An evaluation of occupational health risk assessment methodologies from South African enterprises: noise risk assessment field study

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ABSTRACT

Background: The South African occupational health and safety regulations, prescribing risk assessments be conducted by employers, are non-prescriptive with regard to the tools and techniques to be used. Consequently, companies freely adopt the numerous available tools and techniques from which risk management decisions are derived. Thus, risk management, ensuing from the results derived from these tools and techniques, is likely to vary from company to company.

Objective: The objective of the study was to evaluate risk assessment processes and methodologies that are used and recorded in noise risk assessment reports, in four manufacturing companies.

Methods: This was a case study, whereby risk assessment records were obtained from four South African companies with different operational units, from the manufacturing and utilities sectors.

Results: There were inter- and intra-company variations in the processes related to the legal context in which the risk assessments were conducted, the risk assessment tools and techniques used, the risk criteria definitions, the statements about the effectiveness of controls in use, and the risk evaluation outcomes. Inter- and intra-company variations in risk rankings and risk prioritisation outcomes were also observed – a consequence of the risk perceptions of the assessors assigning a risk level to the noise hazard. In some instances, the adopted risk assessment tools and techniques categorised the risk from noise that was at or above regulated health and safety standards as 'insignificant', which those companies used as justification for taking no further measures to eliminate or reduce the risk.

Conclusion: The use of different risk assessment processes, tools and techniques resulted in some facilities categorising noise as an insignificant hazard, which may contribute to high noise emissions and uncontrolled exposures.

INTRODUCTION

The management of health and safety at work is a challenge faced by all companies.[1] Risk prevention starts with a comprehensive assessment of risks, followed by a judgment about the probability of ill health, and implementation of preventive measures to minimise the severity of these risks. Some companies have implemented complementary occupational health and safety (OHS) systems, such as the International Organization for Standardization (ISO)/South African National Standard (SANS) 45001, to manage inherent risks.[2] The ISO/SANS 45001 system relies on the assessment of risk, but does not guarantee a safe and healthy workplace, although it facilitates the standardisation of methods for the identification of hazards and risks by industry type, risk prioritisation, and implementation of control measures.[3]

The field of risk assessment and risk management, although less than five decades old, has seen the development and introduction of new and sophisticated analytical tools and techniques across different sectors.[4] The iterative steps of assessing risks to health include: a) a definition of the extent of the assessment, b) gathering of exposure information, c) exposure assessment, d) identification of actions, e) recording of the assessment, f) implementation of identified corrective actions, and g) review of the assessment.[5]

Risk assessments are conducted by employers, worldwide, to fulfil legal obligations.[6-15] Occupational health risk assessments conducted by employers in South Africa in both the manufacturing and utilities sectors are designed to comply with health regulations, such as the Noise-Induced Hearing Loss (NIHL), Lead, Hazardous Chemical Agents, Hazardous Biological Agents, and Asbestos Abatement Regulations. The risk assessments prescribed by these regulations are conducted biennially, although reassessments are required for any material process changes that might affect the current risk categorisation.[8-10,12,13,16]

The various health regulations do not prescribe the steps to be followed when conducting a risk assessment. The ISO/SANS 31000 standard, however, offers generic guidance, including that there should be defined risk criteria[17] as a first step in the risk management process. Companies in South Africa are therefore at liberty to select risk analysis and risk evaluation tools and techniques suited to their operations, following the risk identification phase,[18] in the

absence of a national harmonised regulatory guideline. These tools and techniques include bow tie analysis, risk indices, cost-benefit analysis, and cost-and-effect analysis, amongst others.[19]

Equally important is the selection and adoption of corresponding risk matrixes, which can be qualitative, semi-quantitative, or quantitative.[20] A company should select a technique that is consistent with its predetermined risk criteria, and should provide a reason for the choice with regard to relevance and suitability.[19,21] Risk assessment methodologies, tools, and techniques are continuously being developed,[22] and impact downstream risk management processes.

A national framework for the acceptability of risk can provide clarity about risk assessment procedures and clarify the level of risk tolerability, thereby assisting companies to manage risks.[19] Such a framework is, however, absent in South Africa, apart from the prescribed health and safety standards relating to exposure to occupational health hazards.[8-10,12,13] Internationally, the Health Safety Executive (HSE) in the United Kingdom (UK) has published a tolerability of risk framework[23] in which the outcomes of the risk assessment process are required to be recorded in a report.[8-10,12,13]

In this paper, we report the results of an evaluation of noise risk assessment processes and methodologies used by four South African companies from the manufacturing and utilities sectors.

