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Legal and Ethical Accountability in Occupational Safety: An Evaluation of Compliance Gaps Regarding Noise Hazards in Plastic Recycling Operations

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ABSTRACT

The study aims to examine measures that can be used to mitigate noise hazards at a Plastic Recycling Company considering the dangers caused by exposure to high sound intensity in grinding plastic materials. With a research design that involves ergonomics, planning, and barrier simulation, the study finds that the noise level was 111.56 dB and the noise dose was 1967% in 8 hours. Some of the methods applied include the use of vibration dampening pads and visual indicators as well as different barriers to noise. The findings reveal that the combination of noise reduction blanket, gypsum board, and mineral wool is the best barrier for mitigating noise problems as it brings down the noise level to 88.35 dB and the noise dose to 85.38%. Moreover, the cost-effectiveness study suggests that there are substantial savings in medical compensation and regulatory fines.

Keywords: *Occupational Safety, Noise Mitigation, Plastic Recycling Operations, Sound Pressure Level (SPL), Noise Dose, Ergonomic Assessment, Barrier Simulation, Hierarchy of Controls, OSHA Standards, Acoustic Barriers, Cost-Benefit Analysis, Regulatory Penalties, Compliance Gaps*

INTRODUCTION

Hearing is the primary sense through which individuals perceive their surroundings; it is through auditory perception that people interact with their environment, facilitate interpersonal communication, articulate ideas, and acquire knowledge (WHO, 2021). Consequently, auditory stimuli account for at least 10% of a human's total information intake. (Man D., & Olchawa R., 2018) Despite this significance, noise control remains a frequently overlooked aspect of industrial safety, even though noise is recognized as a major occupational risk factor for hearing loss, one of the most widespread occupational diseases globally. (E.I. Denisov, 2018). In many industrial settings, noise levels reach intensities that constitute significant health hazards. (Prashanth, K. M., & Sridhar, V. (2008). Constant noise is an unavoidable reality that fundamentally impacts their daily lives and future health. (Li X. et al., 2019) Research also emphasizes that the consequences of noise exposure extend far beyond auditory impairment, triggering complex physiological and psychological reactions that diminish workplace productivity and compromise overall employee wellness. (Burns et al., 2019) & (Masullo et al., 2022).

The impact of noise on a workforce is primarily determined by three critical factors: the intensity or perceived loudness, the duration of exposure, and the frequency or pitch. These factors can cause distracting negative emotions, disrupt sleeping patterns, and even trigger "startle responses" that interfere with essential cognitive processes such as attention and critical thinking. (Kryter KD, 2023)

The plastic recycling company is currently dealing with serious safety risks in its grinding operations, where noise levels far surpass regulatory standards. Internal reviews show that employees are working in environments that exceed the OSHA limit of 90 dB for an eight-hour workday. With recorded peaks reaching 111.56 dB, the site has documented a noise dose of 1967%, representing a massive violation of safety thresholds and a severe threat to worker health.

There are two key issues that are bound to arise when considering occupational safety in the plastic recycling industry. These include the installation of highly efficient engineering controls and effective management systems. While engineering controls are used to tackle technical hazards, such as mitigating dangerous sound pressure levels, a management system will deal with the human and organizational components of workplace safety, which require high levels of leadership in achieving favorable results (Balagtas & Mallari, 2025; Cayanan et al., 2025). In essence, as indicated in the latest studies in management, the utilization of varied approaches, such as democratic and innovative leadership, significantly determines the efficiency of organizations and their safety performance.

A disregard for these noise hazards will result in both ethical and legal issues. Biologically, employees may suffer from hearing problems that range from temporary threshold shift to permanent NIHL. However, legally and ethically, the failure of organizations to observe safety standards will attract harsh penalties from relevant authorities, including huge financial penalties from the government and considerable liabilities with respect to medical care.

Objective of the Study

The main objective of this study is to evaluate compliance gaps and test the efficacy of noise improvement interventions at the Plastic Recycling company.

To achieve the general objective, the study seeks to:

a. Determine the total sound pressure level and current noise dose for workers in the facility.
b. Evaluate the effectiveness of various soundproofing materials and combinations through on-site simulations.
c. Identify the most cost-efficient and effective noise reduction solution to meet OSHA standards.
d. Perform a cost-benefit analysis comparing implementation costs against potential legal penalties and injury compensation.

Significance of the Study

This research shows how important it is for employees to feel at work and for the workplace to get things done. When we deal with risks related to noise it helps us see how specific actions to keep workers safe can meet the rules and do two things: keep workers safe and make sure they can keep working well. For the Plastic Recycling Company, the application of these strategies reduces the chances of being held liable and incurring huge costs for injury and fines (Abad, J. M. 2026). Apart from this benefit, there is evidence that companies with strong safety cultures exhibit increased efficiency levels coupled with minimal downtimes (Bernal, I.B. et al., 2024). The implementation of safety strategies provides workers with security and safety, which protects them from health risks such as exposure to noise hazards.

In addition to safeguarding worker health, the study demonstrates how the Hierarchy of Controls can be applied in practice. It shows how engineering solutions, such as acoustic barriers, can be complemented by administrative measures like visual indicators, offering a comprehensive approach to occupational safety. For management, the cost-benefit analysis underscores a compelling financial case. The most effective barrier produced a return ratio of 2.17, demonstrating that upfront investment in noise control translates into significant savings by reducing fines, compensation claims, and productivity losses.

