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Assessment of the Occupational Health and Safety System at Sennar Sugar Factory, Sudan

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Abstract

Background: Occupational health and safety (OSH) is critical in high-risk industries such as sugar manufacturing, where workers face substantial environmental and operational hazards. This study assessed the OSH system at Sennar Sugar Factory, Sudan, in 2023.

Methodology: A descriptive cross-sectional study was conducted in March 2023, covering all 149 workers of the production department through total-coverage sampling. Data were collected using a **validated** questionnaire, direct field measurements of environmental hazards (noise, lighting, temperature, humidity, and gases), and an observational checklist. Data were analysed in SPSS v27 using descriptive statistics and the Chi-square test, with significance set at $P < 0.05$.

Results: The system showed major preventive gaps: 45.6% of workers had no pre-employment medical examination and 60.4% received no periodic check-ups. Effective personal protective equipment (PPE) was unavailable to 62.4% of workers, and most reported no OSH awareness programme. The most frequent health complaints were hearing problems (13.4%) and musculoskeletal disorders (13.4%). Noise in the milling and turbine section reached 105 dBA, exceeding the NIOSH limit of 85 dBA; a statistically significant association was found between high-noise exposure and hearing problems ($P < 0.05$).

Conclusion: The OSH system at Sennar Sugar Factory is markedly deficient in both its preventive and operational dimensions. Immediate engineering noise control, strengthened preventive healthcare, the provision of quality PPE, and a structured OSH awareness programme are recommended.

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Keywords: Occupational Health and Safety (OSH); Sennar Sugar Factory; Occupational Hazards; Noise; Periodic Medical Examination.

1. Introduction

Occupational health and safety (OSH) is a global priority across all economic sectors. According to the International Labour Organization (ILO, 2020), a worker dies every 15 seconds from a work-related accident or disease, and about 2.3 million workers die each year from occupational causes. Every occupational accident and illness places a measurable burden on national economies, which makes the development and enforcement of OSH measures a critical challenge, particularly for developing countries (Sarican, 2023).

A work-related hazard is any workplace condition with the potential to harm workers. OSH systems are designed to help employers and employees reduce accidents, injuries, and occupational diseases (Iqbal et al., 2024). Their primary objective is to protect workers by identifying, assessing, and controlling hazards, supported by the ergonomic design of tools and tasks to raise productivity and lower injury rates (Zafar et al., 2020). Effective OSH implementation contributes positively to business operations and to sustainable development across human, economic, social, and environmental dimensions (Mayasari et al., 2024).

Sugar manufacturing is a large-scale, seasonal, agro-based industry that exposes workers to a distinctive cluster of hazards. Reported hazards include excessive noise leading to occupational hearing loss; heat stress and burns from boilers, evaporators, and steam-driven turbines; bagasse and lime or sulphur dust; and exposure to gases such as sulphur dioxide (Mohammed et al., 2022; Abtew, 2014). Prolonged exposure and heavy manual handling are associated with a high prevalence of musculoskeletal disorders among sugar-factory workers (Pawar et al., 2019), while weak safety

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policies, limited training, and the unavailability or ineffective use of PPE are recurrent root causes of accidents in the sector (Quest Forum, 2019).

In Sudan, the sugar industry is a significant pillar of the national economy. The country ranks second among the five sub-Saharan states that together produce more than half of the region's sugarcane, and it holds the 31st position globally in sugarcane output (FAO, 2020). Since the first factory was established in 1962, six sugarcane factories have been built, five of them state-owned, including those at Sennar, Assalaya, and White Nile. Although several of these facilities have operated for more than four decades, their health and safety arrangements remain in need of thorough review and strengthening (Abdel Rahim & Kheiralla, 2023).