METHODS

Risk-based criteria were used to identify companies for invitation to participate in the study through the review of company annual sustainability reports, as described by Rikhotso et al. (2022).[24] Only companies with historic NIHL case disclosures reported in annual sustainability reports and operating in the manufacturing and utilities sectors were considered for participation in the study.

The annual sustainability reports of 20 companies (19 from the manufacturing sector and one from the utilities sector) were reviewed. Eleven of the 20 companies had reports of NIHL cases and were invited to participate in the study. Four companies participated, viz. an electricity generation company (Company A, with 11 operational facilities), a petroleum refinery (Company B, with two operational facilities), a radioisotope manufacturing company (Company C, with six operational facilities), and a cement manufacturer (Company D, with two operational facilities). An operational facility represents a single plant or business unit of the parent company, and operates as an independent entity.

The four companies submitted their reports from their most recent risk assessments. We evaluated the risk assessment methodologies, the risk prioritisation processes, and the risk treatment processes, in line with SANS/ISO 31000 guidelines, in

Table 1. Health risk assessments conducted in the facilities of the four companies

Company/ facility	Regulation/Act								
	Noise-Induced Hearing Loss Regulations	Regulations for Hazardous Chemical Agents	Lead Regulations	Regulations for Hazardous Biological Agents	Environmental Regulations for Workplaces	Asbestos Abatement Regulations	Ergonomics Regulations	Hazardous Chemicals Act	Reference standards and guidelines adopted to guide risk assessment§
Company A									
Facility 1	✓	✓	-	✓	✓	-	✓	-	×
Facility 2	✓	✓	-	-	✓	-	✓	-	×
Facility 3	✓	✓	-	✓	✓	-	✓	-	×
Facility 4	✓	✓	-	✓	✓	-	✓	-	×
Facility 5	✓	✓	-	✓	✓	-	✓	✓*	✓
Facility 6	✓	✓	-	✓	✓	-	✓	-	✓
Facility 7	✓	✓	-	✓	✓	-	✓	-	✓
Facility 8	✓	✓	-	✓	✓	-	✓	-	✓
Facility 9	✓	✓	-	✓	✓	-	✓	-	×
Facility 10	✓	✓	-	✓	✓	-	✓	-	×
Facility 11	✓	✓	-	✓	✓	-	✓	-	×
Company B									
Facility 1	✓	✓	-	✓	✓	-	✓	✓†	×
Facility 2	✓	✓	-	✓	✓	-	✓	-	×
Company C									
Facility 1	✓	✓	-	-	✓	✓	✓	✓‡	✓
Facility 2	✓	✓	✓	✓	✓	-	✓	✓‡	✓
Facility 3	✓	✓	-	-	✓	-	✓	✓‡	✓
Facility 4	✓	✓	-	-	✓	-	✓	-	✓
Facility 5	-	✓	-	-	✓	-	✓	✓‡	✓
Facility 6	✓	✓	-	✓	✓	-	✓	✓‡	✓
Company D									
Facility 1	-	✓	-	-	✓	-	-	-	×
Facility 2	-	✓	-	-	✓	-	-	-	×

✓ present, × absent, * microwave radiation, † X-rays, ‡ X-rays and other radiation types, § e.g. ISO/SANS 31000, internal company risk assessment guidelines

which principles, a framework, and a process for managing risk are provided.[17] The acceptability of risk, especially following risk treatment, was included as one of the defined risk criteria.

Document analysis

Document analysis was used to evaluate the health risk assessment reports.[25] According to Bowen (2008),[25] document analysis can be systematically applied in the evaluation of documents that are in print or electronic form. To aid the evaluation, the READ approach[26] to document analysis was used in extracting meaningful data from the reports by following the iterative steps of 1) readying the materials, 2) extracting the data, 3) analysing the data, and 4) distilling the findings. Themes were identified and the outcomes were tabulated to report on the regulatory context, risk assessment tools and techniques used, risk assessment criteria, risk assessment processes, risk prioritisation outcomes, and risk assessment document quality aspects.

Ethical clearance for the study was obtained from the Tshwane University of Technology (TUT) Research Ethics Committee: FCRE 2020/10/015 (FCPS 02) (SCI).

RESULTS

Even though the different health regulations require individual risk assessments, companies conduct a single risk assessment for all regulated occupational health hazards, a practice that was observed for all of the four participating companies. Twenty-one risk assessment reports were evaluated, covering the period 2018 to 2021.

Establishing the regulatory context

South African legislation requires companies to conduct risk assessments. OHS hazards covered by the NIHL Regulations, the Regulations for Hazardous Chemical Agents (for various agents, excluding lead and asbestos), the Lead Regulations, the Asbestos Abatement Regulations, the Environmental Regulations for Workplaces (for lighting, heat, cold stress, and ventilation), and the Ergonomics Regulations were addressed in the risk assessments of all four participating companies (Table 1).