Finally, this study lays the groundwork for future research. It offers a technical framework that others can use to simulate and assess the effectiveness of acoustic materials in hazardous recycling environments.

METHODS

Research Design

This study utilized a descriptive and developmental research method to systematically evaluate and mitigate occupational noise hazards within the Plastic recycling environment. The researchers followed a three-phase systematic approach designed to identify compliance gaps and test the efficacy of engineering interventions.

- ***Phase I: General Ergonomics Assessment of the Facility*** **-** This diagnostic phase involved ocular visits, one-on-one worker interviews, and initial noise level monitoring to establish the baseline acoustic environment and identify specific safety concerns.
- ***Phase II: Improvement Proposal Making and Planning*** **-** Utilizing the Hierarchy of Controls framework, this phase focused on brainstorming and designing feasible solutions, ranging from administrative visual indicators to complex engineering barriers.
- ***Phase III: Barrier Simulation*** **-** An experimental simulation was conducted to test the performance of various soundproofing material combinations (e.g., gypsum, wool, and acoustic blankets). This allowed for a comparative analysis of noise reduction efficiency before and after intervention to ensure the final recommendations met OSHA and OSH standards. (OSHA, 2023)

By integrating qualitative worker perceptions with quantitative noise dosimetry, the design ensured a holistic evaluation of both the legal and ethical accountability of the facility's safety operations.

Population and Sample of the Study

The research population consists of the industrial workforce in a Plastic Recycling Company.

The sample includes Eleven (11) Male workers from the grinding facility who participated in one-on-one interviews. The respondents included both probationary and regular employees.

Sampling size consideration was done in accordance with the number of employees needed in the production line in order to complete one cycle of production from receiving plastic rejects through packing of the final reprocessed materials or regrind plastic materials.

Research Instruments

To ensure the precision and reliability of the data, the study utilized three (3) primary instruments for data collection:

1. ***Digital Sound Level Meters (Extech 407730)*** **-** Used for gathering precise noise measurements
2. ***Structured Questionnaire****-* Adapted to evaluate workplace attitudes and perceptions.
3. ***Mathematical Formulas-*** Used to calculate total sound pressure level (SPL), permissible duration of exposure (T), and noise dose (ND).

Data Collection Procedure

The data collection procedure was executed through a systematic, multi-stage process to ensure the accuracy and reliability of the acoustic analysis.

Initially, the researchers conducted ocular visits and one-on-one interviews with facility personnel to understand operational workflows and identify perceived safety hazards. To establish a quantitative baseline, noise measurements were gathered using an Extech 407730 Digital Sound Level Meter, targeting the three primary grinding lines during active operation. These recordings were taken at standardized

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distances of one (1) meter and three (3) meters from the noise sources for a duration of 15 seconds per trial, specifically ensuring that only the machine being tested was active to prevent cross-line interference.

Following the baseline assessment, the procedure transitioned into an experimental simulation phase where various soundproofing material combinations, including gypsum board, mineral wool, mass-loaded vinyl, and acoustic blankets, were installed on a customized barrier frame. Data was again collected at the same one-meter and three-meter intervals to provide a rigorous basis for comparison.

Throughout the process, the researchers maintained operational continuity by coordinating with facility workers to collect data without disrupting production schedules. Final data points were recorded in decibels (dB) and subsequently used for the calculation of total sound pressure levels and cumulative noise doses.

RESULTS AND DISCUSSION

The analysis of the data collected from the Eleven (11) workers operating in the Plastic Recycling facility provides a complete study of the impact of the existing noise levels exposure, along with the management-driven safety measures on the future health and status of the workers. The following discussion is a perfect illustration of the compliance gap existing between the regulatory policies and the practical operations in the workplace.

Assessment of Baseline Sound Pressure Levels and Worker Noise Dosage

The initial phase of the study focused on quantifying the acoustic environment to establish a baseline for worker risk.

Interview Responses

Variable	Subcategory	Percentage (%)
Age	18 – 24 years old	27.27
	25 – 34 years old	36.36
	35 – 44 years old	18.18
	45 – 54 years old	18.18
	55 – 64 years old	-
	65+ years old	-
Height	5'0" – 5'2"	18.18
	5'3" – 5'5"	27.27
	5'6" – 5'8"	36.36
	5'9" – 5'11"	18.18
	6"0" +	-
Working Hours	8 hours	100
Smoker	Smoker	63.6
	Non-Smoker	36.4
Family History	Asthma	9.09
	Gout	9.09
	High Blood	27.27
	None	54.55

Table 1. General Profile of the respondents (N=11)

From the general demographics and health profiles of the eleven (11) workers at the Plastic Grinding Facility (N=11) from Table 1, the following health characteristics were noted:

- ***Age Distribution:*** The majority of workers (36.36%) fall within the 25–34 age range.
- ***Physical Characteristics:*** Regarding height, the largest group of respondents (36.36%) stands between 5'6" and 5'8". Smaller percentages are represented by heights of 5'3"–5'5" (27.27%), 5'0"–5'2" (18.18%), and 5'9"–5'11" (18.18%).
- ***Working Conditions:*** Every worker in the sample consistently works a full 8-hour shift.
- ***Lifestyle Factors:*** A significant majority (63.6%) of the workforce are smokers, while 36.4% are non-smokers.

