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A method to reduce wall mounted boiler noise pollution by a sustainable approach

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ABSTRACT

The mechanisms involved in the operation of the wall-mounted boilers are the primary source of noise pollution, which bothers users while operating. One of the most basic solutions is to control the amount of noise by using insulator materials. The material must have acoustic absorption characteristics and high heat resistance. In this study, four acoustic materials based on polymer resins, glass wool and stone, and jute fabrics that have good degradability in nature have been studied as noise control materials. Based on the physical and chemical properties of the acoustic insulating polymers, high noise absorption is generated and flammability is preserved at high temperatures too. The nature of acoustic absorption and high degradability is also noticeable in jute fabrics. For the shell sound control tests, several wall-mounted boilers have been used in this study, and the sound waves have been measured using a B&K 2260 measuring device. The overall rate of noise reduction in monolayer and blended double-layer insulators has been compared. Although the monolayer or double-layer insulators perform better than jute ones, the acoustic absorption standard of the wall-mounted boilers can also be achieved by using jute. Therefore, due to environmental conditions, the jute is approved as a sound insulator.

1.Introduction

Possible strategies for noise control are always available for new and emerging features and products. As a result, including noise control considerations at the design stage is always more

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cost-effective than accepting complaints about the final product and its redesign [1]. Although sound waves are an essential feature of human life as a communication factor, in some cases, and under certain circumstances, these sounds are not very welcomed. Sound waves that can be harmful to our hearing are called noise pollution [2]. Noise pollution and its associated health effects are not only confined to industrial and workplace noise. The Noise generated by the product is one of the main concerns of users. Sound pollution can disrupt human life and is a major health problem in many industries. Prolonged exposure to unwanted long-lasting noise may cause physiological, psychological, as well as basic cognitive impairments, including memory and attention disorders, and it can disturb other behavioral activities in individuals. Millions of people die from heart attacks every year, and the main cause is hypertension. The findings indicate that there is a significant relationship between noise pollution and blood pressure [2]. Noise problems can be handled by using sound-absorbing material. Another important aspect of the design is to consider the environmental impact of products. Recently, the use of green materials has been recognized by researchers and practiced. By focusing on the developed affordable and renewable materials, Jute can be considered as a natural fiber source widely available to users [3]. There are some important advantages of using natural fibers rather than synthetic ones. Natural fibers have less environmental pollution, high availability, and low cost. Also, the high diversity of vegetation in Iran and the high volume of natural fibers that remain as wastes in the environment provide an optimal source of studies in the country. Polymer-based insulators can also be of interest in this area because of their high absorbency, flammability, and direct application without any intermediate in the product.