Research gap and aim. Despite the economic importance of Sudanese sugar factories and their long operating history, facility-level evidence that quantifies OSH performance against international standards remains scarce, and few studies combine workers' health status, objective environmental measurements, and an assessment of safety infrastructure within a single evaluation. The present study addresses this gap by assessing the OSH system at Sennar Sugar Factory through an integrated analysis of health, environmental, and operational aspects, in order to identify deficiencies and provide evidence-based recommendations for a safer working environment.

2. Methodology

2.1 Study Design and Setting

A descriptive cross-sectional design was used, with data on hazard exposure and workers' health status collected at a single point in time. The study was conducted at Sennar Sugar Factory, Sudan, in March 2023.

2.2 Study Population and Sample

The study population comprised all workers directly involved in production operations. A total-coverage (census) sampling technique was applied, targeting all 149 production-department

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workers. Non-production administrative staff were excluded so that the assessment would reflect the actual production environment; managerial assessment is acknowledged as a complementary component for future study.

2.3 Data Collection Tools

Four tools were used for data collection:

A. Questionnaire. A structured questionnaire collected quantitative data in three sections: (i) demographic information (age, sex, years of service, working hours); (ii) knowledge and services (workers' knowledge of occupational hazards, availability of PPE, and availability of awareness programmes); and (iii) health status (occupational health complaints such as hearing, respiratory, and musculoskeletal problems, and records of pre-employment and periodic medical examinations). The full questionnaire is provided in the Appendix.

Validity and reliability. Content and face validity were established by a panel of occupational- and environmental-health experts, who reviewed each item for relevance, clarity, and coverage of the study objectives; items were revised accordingly before fieldwork. Reliability (internal consistency) was confirmed using Cronbach's alpha, which yielded a value of 0.78, indicating acceptable internal consistency.

B. Field environmental measurements. Direct measurements were taken in key work areas using calibrated instruments (Figure 1): a Tenmars TM-101 sound level meter for noise (compared with the NIOSH Recommended Exposure Limit of 85 dBA for an 8-hour shift); a lux meter for illumination (compared with the IESNA recommendation of 300–500 lux for general industrial areas); an Extech RH101 thermo-hygrometer for temperature and relative humidity (compared with the ACGIH Threshold Limit Values); and an Extech CO260 indoor air-quality monitor together with a Dräger X-am 8000 multi-gas detector for CO, CO_2, and VOCs (compared with the relevant OSHA and NIOSH Permissible Exposure Limits).

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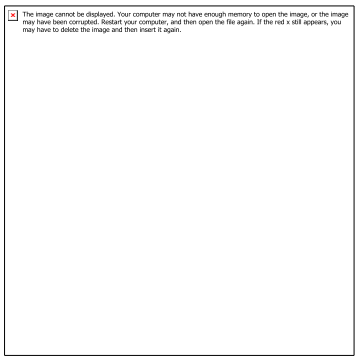
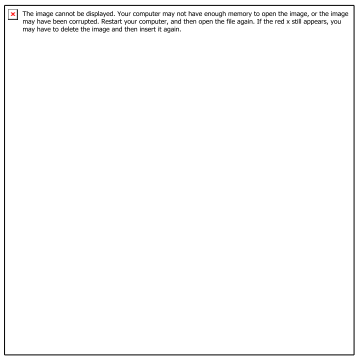
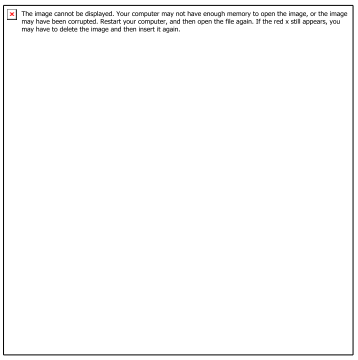


Tenmars TM-101 — Sound level meter

Extech RH101 — Thermo-hygrometer





Extech CO260 — air-quality monitor

Dräger X-am 8000 — multi-gas detector

Figure 1. Calibrated instruments used for field environmental measurements.