- ***Health and Family History:*** While over half of the respondents (54.55%) reported no relevant family medical history, nearly a third (27.27%) cited a family history of high blood pressure. Asthma and gout were each reported by 9.09% of the participants.

Attitude and Perception of the Workplace

Question	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
I am overall satisfied with the working conditions and environment of my job	-	-	9.1	63.6	27.3
The workstation design is easily accessible and maneuverable	-	-	18.2	36.4	45.5
I am satisfied with the equipment in the facility	-	-	9.1	18.2	72.7
The working environment is comfortable	-	-	18.2	36.4	45.5
The equipment is difficult to use and operate	54.5	36.4	-	9.1	-
We have sufficient ventilation and air condition at work	-	-	18.2	45.5	36.4
The brightness of the lights in the facility are too dark and make it difficult to see clearly	72.7	9.1	9.1	9.1	-
There is a lot of noise caused by the machinery that is uncomfortable	36.4	18.2	18.2	27.3	-
I am exposed to a lot of harsh chemicals, heat, and radiation	36.4	18.2	18.2	18.2	9.1

Table 2. Attitude and Perception of the Workplace. (N=11)

The data provided in Table 2 presents an evaluation of worker attitudes and perceptions regarding their workplace at a Plastic Recycling Facility, based on a sample of 11 respondents.

The majority of the respondents regard the facility as being comfortable to work in considering its environment and the equipment that has been put in place by the firm. However, out of the various challenges faced by the employees, 27.3% consider noise as being uncomfortable, whereas 54.6% regard noise as being irrelevant.

The responses suggest that many workers view noise as something they simply adapt to, rather than a hazard requiring intervention. This attitude reflects a normalization of risk that undermines compliance with safety standards.

Ergonomic or Work Safety Concerns in the Workplace

Question	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
I experience a lot of sweating and often feel dehydrated at work	63.6	36.4	-	-	-
We have the proper equipment to tackle any issues of noise or air pollution (earbuds, etc.)	-	9.1	-	27.3	63.6
My back tends to hurt often because I slouch a lot at work	63.6	27.3	9.1	-	-
We have the proper equipment to tackle any issues of harsh chemicals and excess heat or radiation (proper suits, gloves, proper handles, masks, etc.).	-	-	9.1	81.8	9.1
I have gotten sick several times ever since I started working at this facility.	81.8	9.1	9.1	-	-

Table 3. Ergonomic/Work Safety concerns in the Workplace. (N=11)

The table 3 presents views of the respondents on the state of their health and availability of safety gear.

The majority of the respondents (89.9%) are in agreement that the personal protective equipment that they have is enough to cope up with the hazards encountered while on duty. Respondents agreed that while current protective equipment is adequate, higher-quality gear would be preferable if available.

Moreover, one of the respondents claimed that he had lost his hearing capabilities as a result of being inside the facility for several years. He never had himself checked in any hospital for his hearing problem despite feeling that it had caused him pain in his ears.

Question	Subcategory	Percentage (%)
After a day of work, what are the body parts that hurt/feel sore?	Back and Feet	9.1
	Back and Forearm	9.1
	Forearm	9.1
	Thighs	9.1
	None	63.6

Table 4. Ergonomic/Work Safety Concerns in the Workplace (Follow up). (N=11)

In Table 4, the workers were also asked if they experienced body pains after working a single shift. The most reported body ache among these workers was that of their back and forearms, and they reported 27.3% to consider it a problem which reoccurs at work. Workers acknowledged recurring discomfort, such as back and forearm pain, but often regarded these issues as unavoidable aspects of the job.

Technical Design

To reduce equipment noise, the proposed design involves installing barriers that enclose the back and sides of the machine. The front will remain open to allow operators to access the platform for feeding plastic materials into the processor. At the request of the company, the sides of the platform will also remain unobstructed to ensure the worker's range of motion is not restricted. Additionally, a top cover will be installed on the machines to block sound from reflecting or diffracting off the corrugated metal roofing, which would otherwise redirect noise back toward the staff.

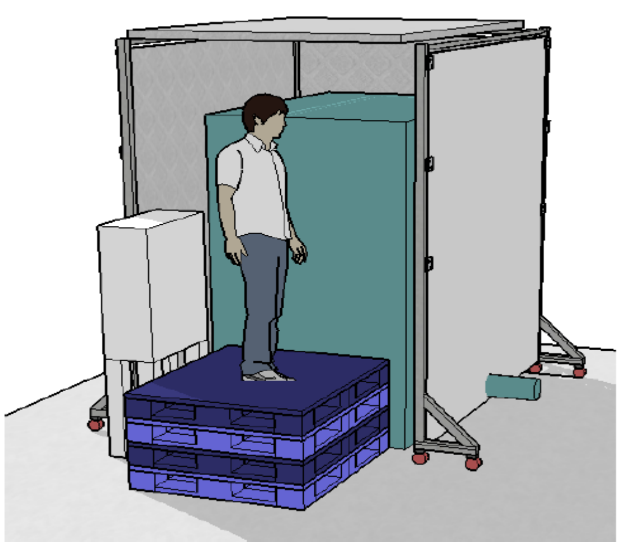

Figure 1. *Barrier Design Draft*

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The construction of each partition will involve a combination of various materials and specialized noise blankets intended to maximize sound absorption. Despite these plans, the company has restricted production to a single prototype because of constraints regarding both time and funding. This barrier will serve as a test case to evaluate the effectiveness of different design features and material configurations before further implementation is considered.

