are assessed through L_{Aeq} when the results of the measurements considered the L_{Aeq} s are found to be around 74-76 dB which actually are not above the standards set forth by ISO, WHO, END, OSHA and HSE. However, if the results examined in detail it can be seen that there are intermittent noise levels over 90 dB. In order to understand how these sound levels were reached, the results of the collected data were also taken into consideration by considering the L_{max} values and these results were compared with the event log which was kept during the measurement. After this comparative analysis of the results, the sound sources that endanger human health can be determined.

At the first glance, the graphs show that the minimum noise level (L_{min}) in the whole measurement area is 62.2 dB(A)[1]. This level does not pose any threat to human life thus the people working in the area. However, this value is not an indicator for the majority of the measurement area because the measurement point was selected near the bow of a 300 meters LOA ship where there happened no cargo handling operations hence noise. According to the log taken during the measurements in the area, this value (62.2 dB) sources from the movements of the YTTs in the area only. On the other hand, again at the first glance, the maximum noise level is found to be 91.9 dB(A) which pose a serious threat to human health when exposed over a period of time. Yet, this value does not fully represent the overall noise level in the designated measurement area. Measurement logs show that this high noise figure sources from the movement warning signal of the RTGs in the storage area which is behind Berth 7(designated area 1). In addition to overall environmental noise level, the alarm sound coming from RTGs, increased the measured noise level until their movements are completed. Hence, it is not possible to project those peak levels onto the whole measurement period. For this reason, the maximum noise levels are considered to be intermittent. In this chapter the most significant results per designated areas are shown. The detailed results obtained from the 7815 Noise Explorer software, are presented below as per each designated measurement area:

- Berth 1 (designated area 7): During the measurements in Berth-1 area (see figure 4.6.), a 299.9 m container ship was being loaded/discharged by 3 SSGs. In this area a total of 5 measurements were taken. In order to display the results, 3 of the analysis results are examined in detail below. One the results involves displaying the graphics of measuring point 30 which had no machinery working other than YTTs. The second result displayed for Berth 1 involves the sample of measurement for hatch cover opening operation (measuring point 27). And the third one involves a 10 minutes sampling of the measurement area under operation which includes SSGs, YTTs and RTGs operating as required (measuring point 28).

[1] Through the measurements there actually was a lower noise figure (60.3 dB(A)). However, this measurement was taken in the shore crew mess where there was no machinery related noise source due to its distance from the operational area. The measurement was taken in order to compare the noise level of the rest area of the workers, to the noise level of working area when there was no operational noise addition.

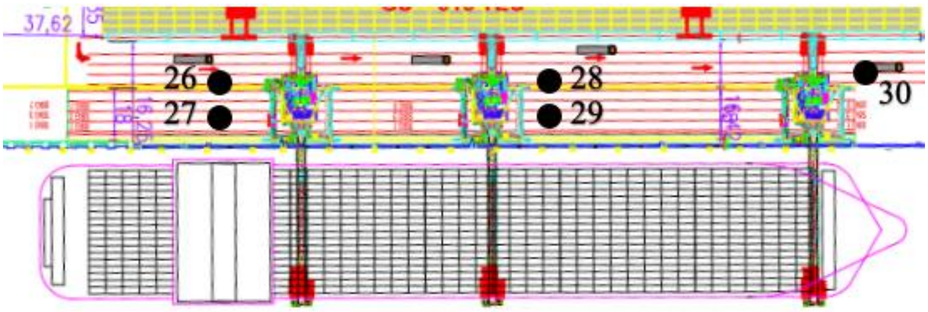


Figure 4.6. Berth-1

- The L_{Aeq} values displayed in figure 4.7. and 4.8. for measuring point 30 shows that the noise level fell down to 60 dB levels which actually does not pose danger to human life. This is a normal result because in measuring point 30 there were no machinery actively working apart from YTTs, hence there were no sources to create excessive noise.

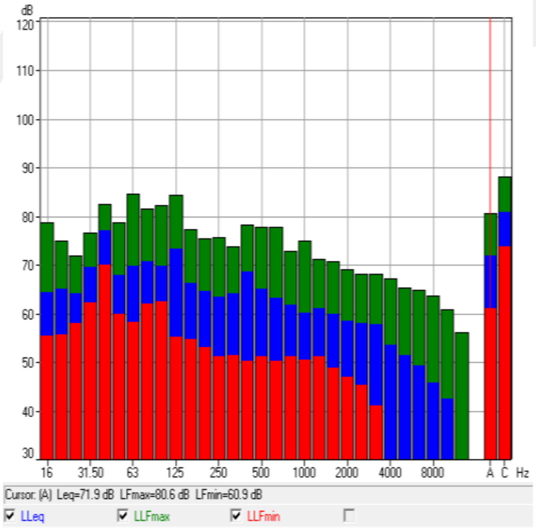


Figure 4.7. SPL versus Frequency Cumulative Graphic of Measurement 30

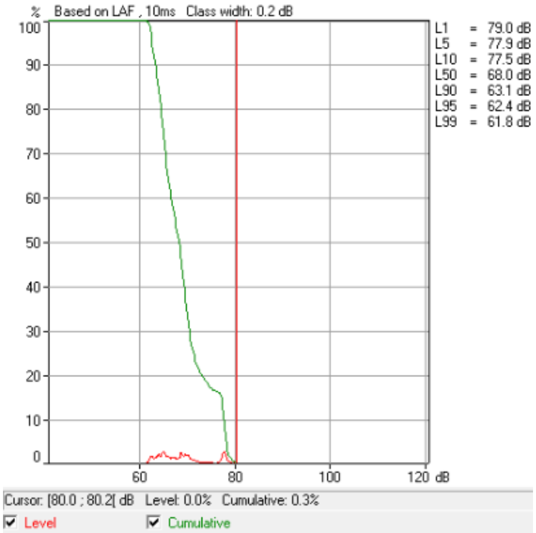


Figure 4.8. Percentage versus SPL Cumulative Graphic of Measurement 30

- In the measuring point 28 which is a 10 minutes sampling of an operating SSG. As it is seen in the below results (figure 4.9. and 4.10.), LAeq value of the whole measurement is 76.2 dB. During the measurement there were an only crane movement for discharging and YTTs passed by the area. So, the noise sources were the container being laid on the YTT and the engine sound of the YTTs which raises the LA max values over 80 dB.

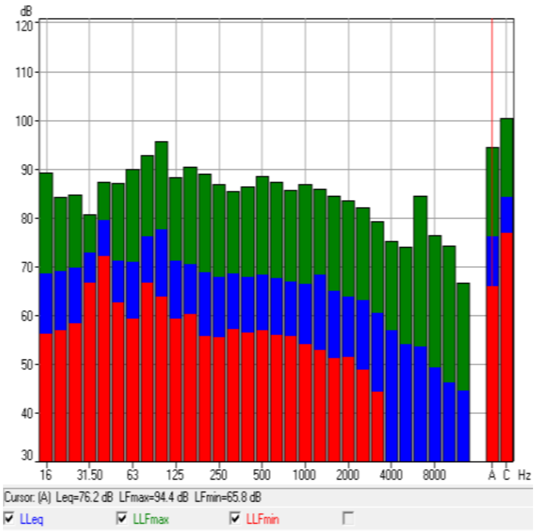


Figure 4.9. SPL versus Frequency Cumulative Graphic of Measurement 28

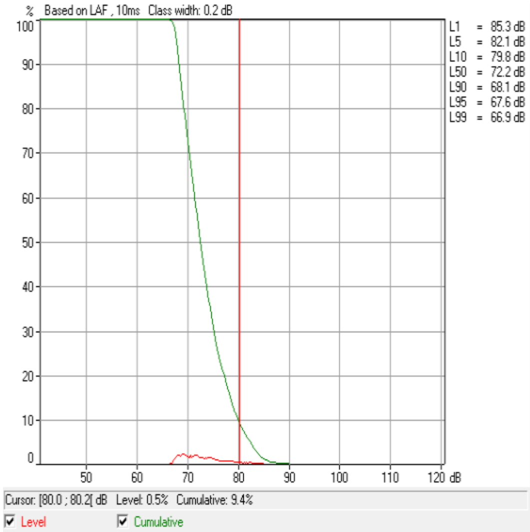


Figure 4.10. Percentage versus SPL Cumulative Graphic of Measurement 28

- In the measuring point 27 which involves hatch cover opening, the figure 4.11. and 4.12. that the noise levels reached almost 100 dB in the lower frequencies (approx. 32-60 Hz). This was due to loud noise coming from the hatch cover being laid on the ground by the SSG's spreader. According the ISO 1999:2013 this level if exposed for periods of time can be harmful to human health.

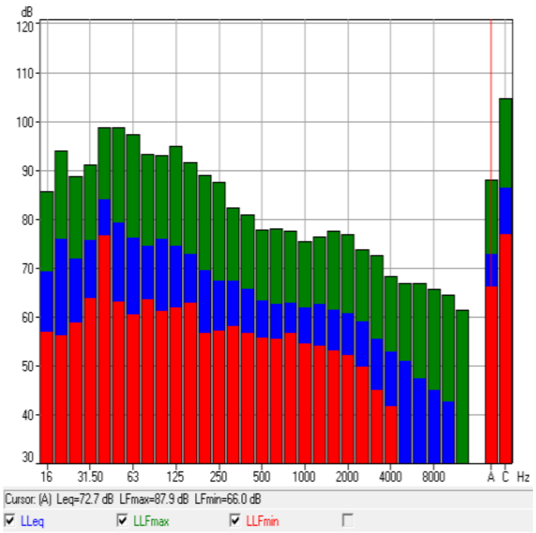


Figure 4.11. SPL versus Frequency Cumulative Graphic of Measurement 27

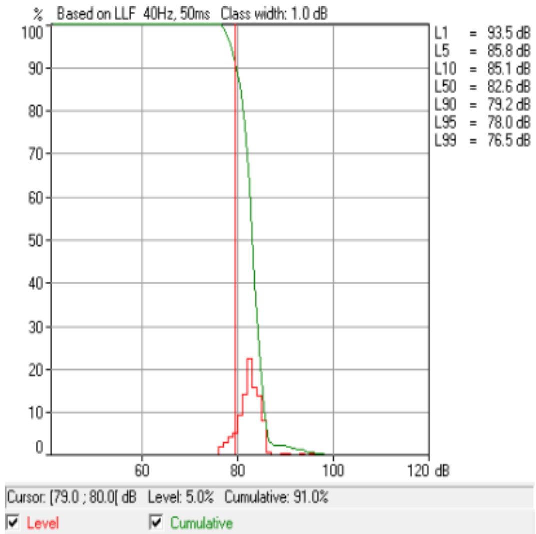


Figure 4.12. Percentage versus SPL Cumulative Graphic of Measurement 27

- Berth 3 (designated area 6): During the measurements in Berth-3 area (see figure 4.13.), a 168.8 m container ship was being discharged by 1 SSG. A total of 2 measurements of 10 minutes were taken, one on each side of the SSG at this berth. During these 2 measurements of 10 minutes, the crane carried out only discharging operations. Although there was no intentional interruption during the operation, the flow of containers to be loaded was not continuous. For this reason, the average number of vertical crane movements in 10 minutes was 2. In the light of this information, one of the measurements (measuring point 23) is examined with the figures 4.14.and 4.15.