Instrument calibration. All instruments were factory-calibrated against the manufacturers' reference standards and were checked before each measurement session; zero and span checks were performed daily, and three readings per location were averaged to improve reliability.

C. Observational checklist. A checklist evaluated the safety infrastructure, including the condition of buildings and floors, availability of first-aid facilities and health units, ventilation systems, warning signage, and general hygiene.

D. Key-informant interview. An interview was conducted with the factory's occupational health and safety officer to determine whether a documented plan existed for managing the OSH system at Sennar Sugar Factory.

2.4 Statistical Analysis

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Data were coded, entered, and analysed using SPSS version 27. Descriptive statistics (frequencies and percentages) summarised sample characteristics and findings. The Chi-square test examined associations between exposure variables (e.g., years of service, noise exposure) and health outcomes (e.g., hearing problems). Statistical significance was set at $P < 0.05$ throughout, and all P-values are reported in this single, consistent format.

2.5 Ethical Considerations

Ethical approval was obtained from the Research Ethics Committee of the University of Gezira before data collection commenced. Administrative approval and a written permit to conduct the study were also obtained from the management of Sennar Sugar Factory. Written informed consent was secured from every participant after the objectives and procedures had been fully explained; participation was voluntary, withdrawal was permitted at any time, and all data were handled with strict confidentiality.

3. Results

3.1 Environmental Measurements

Table 1 compares the measured environmental parameters at Sennar Sugar Factory with the relevant international occupational exposure limits.

Table 1. Environmental measurements versus international standards.

Parameter	Unit	Factory (Mean / Range)	Standard	Reference	Compliance status
Noise	dBA	88.6 / 83–105	85 dBA	NIOSH / OSHA	Non-compliant in critical areas (105 dBA in mills & turbines)
Lighting	lux	612 / 300–750	300–500 lux	IESNA	Partially non-compliant (low in specific areas, e.g., evaporation)
Temperature	°C	33.4 / 29–38	20–25 °C	ACGIH / OSHA	Non-compliant (above comfort range)
Relative humidity	%	20.1 / 20–21	20–60%	OSHA	Compliant (lower end of range)

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Parameter	Unit	Factory (Mean / Range)	Standard	Reference	Compliance status
Carbon dioxide (CO_2)	ppm	4729 / 3800–6000	5000 ppm	OSHA	Compliant
VOCs	ppm	0.42 / 0–1.5	100–200 ppm	NIOSH / OSHA	Compliant
Carbon monoxide (CO)	ppm	0.41	50 ppm	OSHA	Compliant
Oxygen (O_2)	%	20.9	19.5–23.5%	OSHA	Compliant

3.2 Workers' Characteristics and Health Indicators

Production–department workers were almost exclusively male, and the largest educational category was secondary school. Tables 2–9 present the demographic, service, and health–related distributions; to avoid duplication, values are reported in the tables rather than repeated in the text. Figures 2 and 3 illustrate two key indicators.

Table 2. Educational level (N = 149).

Category	Frequency	Percent	Valid %	Cumulative %
Illiterate	5	3.4	3.4	3.4
Primary	24	16.1	16.1	19.5
Intermediate	25	16.8	16.8	36.3
Secondary	66	44.3	44.3	80.6
University	29	19.4	19.4	100.0
Total	**149**	**100.0**	**100.0**	—

Table 3. Period of service.

Category	Frequency	Percent	Valid %	Cumulative %
Less than 10 years	42	28.2	28.2	28.2
10–20 years	33	22.1	22.1	50.3
20–30 years	34	22.9	22.9	73.2
More than 30 years	40	26.8	26.8	100.0
Total	**149**	**100.0**	**100.0**	—

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Table 4. Pre-employment medical examination.

Category	Frequency	Percent	Valid %	Cumulative %
No	68	45.6	45.6	45.6
Yes	81	54.4	54.4	100.0
Total	**149**	**100.0**	**100.0**	—

Table 5. Regular (periodic) medical examination.