Risk assessments were conducted in all facilities for compliance with the Regulations for Hazardous Chemical Agents and the Environmental Regulations for Workplaces. Most of the facilities conducted risk assessments for compliance with the Ergonomics Regulations (n = 19, 90.5%) and the NIHL Regulations (n = 18, 85.7%), while fewer conducted risk assessments for hazardous biological agents (n = 14, 66.7%), or hazardous chemicals (n = 7, 33.3%). In only one facility was a risk assessment conducted for the assessment of lead, while in one other asbestos was considered as a hazard. Ten (n = 10, 47.6%) operating facilities from Companies A and C indicated the reference documents used for the adopted risk assessment methods, whereas none was mentioned for Companies B and D.

Risk assessment techniques/tools

The consequence/probability matrix risk assessment technique was used by 18 of the 21 facilities (85.7%) (Table 2). Two facilities used checklists, and no information could be found for one facility. The consequence/probability matrix allows risk assessors

Table 2. Risk assessment techniques/tools and outputs for each facility

Company/facility	Risk assessment technique/tool	Output in risk assessment report
Company A		
Facility 1	Consequence/probability matrix	Rating for each risk
Facility 2	Consequence/probability matrix	Rating for each risk
Facility 3	Consequence/probability matrix	Rating for each risk
Facility 4	Consequence/probability matrix	Rating for each risk
Facility 5	Consequence/probability matrix	Rating for each risk
Facility 6	Consequence/probability matrix	Rating for each risk
Facility 7	Consequence/probability matrix	Rating for each risk
Facility 8	Consequence/probability matrix	Rating for each risk
Facility 9	Consequence/probability matrix	Rating for each risk
Facility 10	NI	NI
Facility 11	Consequence/probability matrix	Ranked list of risks with significance levels† defined
Company B		
Facility 1	Consequence/probability matrix	Rating for each risk
Facility 2	Consequence/probability matrix	Rating for each risk
Company C		
Facility 1	Consequence/probability matrix	Rating for each risk*
Facility 2	Consequence/probability matrix	Rating for each risk*
Facility 3	Consequence/probability matrix	Rating for each risk*
Facility 4	Consequence/probability matrix	Rating for each risk*
Facility 5	Consequence/probability matrix	Rating for each risk*
Facility 6	Consequence/probability matrix	Rating for each risk*
Company D		
Facility 1	Checklist	List of control failures and action list
Facility 2	Checklist	List of control failures and action list

NI: not indicated, * rating for each risk with explanatory text in executive summary of report, † options for significance levels include insignificant, low, medium, high, moderate, and acceptable

to rate and rank each of the risks, in terms of significance level. Checklists enable the company to list control failures and develop action lists.

Risk assessment criteria

To establish internal (OHS management system) and external (legal) compliance, companies define the risk criteria aligned to the selected risk assessment techniques. The risk criteria reflect a company's willingness to accept (or not) a certain level of risk in view of internal risk management policies, which state the objectives, values, and resources dedicated to risk management.

Most of the facilities described all five of the risk assessment criteria (consequence measurement, probability expression, risk level determination, risk categorisation/prioritisation, and risk treatment (n = 14, 66.7%)) (Table 3). Each criterion has an associated scale, which assists in determining the level of risk. Company C was most 'compliant' in this regard (assessed the risk, using all five criteria in Table 3), followed by company B. Company D described only the risk level determination and risk treatment criteria in the risk assessments in both of its facilities. Company B excluded the risk treatment criterion.

Although risk assessments should include clear frameworks for determining risk tolerability, as described by the UK's HSE,[23] none of the participating companies addressed this. This criterion was not expected to be included, as there is no national guideline in which risk tolerability is comprehensively described.

Risk assessment process

Risk assessments are conducted in phases (risk identification, risk analysis, and risk evaluation), with the information collected during each phase used in the ensuing phases. The risk assessment processes followed by each company, which comprise the three phases, are shown in Table 4.

Risk identification, which involves identifying and recording risks (a basis for the entire risk assessment process), was an established practice in all companies. During the risk analysis phase, current exposure controls are identified and their effectiveness assessed, using qualitative, semi-quantitative, or quantitative approaches. Companies A, B and C identified and recorded current controls as part of the risk assessment process, but Company D had no record of doing this. Company C assessed the effectiveness of the control measures as a business practice; however, there was variability between the facilities in Company A in this regard (only n = 7, 63.6% assessed control effectiveness). Companies C and D did not include assessing the effectiveness of controls in use as part of the risk analysis phase.