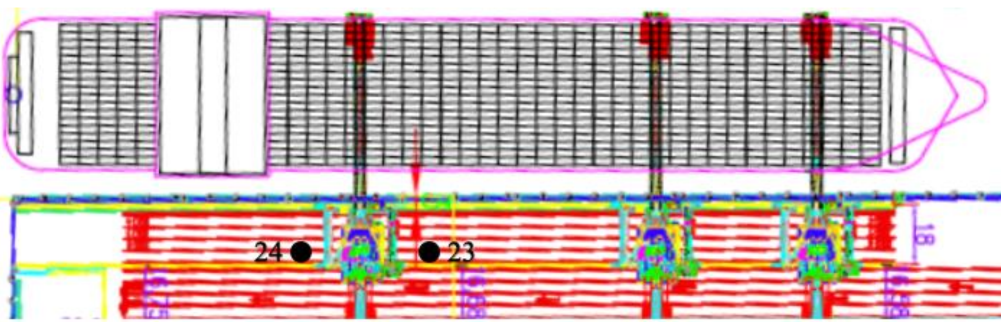


Figure 4.13. Berth-3

  - As it is seen in the below results of the measurement point 23 of 10 minutes, equivalent noise level is 74 dB. However, in the measuring point 23 where the noise sources were vertical SSG movements and YTTs, the graphic shows that the maximum noise levels reached almost 90 dB in a very wide range of frequencies. This was due to loud noise coming from the discharged containers being put on YTTs by the SSG.

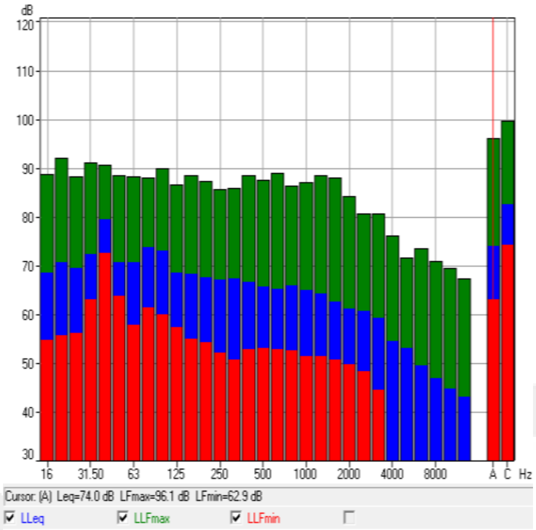


Figure 4.14. SPL versus Frequency Cumulative Graphic of Measurement 23

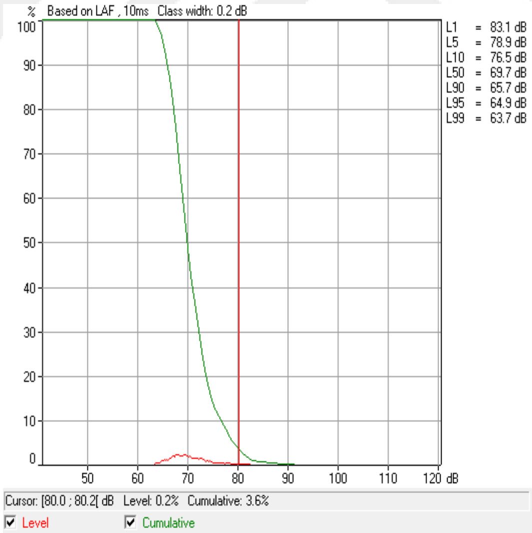


Figure 4.15. Percentage versus SPL Cumulative Graphic of Measurement 23

- YTT road between berths (designated area 5): This road is located between the main terminal and the west terminal of the port and used by yard towing trucks. Although there are no stevedores working there, a total of 4 (3+1) measurements of 2 minutes were taken along the road because the noise generated there contributes to the environmental noise (see Figure 4.16.). The extra measurement was taken at shore crew mess (measurement point 20) to see the lower limit of the environmental noise in the port region. The results of measuring point 19 (Figure 4.17. and 4.18.) are discussed below.

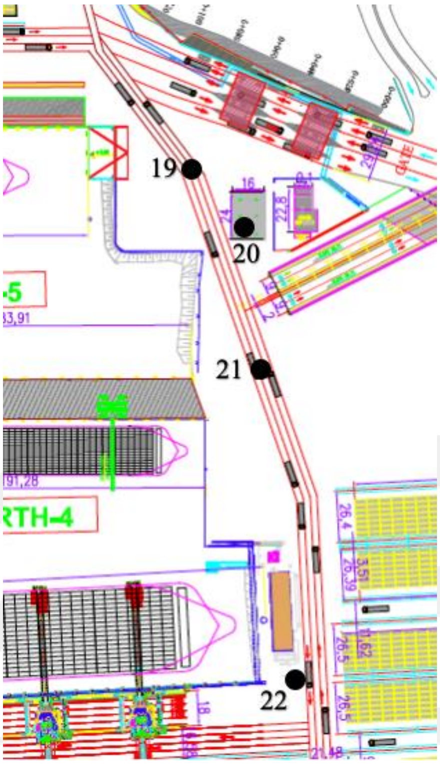


Figure 4.16. YTT Road Between Berths

- The only noise source in the measuring point 19 is the YTTs that work between the storage areas and the berths. Although the speed limit is 20km/h, sometimes YTTs exceed the limit here.

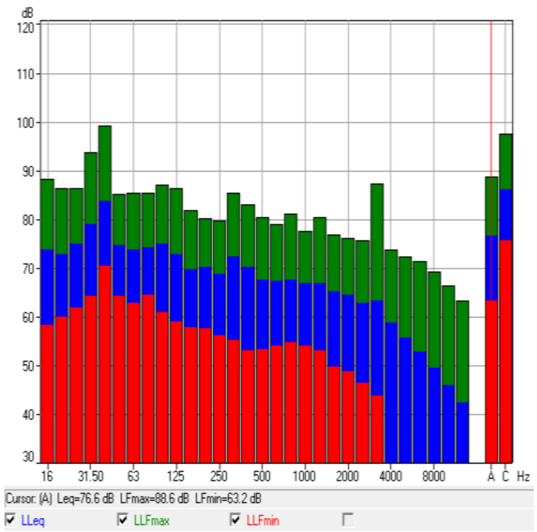


Figure 4.17. SPL versus Frequency Cumulative Graphic of Measurement 19

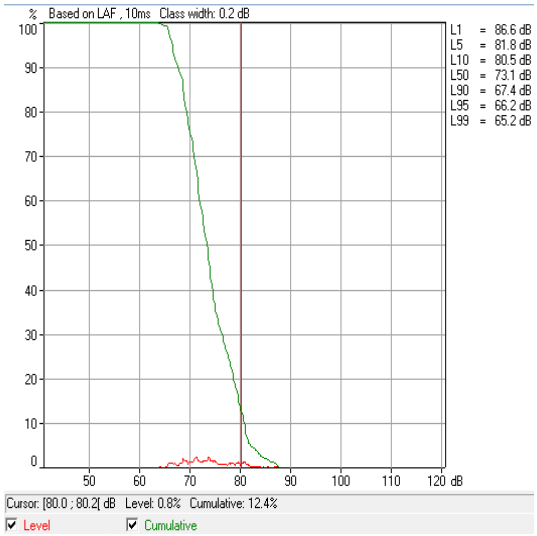


Figure 4.18. Percentage versus SPL Cumulative Graphic of Measurement 19

- Berth 5 (designated area 4): The berth 5 and 6 are next to each other and on this quay, there are only MHCs used in lieu the SSGs. Along this quay 4 measurement points were selected (see Figure 4.19.). These were 10 minutes measurements. 1 MHC was loading/discharging a 166.2 m container ship during the measurements in Berth-5. According to the event log that was kept during the measurements, the MHC working for the ship in berth-5 was located near the vessel's aft. Therefore, the measurement point 17 was chosen near the MHC in a safe distance which is also convenient for noise measurement. The measurement point 16 was located between the berth-5 and berth-6, in other words, between the two MHC working for 2 separate ships.

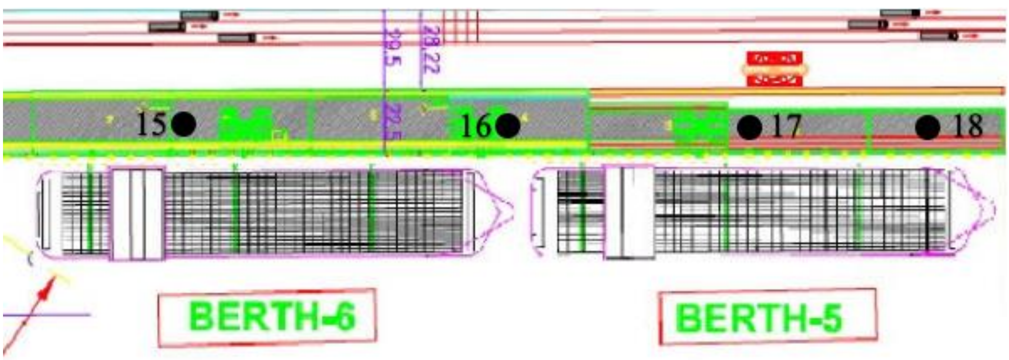


Figure 4.19. Berth-5 & Berth-6

- At the measuring point 17 there was only 1 MHC for loading. Since the MHCs are not easy to use as much as the SSGs, placing a container can be harder. So, operators generally lock at least one of the corners of the container and then land the other corners by lifting and trying a couple of more times to find the right place (see Figure 4.20.and 4.21.) Hence, these actions (hitting/slamming the container in order to place it) create maximum noise levels over 80 dB. As it can be seen in Figure 4.20 L_{max} of the whole measurement is 93.4 dB.

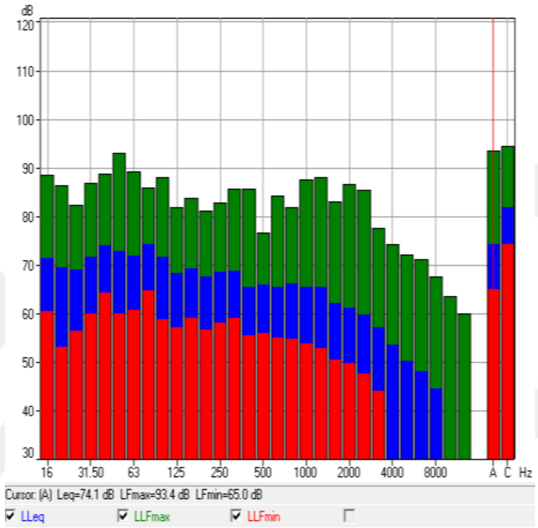


Figure 4.20. SPL versus Frequency Cumulative Graphic of Measurement 17

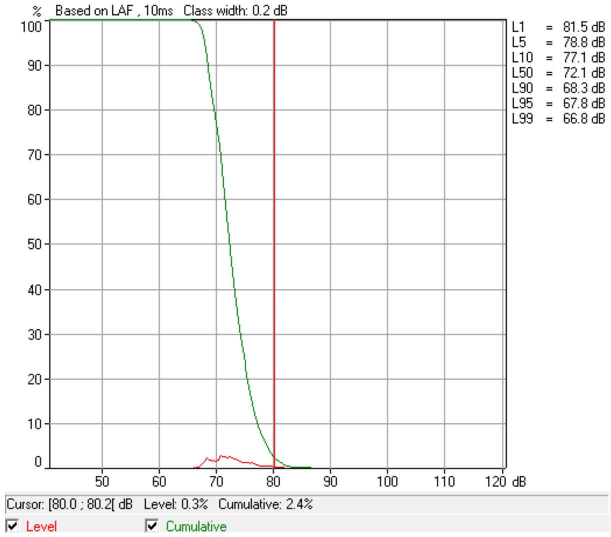


Figure 4.21. Percentage versus SPL Cumulative Graphic of Measurement 17

- The measuring point 16 was chosen to be located between the MHCs loading on two separate ships. However, there is another significance of this measurement due to the fact that the Berth 5 and 6 are located right next to the road used by other port vehicles too. There is an extra noise in this area in addition to the loading/discharging operations that causes the maximum noise levels to reach up to 100 dB(A) as seen in figure 4.22. and 4.23.

