

Noise Pollution in Metalwork and Woodwork Industries in the Kingdom of Saudi Arabia

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This study was conducted in metalwork and woodwork industries in Jeddah Industrial Estate. The purpose of this study was to assess the magnitude of industrial noise exposure and to propose remedial actions. Noise was measured at different times of a day in 28 randomly selected factories and workshops. Results indicated that noise levels varied according to the type and size of a factory, and the type and number of machines used. Mean noise levels in metalwork factories were higher than those in woodwork factories. The highest noise levels were observed while manufacturing cans and forming steel reinforcement for concrete, where noise levels exceed 90 dB(A). All mean noise levels in all studied metalwork factories and in 50% of studied woodwork industries were higher than the standard level of 85 dB(A).

industrial noise metalwork woodwork noise control Saudi Arabia

1. INTRODUCTION

The importance of the relationship between noise at a workplace and workers' health, particularly hearing loss, has been described in previous studies [1, 2, 3, 4]. The selection of the studied industries in the Kingdom of Saudi Arabia has been based on the National Occupational Hazards Survey conducted by National Institute for Occupational Safety and Health (NIOSH) [5, 6, 7]. Lumber and wood, textile, petroleum, utility, metal, print and paper industries were the industries with the highest percentage of workers exposed to noise of 85 dB(A) or higher. NIOSH rates noise-induced hearing loss as one of the work-related problems involving 11 million workers in the USA [8]. Similar findings were reported by the Occupational Safety and Health Administration (OSHA) [9, 10]. According to a report from 1985, 700000 workers in the UK were exposed to noise levels exceeding the government's recommended level of 85 dB(A) [11]. The problem of industrial noise was aggravated by the use of high speed and production machines in textile mills and other industries.

This study discusses noise pollution in metalwork and woodwork factories and workshops in the Kingdom of Saudi Arabia. Previous studies described noise pollution in textile, printing and publishing industries [1], and noise in utility industries [12].

There has been great global concern about the magnitude of industrial noise exposure in metalwork and woodwork industries (in the USA [2, 3, 4, 5, 6, 13, 14, 15, 16, 17, 18, 19, 20, 21], Canada [22, 23], Japan [24], Denmark [25, 26, 27], Germany [28], Sweden [29], the Netherlands [17], Italy [30], Australia [31] and New Zealand [32, 33, 34]). In developing countries, there has been a great concern about the magnitude of industrial noise, particularly in the textile industry in Egypt, India, China, Thailand and Tanzania [1], and in metalwork and woodwork industries in the USSR/Russia [35, 36], Bulgaria [37], the Czech Republic and Slovakia [38], Poland [39, 40, 41, 42], Turkey [43, 44], Cyprus [45], Portugal [46], India [47, 48, 49, 50, 51], Pakistan [52], Malaysia, Thailand, Indonesia and Vietnam [53, 54, 55], Korea [56], Hong Kong [57], Singapore [58], Iran [59], Kuwait [60] and Ghana [61].

Results of a few studies in the Kingdom of Saudi Arabia investigating industrial noise, including a survey in the late 1980s of 78 factories in Jeddah Industrial Estate [62], showed that in 86.6% of the studied factories noise exceeded the permissible level of 85 dB(A) [63]. More detailed studies in selected industries are recommended. Ahmed, Dennis, Badran, et al. investigated the prevalence of hearing loss associated with occupational noise exposure in two plants in the eastern region of the Kingdom of Saudi Arabia [64]. Ahmed, Dennis and Ballal tested the accuracy of identifying subjects occupationally exposed to high noise levels and those with hearing loss using a noise dosimeter and a pure-tone air conduction audiometric test as the gold standards [65].

This study was part of research on noise pollution in selected high risk Saudi industries. The scope of this study includes metalwork and woodwork industries in Jeddah. The specific objectives of this study were to map noise levels in selected industrial premises belonging to metalwork and woodwork industries, to check compliance with standards on industrial noise exposure and to provide recommendations for noise reduction and health protection of employees.