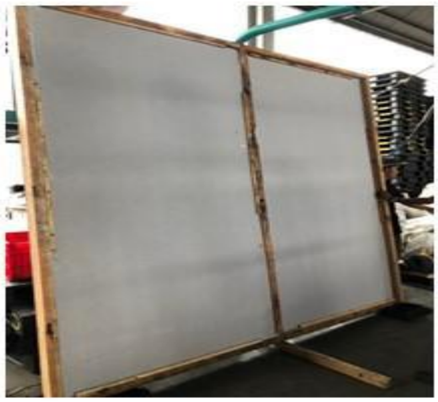

Figure 2. *Barrier Design (Actual)*

Noise Measurement Analysis

The proposed testing configurations are divided into two primary groups to evaluate different material combinations. The first set of experiments on Line 1 focuses on Gypsum Board as a base, comparing it against more complex layers that incorporate Rockwool, Foam, and Mass Loaded Vinyl to measure sound insulation.

The second series of tests on Line 3 explores the efficacy of Cork as a primary material. These variations range from simple single and double layers of Cork to multi layered assemblies that include Mass Loaded Vinyl and Gypsum Board. Furthermore, the tests will assess the performance of specialized Noise Reduction Blankets, both as standalone solutions and when combined with Wool or the full composite of Cork, Vinyl, and Gypsum Board.

Testing was conducted based on machine availability to prevent any disruption to the recycling facility's workflow. The Researcher used an Extech 407730 Digital Sound Level Meter to capture noise levels both before and after installing the barriers, allowing for a direct comparison of their effectiveness. These recordings were taken at distances of one and three meters over 15 second intervals, with only the target machine running to ensure data precision.

Despite these efforts, several limitations impacted the absolute accuracy of the findings:

- **Inconsistent Data Grouping:** Differences in the two data sets made direct comparisons difficult, as external environmental factors likely influenced the initial baseline readings.
- **Partial Enclosure:** Because the barriers only covered one side of the equipment, noise could still leak into surrounding areas, skewing the overall sound measurements.
- **Time Constraints:** To avoid hindering production, recordings were limited to 15 seconds, which is insufficient for capturing the true maximum noise levels. A more reliable standard would involve at least 30 minutes of continuous monitoring.
- **Variable Machine Load:** The intensity of the noise fluctuated depending on the volume of plastic being processed, which, combined with the short testing window, may have altered the results.
- **Unstable Installation:** Since the barriers were not permanently fixed, they had to be held in place manually or by a forklift, leading to potential inconsistencies in placement.

To fully understand the facility's acoustic environment and develop appropriate solutions, it is essential to calculate the total sound pressure level, the allowable exposure duration for those levels, and the cumulative noise dose. These values are determined using the following three mathematical formulas:

$$SPL_{tot} = 10\log(\sum_{i=1}^{n} 10^{0.1SPL_i})$$

Figure 3. *Formula for Total Sound Pressure Levels (SPLtot)*

$$T_{pde} = \frac{8}{2^{0.2(SPL-90)}}$$

Figure 4. *Formula for Permissible Duration of Exposure (Tpde)*

$$ND = 100\sum\frac{T_{ex\ j}}{T_{pde\ j}}$$

Figure 5. *Formula for Noise Dose (ND)*

Given:

Decibels (dB) taken - 1st Visit	**Average Machine Run-Time (taken from Historical Data)**
Line 1 - (Leq) - 108 dB	4.8 Hours
Line 2 - (Leq) - 108.1 dB	5.4 Hours
Line 3 - (Leq) - 101.9 dB	6.3 Hours

During an 8-hour shift, the workers are exposed to three different noise sources, 108.00 dB for 4.80 hours, 108.1 dB for 5.40 hours, and 101.9 for 6.30 hours. The researcher would like to determine (a) the total sound pressure level of the three sources, (b) the permissible duration of exposure for this sound pressure level, and (c) the noise dose for all three exposures.

(a) $SPLtot = 10log(10^{0.1(108)} + 10^{0.1(108.1)} + 10^{0.1(101.9)})$

$SPLtot = 111.56$ dB

(b) $Tpde = 8 \div 2^{0.2(111.56-90)} = 0.40$ hours or 40 minutes

(c) $Tpde1 = 8 \div 2^{0.2(108-90)} = 0.66$ hours

$Tpde2 = 8 \div 2^{0.2(108.1-90)} = 0.65$ hours

$Tpde3 = 8 \div 2^{0.2(101.9-90)} = 1.54$ hours

$ND = 100(4.80 \div 0.66 + 5.40 \div 0.65 + 6.30 \div 1.54)$

$ND = 1967\%$

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Before the Implementation of Barriers

	Line 1 (Max Value in dB)	Line 2 (Max Value in dB)	Line 3 (Max Value in dB)
1-meter distance	105.1	105.7	87.7
3-meter distance	101.6	100.1	84.9

Table 5. Maximum Values Before Barriers

	Distance	Sound Pressure Level (dB)	Duration of Exposure (Hrs)	Noise Dose
Without Barrier	1-meter 3-meter	108.46 103.98	0.62 1.15	1135% 612%

Table 6. Computed Values Prior to Implementation of Barriers

Tables 5 and 6 detail the baseline noise measurements taken prior to the installation of the barriers. To prevent acoustic interference, only the specific machine under observation remained operational during these recording sessions. Data was collected at distances of one meter and three meters to simulate the exposure experienced by both direct machine operators and employees moving through the general vicinity.