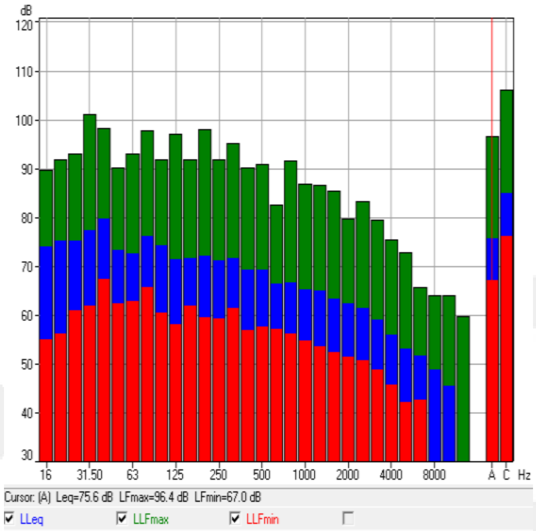


Figure 4.22. SPL versus Frequency Cumulative Graphic of Measurement 16

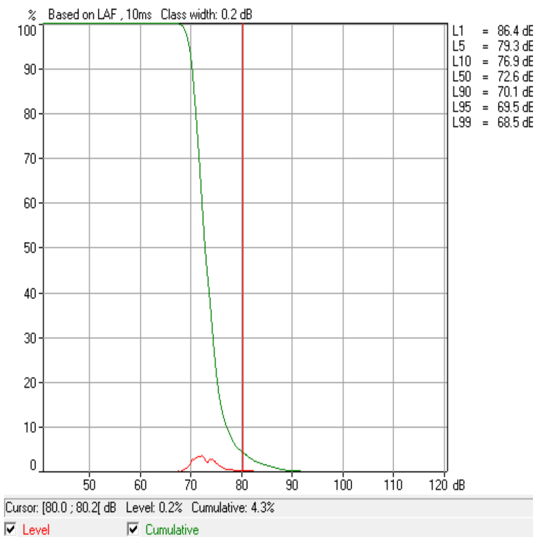


Figure 4.23. Percentage versus SPL Cumulative Graphic of Measurement 16

- Berth 6 (designated area 3): As stated above the berth 5 and 6 are next to each other and there are only MHCs working. Only 1 MHC was loading/discharging a 156 m container ship during the measurements in Berth-6. Between the 4 measurement points, one of them was near the MHC working on the ship at Berth-6 (measurement point 15). This measurement is very similar to the results of point 17. The only difference is that there has been more difficulty in placing the container and it has caused maximum noise level to reach 98 dB with harder movements as seen in figure 4.24. and 4.25.

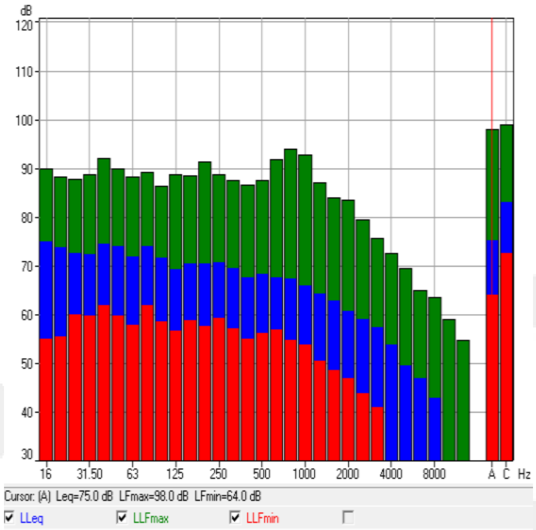


Figure 4.24. SPL versus Frequency Cumulative Graphic of Measurement 15

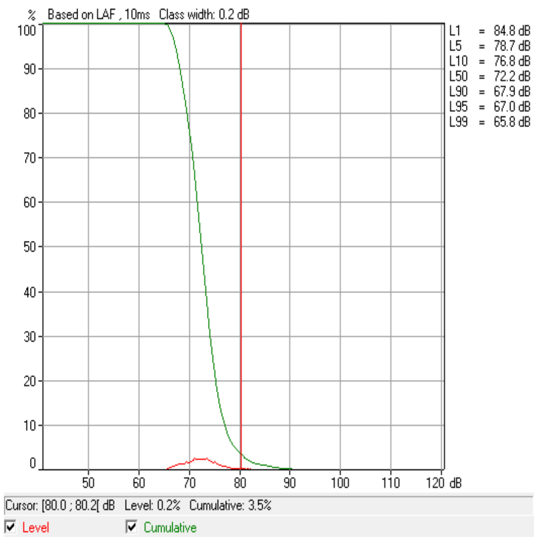


Figure 4.25. Percentage versus SPL Cumulative Graphic of Measurement 15

- Storage area behind Berth-7 (designated area 2): To illustrate the noise in storage areas, the storage area behind the Berth-7 is chosen as a sample region (see Figure 4.26.). A total of 7 measurements of 2 minutes were taken in this designated area with the necessary permits and security measures because normally the pedestrians are not allowed in storage areas. Out of 7 measurements 1 significant measurement is displayed below.

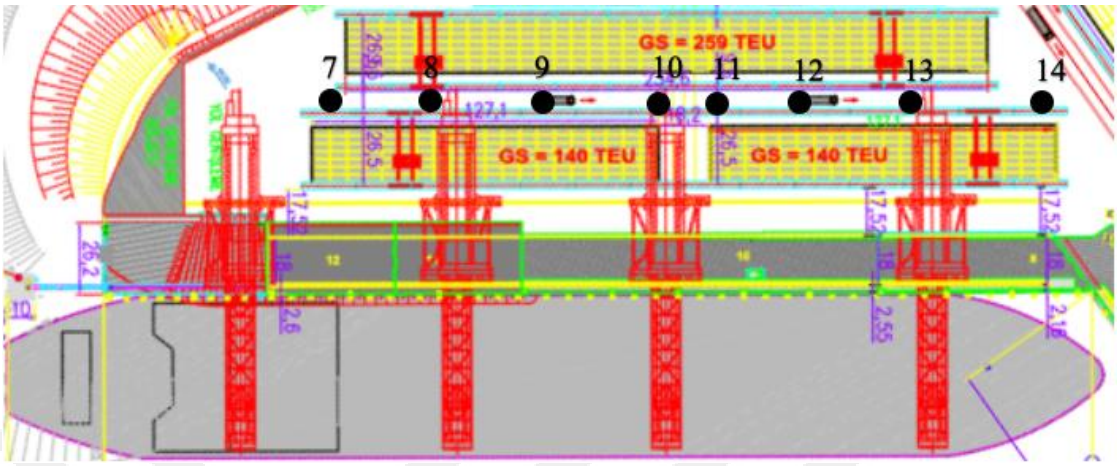


Figure 4.26. Storage Area Behind Berth-7

- There is no specific pattern of operations in storage areas as in throughout the container port. Here, in measurement point 12 (a location in storage area), the containers to be loaded to the ships or the containers discharged from the ships are handled by RTGs. Therefore, both vertical and horizontal movements of RTGs are quite often. Not the vertical but the horizontal movement of an RTG should be highlighted in terms of noise cause the warning signal while it moves is considerably high. As it can be seen from the below results of measurement point 12 (figure 4.27. and 4.28.), the maximum values reach 90 dB and above.

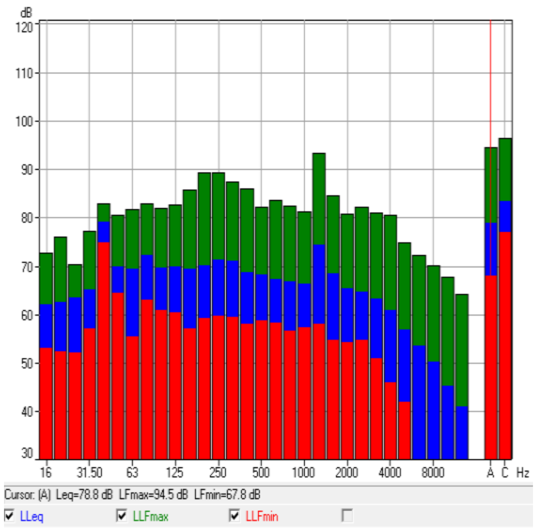


Figure 4.27. SPL versus Frequency Cumulative Graphic of Measurement 12

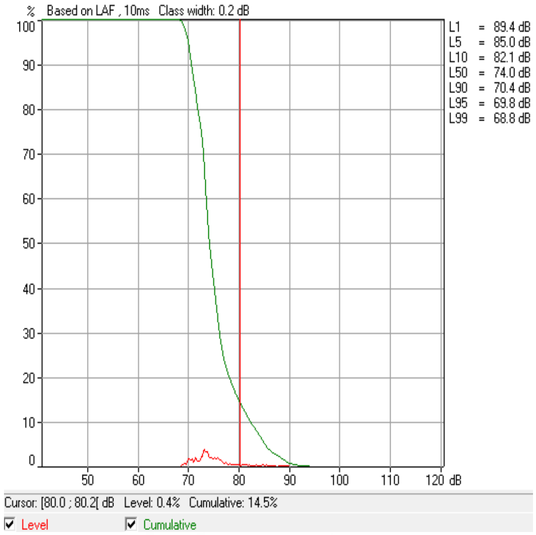


Figure 4.28. Percentage versus SPL Cumulative Graphic of Measurement 12

- Berth 7 (designated area 1): During the measurements in Berth-7 area (see figure 4.29.), a 366.1 m container ship was being loaded/discharged by 4 SSG. A total of 6 measurements of 10 minutes were taken. During these measurements, the ship was being loaded and discharged at the same time. The SSGs movements were both vertical and horizontal. The average number of vertical crane movements in 10 minutes was 5 which means that the cargo flow was continuous. 5 of the 6 measurements were taken next to the SSGs. However, one of them was taken right under the SSG where a stevedore cabin exists (measurement point 4). So, results of measuring point 1 and 4 are examined below with the graphs.