2. METHODOLOGY

2.1. Selection of Factories

A list of woodwork factories and workshops, and metal processing and manufacturing industries were obtained from Jeddah Chamber of Commerce and Industry. Twenty-eight factories (15% of all factories and workshops) were selected for this study. The sample group included 14 woodwork factories and workshops, two beverage cans manufactures, two steel reinforcement forming factories, four steel sheets forming and processing factories, two factories manufacturing industrial and household metal utilities, and four aluminium forming and processing factories.

2.2. Noise Measurement and Analysis

On the basis of a plan of a factory showing the area and the distribution of machinery, each factory was divided into locations for noise measurements depending on the number, type and distribution of

machinery. The workers in the selected noise measurement locations stayed at their workstations and did not move around. Consequently, the measured noise levels represented workers' exposure. Relevant data (other than data on the type of industrial activity, type and number of machinery) such as job description and construction material of roofs, floors, walls and ceilings, were also recorded. Basic noise assessment procedures and methods for this study were performed in accordance with Standard No. ISO 1996-1:2003 [66], while calculations and adjustments for sound pressure levels were performed in accordance with Standard No. ISO 1996-2:2007 [67].

Noise at each location was measured with a sound level meter 2236 (Brüel & Kjær, Denmark). This model is a type 1, which is recommended for a field measurement because of its precision and cost-effective controls [68]. Noise was measured at workers' head level. An omnidirectional microphone type 4188 (Brüel & Kjær, Denmark) was used with the sound level meter to include noises from all sources. Calibration of instruments was checked before and after measurements [69]. The equivalent continuous noise level (L_{eq}), the maximum sound pressure level (SPL_{max}) and the minimum sound pressure level (SPL_{min}) were recorded in dB(A) during 10-min measurements at each location.

Excel was used to analysed data. Each factory was given a number between 1 and 14. Tables including L_{eq} , SPL_{max} and SPL_{min} were prepared for each factory. Mean L_{eq} , SPL_{max} and SPL_{min} were computed. For individual factories, L_{eq} , SPL_{max} and SPL_{min} were computed at the different octave bands. The same analyses were performed for each type of industry by pooling the data on related factories.

3. RESULTS AND DISCUSSION

Tables 1–2 and Figures 1–2 show mean L_{eq} , SPL_{max} and SPL_{min} of the studied metalwork and woodwork factories and workshops. The highest noise exposure in metalwork industries was in beverage cans manufacturing industries, where most recorded measurements (L_{eq} , SPL_{max} and SPL_{min}) were over 90 dB. This was attributed to

the high noise emitted during processing thin steel and aluminium sheets, and to the machines used, especially a high speed hydraulic press. The next highest exposure to noise was in steel reinforcement forming for concrete, where mean L_{eq}

was higher than 90 dB, because of the nature of the industrial operations including press cutting, shearing, press-forming, etc. In steel sheets forming and processing in manufacturing construction equipment and accessories, auto-exhaust systems,

TABLE 1. Mean L_{eq} , SPL_{max} and SPL_{min} in studied metalwork factories, dB(A).

Factory	L_{eq} (SD)	SPL_{max}	SPL_{min}
Group A: beverage cans manufacturing			
1. Jeddah Beverage Cans' Manufacturing Co.	98.3 (1.0)	99.5	96.6
2. Saudi Cans' Co. Ltd.	91.5 (1.9)	96.1	89.4
Group B: steel reinforcement forming for concrete			
3. Saudi B.RC. Al-Fadl Co. Ltd.	95.0 (2.8)	99.3	90.7
4. Saudi Reinforcing Steel Co. Ltd.	90.5 (4.0)	98.7	82.9
Group C: steel sheets forming and processing			
5. Al-Yamamah Steel Manufacturing Co. Ltd.	90.9 (5.7)	97.2	85.8
6. Saudi Exhaust Systems Co.	88.4 (5.1)	98.5	77.4
7. Al-Hamrani Industrial Group-Drum Factory	87.8 (1.2)	96.7	82.0
8. Saudi Building Systems Manufacturing Co.	86.7 (2.0)	95.2	76.8
Group D: industrial and household appliances manufacturing			
9. Shuaib Ovens Manufacturing	85.5 (1.9)	96.3	74.1
10. Al-Nasser Industrial Co.	84.5 (5.4)	94.9	73.6
Group E: aluminium forming and processing			
11. Binladen Factory for Metal Works	81.9 (4.2)	87.4	75.4
12. Al-Haramain Aluminum and Metal Factory	81.3 (4.9)	93.7	72.2
13. Binladen Industrial Co. Ltd.	80.3 (3.0)	94.0	70.6
14. Saudi German Aluminum Products	78.7 (6.7)	84.6	74.5