The initial assessment identified Line 1 as the loudest source and Line 3 as the quietest. Regardless of the specific line, the recorded data confirmed that noise intensities consistently exceeded 100 decibels at both distances, making the environment unsafe for a standard eight-hour shift. A later measurement for Line 3 showed an unexpected peak of 103.4 decibels, likely influenced by the volume of material being processed or other external variables.

On a facility wide scale, the total sound pressure reached 108.46 decibels at one meter and 103.98 decibels at three meters. These levels result in a noise dose that surpasses safety limits by 1035% and 512% respectively, highlighting a critical risk for full time workers. Furthermore, given the inconsistencies observed in the Line 3 data, it is probable that the actual environmental hazards are even more severe than these calculations suggest.

Evaluation of Compliance Gaps

Baseline measurements recorded intensities reaching 111.56 dB, yielding a noise dose of 1967% for an 8-hour shift. Under OSHA standards, a 100 dBA environment is restricted to just two hours of permissible exposure. However, facility machines run for an average of 4.8 to 7 hours. This creates a critical compliance gap where the noise dose is nearly 20 times the legal limit.

RESULTS

The experimental phase involved a comparative analysis of various soundproofing material combinations to determine their acoustic attenuation efficacy. The simulation data revealed that material composition significantly influences decibel reduction and cumulative noise exposure

- ***Gypsum Board Only*:** Achieved an 11.38% decibel reduction at 1 meter. While it utilizes the noise absorption capabilities of low-density boards, it proved insufficient on its own to reach full safety compliance.
- ***Blanket, Gypsum, and Wool*:** The most effective combination, reducing noise by **17.23%** and lowering the noise dose to **85.38%**

The significant improvement between the baseline noise dose of 1967% and the post-intervention dose of 85.38% underscores the necessity of high-density composite barriers in mitigating extreme industrial noise.

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After the Implementation of Barriers

	Line 1 (Max Value in dB)	Line 3 (Max Value in dB)
1-meter distance	104.6	88.2
3-meter distance	100.8	84.5

Table 7. Maximum Values of Lines 1 & 3 After Barriers (Group 1)

Materials	Distance	Max Values (Before in dB)	Max Values (After in dB)	Reduced
Gypsum Only	1-meter 3-meter	99.3 93.9	88.0 88.4	11.38 % 5.86 %
Gypsum, Foam, and MLV	1-meter 3-meter	98.9 97.4	87.8 89	11.22 % 8.62 %
Gypsum, Wool, and MLV	1-meter 3-meter	99.2 97.8	91 86.3	8.27 % 11.76 %

Table 8. Results of Experimentation of Soundproofing Materials (Group 1)

Group 1 results show that the best barrier depends on distance. For close proximity, the Gypsum Board alone achieved the highest reduction at 11.38%, supporting research that lower-density materials excel at absorbing nearby sound. In contrast, the Gypsum, Wool, and MLV combination performed best at three meters, reaching an 11.76% reduction. This multilayered approach effectively weakens sound waves over distance by combining lightweight materials for absorption with denser materials for superior soundproofing.

	Line 1 (Max Value in dB)	Line 2 (Max Value in dB)
1-meter distance	102.4	100.4
3-meter distance	101.7	99.8

Table 9. Maximum Values of Lines 1 & 2 After Barriers (Group 2)

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Materials	Distance	Max Values (Before in dB)	Max Values (After in dB)	Reduced
Cork only	1-meter 3-meter	103.4 99.1	98.8 93.9	4.45% 5.25%
Double-layer Cork	1-meter 3-meter	99.3 98.7	91.7 94.5	7.65% 4.26%
Cork and MLV	1-meter 3-meter	101.8 99.6	90.4 92.7	11.20% 6.93%
Gypsum, Cork, and MLV	1-meter 3-meter	103.1 101.3	93.6 91.3	9.21% 9.87%
Blanket	1-meter 3-meter	100.8 97.3	85.5 91.9	15.18% 5.55%
Blanket, Gypsum, Cork, and MLV (Outside)	1-meter 3-meter	100.3 100.8	92.5 94.2	7.78% 6.55%
Blanket, Gypsum, Cork, and MLV (Inside)	1-meter 3-meter	101.4 99.4	87.9 91.0	13.31% 8.45%
Blanket, Gypsum, and Wool	1-meter 3-meter	99.8 99.2	82.6 89.7	17.23% 9.58%

Table 10. Results of Experimentation of Soundproofing Materials (Group 2)

In the Group 2 experiments, the combination of a noise blanket, gypsum, and wool proved most effective at a one-meter distance, achieving a 17.23% reduction. This highlights the significant impact of the blanket, which provided a 15.18% reduction even when used alone. For the three-meter distance, the mixture of gypsum, cork, and MLV performed best. However, the blanket's overall effectiveness at further distances was likely compromised because its size was insufficient to fully enclose the machine, allowing sound to escape.