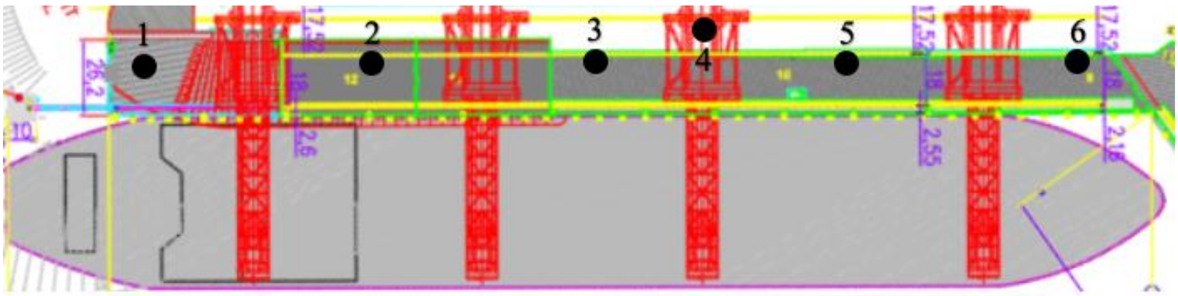


Figure 4.29. Berth-7

  - The measurement taken at the measuring point 4 was taken under the SSG. This crane was loading during the measurement. Stevedores put twistlock on the incoming containers' four corners for loading, but this time one of these corners was crushed by an impact and the twistlock could not be placed.

Therefore, they tried to expand by hitting with a hammer. This is not a rare case and it caused high noise levels as seen in figure 4.30. and 4.31.

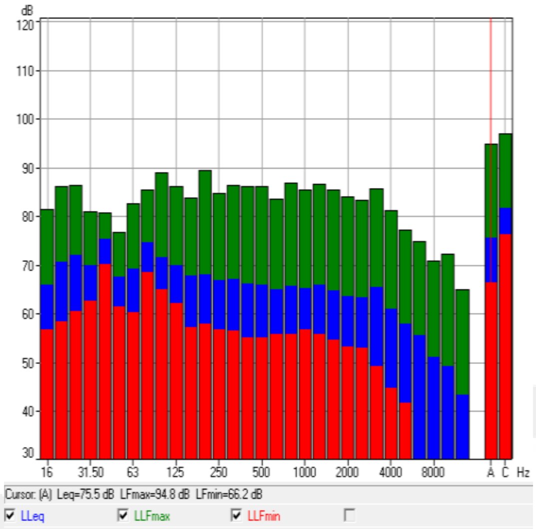


Figure 4.30. SPL versus Frequency Cumulative Graphic of Measurement 4

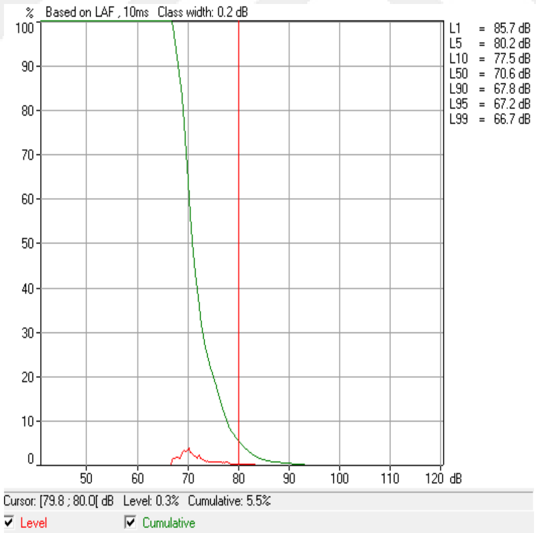


Figure 4.31. Percentage versus SPL Cumulative Graphic of Measurement 4

- All the YTTs coming to Berth 1 compulsorily passes through this measurement point. Therefore, when the sound sources are determined in this location, the noise of YTTs found to be the most noticeable in addition to the noise generated during the discharge. It was also observed that the average movement per hour of a vertical movement of 4 SSGs working on the same vessel was 30. This means that the flow of incoming or outgoing containers was quite frequent. On the other hand, as seen in most of the measurements taken at the port, there is a peak noise caused by every vertical movement of the crane coming out of metal parts' contact. In the light of all these, as we can see in the below results of measurement point 1 (figure 4.32. and 4.33., the max noise levels are above 80 dB.

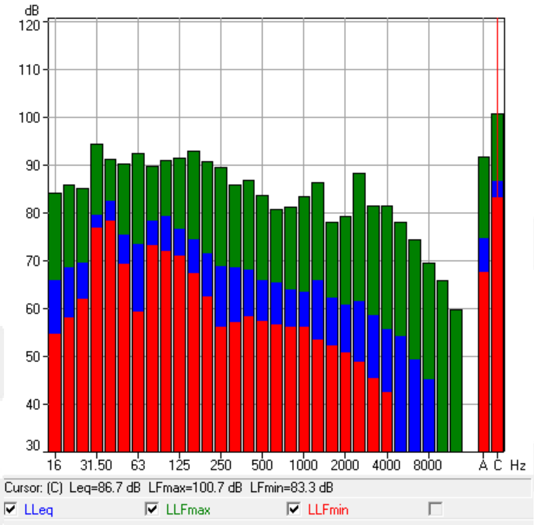


Figure 4.32. SPL versus Frequency Cumulative Graphic of Measurement 1

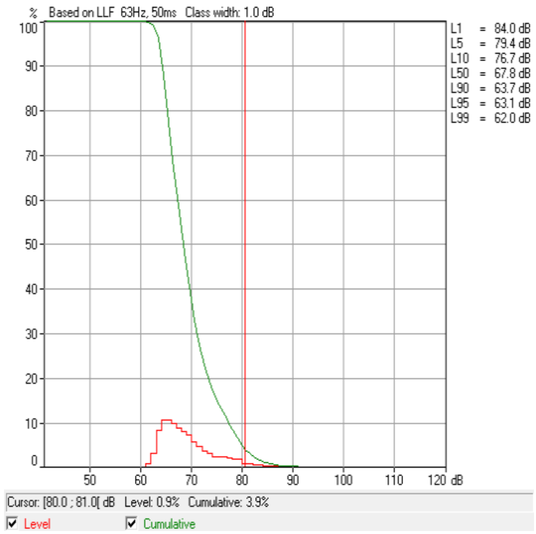


Figure 4.33. Percentage versus SPL Cumulative Graphic of Measurement 1

Figure 4.34. Generated Noise Map of Marport Container Terminal

To sum up, one major finding obtained from all of the measurements in all 7 designated areas is that in 5 of the berths, measured maximum noise levels are above the noise exposure level (80dB) for a nominal 8 h working day ($L_{EX,8h}$) according to ISO 1999:2013. Also, it was explained that this standard applies to noise at frequencies less than approximately 10 kHz which is steady, intermittent, fluctuating, irregular. So, even the equivalent noise levels continued to be below the limit, ISO 1999:2013 is valid for intermittent noises too which in our study found to be exceeding limits and has a harm on human health as well. However, it also should be underlined that though continuous noise levels are measured to be below the set standards they are still very close to harmful limits as seen in the Table 4.1.

Table 4.1. Summary of measurements taken in Marport

Designated Area of Measurement	Measurement Points	LAeq	Lmax	Lmin	LEX,8h
1	1	74.9	91.0	67.9	**80 dB (A)**
	2	73.2	88.4	65.5	
	3	72.8	85.5	64.4	
	4	75.5	94.8	66.2	
	5	76.4	91.1	63.6	
	6	73.8	86.7	64.9	
2	7	75.9	87.0	62.5	
	8	**80.9**	**94.7**	**62.0**	
	9	67.5	71.6	61.1	
	10	72.4	82.5	63.2	
	11	74.3	81.9	64.9	
	12	78.8	94.5	67.8	
	13	77.6	86.3	73.5	
	14	76.1	89.2	63.3	
3	15	75.0	98.0	64.0	
	16	75.6	96.4	67.0	
4	17	74.1	93.4	65.0	
	18	73.4	90.4	61.9	
5	19	76.6	88.6	63.2	
	20	72.5	85.4	59.5	
	21	69.9	77.7	61.9	
	22	76.1	93.0	67.8	
6	23	74.0	96.1	62.9	
	24	69.9	82.6	62.3	
	25	72.0	84.3	62.0	
7	26	73.8	93.0	64.7	
	27	72.7	87.9	66.0	
	28	76.2	94.4	65.8	
	29	73.8	93.1	64.8	
	30	71.9	80.6	60.9	

5. CONCLUSION AND RECOMMENDATIONS

This study investigated the level of environmental noise shore-based crew exposed at container terminals. The research also tried to assess how much new technology contributes to diminishing the level of noise in such areas.

Today, what we know as sound and noise have changed not only their tones but also their magnitudes in daily life. In parallel to technological and industrial developments, both altered the way they affect people. As new instruments and gadgets are introduced in the daily routine they came with new sound signatures and amplitudes contributing to noise levels. the sound they make also came into play. Likewise, in the industrial areas like ports, new technology while facilitating the operations and tasks involved, also brings in new noises with a variety of frequency and amplitude. Technology, on the other hand, has replaced the existing noises with new forms of noise.

Taking the past studies into account, this paper firstly made sure that noise is still a problem from the occupational point of view in working areas. Previous studies were found to be involving not only residential and urban areas but also industrial areas such as airports, construction sites and ship recycling yards. Most of the previous studies dealt with noise mapping in residential areas and suggesting possible remedies for the problem. Especially in the EU, to contribute the quality of life in the areas close to port facilities, target oriented projects have dealt with either noise pollution or setting the European wide practicing the European noise related standards and directives. Other past suggestions mainly included re-planning of noise creating processes in the industrial sites, considering noise related factors when expanding residential and industrial areas. Unlike the majority of the previous ones, this study specifically narrowed its focus on evaluation of noise levels through noise mapping at container ports and assessing its relation with occupational health and safety standards. Two assumptions were proposed to accomplish this goal. The first one suggested that noise, sourcing from port operations is high enough to make adverse effects on port workers (stevedores). The second one complements the first one by suggesting that effects of inevitable noises sourcing from port operations are not directly related to technological development of terminal equipment. This way a humble contribution to literature through port based environmental noise study that includes sound pressure levels and noise mapping in a combined research was realized. This is because ports are excluded from industrial areas as far as noise pollution and mapping are concerned in Turkey. For this reason, this study while presenting a good account of noise levels in busy container port, also contributes to possible remedies for increasing life quality of shore-based crew in routine working area.

Within the course of the study, knowledge pertaining to sound theory has been kept at such a level that the content would be sufficient for clearly understanding the theoretical details which would ultimately explain the noise terminology. This was important because understanding the actual noise measurements would be possible only through clearly understanding the variables of sound theory such as frequency, sound pressure level, dB. All the focus of measurements naturally directed on audible sound which covers the range from 20 Hz to 20 kHz which actually means A-weighted range. As there are different kinds of equipment used for measuring the noise levels, this study utilized the most suitable sound level meter which perfectly served the purpose. For open-air measurements the study used a Type 1 SLM. This SLM measures the environmental noise in an area to accommodate 3 different parameters. These parameters included equivalent sound level (L_{Aeq}), minimum sound level (L_{min}) and maximum sound level (L_{max}) for a specified period of time. For precision of measurements the equipment was set to measure 1/3 octave scale. L_{Aeq} values indicated equivalent sound level in the designated measuring areas where cargoes of 5 container ships were actively being handled using all available yard equipment simultaneously.