Notes. L_{eq} = equivalent continuous level, SPL_{max} = maximum sound pressure level, SPL_{min} = minimum sound pressure level.

TABLE 2. Mean L_{eq} , SPL_{max} and SPL_{min} in studied woodwork factories and workshops, dB(A).

Factory	L_{eq} (SD)	SPL_{max}	SPL_{min}
The Top Furniture and Wooden Decoration Industries Co. Ltd.	87.3 (2.8)	91.7	82.8
Ziziniah Carpentry Workshop	86.9 (2.6)	93.9	79.8
Al-Haddadi Carpentry Workshop	86.3 (2.3)	93.2	82.8
Al-Mutawalli Carpentry Workshop	86.0 (6.2)	95.5	80.8
Asilah Carpentry Workshop	85.6 (6.4)	94.2	77.2
Al-Aalamiyah Furniture Factory	85.6 (2.8)	91.2	81.8
Fahad Trading and Decoration Co.	85.2 (2.3)	92.8	78.4
Al-Homeyani Carpentry Workshop	84.6 (3.9)	90.4	81.3
Al-Hamid Carpentry Workshop	84.4 (2.4)	90.2	81.0
Modern Wood Factory	81.9 (5.3)	87.2	78.5
Al-Kayan Decoration Co.	81.1 (1.8)	84.9	78.5
The Carpentry Workshop for Public Buildings & Airports (Saudi Binladin Group)	81.0 (3.6)	89.9	73.6
Al-Marwan Carpentry Workshop	80.9 (2.3)	89.4	76.9
Al-Bawadi Carpentry Workshop	79.4 (3.1)	89.8	75.3

Notes. L_{eq} = equivalent continuous level, SPL_{max} = maximum sound pressure level, SPL_{min} = minimum sound pressure level.

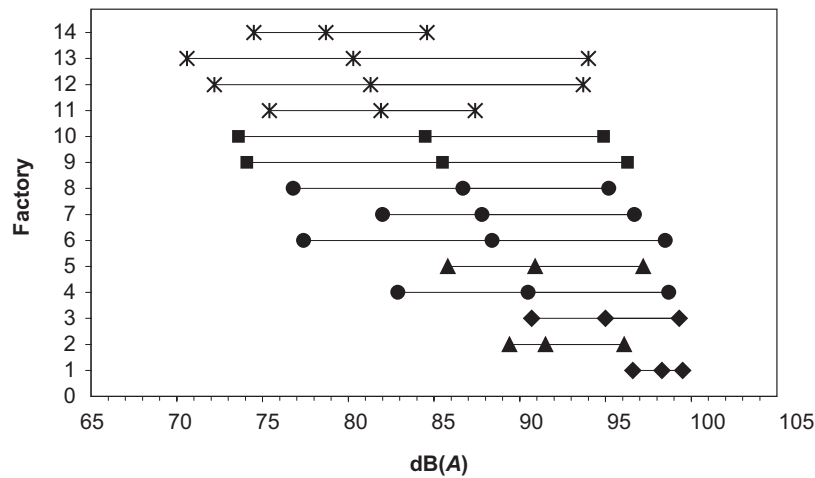


Figure 1. Mean L_{eq} , SPL_{max} and SPL_{min} in studied metalwork factories. Notes. ♦ = group A: beverage cans manufacturing, ▲ = group B: steel reinforcement forming for concrete, ● = group C: steel-sheet forming and processing, ■ = group D: industrial and household appliances manufacturing, * = group E: aluminium forming and processing.