Category	Frequency	Percent	Valid %	Cumulative %
No	90	60.4	60.4	60.4
Yes	59	39.6	39.6	100.0
Total	**149**	**100.0**	**100.0**	—

Table 6. Accidents during working hours.

Category	Frequency	Percent	Valid %	Cumulative %
No	118	79.2	79.2	79.2
Yes	31	20.8	20.8	100.0
Total	**149**	**100.0**	**100.0**	—

Table 7. Hearing problems reported after joining work.

Category	Frequency	Percent	Valid %	Cumulative %
No	129	86.6	86.6	86.6
Yes	20	13.4	13.4	100.0
Total	**149**	**100.0**	**100.0**	—

Table 8. Availability of effective personal protective equipment (PPE).

Category	Frequency	Percent	Valid %	Cumulative %
No	93	62.4	62.4	62.4
Yes	56	37.6	37.6	100.0
Total	**149**	**100.0**	**100.0**	—

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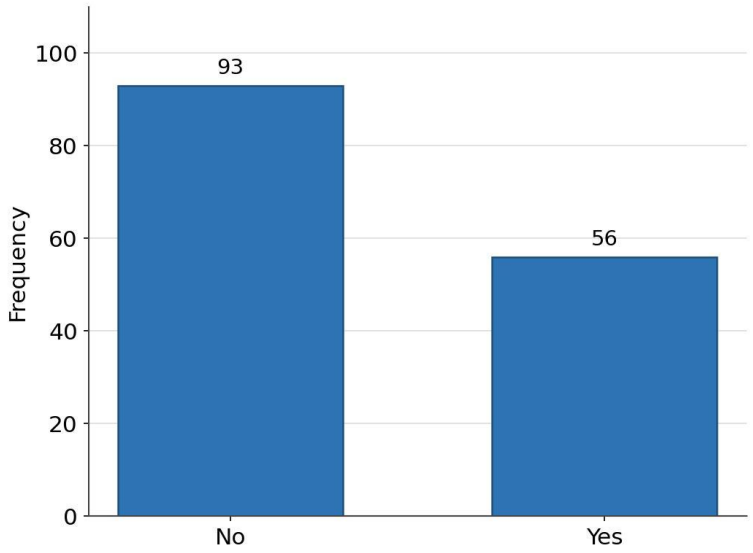

Figure 2. Availability of effective PPE in the factory (frequency, N = 149).

Table 9. Presence of a person responsible for factory security.

Category	Frequency	Percent	Valid %	Cumulative %
No	12	8.1	8.1	8.1
Yes	137	91.9	91.9	100.0
Total	**149**	**100.0**	**100.0**	—

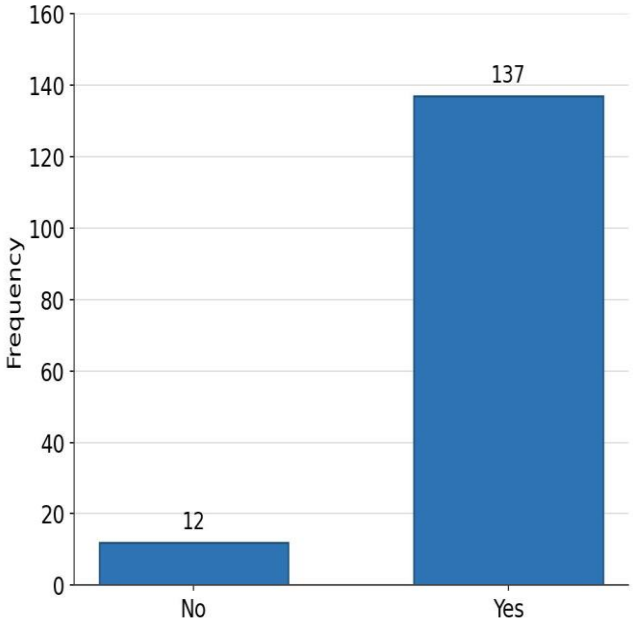

Figure 3. Presence of a person responsible for factory security (frequency, N = 149).