The data processed within the study was obtained from 7 different designated measurement areas at 30 measurement points for duration specified by the researcher to best sample the operational conditions with shore-based crew actively working in hand. For this reason, the environment and the conditions in which the measurements were taken presented best possible options for taking sound measurements and for generating an area specific noise map. After the measurements are obtained across the audible frequency for a user defined period of time. The evaluation of the measurements is performed by a software specifically designed for the purpose. 7815 Noise Explorer software basically gives graphical evaluation of measurements taken. The study utilized two main graphics produced by the software to evaluate the results. The SPL (dB) versus Frequency (Hz) graph displayed Lmax, LAeq and Lmin levels across the audible frequency band. The other graphic displayed cumulative noise as SPL (dB) versus percentage of time frame measurement performed. As stated before, the adverse effect of noise is evaluated by time a person exposed to dangerous noise levels specified by the international standards. Therefore, this graph helped assessing the duration of time that the noise levels exceeded or fell behind the safe noise levels put forward by international standards. A quick summary of prominent results is presented in the following Table 5.1.

Table 5.1. Prominent results of measurements taken in Marport

<table>
<tr><th>Measurement Points</th><th>LAeq</th><th>Lmax</th><th>Lmin</th><th>LEX,8h</th></tr>
<tr><td>1</td><td>74.9</td><td>91.0</td><td>67.9</td><td rowspan="12">80 dB (A)</td></tr>
<tr><td>4</td><td>75.5</td><td>94.8</td><td>66.2</td></tr>
<tr><td>5</td><td>76.4</td><td>91.1</td><td>63.6</td></tr>
<tr><td>8</td><td>80.9</td><td>94.7</td><td>62.0</td></tr>
<tr><td>12</td><td>78.8</td><td>94.5</td><td>67.8</td></tr>
<tr><td>15</td><td>75.0</td><td>98.0</td><td>64.0</td></tr>
<tr><td>16</td><td>75.6</td><td>96.4</td><td>67.0</td></tr>
<tr><td>17</td><td>74.1</td><td>93.4</td><td>65.0</td></tr>
<tr><td>23</td><td>74.0</td><td>96.1</td><td>62.9</td></tr>
<tr><td>26</td><td>73.8</td><td>93.0</td><td>64.7</td></tr>
<tr><td>28</td><td>76.2</td><td>94.4</td><td>65.8</td></tr>
<tr><td>29</td><td>73.8</td><td>93.1</td><td>64.8</td></tr>
</table>

Table 5.2. Statistical Noise Values of Marport

	L_1	L_{50}	L_{90}
Throughout the container terminal (MARPORT)	94.0 dB(A)	76.5 dB(A)	74.5 dB(A)

In the table 5.1., the results obtained from the 7815 Noise Explorer software indicate that the sound pressure level is mostly stable and remains within the safe limits suggested by the international noise exposure standards. L_{Aeq} levels are mostly stable around 76 dB with one exception of 80.9 dB and do not pose serious threat to human life from occupational health and safety aspects. However, within the L_{Aeq} levels there are few peak noise levels which exceed the international safe limits for a very limited period of time. And the other table (Table 5.2.) confirms that those peaks mentioned take place between 1% and 5% of the measurement time.

The tables 5.1. and 5.2., also indicate that for periods when yard equipment was not operating, thus no peak was produced, sound pressure levels remained minimum not posing any health threat to shore-based workers. Both tables also indicate that the noise levels in the measurement areas reached levels well beyond the international exposure limit for a nominal working hour ($L_{EX,8h}$). However, these results do not pose a serious health threat because exposure to high noise levels threatens human health only when there is enough exposure time. The results showed that these peak levels, which are sourcing mainly from containers' hitting sounds, were only intermittent and did not last for a long period of time.

The results that assess noise related issues at the container terminal in question proved to have contribution to the existing knowledge. When the overall results are evaluated, it can be inferred that when container terminals are fully operational with all ground equipment active, the ground crew who handles the cargo are subject to a variety of noise levels most of which remain within acceptable range. When there is no cargo handling operation, the continuous noise level at a container port remains to be safe, that is, it remains below 80 dB ($L_{EX,8h}$). However, when cargo handling operations with full equipment active noise levels reach up to 80.9 dB (L_{Aeq}) which actually is above the danger limit of 80 dB. In addition, while handling the containers the noise created by individual container movements such as the moment container hits the ground or a container being placed top of another create unacceptable peak sounds like 98 dB (L_{max}). Another unacceptable peak noise level was created when cranes (RTGs, SSGs and MHCs) start moving horizontally which caused warning signal to be initiated and sustained until the horizonal movement was finished. The alarm sound cause most of the peak levels through the course of measurement process. This is a good indication of the fact that, technological improvements (diesel engine to electrical machinery such as MHC to SSG) do not eliminate the inevitable noises and their adverse effect on human beings. This is because as long as the ground crew is a part of cargo handling process, the warning signals will not cease to exist. And, hence, high and harmful levels of noise caused by those warning signals will keep on posing adverse effects to human health. One last issue that needs to be pointed out is the noise created in the lower frequencies. The graphical results revealed that a number of peak noise levels were created around the low frequencies like 31.5 Hz over 100 dB. As explained before, this fact requires C-weighting measurements to be made as it may be more harmful to hearing than it sounds.

To sum up, the noise sources in the container terminal were determined as stated below;

- The noise created by individual container movements such as the moment container hits the ground or a container being placed top of another.

- Warning signal of cranes (RTGs, SSGs and MHCs) when they move horizontally which sustains until the horizonal movement was finished.

- The noise created while hatch cover movements such as the moment hatch cover hits the ground or placed to the vessel.

- The noise created by YTTs.

Under the light of these conclusions, this study proposes possible remedies and solutions to the problems stated by the results of the research.

- Some of the proposals require using protective equipment as some momentary noise sources (such as container hitting noises) cannot be isolated or eliminated. In this regard, against intermittent and high level momentary single impulse noises ground crew should be equipped with ear plugs which protects them from high and harmful noise sources without interfering the safety of operation in hand.
- The results derived from the measurements clearly show that the noise sourcing from cargo handling operations at port can be harmful to human health when exposed over a period of time. As the cargo equipment ashore wears off, the noise they produce may get loud and worse. Likewise, new equipment introduced to cargo handling area may introduce new noise sources to the working environment. The crane operators depending on their experience and skill levels unwillingly may contribute to high noise levels. For all those reasons, noise measurements and mapping of container terminals must be regularly done to eliminate any unforeseen noise related hazard.
- Another proposal for overcoming noise related hazards to human beings that in the long run may be investing in automation and eliminating workers in the cargo handling area.

- One last proposal involves further studies on the matter. Noise related measurements can be performed both area and individual based simultaneously to compare the environmental noise with individual exposure level in the same area. This will present more precise figures per worker through their shift. This type of further study may also be enhanced by a variety of measurement and comparison methods in which individual exposure is measured after a thorough assessment of the area only in the high-risk zones.

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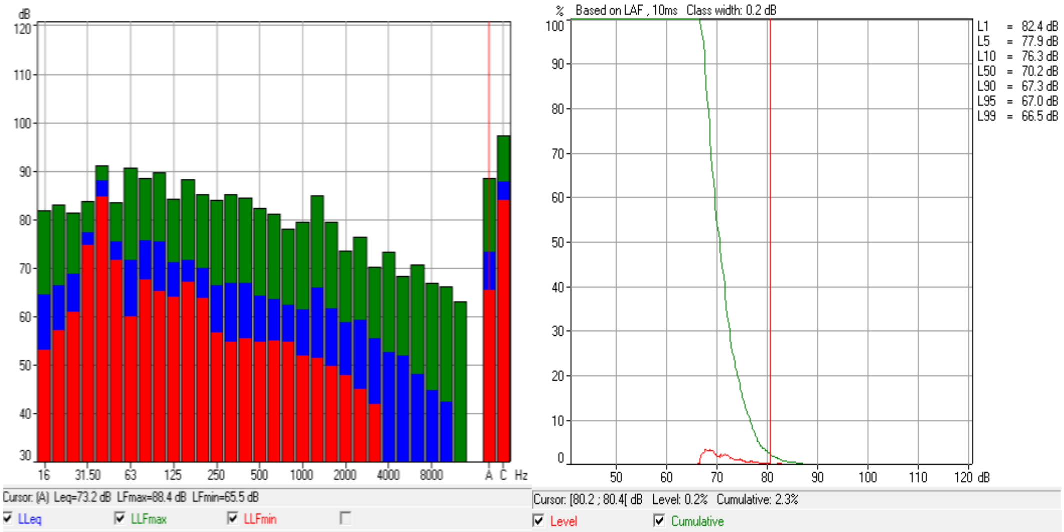
ANNEX – A

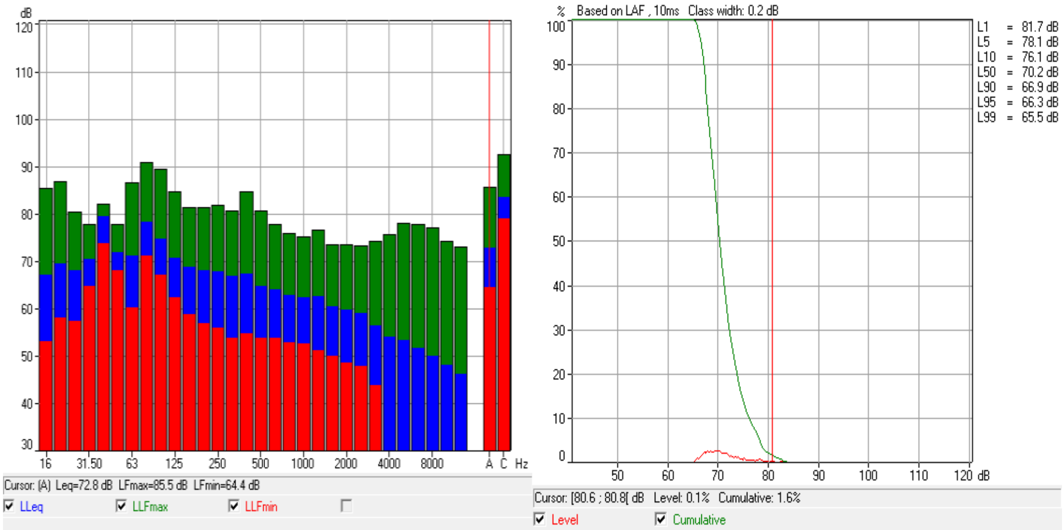
- Measurement Point 2



[a] [b]

Figure A.1. Graphical Output of Processed Measurement 2; SPL versus Frequency [a] and Percentage versus SPL [b]