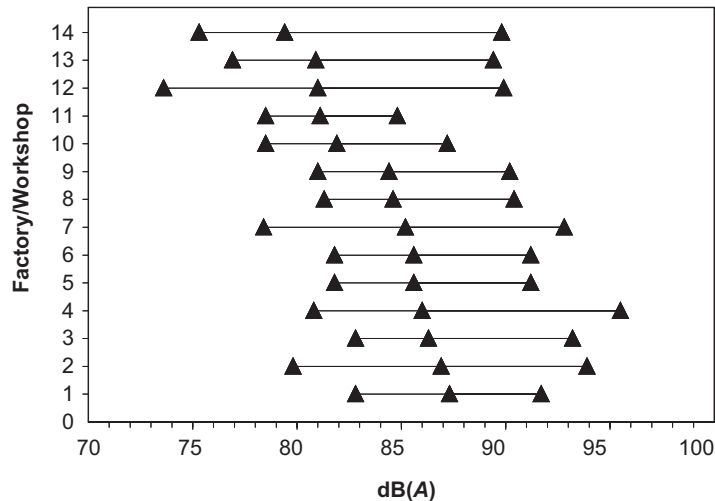


Figure 2. Mean L_{eq} , SPL_{max} and SPL_{min} in studied woodwork factories and workshops.

drums, and industrial and household appliances, mean L_{eq} was over the permissible noise exposure level of 85 dB(A) [63]. Exposure was lowest exposure in aluminium forming and processing, where mean L_{eq} was under 85 dB; however, the maximum dB(A) levels in the two studied factories were up to 94 dB (Table 1).

Mean L_{eq} in seven studied woodwork industries (two large factories and five workshops) was higher than the permissible noise exposure level of 85 dB(A). Mean L_{eq} in the other workshops was under 85 dB(A) (Table 2). The noise levels depended on the number and type of the operating machines and the number of workers at the workplace. The contribution of construction materials in the woodwork factories and workshops (i.e., on

their development of reverberant noise) to overall noise exposure was insignificant.

L_{eq} had varying degrees of variance ranging from 1.0^2 dB(A) in factory 1 to 6.7^2 dB(A) in factory 14 in the metalwork industries (Figure 1), and from 1.8^2 dB(A) in factory 11 to 6.4^2 dB(A) in factory 5 in the woodwork industries (Figure 2). The variations were higher in the metalwork industries than in the woodwork industries. For the factories with low variance of L_{eq} , general noise control and reduction techniques could be recommended. For the factories with high variance of L_{eq} , individual noise control at the sources and general measures could be recommended.

Figures 3–4 show mean L_{eq} , SPL_{max} and SPL_{min} at the different octave bands for the metalwork