Companies A (10 facilities), C (one facility), and D (all facilities) used qualitative risk assessments. Company B used a combination of semi-quantitative and quantitative risk assessments. Company C used all three risk analysis assessment methods, viz. qualitative, semi-quantitative, and quantitative. Uncertainties and sensitivities associated with the respective risk analysis techniques were not recorded in any of the companies' risk assessment reports.

Table 3. Risk assessment criteria included in the reports of each facility

	Risk assessment criterion					
Company/facility	**Consequence (of exposure) measure**	**Probability* (of exposure) expression**	**Risk level determination**	**Risk categorisation/ prioritisation**	**Risk treatment**	**Risk tolerability**
Company A						
Facility 1	✓	×	×	×	✓	×
Facility 2	✓	✓	✓	✓	✓	×
Facility 3	✓	✓	✓	✓	✓	×
Facility 4	×	✓	✓	×	✓	×
Facility 5	✓	✓	✓	✓	✓	×
Facility 6	✓	✓	✓	✓	✓	×
Facility 7	✓	✓	✓	✓	✓	×
Facility 8	✓	✓	✓	✓	✓	×
Facility 9	✓	✓	✓	✓	✓	×
Facility 10	×	×	×	×	×	×
Facility 11	✓	✓	✓	×	×	×
Company B						
Facility 1	✓	✓	✓	✓	×	×
Facility 2	✓	✓	✓	✓	×	×
Company C						
Facility 1	✓	✓	✓	✓	✓	×
Facility 2	✓	✓	✓	✓	✓	×
Facility 3	✓	✓	✓	✓	✓	×
Facility 4	✓	✓	✓	✓	✓	×
Facility 5	✓	✓	✓	✓	✓	×
Facility 6	✓	✓	✓	✓	✓	×
Company D						
Facility 1	×	×	✓	×	✓	×
Facility 2	×	×	✓	×	✓	×

* changed to 'likelihood' in 2020 SANS 31010, ✓ present, × absent

None of the companies recorded the status of previous or current decisions regarding risk treatment and the priority thereof during risk evaluation. Nonetheless, the risk assessment records for all four companies (all facilities) outlined proposed control solutions for identified risks.

Noise risk analysis outcomes

The inter- and intra-company risk analysis comparisons are shown in Table 5. Companies A, B and C had variable consequence and probability/likelihood ratings, which affected their risk priority rankings. Such variations are expected when different risk assessment criteria are used to determine the level of risk. The risk priority rankings in four facilities (5, 7, 8, and 9 of Company A) were inconsistent with the risk matrices (consequence and probability ratings).

At Company B, where both semi-quantitative and quantitative risk analysis techniques were used, the variation was consistently assigned two similar consequence, probability/ likelihood, and risk priority scores, highlighting an advantage of these techniques over the qualitative approach. Inter- and intra-company variation also extended to whether the untreated and residual noise risk was interpreted as low, medium, or high, which is critical for informing employers about the need to institute additional control measures.

The companies used different risk matrices, which are listed, together with their corresponding descriptors, in Supplementary Table 1. The table provides an overview of Companies' A, B and C risk matrices from which consequence and probability ratings, risk priority rankings, and/or risk scores were derived, for the risk analysis outcomes in Table 5. Company A facilities (other than Facility 11) used risk ranking/ categorisation to determine actions for control. To make decisions regarding the implementation of additional controls at Company B, an additional matrix, which included the hazard rating, exposure rating, and exposure bands, was used in decision-making for appropriate corresponding action. Company C's risk matrix comprised the calculated risk scores (consequence x probability ratings) for rating the risk, which determines the priority of control. It is important to note that the risk matrix outcomes and interpretations are influenced by the risk assessor.

Risk assessment documentation quality aspects

The risk assessment results should be clearly documented in the report. The extent of the assessed risk assessment reports regarding the content and quality aspects are shown in Table 6. The 12 criteria are aligned with the SANS 31000 guidelines.[17]

The companies' risk assessment reports had several discernible quality-related shortcomings. Addressing all the report quality aspects (shown in Table 6) increases confidence in the risk assessment process, the outcomes of which employers use to make risk treatment decisions. The 'discussion of results' and 'conclusions' support the outcomes of the risk analyses and locate the risk assessor's practical knowledge and experience, regarding the credibility of