Evaluation of Alternatives

Line	Gypsum Only	Gypsum, Foam, and MLV	Gypsum, Wool, and MLV
1 Meter			
Line 1	92.70	92.86	95.95
Line 2	88	87.8	91
Line 3	78.16	78.30	80.91
3 Meter			
Line 1	94.89	92.11	88.95
Line 2	88.4	89	86.3
Line 3	79.55	80.60	74.56

Table 11. Estimated Noise Reduction Levels of Group 1

Line	Cork only	Double layer Cork	Cork and MLV	Gypsum , Cork, and MLV	Blanket	Blanket, Gypsum , Cork, MLV (Out)	Blanket, Gypsum , Cork, MLV (In)	Blanket, Gypsum ,Wool
1 Meter								
Line 1	98.8	94.6	90.9	93.0	86.9	94.4	88.8	84.8
Line 2	95.9	92.7	89.2	91.2	85.2	92.6	87	83
Line 3	93.6	98.8	90.4	93.6	85.5	92.5	87.9	82.6
3 Meter								
Line 1	97.2	97.4	94.7	91.7	95.1	95.0	93.1	92.0
Line 2	94.6	95.5	92.9	89.9	94.3	93.3	91.4	90.2
Line 3	93.9	94.5	92.7	91.3	91.9	94.2	91.0	89.7

Table 12. Estimated Noise Reduction Levels of Combinations of Group 2

Since Group 1 tested only Line 2 and Group 2 tested only Line 3, researchers applied the observed reduction percentages to the remaining lines to estimate facility-wide impact. This allowed for the calculation of total sound pressure levels, exposure durations, and noise doses as if the barriers were installed across all operations. The resulting data, used to determine the final noise dose, is detailed in Table 13.

	Gypsum Only	Gypsum, Foam, MLV	Gypsum, Wool, MLV
1 Meter			
Tpde1	5.50	5.38	3.51
Tpde2	10.56	10.85	6.96
Tpde3	41.28	40.48	28.22
3 Meter			
Tpde1	4.06	5.97	9.26
Tpde2	9.99	9.19	13.36
Tpde3	34.07	29.46	68

Table 13. Estimated Values of Noise for all Machines (Group 1)

	Cork only	Double layer Cork	Cork and MLV	Gypsum , Cork, and MLV	Blanket	Blanket, Gypsum , Cork, MLV (Out)	Blanket, Gypsum , Cork, MLV (In)	Blanket, Gypsum ,Wool
1 Meter								
Tpde1	2.36	4.23	7.06	5.28	12.30	4.35	9.45	16.45
Tpde2	3.53	5.50	8.94	6.77	15.56	5.58	12.13	21.11
Tpde3	4.86	2.36	7.57	4.86	14.93	5.66	10.70	22.32
3 Meter								
Tpde1	2.95	2.87	4.17	6.32	3.94	4.00	5.21	6.06
Tpde2	4.23	3.73	5.35	8.11	4.41	5.06	6.59	7.78
Tpde3	4.66	4.29	5.50	6.68	6.15	4.47	6.96	8.34

Table 14. Estimated Values of Noise for all Machines (Group 2)

	Line 1 (Hours)	Line 2 (Hours)	Line 3 (Hours)
Average Machine Run - Time	4.8	5.4	6.3

Table 15. Average Machine Run-time per 8-hour Shift

Materials	Group No.	Distance	Sound Pressure Level (dB)	Duration of Exposure (Hrs)	Noise Dose
Gypsum Only	1	1-meter 3-meter	94.08 95.87	4.54 3.55	153.67% 190.77%
Gypsum, Foam, and MLV	1	1-meter 3-meter	94.1 93.93	4.53 4.64	150% 160.55%
Gypsum, Wool, and MLV	1	1-meter 3-meter	96.96 90.93	3.05 7.03	236.66% 101.52%
Cork only	2	1-meter 3-meter	101.39 100.25	1.65 1.93	485.99% 425.56%
Double layer Cork	2	1-meter 3-meter	100.91 100.74	1.76 1.81	450.51% 458.87%
Cork and MLV	2	1-meter 3-meter	94.99 98.30	4.01 2.53	213.05% 330.59%
Gypsum, Cork, and MLV	2	1-meter 3-meter	97.49 95.80	2.83 3.58	297.85% 236.85%
Blanket	2	1-meter 3-meter	90.70 98.74	7.26 2.38	118.07% 346.72%
Blanket, Gypsum, Cork, MLV (Out)	2	1-meter 3-meter	98.03 98.99	2.63 2.30	326.41% 367.66%
Blanket, Gypsum, Cork, MLV (In)	2	1-meter 3-meter	92.73 96.70	5.47 3.16	156.04% 264.59%
Blanket, Gypsum, Wool	2	1-meter 3-meter	88.35 95.52	10.06 3.72	85.38% 224.16%

Table 16. Data of All Lines

Once the calculations for sound pressure levels, exposure times, and noise doses were finalized, the combination of the Blanket, Gypsum, and Wool emerged as the most effective solution. This configuration reduced the total sound pressure to 88.35 dB and extended the allowable exposure time to 10.06 hours, resulting in a noise dose of 85.38%. These improvements successfully brought the facility's noise levels within OSHA safety standards.

Comparing the initial data to the post-installation results reveals a substantial improvement in workplace safety. The noise dose, which originally ranged from a hazardous 612% to 1135%, was reduced to between 85.38% and 485%. This significant decrease demonstrates that the barriers are an effective tool for managing noise and protecting worker health.