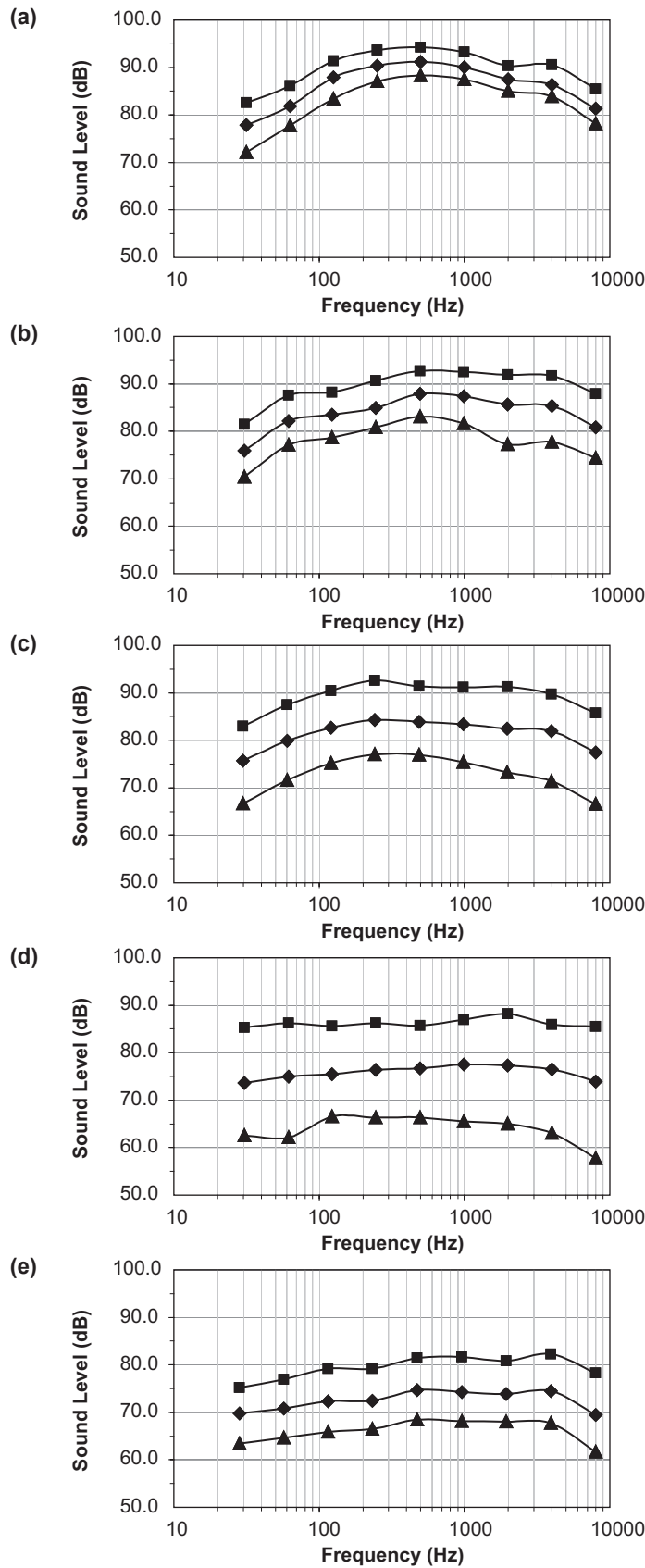


Figure 3. Mean L_{eq} , SPL_{max} and SPL_{min} at different octave bands in studied metalwork factories.
Notes. a = group A: beverage cans manufacturing, b = group B: steel reinforcement forming for concrete, c = group C: steel-sheet forming and processing, d = group D: industrial and household appliances manufacturing, e = group E: aluminium forming and processing; $\blacklozenge = L_{eq}$, $\blacksquare = SPL_{max}$, $\blacktriangle = SPL_{min}$.