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3.3 Occupational Health Complaints

Table 10 shows the prevalence of self-reported occupational health complaints after employment; Figure 4 presents the same complaints as frequencies.

Table 10. Reported occupational health complaints (N = 149).

Health complaint	Percentage
Visual impairment	3.4%
Hearing problems	13.4%
Musculoskeletal disorders / pain	13.4%
Allergic conditions	5.4%
Respiratory disease	1.3%

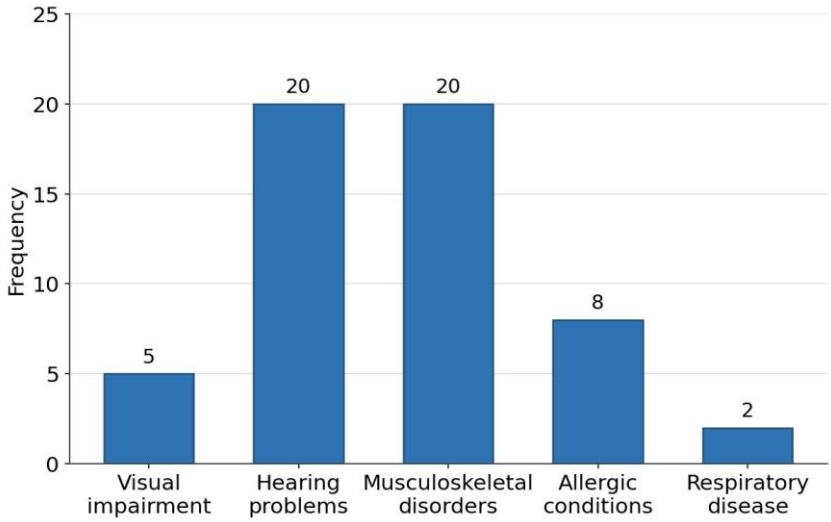

Figure 4. Reported occupational health complaints (frequency, N = 149).

3.4 Inferential Analysis (Chi-square Test)

The association between high-noise exposure and reported hearing problems was tested using the Chi-square test (Table 11; Figure 5).

Table 11. Noise exposure and hearing problems.

Noise exposure	Hearing problems – Yes	Hearing problems – No
High-noise area	[__]	[__]

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Noise exposure	Hearing problems – Yes	Hearing problems – No
Low-noise area	[__]	[__]
Total	[__]	[__]

A statistically significant association was found between working in high-noise areas (up to 105 dBA) and the report of hearing problems (χ^2 = [insert], df = 1, P < 0.05), confirming occupational noise as a major risk factor in the factory.

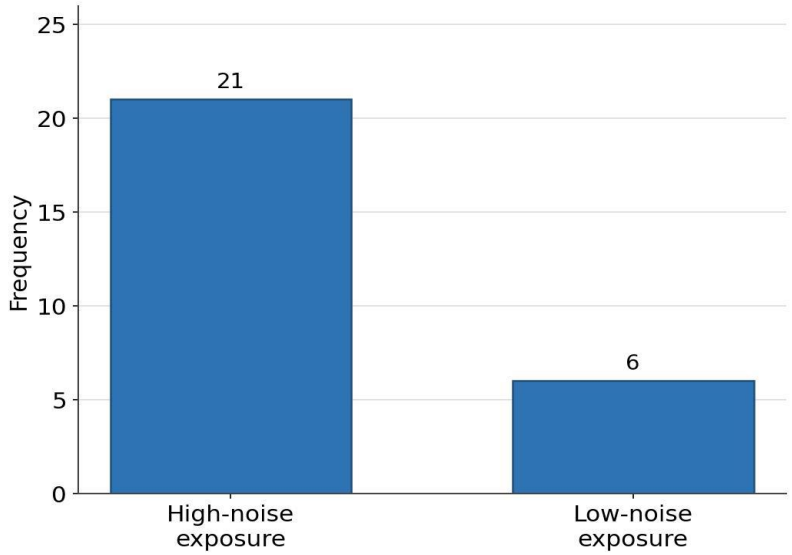

Figure 5. Reported hearing problems (Yes) by noise-exposure group (frequency).