Table 4. Health risk assessment processes followed in each facility

Company/ facility	Risk assessment process										
	Risk identification*	Risk analysis						Risk evaluation and decisions			
		Controls assessment		Assessment method			Uncertainties and sensitivities	Decision on risk treatment	Priorities for treatment	Activity status	Treatment paths
		Current controls identified	Control effectiveness	Qualitative	Semi-quantitative	Quantitative					
Company A											
Facility 1	✓	✓	✓	✓	-	-	×	×	×	×	✓
Facility 2	✓	✓	×	✓	-	-	×	×	×	×	✓
Facility 3	✓	✓	✓	✓	-	-	×	×	×	×	✓
Facility 4	✓	×	×	✓	-	-	×	×	×	×	✓
Facility 5	✓	✓	×	✓	-	-	×	×	×	×	✓
Facility 6	✓	✓	✓	✓	-	-	×	×	×	×	✓
Facility 7	✓	✓	×	✓	-	-	×	×	×	×	✓
Facility 8	✓	✓	×	✓	-	-	×	×	×	×	✓
Facility 9	✓	✓	✓	✓	-	-	×	×	×	×	✓
Facility 10	✓	✓	×	✓	-	-	×	×	×	×	✓
Facility 11	✓	✓	×	-	✓	-	×	×	✓	×	✓
Company B											
Facility 1	✓	✓	×	-	✓	✓	×	×	×	×	✓
Facility 2	✓	✓	×	-	✓	✓	×	×	×	×	✓
Company C											
Facility 1	✓	✓	✓	✓	✓	✓	×	×	×	×	✓
Facility 2	✓	✓	✓	✓	✓	✓	×	×	×	×	✓
Facility 3	✓	✓	✓	✓	✓	✓	×	×	×	×	✓
Facility 4	✓	✓	✓	✓	✓	✓	×	×	×	×	✓
Facility 5	✓	✓	✓	✓	-	-	×	×	×	×	✓
Facility 6	✓	✓	✓	✓	✓	✓	×	×	×	×	✓
Company D											
Facility 1	✓	×	×	✓	-	-	×	×	×	×	✓
Facility 2	✓	×	×	✓	-	-	×	×	×	×	✓

* risks recognised and recorded, ✓ present, × absent

Table 5. Inter- and intra-company methodological comparisons of noise risk analysis outcomes

Company/facility	Consequence (severity) rating	Probability (likelihood) rating	Risk priority ranking and/or risk score	Risk matrix priority ranking interpretation (risk categorisation and/or prioritisation)
Company A				
Facility 1*	2	2	III	Low – minor or no action required
	3	3	IV	Medium – action required, probably at administrative level
Facility 2	4	1	II	High – strong mandatory action required
		3	IV	Medium – action required, probably at administrative level
Facility 3	6	2	II	High – strong mandatory action required
Facility 4	NI	NI	NI	Low – minor or no action required
Facility 5	4	B	III†	Medium – action required, probably at administrative level
Facility 6	4	3	NI	Low – minor or no action required
Facility 7	4	B	III†	Medium – action required, probably at administrative level
Facility 8	4	2	III†	Medium – action required, probably at administrative level
Facility 9	4	2	III†	Medium – action required, probably at administrative level
Facility 10	NI	NI	NI	Acceptable§
Facility 11‡	NI	NI	Low, medium, high**	Not indicated
Company B				
Facility 1 – hazard inventory	2	D	2D	Medium – second priority
Facility 1 – task appraisal	3	C	3C	Medium – third priority
		D	3D	Medium – first priority for action
	3	E	3E	High – first priority for action
Facility 2 – hazard inventory	2	D	2D	Medium – second priority
Facility 2 – task appraisal	3	C	3C	Medium – third priority
		D	3D	Medium – first priority for action
Company C				
Facility 1	3	1	3††	Very low priority
Facility 2	4	2	8††	Low priority
Facility 3	NI	NI	Low§§	Low priority
Facility 4	4	2	8††	Low priority
Facility 5	NA	NA	NA	NA
Facility 6	3	1	Low§§	Low priority
Company D				
Facilities 1 and 2	NI	NI	NI	NI

* risk matrix considered inherent and residual risk, † risk priority ranking inconsistent with risk matrix descriptors, § risk assessment report omitted the risk matrix explaining 'acceptable' risk, ‡ consultant risk matrix used in the assessment, ** risk matrix used only categorised risks and proposed specific control measures for each assessed risk, †† risk scores, §§ no risk score shown on source document, NA: not applicable, NI: not indicated

Table 6. Risk assessment report quality aspects

Quality aspect	Company A	Company B	Company C	Company D
Objectives and scope	✓	✓	✓	×
Risk criteria application	✓	✓	✓	×
Limitations, assumptions, and justification of hypothesis	×	×	×	×
Assessment methodology	✓	✓	✓	×
Risk identification results	✓	✓	✓	✓
Data, assumptions, and their sources and validation	×	×	✓	×
Risk analysis results and their evaluation	✓	✓	✓	✓
Sensitivity and uncertainty analysis	×	×	×	×
Discussion of results	×	×	×	×
Conclusions	×	×	×	×
Recommendations	✓	✓	✓	✓
References	✓	×	×	×

✓ present, × absent

sources of information and factors (consequence and probability descriptors), considered during the risk analysis process. These methodological aspects also facilitate alignment of the risk assessment, by ensuring that the objectives defined during the risk identification phase have been met. Although not explicitly mentioned in the respective risk assessment reports, it is assumed that conclusions relate to priority rankings, based on the stated risk assessment objectives.