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Administrative and Engineering Controls

Beyond structural barriers, the study evaluated supplemental controls to address worker behavior and mechanical noise sources. Interviews revealed that personnel often avoid wearing earmuffs because they need to "hear" the machines to detect operational malfunctions or jams.

As highlighted by Cayanan et al. (2025), the traits of democratic leadership have been proven to be highly correlated with performance and motivation. In this regard, the use of democratic leadership in which the employees get involved in selecting better quality PPE (such as SNR 34 dB ear muffs) and developing safety procedures can lead to compliance.

To address this ethically and safely, the study recommends:

- **Visual Status Indicators:** Implementing RPM gauges and light status indicators (Green for running, Red for error) removes the perceived need for auditory monitoring, allowing workers to maintain hearing protection while remaining aware of machine conditions.

- **Vibration Dampening:** The use of anti-vibration pads composed of rubber and EVA foam was identified as a necessary engineering control to lessen the amount of vibrations and noise generated by the machines into the floors.
- **PPE Upgrades:** While PPE is the last line of defense, providing higher-quality earmuffs (SNR 34 dB) and earplugs (SNR 38 dB) was requested by workers to improve comfort and resistance over current standard-issue equipment

Moreover, the shift towards the use of Visual Status Indicators (RPM gauges and light indicators) constitutes a technical development in terms of monitoring operations. According to Balagtas and Mallari (2025), the digital leadership concept plays an essential role in making the process more efficient. Therefore, by implementing digital leadership, it will be possible to handle the transition of the monitoring process from the auditory system to the digital visual system.

Cost-Benefit Analysis

Materials	Distance (in meters)	Max Values (Before in dB)	Max Values (After in dB)	Reduced	Price	Decrease of dB compared to gypsum	Increase in Price
Gypsum	1	99.3	88	11.38%	₱550.00	Base	Base
	3	93.9	88.4	5.86%		Base	
Gypusm, Foam, and MLV	1	98.9	87.8	11.22%	₱14,219.00	-1.37%	2485.27%
	3	97.4	89	8.62%		47.24%	
Gypsum, Wool, and MLV	1	99.2	91	8.27%	₱19,804.00	-27.36%	3500.73%
	3	97.8	86.3	11.76%		100.75%	
Cork	1	103.4	98.8	4.45%	₱1,993.50	-60.91%	262.45%
	3	99.1	93.9	5.25%		-10.42%	

Double layer cork	1	99.3	91.7	7.65%	₱3,987.00	-32.74%	624.91%
	3	98.7	94.5	4.26%		-27.35%	
Cork and MLV	1	101.8	90.4	11.20%	₱14,142.50	-1.59%	2471.36%
	3	99.6	92.7	6.93%		18.27%	
Gypsum, Cork, and MLV	1	103.1	93.6	9.21%	₱14,692.50	-19.03%	2571.36%
	3	101.3	91.3	9.87%		68.54%	
Blanket	1	100.8	85.5	15.18%	₱15,000.00	33.38%	2627.27%
	3	97.3	90.9	6.58%		12.30%	
Blanket, Gypsum, Cork, and MLV (Outside)	1	100.3	92.5	7.78%	₱29,692.50	-31.66%	5298.64%
	3	100.8	94.2	6.55%		11.79%	
Blanket, Gypsum, Cork, and MLV (Inside)	1	101.4	87.9	13.31%	₱29,692.50	16.99%	5298.64%
	3	99.4	91	8.45%		44.28%	
Blanket, Gypsum, and Wool	1	99.8	82.6	17.23%	₱22,655.00	51.45%	4019.09%
	3	99.2	88.7	10.58%		80.71%	

Table 17. Cost per Decibel Decrease

The following analysis compares various material configurations to identify the most efficient balance between cost and soundproofing performance. Gypsum board served as the baseline material due to its affordability and its ability to provide structural stability when paired with other components.

Performance of Cost-Effective Options

When used as a standalone barrier, Gypsum Board achieved noise reductions of 11.38% at one meter and 5.86% at three meters. While these figures are modest, they provide a sufficient baseline for moving toward the OSHA standard of 90 dB. Other single-material alternatives proved to be less effective and carried higher price tags, making Gypsum the most viable budget-friendly choice.

Premium and Alternative Solutions

If budget constraints are removed, the research suggests that the Blanket, Gypsum, and Wool combination is the superior choice. Its performance far exceeds that of the Gypsum base:

- At one meter, it is 51.45% more effective.
- At three meters, it is 80.71% more effective.

For a facility seeking a middle ground or an alternative to the multi-layered composite, the Noise Blanket used on its own represents the next best option for noise mitigation.