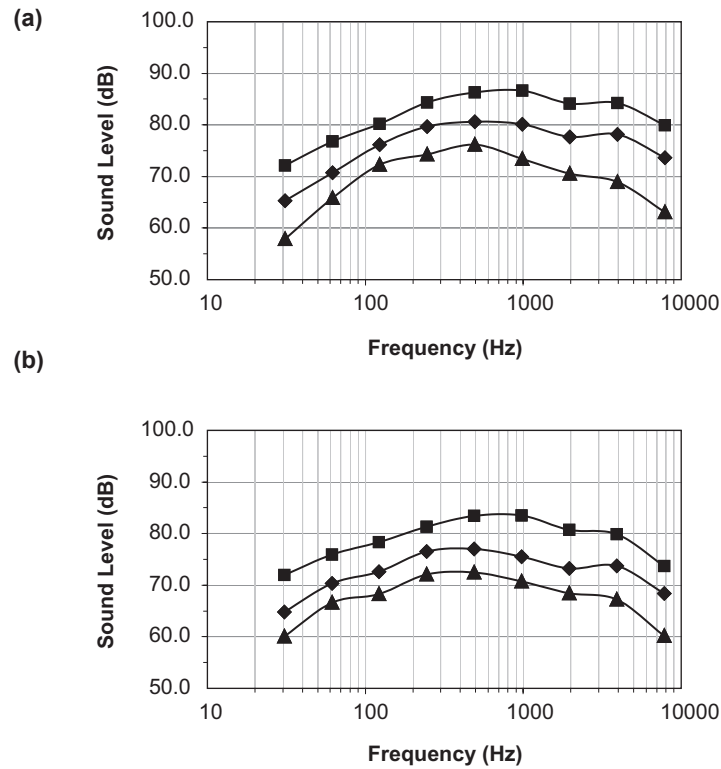


Figure 4. Mean L_{eq} , SPL_{max} and SPL_{min} at different octave bands in studied woodwork factories and workshops. Notes. a = $L_{eq} \geq 85$ dB(A), b = $L_{eq} < 85$ dB(A); $\diamond = L_{eq}$, $\blacksquare = SPL_{max}$, $\blacktriangle = SPL_{min}$.

and woodwork factories. L_{eq} at the different octave band frequencies were similar. Mean L_{eq} reported in this study was lower than the noise levels reported in previous studies in similar industries in other countries [13, 14, 16, 25, 26, 27, 28, 29, 31, 35, 55, 57]. This might result from the improved design of the machinery and factory installations in Saudi industries, since industrialization began recently, using recent machinery improvements to reduce noise emission. When the noise levels over 85 dB(A) occurred at the frequencies under 1 kHz, they steadily extended to 4 KHz and then decreased. These result are different than the results of a previous study on textile, printing and publishing industries [1]. The applied noise reduction techniques should focus on the frequencies to which the human ear is highly sensitive (3–4 kHz), and the speech frequencies (under 3 kHz). The reduction in noise at these frequency ranges will reduce the possibility of hearing loss among exposed workers. Reduced noise will interfere with workers' speech, because human speech ranges from 300 to 700 Hz and most vowels are under 1 kHz [70].

4. CONCLUSIONS AND RECOMMENDATIONS

Industrial noise pollution could be a reason of health and social problems of workers in metalwork and woodwork industries in the Kingdom of Saudi Arabia. Noise levels in most studied factories exceeded the standard acceptable industrial level. Noise control strategies should be implemented in some of these factories. The following recommendations may improve the overall situation in industries:

- Workers' exposure to noise should be identified and quantified. The risk of hearing loss does not only depend on noise levels, but also on their duration. The duration of noise exposure varies because noise varies unpredictably at the workplace and because workers move around at the workplace while performing their jobs.
- The total amount of noise to which workers are exposed while working, i.e., noise dose (L_{eq} of noise expressed in percentage of allowed exposure), should be determined. If the dose is over 100%, hot spots (i.e., sources

that produce high noise) should be identified in individual factories, particularly where mean dB(A) exceeds 85 dB in woodwork factories, and the A, B and C groups (Table 1) of the studied metalwork industries. Noise control measures such as replacing or modifying noisy machines, enclosing and/or isolating noisy sources, should be adopted. Many examples of noise control methods were described in literature [71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82]. There are also many reports on noise control in woodwork [16, 35] and metalwork industries [13, 28, 31, 57].

- When it is not possible to reduce the noise, workers whose noise doses exceed 100% (after the application of engineering noise control) should be protected. Workers should wear earplugs or earmuffs. Workers at noisy workplaces could change with workers at quieter workplaces.
- The limit of a 100%-dose will protect most workers, but not necessarily all. Methods used to protect workers may not be perfect or may not be used properly. An industrial hearing conservation programme should be tested twofold to guarantee success. Firstly, the programme directly verifies the efficacy of methods used to reduce noise or to protect workers. Secondly, it allows to detect hearing damage before a worker has difficulties in comprehending normal speech. The periodical use of such tests is an effective prevention method.
- Testing workers before they start to work in a particular factory, besides checking their personal and family health histories (i.e., pre-placement examination), is important. Firstly, tests can help to avoid placing workers who may be sensitive to noise in noisy areas, and to compare condition of hearing acuity with the initial test. Secondly, tests protect employers from responsibility for any hearing damage incurred in previous workplaces.

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