DISCUSSION

Regulatory context

Noise risk assessments were conducted by the four participating companies within a regulatory context. In doing so, employers fulfil the legal duty described in Section 8 of the Occupational Health and Safety Act.[7] With the inspection and enforcement strategy of the Department of Employment and Labour being dominantly self-regulatory in South Africa, it is conceivable that these companies also conducted risk assessments to demonstrate conformance to their own internal standards and guidelines. The latter are voluntary but give workers assurance that health and safety risks are addressed systematically and comprehensively, whilst also complying with regulatory requirements. To achieve the aims and intended outcomes of a voluntary OHS system, organisations need to take effective preventive and protective measures to eliminate hazards and minimise risks.[3]

Risk assessment techniques/tools and risk assessment criteria

The risk assessment techniques[19] selected by the participating companies determine the different inputs (consequence of exposure, probability of exposure) and outputs (rating of each risk, ranked list of risks with significance levels, list of control failures, and action list). The outputs for the consequence/probability techniques, as observed for Companies A, B and C, included either a combination of a rating for each risk or a ranked list of risks with significance levels. Company D's risk assessment output produced a list containing inadequate controls or a list of risks.[19] Regardless of the technique or tool selected, they should increase the understanding and management of risks.[27]

In practice, the consequence/probability matrix is a useful tool for ranking risks and identifying the sources,[19] which fosters the correct risk perception by assessors, and provides a visual platform for communicating the magnitude of the risk. At the same time, the outcomes derived from interpreting the matrix indicate the company's commitment to reducing the identified risk.[28] When using the consequence/probability matrix, however, its intended applications must be defined, as different matrices for safety, environment, health, and economic risks may exist within a company.[28] Constraints of the consequence/probability matrix includes being unable to aggregate risks, difficulties in defining consequence/probability rating criteria unambiguously, subjectivity, and variation in scale interpretation between assessors,[19] as observed in Companies A, B and C.

Using a checklist as a risk assessment tool (Company D) is also useful during hazard and risk identification, and for the assessment of the effectiveness of controls. However, its use inhibits imagination in risk identification, as it only addresses known hazards or risks, and encourages 'tick the box' behaviour whilst also tending to be observation-based, which can result in the omission of hazards or risks being recorded if they are not seen.[19]

The output of the risk assessment techniques adopted by the companies should have had an overall risk criterion (risk tolerability) guided by local legal requirements; this was absent across all four participating companies. In this regard, the consequence/probability matrix and checklists adopted by the respective companies were limited to risk rating and ranking, risk prioritisation, and recommendation for risk treatment, against the backdrop of a regulatory environment in South Africa without a national guideline for the tolerability of risks.

In South Africa, there are prescriptive health and safety standards, rather than regulations, for various occupational health hazards that are used as criteria for tolerability of risk.[7,29] The UK, through the HSE, provides regulatory guidance on the definition of tolerability of risks,[23] which considers risk estimation uncertainties and costs required to reduce the risks.[30] The tolerability of risk, when applying the 'as low as reasonably practicable' principle, requires employers in South Africa to spend a large amount of money to reduce risks that are rated as high and unacceptable. Less significant risks are less costly to reduce.[23,30] In the absence of legal guidance, companies should develop internal tolerability criteria, which none of the companies did. In developing such criteria, companies should consider the nature, probability/likelihood and consequences of the risk, types of exposure databases, measures of risk analysis, the available methods for risk assessment, regulatory requirements, organisational factors such as the safety culture and work flexibility, and individual factors such as risk perception and values.[31] The tolerability of risk criteria should also be aligned with the company's risk management framework, which should be specific with regard to the scope of the activity being considered, and the regulatory requirements against which legal compliance is measured.[17] Although not all risks can be eliminated or removed, the risk criteria provide decision-makers with a tool to decide on the tolerability of residual risks.[31]