Cost-Benefit Analysis (With implemented solutions)				
PARTICULARS	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Savings from risk and injury compensation	₱100,000.00	₱100,000.00	₱100,000.00	₱100,000.00
Fine due to violation of RA 11058	₱700,000.00	-	-	-
Non-compliance of OSH standards	₱280,000.00			
Use of approved or certified devices and equipment for the task	₱350,000.00			
Total Benefits	**₱1,730,000.00**			
Cost of Insurance (total)	₱96,000.00	₱108,000.00	₱120,000.00	₱120,000.00
Cost of Anti-Vibration Pads	₱8,331.00	-	-	-

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Cost of Visual Indicator	₱83,382.00	-	-	-
Cost of New Earmuffs and Earplugs	₱4,650.00	₱150.00	₱150.00	₱150.00
Cost of Noise Barriers	Refer to Table 19	-	-	-
Total Costs	Refer to Table 19			
Cost-Benefit Ratio	Refer to Table 19			

Table 18. Cost-Benefit Analysis Summary

Cost-Benefit Analysis (With implemented solutions)				
PARTICULARS	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Savings from risk and injury compensation	₱100,000.00	₱100,000.00	₱100,000.00	₱100,000.00
Fine due to violation of RA 11058	₱700,000.00	-	-	-
Non-compliance of OSH standards	₱280,000.00			
Use of approved or certified devices and equipment for the task	₱350,000.00			
Total Benefits	**₱1,730,000.00**			
Cost of Insurance (total)	₱96,000.00	₱108,000.00	₱120,000.00	₱120,000.00
Cost of Anti-Vibration Pads	₱8,331.00	-	-	-

Material/Combination	**Cost of Noise Barriers**	**Total Project Costs**	**Cost-Benefit Ratio**
Gypsum	₱23,400.00	₱564,213.00	**3.07**
Blanket	₱162,000.00	₱702,813.00	**2.46**
Blanket, Gypsum, Wool	₱254,880.00	₱795,693.00	**2.17**

Table 19. Cost-Benefit Ratio per Material/Combination

Tables 18 and 19 evaluate the financial impact of three specific noise reduction strategies. By calculating the ratio of project costs against avoided expenses, the study found a cost-benefit ratio of 3.07 for Gypsum, 2.46 for the Blanket alone, and 2.17 for the combined Blanket, Gypsum, and Wool solution. These ratios demonstrate that every peso spent on noise mitigation yields significantly higher returns by eliminating substantial financial liabilities.

Avoided Penalties and Operational Costs

The facility currently faces significant legal exposure under Department of Labor and Employment (DOLE) and OSH standards. If the company fails to implement certified safety devices or meet general safety standards, it faces cumulative fines. For a single week of non-compliance, total penalties, including a baseline administrative fine of Php 100,000 and a 50% surcharge for repeated violations, are estimated at Php 1,330,000. Furthermore, the analysis projects an annual expense of Php 100,000 for medical fees and injury compensation, assuming at least one work-induced injury occurs every year without these safety measures.

The study found that every peso spent on the composite barrier system (CBR 2.17), anti-vibration pads, and visual indicators serves as a strategic hedge against these liabilities. This alignment of safety and financial performance is supported by the findings of Balagtas and Mallari (2025), who suggest that modern leadership strategies are key to maximizing the impact of infrastructure investments on management efficiency and operational outcomes.

Implementation Costs

To secure the facility, the proposal includes several engineering and administrative controls across three production lines (Lines 2, 3, and 4):

Barriers: Depending on the material choice, costs range from Php 2,600 to Php 28,320 per barrier. A total of nine units are required to enclose the targeted machinery.

Anti-Vibration Pads: Installed under machine feet at a cost of Php 2,777 per machine (Php 8,331 total) to reduce structural noise.

Visual-Audio Indicators: These systems cost Php 27,794 per machine (Php 83,382 total). They allow operators to monitor machine health through visual cues rather than relying on hearing, which is critical in high-noise environments.

Upgraded PPE: An initial investment of Php 4,650 provides 20 sets of earmuffs and earplugs, with an allowance for annual earplug replacements.

Summary of Findings

The investigation confirms that excessive noise is the primary occupational hazard within the Plastic Recycling facility, with initial measurements of 111.56 dB significantly exceeding OSHA safety standards. Baseline assessments revealed a staggering 1967% noise dose for an eight-hour shift, highlighting a critical compliance gap. While the use of Gypsum Board alone proved to be the most cost-efficient single-material solution, the experimental simulation determined that only the multi-layered composite barrier, consisting of a Noise Reduction Blanket, Gypsum Board, and Mineral Wool, reduced sound pressure levels effectively enough to achieve full regulatory compliance.

CONCLUSIONS

Legal Accountability: The facility remains at high risk for substantial administrative penalties, with estimated potential fines for repeated OSH violations reaching up to Php 1,330,000.

Ethical Accountability: Chronic exposure to current noise levels places the workforce at imminent risk for permanent noise-induced hearing injuries and acoustic trauma.

Efficacy of Interventions: Engineering controls through specialized sound isolation successfully mitigated noise to a compliant level of 88.35 dB, bringing the cumulative noise dose down to 85.38%

Recommendations

The recommendations of the study:

- ***Primary Implementation:*** Install multi-layered composite barriers (Blanket, Gypsum, and Wool) around high-noise grinding lines to restrict sound emissions and meet OSHA standards.
- ***Visual Status Indicators:*** Redesign machine interfaces to include RPM gauges and light status indicators; this removes the worker's perceived need for auditory monitoring and encourages the consistent use of hearing protection.
- ***Vibration Control*****:** Install anti-vibration pads under each machine foot to dampen mechanical vibrations, reduce transmitted floor noise, and prevent long-term structural damage to the facility.
- ***Personal Protective Equipment (PPE) Upgrades*****:** Provide high-quality, high-resistance earmuffs and earplugs (targeting SNR ratings of 34–38 dB) to improve worker comfort and provide secondary defense against residual noise.

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