Natural reinforced fibers are being studied by researchers because of their significant features such as being economical, biodegradable, recyclable, and environmentally friendly. Shenoda *et al.* [4] have investigated the natural fibers of Egyptian cotton as acoustic materials in various forms. It is an effective and inexpensive product with a high absorption coefficient. Satyanarayana *et al*. [5] conducted systematic research on natural fibers such as jute, quartz, and sisal and described the structure of these fibers and their relationship, including fracture methods. Besides, the studies by Shushani and Rosman House [6] determine the relationship between the sound absorption coefficient of the fabric coating and its intrinsic parameters such as fiber content, coating factor, the air gap between the fabrics, and so on. Hannah and Kendil [7] have studied the absorption coefficient of sound based on woven fabric. Previous researches investigated mechanical properties such as modulus, Poisson's ratio, and strength of non-woven reinforced polyester composites [8, 9]. The potential of renewable natural fiber sources for use in some products is also studied [10]. A comparison of natural fibers and glass fiber is made by Joshi *et al*. [11]. The results showed that natural fiber composites are more environmentally friendly than glass fiber composites. Also, in the field of audio, Zulkifli *et al*. [12-15] did significant studies on noise reduction based on natural fiber. They evaluated acoustic properties such as the absorption coefficient and the refractive index of natural coconut coir fiber [12]. Their work showed that the cavities and thickness of the air gap have great effects on the sound properties of the coconut coir sound absorption [13]. A comparison also made between coconut coir fiber and palm fiber sound properties [14]. The results illustrated that the average absorption coefficient of coconut coir fiber is 0.50 and palm fiber is 0.64. Zulkifli *et al*. [15] investigated the potential of using coconut coir fiber as a sound absorber. Sound absorption properties for other types of natural sound-absorbing materials, such as tea waste fiber, studied by Ersoy and Kucuk [16]. Kolya and Kang [17] choose most useful ten different hardwood species and analysis of basic properties, surface morphology by HR-FESEM, elemental analysis using EDAX, cellulose crystallites by XRD, air permeability by a capillary flow parameter, sound absorption coefficient, and sound transmission loss by microphones transfer function method using impedance tube is discussed in detail. Saini and *et al* [18] measured experimentally transmission loss (TL) of the natural fiber materials (jute fibers, kenaf fibers, banana fibers, coconut coir fibers, and hemp fibers) at one-third octave band harmonic and broadband frequencies. It is observed that the combination of jute-air-kenaf is absorbing more sound as compared to jute-air-banana fibers and hemp-air-coconut coir fibers. Yuvaraj and *et al* [19] studied on development of a novel acoustic panel that constitutes more natural fiber rather than a resin matrix, and the effect of perforation depth in the composite panel is investigated. It has recently shown that jute fiber and its composite have better acoustic coefficient and flammable properties in comparison to glass fibers in terms of oxygen index, flame diffusion, and smoke density [3]. Using noise measurement methods, Tandon *et al*. [20] conducted sound intensity measurements on a bicycle engine to analyze sources and to rank them.

In this research, first, the noise level produced by the wall-mounted boiler was measured using the B&K 2260 acoustic device. Then, four types of natural and industrial acoustic insulator materials, in both single layer and double layer state were studied.

2.Insulator materials

Synthetic fiber composites of glass, Kevlar, and carbon have been considered very important in the aerospace industry since the 1950s. Advancements in composite design have received considerable attention since the rise of need for aerospace has risen. Furthermore, increased use of electrical and mechanical devices at home and industry has raised concerns about noise pollution. Although synthetic polymer-based insulators have certain properties such as lightweight, high absorption, and direct use, they are not recommended because of their high cost and environmental impacts.

2.1. Foam

The polyurethane foam, studied in this research, is being used as an acoustic absorber in panels. Using acoustic foam panels is a cost-effective approach to improve sound absorption problems by reducing echo and repetition. Flexibility and being cut easily are this material’s advantages. Acoustic sound panels are not only for use on the walls of exteriors but can also be used in equipment and compartments to reduce vibration and sound emission.

2.2.Jute

Jute is one of the cheapest natural, biodegradable and recyclable fibers. It is, therefore, environmentally friendly. Jute fibers can be easily woven. They have specific modulus and are much stronger. However, their tensile strength and Young modulus are lower than fiberglass [3].

2.3. Rockwool

Another sound insulator used in this study is rock wool, which is composed of mineral fibers. That is why sometimes it is called mineral wool. Rockwool is a phenomenal type used for thermal, acoustic, and moisture insulator. The thickness of this insulator is 3 cm and its density is 80 kg / m 3. Rock wool insulator helps to reduce noise in two ways; by reducing sound transmission of components comprising structures, and by absorbing sound at the surface level. The highest amount of noise was caused by adsorption in the product we studied.

2.4.Glass wool

Gases have poor thermal conductivity compared to liquids and solids. The airflow between the glass wool fibers makes it a very strong heat insulator. It also improves the sound performance of walls, floors, ceilings, and transmission of any noise pollution by absorbing acoustic energy. This feature has made glass wool suitable for both outdoor and indoor spaces. In this study, we tried to use it to absorb the noise generated by the wall-mounted boiler. Glass wool is a type of acoustic heat insulator consisting of recycled materials made of melted glass with some ordinary sand and resin [21]. The density of glass wool used in this study is 40 kg / m3 and its approximate thickness is 2 cm.