Company risk assessment processes

Risk assessments are conducted systematically and iteratively, and should be supplemented with additional investigations as the need arises.[17] Hazard and risk identification, a prelude to the entire risk assessment process, was conducted across all the participating companies. All identified hazards should be accompanied by the identification and assessment of existing design, human process, and system controls. The identification of exposure controls in a risk assessment suggests that measures taken by the employer have not been efficient in mitigating exposure. This applies particularly to reliance on personal protective equipment (PPE) such as hearing protective devices, the use of which is affected by low worker acceptance and usage.[32] The existing controls, when assessed during the risk analysis phase, have an impact on the final risk level, based on judgements about whether they are adequate and effective.[3,19] This practice was applied at Company C (all facilities) and nearly all operational facilities of Company A (except Facility 4), whilst being absent at Companies B and D. Judgements on the adequacy and effectiveness of existing controls require proper assurance processes to increase confidence about such judgements.[19] The bow tie analysis,[33] an example of a tool for assessing the adequacy and effectiveness of existing controls, is available for use by assessors.

The use of qualitative, semi-quantitative, or quantitative risk analysis assessment methods plays a role in the ranking of risks,[19] as each method may yield a different risk outcome. The quantitative method is considered to be the most accurate method, provided that there are sufficient data to calculate an absolute value of risk.[31]

Only Companies B and C used quantitative methods. Regardless of the risk analysis method used, a company must develop a procedure to use in assigning hazard and risk rankings.[28]

When conducting a risk assessment, the influence of uncertainty must be addressed[34] to increase trust in the outcome. None of the participating companies included an assessment of uncertainty in their risk analysis phases. This opens the risk assessment process to criticism that the numbers used to express risk are dependent on assumptions,[35] whilst disregarding ethics, values, justice, and fairness.[36] The probabilities used in risk assessment are also subjective, leading assessors to make judgements that overestimate or underestimate risks. This highlights the importance of background knowledge when assigning consequences and probabilities.[35] Other criticisms of risk assessments are that they involve some guesswork on the part of assessors, and that decision-makers can manipulate the results to justify a conclusion that suits their agendas or wallets.[36] Risk assessments are further complicated by scenarios where occurrences of hazards with low probability, but which carry catastrophic consequences, need to be weighed against those with higher occurrence probabilities but less serious consequences.[37] Another criticism is the variance in adverse health effects between individuals due to confounding factors such as general health, proximity to the hazard, experience, weather conditions, and visibility.[28] These issues highlight the potential limitation of inadequately conducted risk assessments with regard to risk management. Such criticism adversely influences the attitudes of decision-makers when interpreting risk assessment results, especially regarding the implementation of feasible and effective risk treatment options.[38]

Noise risk analysis outcomes

The risk analysis that accompanies qualitative assessments, as adopted at Company A, is dependent on the perception of the assessor who subjectively makes decisions based on personal circumstances, such as field or practical experience – a potential contributing factor to the observed inter- and intra-company variations. The results of each risk analysis inform the decisions to 1) do nothing, 2) consider risk treatment options, 3) conduct additional risk analysis, 4) maintain existing controls, or 5) reconsider objectives.[17] In making judgements about risk treatment, following risk evaluation, company decision-makers are required to consult additional information sources and combine this with outcomes from the risk evaluation phase.[4] However, the associations between the risk assessment and decision-making processes are not always clear,[22] as demonstrated in the risk evaluation outcomes of Companies A, B and C (Table 5).

Amidst a plethora of other health hazards, results from a risk assessment should enable prioritisation of decisions regarding which hazards should be reduced; it is impossible and uneconomical to eliminate all hazards.[28] In view of the finite resources available for risk reduction, Griesmeyer and Okrent (1981)[39] posited that a risk management approach that has an allowance for uncertainties, internalisation of residual risk costs, modest risk aversion, and cost-effective reduction of residual risk, should be conducted. The risk ranking matrices allow for priority-setting and enable informed decision-making as it is done by technical or subject-matter experts, using professional judgement within an explicitly defined framework.[40] Inaccurately ranked risks have a societal effect in that technological risk, such as noise, can become acceptable, resulting in society bearing the associated costs that arise.[39] Risk assessment should consider the worst likely health effects.[28] Risk acceptability should thus be addressed in the context of the availability of technology to reduce risks.[39]

Risks that are rated as high should trigger immediate corrective action, whilst discretionary action may be considered for those with low ratings.[28] Internal tolerability of risk criteria, which none of the participating companies had, enables decision-making about the acceptability of residual risks, following the entire risk assessment process.[41] From a technical and legal perspective, risk analysis methods that rate noise levels that exceed the noise rating limit as anything other than intolerable cast doubt on such methods.[42]

Risks rated as medium also require further consideration, using tools such as cost-benefit analysis. However, this should be done with caution as excessive cost estimates that make risk reduction measures unaffordable can discourage employers from introducing controls to reduce levels.[30,39] High cost estimates for proposed risk reduction measures should spur employers to find simpler, more effective risk reduction measures.[30]