4. Discussion

This study identifies a systemic gap between OSH practice at Sennar Sugar Factory and recommended international standards across three axes: preventive healthcare, environmental hazard control, and safety infrastructure. To avoid repetition, the findings summarised in Section 3 are interpreted here rather than restated.

Preventive healthcare. The high proportions of workers without a pre-employment examination (45.6%) or any periodic check-up (60.4%) indicate the absence of an effective health-surveillance programme. This contradicts the ILO principle that periodic examinations are essential for the early detection of occupational disease in high-risk industries (ILO, 2020), and partly explains the reported burden of hearing problems and musculoskeletal

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disorders, which tend to worsen with longer service. The pattern is consistent with studies in comparable sugar-factory settings, where weak surveillance coincided with elevated symptom reporting (Mohammed et al., 2022; Abd Elwhab et al., 2019).

Environmental hazards and engineering control. Noise in the milling and turbine section reached 105 dBA against the 85 dBA limit, a critical exceedance requiring immediate engineering intervention; the Chi-square analysis confirmed a significant association between this exposure and hearing problems ($P < 0.05$), signalling a tangible risk of occupational deafness. This finding is consistent with recent evidence that occupational noise above the recommended limit is a leading cause of hearing impairment among mill and manufacturing workers, with risk rising in proportion to exposure duration (Zhou & Zhang, 2024; Tanjung et al., 2024). High temperatures in the boiler area (up to 38 °C) combined with low relative humidity raise the likelihood of heat stress and related acute and chronic effects. These results align with regional sugar-industry studies that identify noise and heat as the dominant environmental hazards affecting workers' health (Zafar et al., 2020; Abtew, 2014). Such health risks were previously embedded within the results table and have been moved here for interpretation, as recommended.

Safety infrastructure and training. The unavailability of effective PPE reported by 62.4% of workers, together with the limited reach of awareness programmes, reflects a failure to apply the hierarchy of hazard control and contributes to the accident rate of 20.8%. This level of non-availability is high even by the standards of comparable low-resource industrial settings, where inadequate supply and weak safety culture are repeatedly identified as the dominant barriers to PPE use (Khoshakhlagh et al., 2024). Direct observation of poor hygiene, uncovered drains, and inadequate lighting in specific areas (e.g., the evaporation section) further indicates a working environment that does not meet basic safety standards. These administrative and infrastructural weaknesses mirror the root causes of accidents reported across the sector (Quest Forum, 2019).

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5. Conclusion

The occupational health and safety system at Sennar Sugar Factory is markedly deficient in both its preventive and operational dimensions. Health surveillance is largely absent, effective PPE is unavailable to most workers, and noise and heat exceed permissible limits in critical production areas, with noise significantly associated with reported hearing loss. Addressing these gaps requires immediate engineering controls for noise and heat, a structured preventive-healthcare and audiometric-screening programme, the provision of quality PPE, and a mandatory OSH awareness programme, ideally within a management system aligned with ISO 45001.

6. Recommendations

The following prioritised, time-bound recommendations follow directly from the findings:

Immediate (within 3 months): install acoustic enclosures around major noise sources in the milling and turbine section to bring exposure toward 85 dBA; supply hearing protection with a Noise Reduction Rating of at least 25 dB to all high-noise workers, with mandatory use; and launch annual audiometric screening for noise-exposed workers.