Rock wool and fiberglass are not flammable. Rock wool temperature tolerance above 750 ° C and its melting point is 1300 degrees Celsius. Fiberglass, on the other hand, has a lower thermal resistance and its performance reaches up to 250 ° C. It should be noted that elastomeric insulation, which is part of Class B1 insulation, is non-flammable. Jute-based insulation, which is made of 100% biodegradable fibers, is not fireproof, but with the use of refractory silicone adhesives, its thermal resistance can be increased up to 650 ° C.

3.The standard level of sound

Table 1 shows the sound intensity standard in household products. Various products are discussed in this table, one of them is the wall-mounted boiler. As shown in the table, the sound intensity level for this product is set at an average of 62.8 dB.

4. Test method

The hardware used in this experiment is illustrated in Fig. 1, which was used for measuring and analyzing sound waves, b&k 2260 and bz7210 software. The connection cable between the device and the computer is the RS232 computer and the software used to transfer data is 2260 Investigator Link. The case study was a wall-mounted boiler shell and a single source of sound with the same and constant sound level during pre and post insulation tests under the standard of ISO3747-ISIRI 6186 [22] for measurement.

Table. 1: Home appliance Sound Intensity Standard *[23]*

Appliance		Minimum	Average	Maximum
	Slow	58.6	66.1	71.4
Food mixers:	Medium	62.4	71.9	83.2
	Fast	67.4	77.4	85.2
Food mixer	Slow	57.4	62.2	66.4
Liquidizer	Medium	69.6	73.4	75.4
Attachments	Fast	75.4	78.2	80.8
Purpose-built liquidizers		87.2	88.6	89.6
Whistling kettles		68.8	80.8	93.4
Washing machines:	washing	54.0	66.3	73.6
	drying	64.0	72.2	77.6
Hot- air tumble-drier		-	62.6	-
Spin driers		69.2	71.9	74.4
Extractor fans		55.8	58.5	59.8
Dishwasher		-	70.6	-
Waste disposal unit		-	66.6	-
Gas cookers		37.4	44.4	53.8
Gas fires (full on)		28.0	34.3	41.5
Gas water heaters (wall mounted)		58.8	62.8	66.0
Vacuum cleaners		67.0	76.5	82.8
	Fan only	40.6	45.5	52.8
Fan heaters	1kW	37.2	45.7	53.0
	2kW	41.2	47.3	53.4
	3kW	47.0	49.2	51.4
Hair driers:	Hot	65.4	70.9	77.6
	cold	63.2	69.9	79.0

Experiments were conducted at the sound room of the Tabriz Islamic Art University. Before the test began, to ensure the room was acoustic, all noise was measured and recorded numerically that values were near zero. Experiments were carried out inside an acoustic chamber measuring 2x2x2.5 m with wood insulator panels. During the test process, the distance between the device and the case study was set at 20 cm (Fig. 2). The set time for the test was 1 minute and the sound level range was between 80.1 and 0.1 dB, which were considered constantly throughout the experiments. After inserting the source into the shell, the entire set was positioned on the ground.

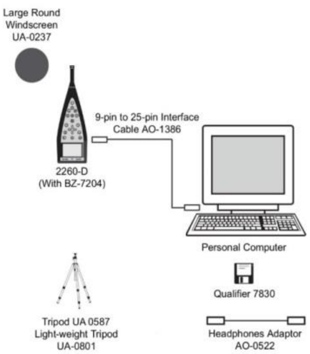

Fig.1*:* General illustration of the system used for sound testing and analysis

Fig.2*:* Test location

The first experiment was performed without any insulation, and the only obstacle between the sound source was the wall-mounted boiler body. Figure 3 illustrates the sound level spectrum at different frequencies in the first experiment performed without insulation. As it is illustrated, at some frequencies, the sound level is higher than the standard average (62.8 dB) presented in Table 2, and boiler insulation is required.