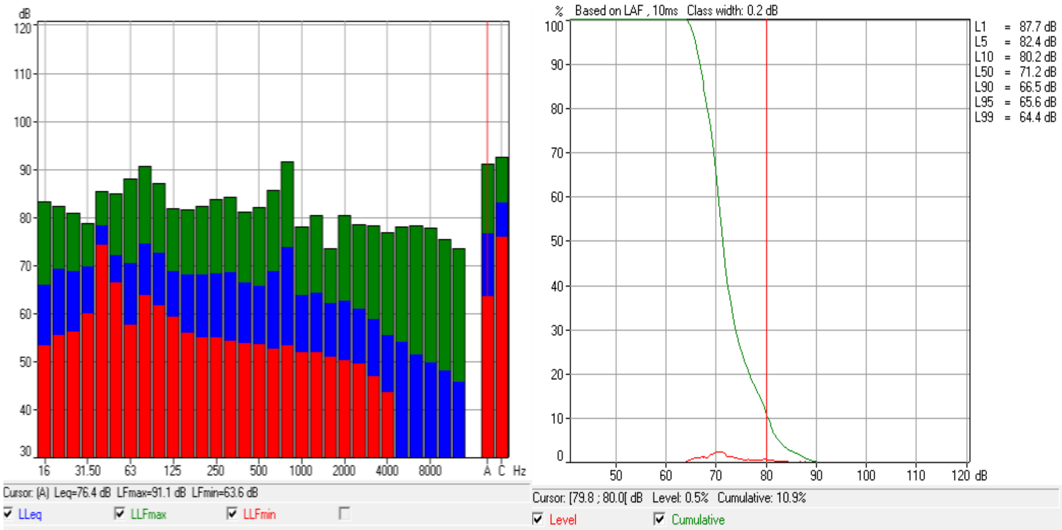
- Measurement Point 3



[a] [b]

Figure A.2. Graphical Output of Processed Measurement 3; SPL versus Frequency [a] and Percentage versus SPL [b]

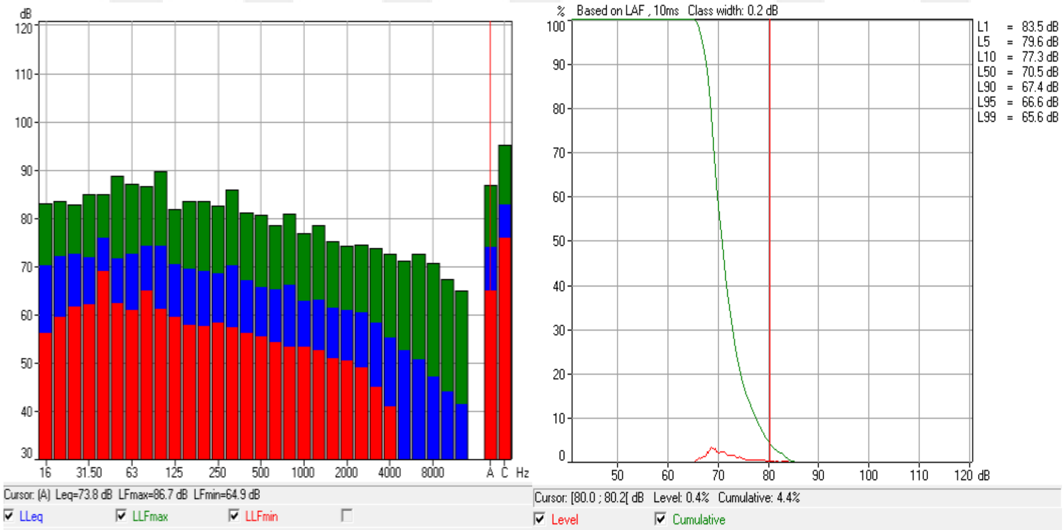
- Measurement Point 5



[a] [b]

Figure A.3. Graphical Output of Processed Measurement 5; SPL versus Frequency [a] and Percentage versus SPL [b]

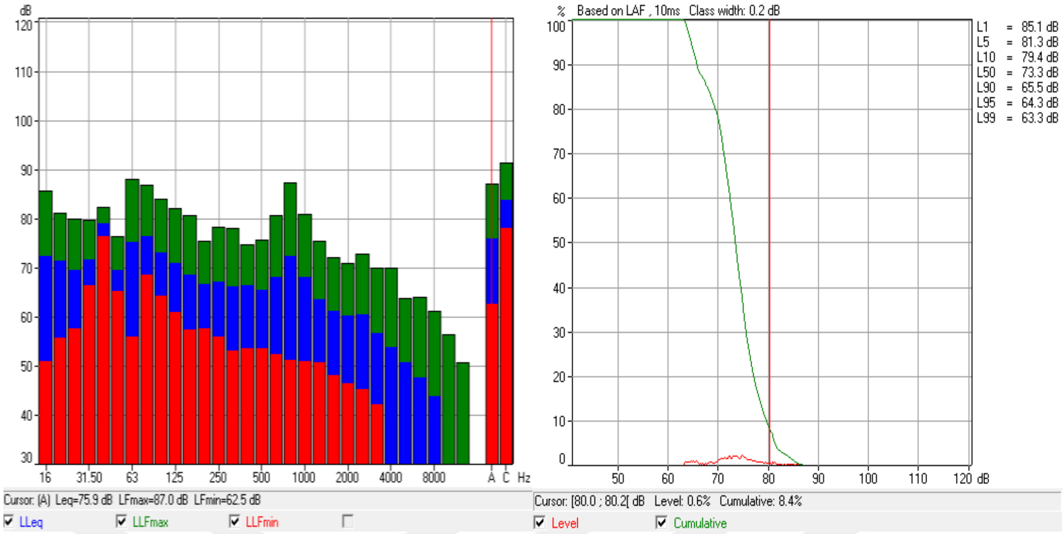
- Measurement Point 6



[a] [b]

Figure A.4. Graphical Output of Processed Measurement 6; SPL versus Frequency [a] and Percentage versus SPL [b]

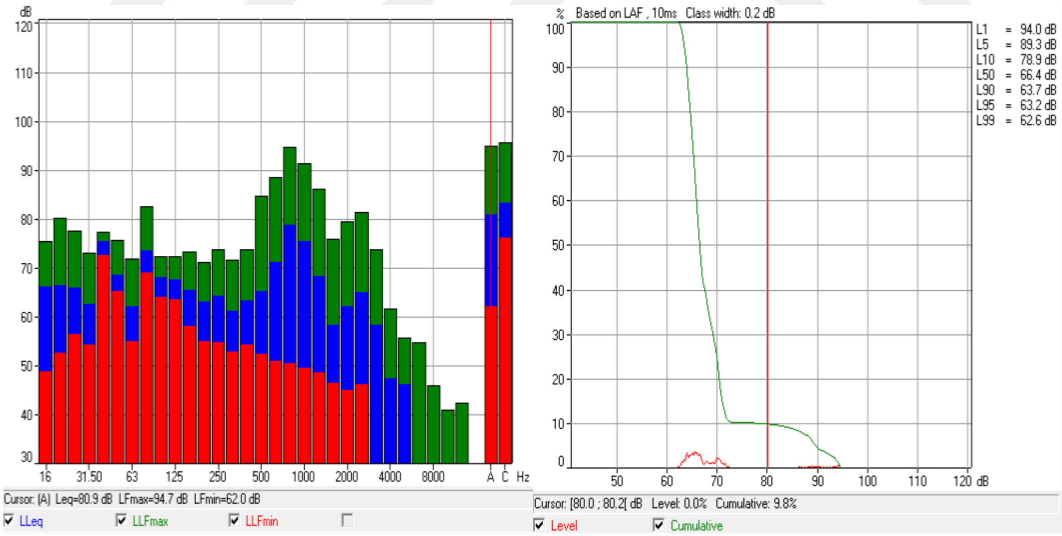
- Measurement Point 7



[a] [b]

Figure A.5. Graphical Output of Processed Measurement 7; SPL versus Frequency [a] and Percentage versus SPL [b]

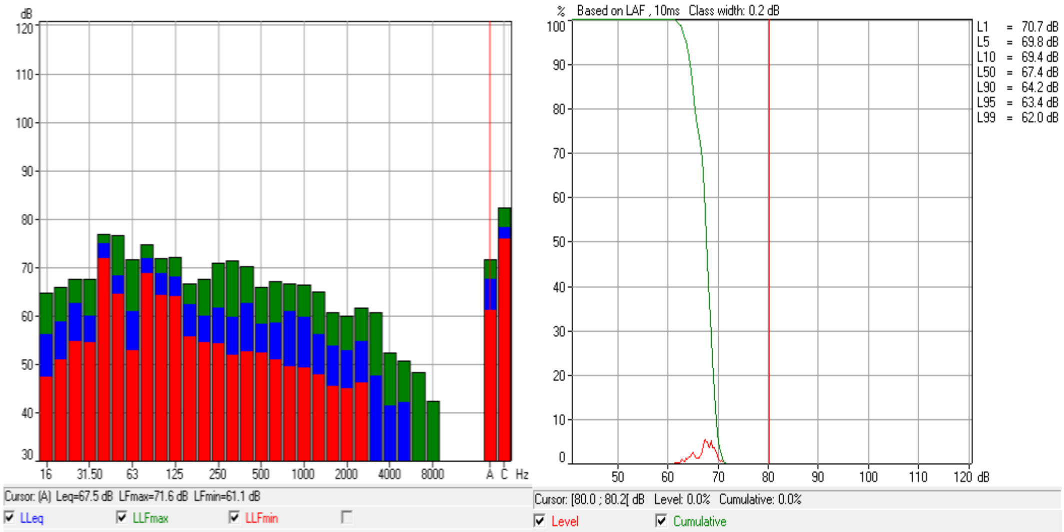
- Measurement Point 8



[a] [b]

Figure A.6. Graphical Output of Processed Measurement 8; SPL versus Frequency [a] and Percentage versus SPL [b]

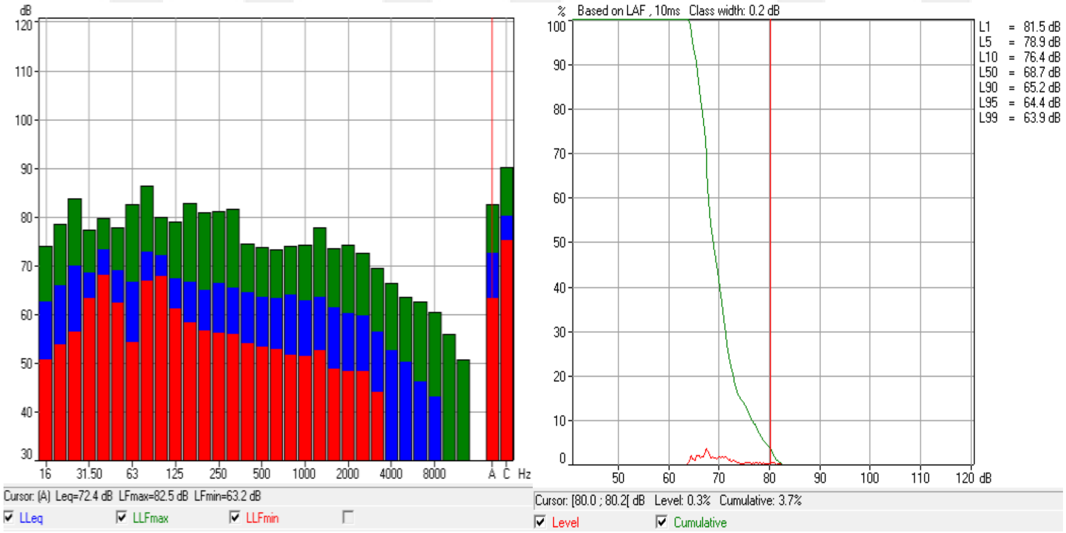
- Measurement Point 9



[a] [b]

Figure A.7. Graphical Output of Processed Measurement 9; SPL versus Frequency [a] and Percentage versus SPL [b]