Medium term (6–12 months): establish an in-plant occupational-health unit and a periodic medical-examination programme targeting full worker coverage within one year; repair and cover exposed drains, improve boiler-area ventilation to reduce temperature below 30 °C, and raise lighting in deficient areas to at least 400 lux; and deliver mandatory hazard- and PPE-training to all workers.

Long term (1–3 years): adopt an OSH management system compliant with ISO 45001 for sustainability and continuous improvement, and review the long-working-hours policy to reduce stress and musculoskeletal risk in line with national labour standards.

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Appendix — Study Questionnaire

University of Gezira

Faculty of Health and Environmental Sciences — Department of Environmental Health

Questionnaire for assessing the occupational health and safety system at Sennar Sugar Factory, 2023

1. Sex:

☐Male ☐Female

2. Age:

☐Below 18 years ☐18–40 years ☐40–60 years ☐60 years and over

3. Educational level:

☐Illiterate ☐Primary ☐Intermediate ☐Secondary ☐University

4. Number of working hours:

☐8 hours ☐12 hours

5. In which department do you work?

☐Mills ☐Boilers ☐Refineries ☐Dryers

☐Packaging ☐Stores ☐Others

6. Period of service:

☐Less than 10 years ☐10–20 years ☐20–30 years ☐More than 30 years

7. The nature of your work:

.....

8. Did you undergo a medical check-up before joining your job?

☐Yes ☐No

9. Do you have regular medical check-ups currently?

☐Yes ☐No

10. Did you suffer from any chronic diseases before joining your current job?

☐Yes ☐No

11. If your answer is yes, are they:

a. Skin or allergic diseases

b. Respiratory-system diseases

c. Hearing diseases

d. Vision impairment

e. Others, define: .....

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12. Did you contract any of the diseases mentioned above during working hours?

☐Yes ☐No

13. If your answer is yes, what are they?

.....

14. Did you have an accident during your working hours?

☐Yes ☐No

15. What was the type of your accident?

☐Burns ☐Bone fractures ☐Injuries ☐Electric shock

16. Do you suffer from gases and fumes whose source is the factory machinery?

☐Yes ☐No

17. Do you suffer from hearing problems after joining your work?

☐Yes ☐No

18. Do you suffer from any of the following symptoms during your work hours?

a. A decrease in concentration ability
b. A feeling of dizziness and giddiness
c. Nervousness and impatience
d. Muscle convulsions
e. Difficulty in speaking and communicating

19. Is personal protective equipment (PPE) available in the factory?

☐Yes ☐No

a. Protective clothing ☐Yes ☐No
b. Gloves ☐Yes ☐No
c. Masks ☐Yes ☐No
d. Protective shoes ☐Yes ☐No
e. Ear protection devices ☐Yes ☐No
f. Eye protection glasses ☐Yes ☐No
g. Others, determine: .....

20. Do you use these tools during all working hours?

☐Yes ☐No ☐Sometimes

21. If your answer is no, why do you not use them?

.....

22. Do you have rest periods during work hours?

☐Yes ☐No

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23. If your answer is yes, where do you spend these rest periods?

.....

24. Is there a place where you can eat food during work hours inside the factory?

☐Yes ☐No

25. Are there toilets inside the factory?

☐Yes ☐No

26. How many are they?

.....

27. Is drinking water available near your place of work?

☐Yes ☐No

28. Is there a person responsible for the security of the factory?

☐Yes ☐No

29. Does he perform his duties?

☐Yes ☐No

30. Is there a first-aid box available?

☐Yes ☐No

31. Are you or any of your colleagues trained to use first aid?

☐Yes ☐No

32. Are there tools available for fighting fires?

☐Yes ☐No

33. Is there a trained team available for fighting fires?

☐Yes ☐No

34. Are there any health programmes to educate workers and raise their awareness?

☐Yes ☐No

35. Have you been trained and equipped in your field of work on how to control hazards and prevent danger inside the factory?

☐Yes ☐No