Four types of materials (foam, glass wool, rockwool, and jute) were prepared as sound insulators of equal thickness. These materials are single layer and double layer respectively, which are a combination of two types of materials according to Table 2. The difference between foam-jute and jute-foam modes is that the first layer is close to the sound source and the second layer is attached to the body. All conditions in these tests were assumed to be identical to those of the first experiment, with only acoustic insulation applied to the body during the tests.

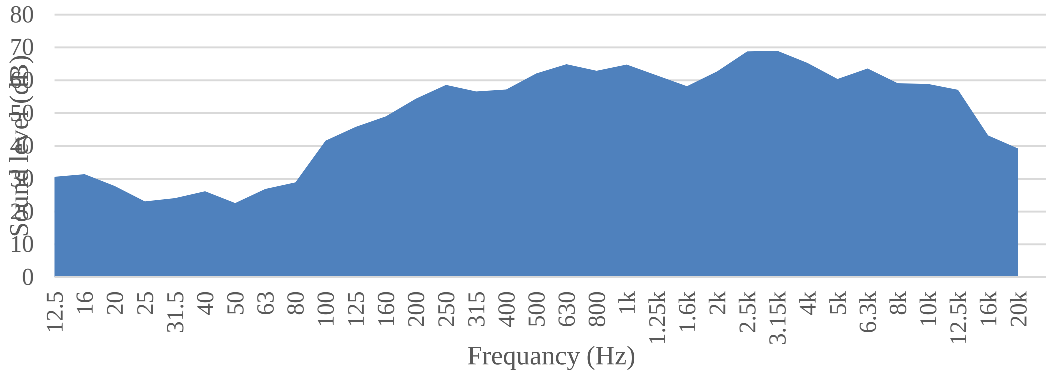

Fig:3. Sound level spectrum at 1/3 octave frequencies for the first experiment in the non-insulated mode

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Table: 2. Material use cases to cover the inner surface of the boiler

	state	Type
foam	1	Monolayers
Jute	2	
glass wool	3	
Rockwool	4	
Foam - glass wool	1	Double layer
Glass-foam wool	2	
Jute-foam	3	
Foam-jute	4	
Rockwool - glass wool	5	
Glass wool - Rockwool	6	
Jute - glass wool	7	
Glass-jute wool	8	
Rockwool - Jute	9	
Jute - rock wool	10	
Foam - Rockwool	11	
Wool - Foam	12	

5. Results

Table 2, shows the materials studied in this research in a single layer form. All of them covered the inner surface of the boiler. Figure 4 illustrates the sound level spectrum at frequencies of 1/3 octaves for single-layer insulator experiments. Because of the large number of frequencies in the soundtrack spectrum chart, and the difficulty of comparison, the below graph of the material is calculated and compared in Table 3. According to Figure 4, rockwool has a better performance as a monolayer than other materials.

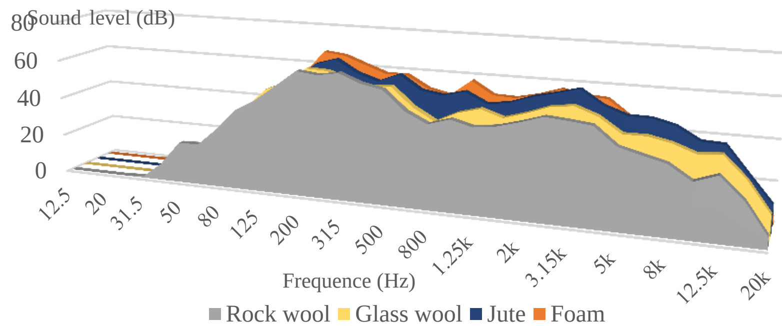

Fig: 4. Sound level spectrum at 1/3 octave frequencies for single-layer insulation experiments