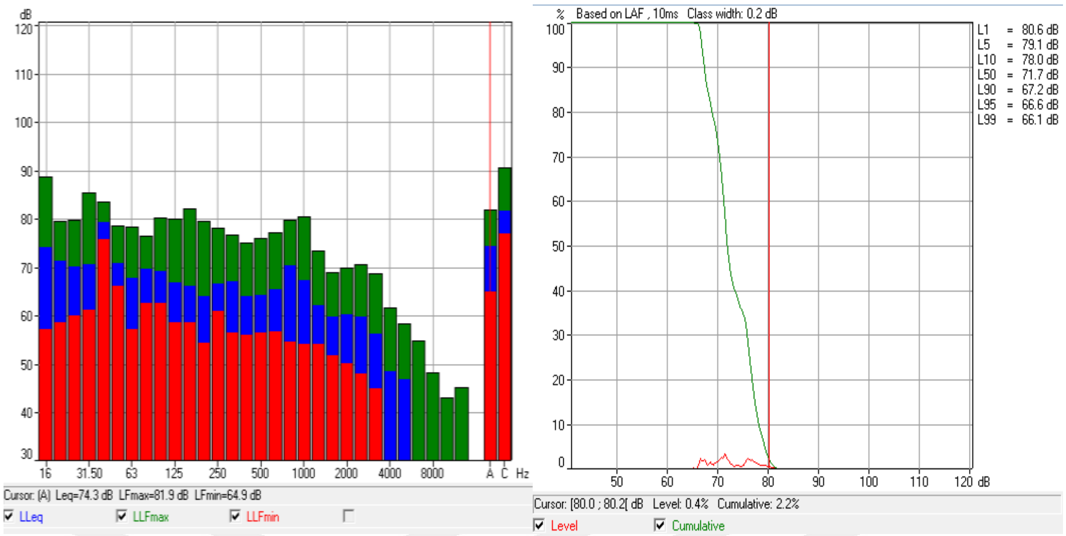
- Measurement Point 10



[a] [b]

Figure A.8. Graphical Output of Processed Measurement 10; SPL versus Frequency [a] and Percentage versus SPL [b]

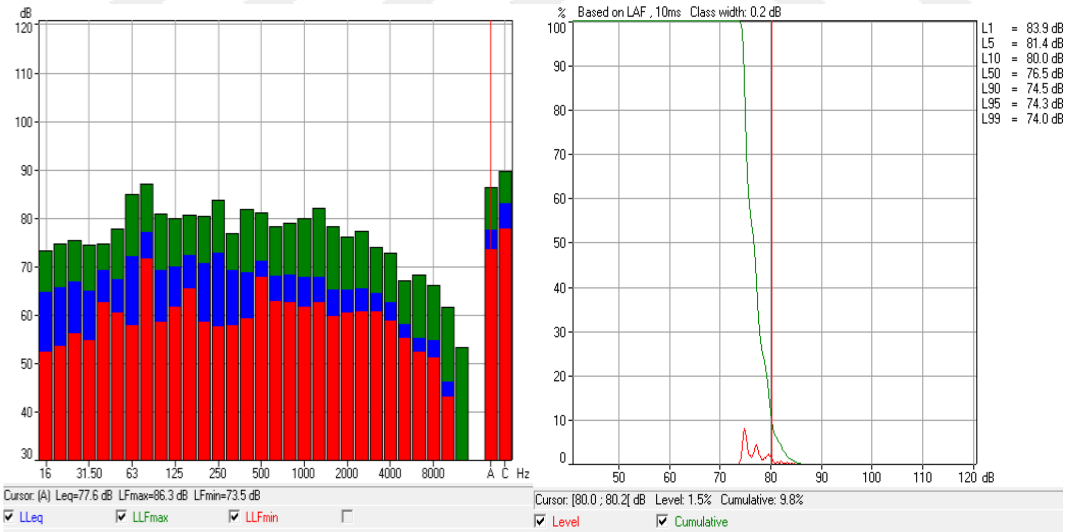
- Measurement Point 11



[a] [b]

Figure A.9. Graphical Output of Processed Measurement 11; SPL versus Frequency [a] and Percentage versus SPL [b]

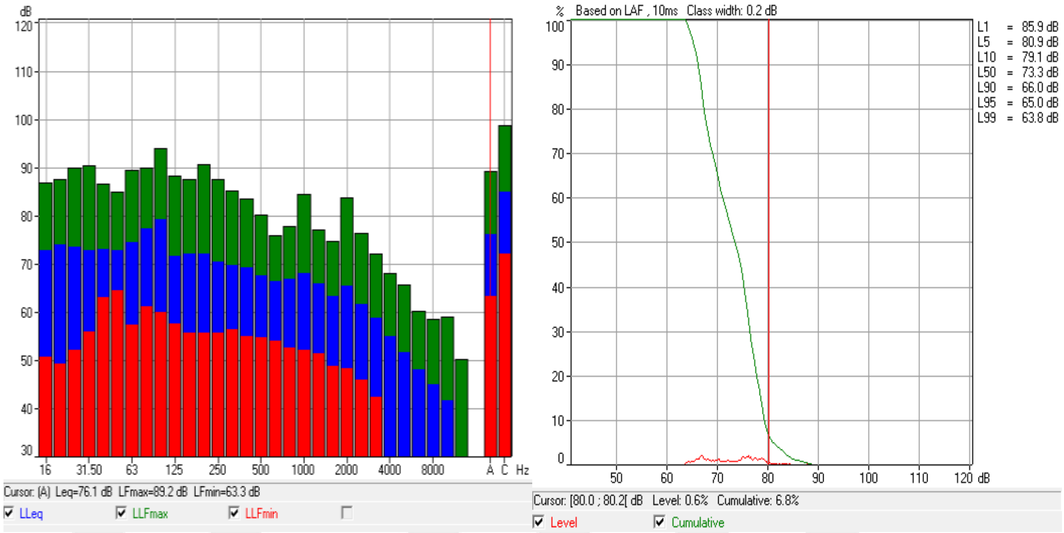
- Measurement Point 13



[a] [b]

Figure A.10. Graphical Output of Processed Measurement 13; SPL versus Frequency [a] and Percentage versus SPL [b]

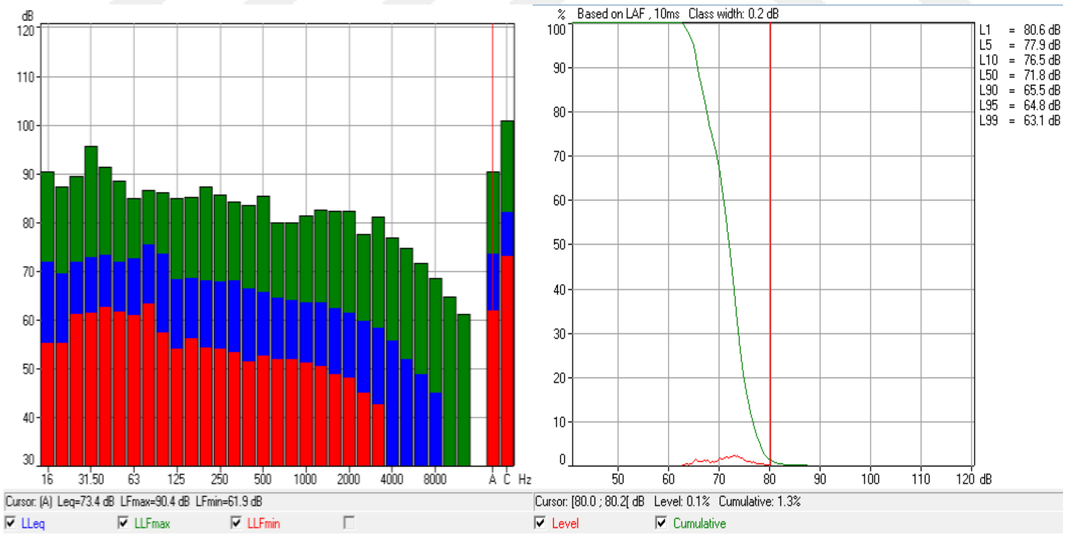
- Measurement Point 14



[a] [b]

Figure A.11. Graphical Output of Processed Measurement 14; SPL versus Frequency [a] and Percentage versus SPL [b]

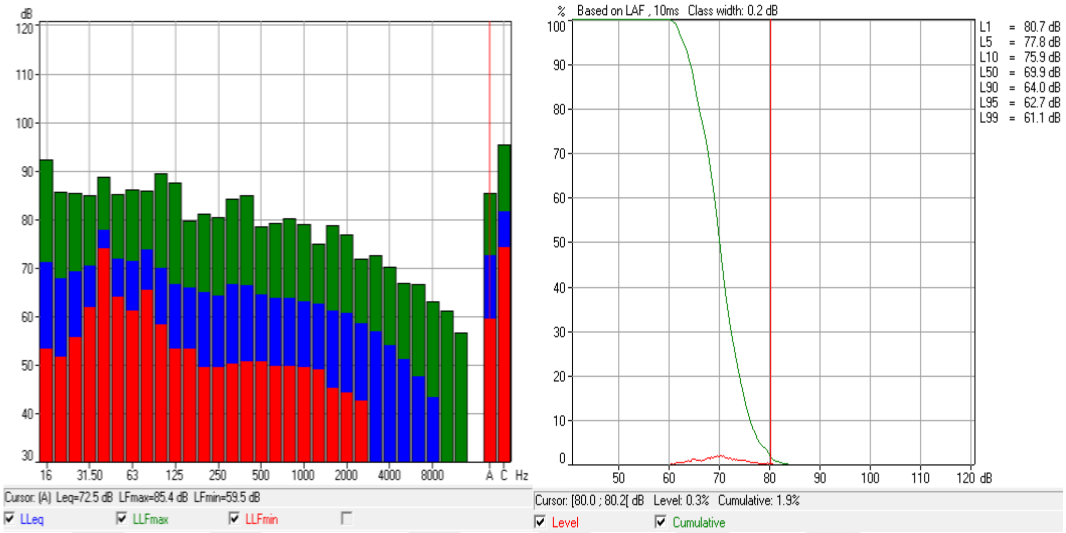
- Measurement Point 18



[a] [b]

Figure A.12. Graphical Output of Processed Measurement 18; SPL versus Frequency [a] and Percentage versus SPL [b]

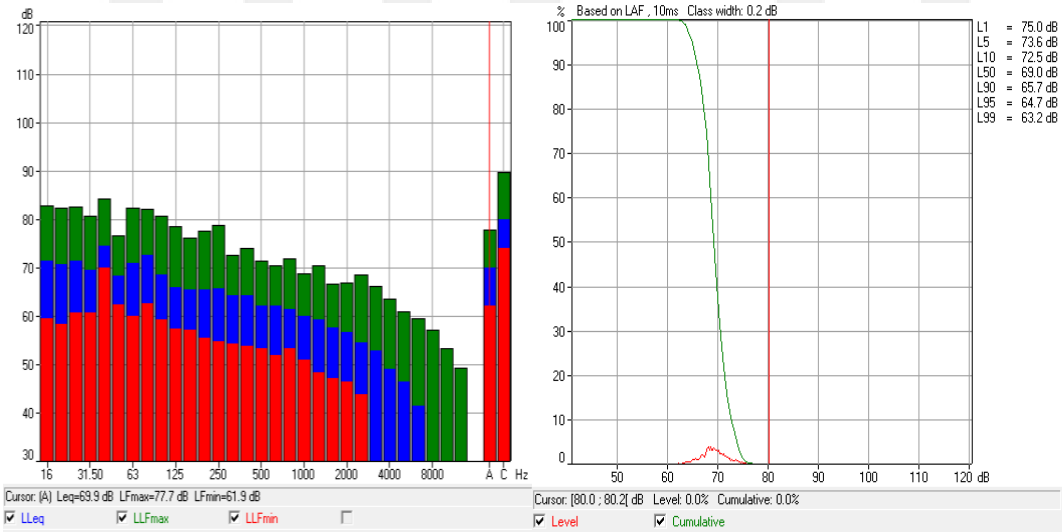
- Measurement Point 20



[a] [b]