Companies that assign noise as a low risk, as observed in some facilities in this study, are within their methodological bounds to do so. Such risk acceptance may be reflective of societal preferences, with economic considerations being a major factor. Risk acceptance should, however, not be based solely on perceived risk and societal acceptance, but should also consider alternatives such as cost effectiveness.[39]

In cases where consequences of risk are unacceptable and impossible to reduce, the magnitude of the risk and the control measures required to prevent occurrence of the hazard should be considered.[30] A multidisciplinary approach should be employed for identifying risk-reduction strategies, normally within the prescripts of the risk-reduction priority scheme (hierarchy of control). If more than one risk-reduction strategy is being considered, the effect of each strategy should be weighed carefully, as this is helpful in the assessment of the acceptability of residual risks.[41] Additionally, worker hazard profiles can be developed to prioritise implementation of workplace exposure controls.[43] Instances where noise is rated as low create dilemmas as there is currently no clear way of treating low risks, and they are either completely ignored or under-emphasised.[35]

Risk ranking models involve a degree of subjectivity where decisions are made amidst missing data and uncertainties. The subjective nature of risk ranking models becomes more apparent when setting priorities for control,[40] demonstrable for Companies A, B and C (Table 5). The subjectivity and resultant inconsistencies have an eroding effect on the trust that employers derive from risk assessments. Risk ranking should therefore be complemented by cost-benefit analysis. When used together, a comprehensive and robust risk analysis can be produced.[40] None of the participating companies' risk assessments included cost-benefit analyses to complement the risk rankings. This is an opportunity for improvement for these companies.

In accordance with the UK's Health and Safety Executive framework on tolerability of risk, a risk regarded as tolerable does not imply that it is acceptable but refers to society, as a whole, being willing to accept the risks for their benefit, provided the risk is adequately controlled. Benefits include employment, lower cost of production, and personal convenience. Nevertheless, these risks should still be reduced using appropriate controls, to a point where they fall within a tolerable range, with the ultimate goal of reducing the risk to the lower end of the broadly acceptable region. This is in line with the 'reasonably practicable' principle.[23]

Risk assessment document quality aspects

To ensure that the risk assessment process complies with expected quality aspects, the completeness, accuracy, and identification of sources of data uncertainties and model/method uncertainties should

be mentioned,[19] a practice that was absent in all the participating companies. Health-related regulations prescribe that records that are kept, regarding risk assessments, should include the recording of information such as sources of exposure, adverse effects of exposure, extent of exposure, nature of work processes, and any reasonable deterioration in, or failure of, any control measures.[8-10,12,13] These aspects were omitted by some of the participating companies (not reported in this paper). The complexity of each risk assessment and internal company reporting requirements influenced how these factors were recorded.[19] These factors vary over time and become important during the monitoring and risk assessment review process.[19] None of the participating companies' risk assessment records included a discussion of the results of the assessment, nor were sensitivity and uncertainty analysis mentioned – these are additional opportunities for improvement.

CONCLUSION

The motivational context for conducting risk assessments across the participating companies stems from the legal duty imposed on employers, by health regulations within the Occupational Health and Safety Act, to assess health risks attached to performed work. The risk identification, control effectiveness assessment, and risk assessment tools and techniques varied across the companies – a result of an absent national prescription or directive for conducting health risk assessments. Inter- and intra-company company variations are anticipated amidst such an operating environment. Risk assessment tools and techniques that assign a low or insignificant risk to noise have a detrimental effect on noise control efforts, desperately required for the South African manufacturing and utilities sectors, to stop the scourge of NIHL. Similarly, risk assessment techniques that assign a high risk to noise should implement risk treatments to eliminate, substitute, or out-engineer noise emission sources. Risk assessment techniques employed by the corresponding companies require optimisation with regard to the impact of control effectiveness, uncertainty, and sensitivity, and use of qualitative, semi-quantitative, and quantitative risk methods.

KEY MESSAGES

1. Risk assessment processes, tools, and methodologies differ between companies and internally, to the detriment of noise abatement interventions.
2. The absence of a tolerability of risk framework in South Africa undermines the effectiveness of risk assessment processes.
3. The risk assessment as a decision-making tool in risk management is diminished by the potentially poor or inappropriate methodology used.

DECLARATION

The authors declare that this is their own work; all the sources used in this paper have been duly acknowledged and there are no conflicts of interest.

AUTHOR CONTRIBUTIONS

Conception and design of the study: OR, TJM, DMM
Data acquisition: OR
Data analysis: OR
Interpretation of the data: OR
Drafting of the paper: OR
Critical revision of the paper: TJM, DMM, OR

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