Table. 1: The below diagram level of the sound level spectrum at 1/3 octave frequencies for single-layer insulation experiments

Material	Rockwool	Glass wool	Jute	Foam
Graph area	634245	743479	798177	686400

Also, according to Table 2, the 12 modes of materials studied. They coated the entire inner surface of the boiler body in a double-layer form. Figure 5 illustrates the sound level spectrum at frequencies of 1/3 octaves in double-layer insulation experiments. The area below the graph of the 12 double-layer materials is also calculated and compared in Table 4. According to calculations, the foam-rock wool has a better performance than the other materials as a double-layer acoustic insulator.

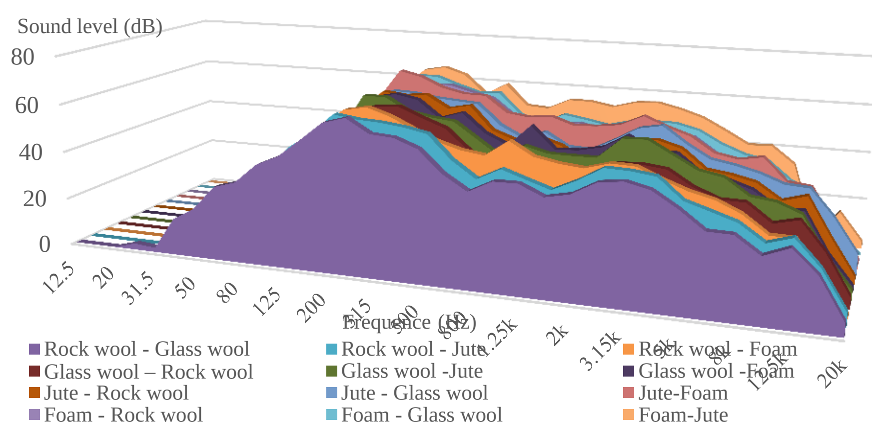

Fig. 5: Sound level spectrum at 1/3 octave frequencies for double-layer insulation experiments

Table. 4: Graph area of the sound level spectrum at 1/3 octave frequencies for double layer insulation experiments.

Material	**Rock wool - Foam**	**Foam – Rock wool**
Graph area	581634.4	529496.8
Material	Jute- Rock wool	Rock wool - Jute
Graph area	628562.15	622529.95
Material	Glass wool -Jute	Jute - Glass wool
Graph area	646972.5	685429.58
Material	Glass wool –Rock wool	Rock wool - Glass wool
Graph area	624942.45	598878.53
Material	Foam-Jute	Jute-Foam
Graph area	573986	662922
Material	Glass wool -Foam	Foam - Glass wool
Graph area	609077	563345

The sound spectra levels of different materials are compared; however, by comparing each sound level of 1/3 octaves and the standard average (62.8 dB) presented in Table 2 we can conclude the following results:

Jute or glass wool can be used as a double-layer insulator because the sound levels of both in the frequency bands exceed the standard average.

The use of foam or rock wool as a single layer insulator is not recommended, because the sound level of 200 and 250 Hz for foam and 200 and 315 Hz for rock wool is above the standard average. Therefore, although rock and foam wool generally perform better, it is recommended to use glass and jute insulators to achieve the standard of the wall-mounted boiler, considering the frequency. Jute is also emphasized because of its biodegradability and naturalness. The use of rockwool-jute or glass wool-rockwool or jute-rockwool or jute-glass wool or foam-rockwool is permissible as an insulator because the noise in the frequency bands is no more than the standard average. Therefore, according to the findings of the present study, jute can be a more effective option as a sound insulator.

6. Conclusion

Our findings demonstrate, due to environmental conditions, natural jute fibers can be utilized as a good sound insulator in single-layer forms as well as in double-layer ones with other investigated materials. Other features of this material, such as the ability of spinning, formability, and low price, make it a sound-absorbing material and can be recommended as a sound insulator in home appliances and industrial products.

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