Figure A.13. Graphical Output of Processed Measurement 20; SPL versus Frequency [a] and Percentage versus SPL [b]

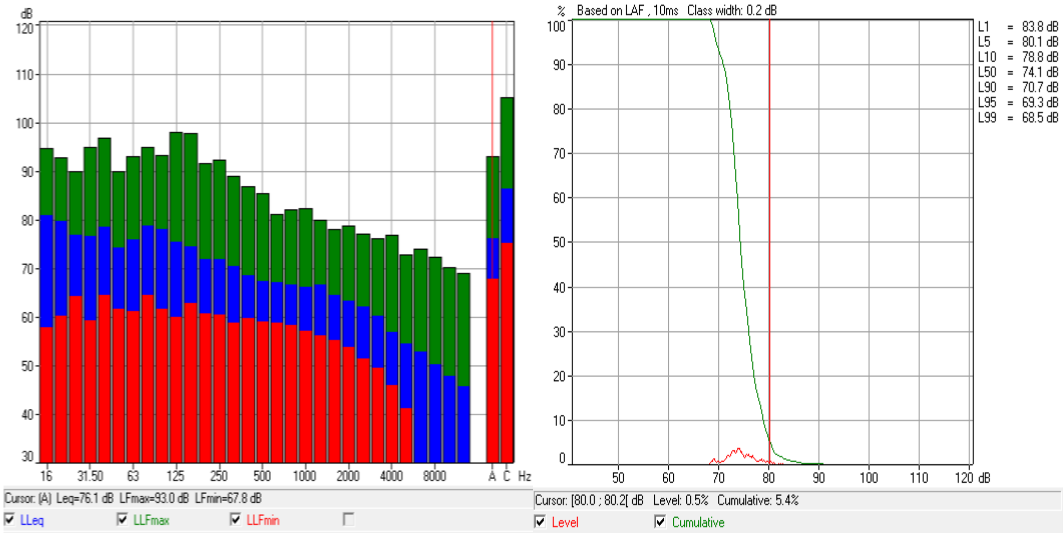
- Measurement Point 21



[a] [b]

Figure A.14. Graphical Output of Processed Measurement 21; SPL versus Frequency [a] and Percentage versus SPL [b]

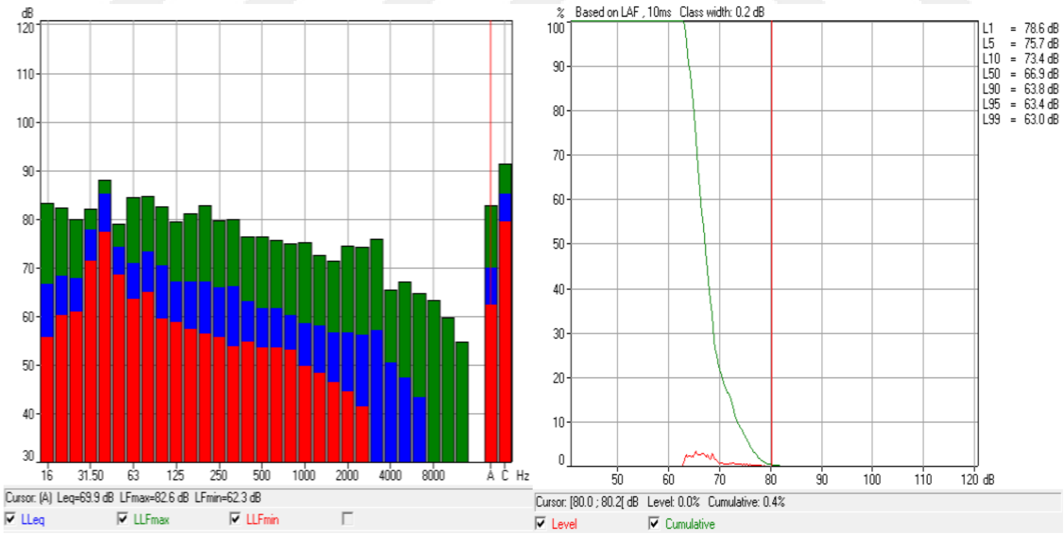
- Measurement Point 22



[a] [b]

Figure A.15. Graphical Output of Processed Measurement 22; SPL versus Frequency [a] and Percentage versus SPL [b]

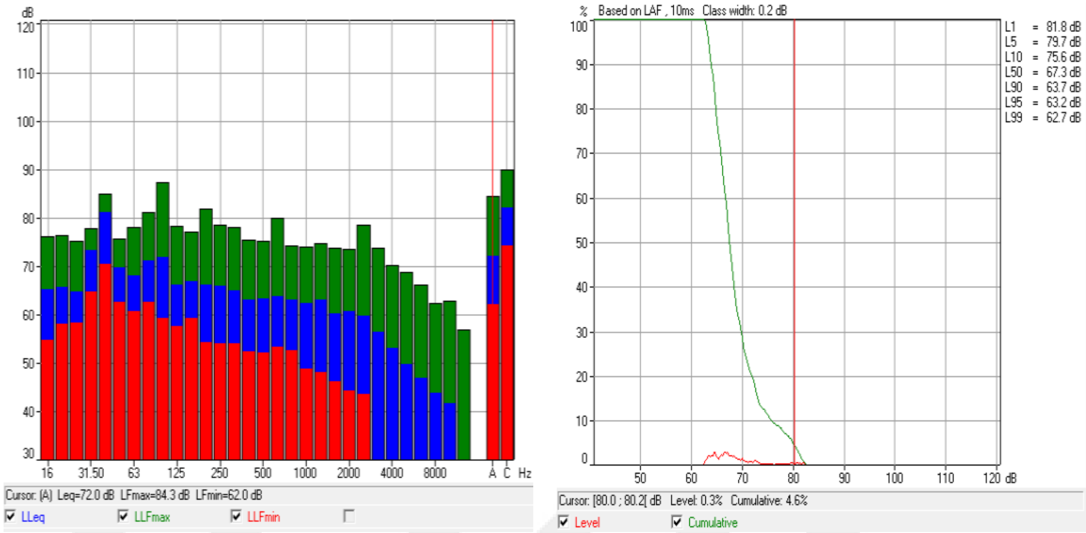
- Measurement Point 24



[a] [b]

Figure A.16. Graphical Output of Processed Measurement 24; SPL versus Frequency [a] and Percentage versus SPL [b]

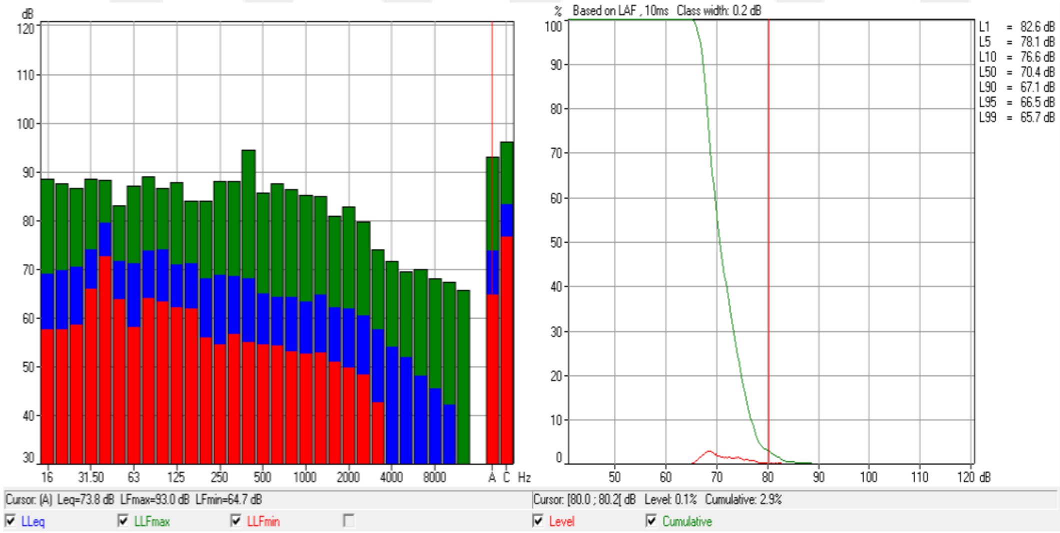
- Measurement Point 25



[a] [b]

Figure A.17. Graphical Output of Processed Measurement 25; SPL versus Frequency [a] and Percentage versus SPL [b]

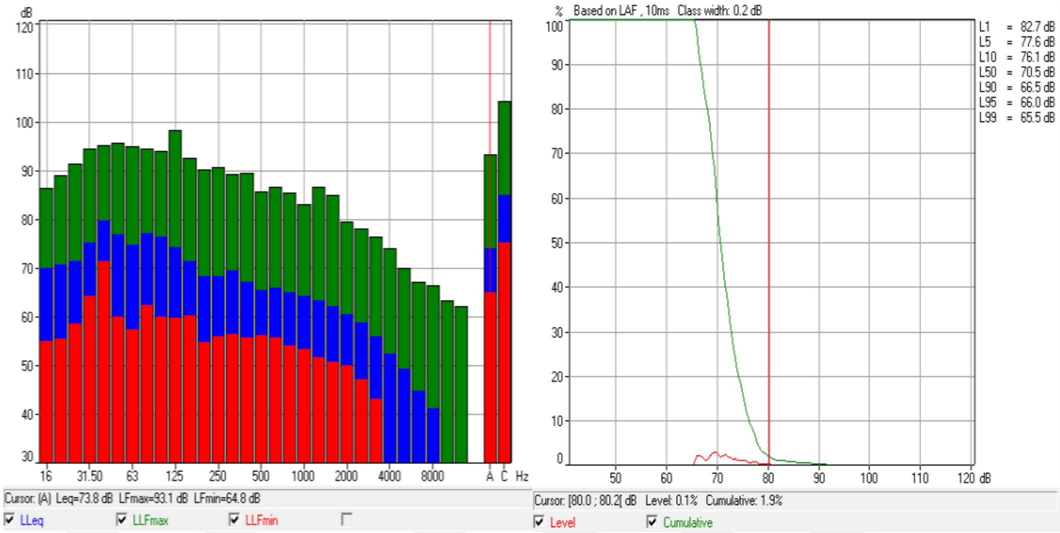
- Measurement Point 26



[a] [b]

Figure A.18. Graphical Output of Processed Measurement 26; SPL versus Frequency [a] and Percentage versus SPL [b]

- Measurement Point 29



[a] [b]

Figure A.19. Graphical Output of Processed Measurement 29; SPL versus Frequency [a] and Percentage versus SPL [b]

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