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A DESCRIPTIVE STUDY OF OCCUPATIONAL NOISE EXPOSURE IN SMALL-SCALE GRAIN GRINDING MILLS IN BULAWAYO (ZIMBABWE) FROM 2003 TO 2005

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg in partial fulfilment of the requirements for the degree of Master of Public Health in Occupational Hygiene.

Johannesburg 2006

DECLARATION

I, Dingilizwe Mazibuko declare that this research is my own work. However, Mr. Farikayi K. Mutasa of the Zimbabwe Open University rendered assistance in the analysis and presentation of data.

The research is being submitted for the Masters in Public Health degree in Occupational Hygiene (MPH:OH) University of the Witwatersrand, Johannesburg, South Africa.

This research has not been submitted for any degree or examination at this or any other university.

I further declare that this research was approved by the Human research Ethics Committee (Medical) of the University of the Witwatersrand, reference no. PC – J/44/dsk10es.

.....

12 January, 2007

Dedicated to my wife Nomuhle and daughters Nandipha and Vuyelwa.

ABSTRACT

Over the past fifteen years, Zimbabwe has experienced a proliferation of small-scale enterprises. Noise is one of the many occupational health and safety hazards identified in these small-scale enterprises. The adverse effects of noise exposure include noise-induced hearing loss or impairment, tinnitus, interference with speech communication, annoyance, headaches, fatigue and high-blood – pressure. Occupationally though, noise-induced hearing loss is the most serious health effect. Despite this, collated statistics on occupational noise levels, noise exposure and cases of noise-induced hearing loss or impairment in this growing informal and small-scale sector remains unavailable in Zimbabwe.

The objectives of the study were to describe prevailing noise levels from 27 small-scale grinding mills in Bulawayo from 2003 to 2005, identify major sources of noise in these grinding mills, compare the prevailing noise levels with national and international noise occupational exposure limits and to recommend appropriate noise preventive and control measures.

The research is a retrospective descriptive study of noise survey results routinely collected by the Factories and Works Department from October 2003 to June 2005. The study population and sample were small-scale grinding mills in Bulawayo employing 10 or fewer employees as compiled from the licensing and registration records of the local authority.

Noise measurements results were statistically analysed to characterise their distribution and relationships to national statutory and international hearing protection standards.

The measured noise levels ranged from 81.2dB(A) to 101.2dB(A). Over 96% of noise levels from grinding machines (mean 96.2dB(A) and de-hulling machines (mean 95.4dB(A) were significantly above the Zimbabwe Statutory Occupational Exposure Limit (OEL) of 90dB(A) and the international recommended OEL of 85dB(A). Sievers on the other hand with mean noise levels of 85,5dB(A) satisfied both Zimbabwean and international noise standards. Grinding and de-hulling operations were the major sources of noise. 85.2% of employees in small-scale grinding mills worked shifts longer than 8 hours and all 27 grinding mills (100%) did not have any form of noise protection or control measures in place.

The results of this study demonstrate that workers in small-scale grinding mills are significantly exposed to noise levels above the national OEL – TWA of 90dB(A), for periods exceeding 8 hours without any form of hearing protection.

There is therefore a need to put in place noise control measures to protect employees from such exposure. Such measures can include engineering, administrative and hearing protection measures, coupled with noise monitoring, health surveillance and training programmes.

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NOMENCLATURE

ILO	International Labour Organisation
ISO	International Organisation for Standardisation
SSE	Small Scale Enterprises
RBZ	Reserve Bank of Zimbabwe
PPC and E	Personal Protective Clothing and Equipment
NIHL	Noise Induced Hearing Loss
NIOSH	National Institute of Occupational Safety and Health
TWA	Time Weighted Average (Exposure)
OEL	Occupational Exposure Limit
SABS	South African Bureau of Standards

CHAPTER 1

1.0 INTRODUCTION

In this chapter, noise is defined and its characteristics discussed. The adverse effects of prolonged, cumulative exposure to moderately high noise are reviewed. Measurement methods and control measures for noise are covered. Literature on small-scale industries in Zimbabwe and sub-Saharan Africa and the prevalence of noise as one of the occupational hazards found in these small-scale industries, including grinding mills is reviewed. The chapter ends with the outlining of the aims and objectives of this study.

1.1 Background

Noise is known as unpleasant or unwanted sound but has been defined as any sound pressure variations in the air or other medium that the human ear can detect (Brüel and Kjaer, 1984). Sound is regarded as noise if it has the potential to interfere with communication or damage people's hearing. It is one of the most ubiquitous hazards in today's occupational environment, affecting workers in diverse employment settings including manufacturing, mining, forestry, agriculture, transportation and the military. High levels of mechanisation resulting from the industrial and agricultural revolutions has led to increased machine speeds and an increase in the number of machines in our workplaces. This has resulted in many workers being exposed to daily noise levels above 85dBA (African Newsletter on Occupational Health and Safety, 1992).

Prolonged exposure to moderately high noise levels is known to cause adverse health effects to workers, especially if they are not using any hearing protection devices. The adverse effects of cumulative noise exposure include noise – induced hearing loss or impairment (either temporary or permanent), tinnitus, interference with speech communication, annoyance, headache, high blood pressure, fatigue, stress and the increased risk of accidents. Noise-induced hearing loss or impairment however, is the most common and probably the most serious adverse effect, occupationally (International Labour Organisation Encyclopaedia, 1998). In South Africa, noise-induced hearing loss was the leading reported compensatable condition between 2000 and 2002 (Compensation Commissioner's Annual Report, 2000/2).

Measurement of sound provides definite and objective means of describing and comparing noise levels and also provides quantifiable means of determining when sound may cause damage to hearing, thus permitting appropriate corrective measures to be taken timely (Brüel and Kjaer, 1984).
Noise measurements are advisable when it becomes necessary to shout in order to be audible to a person about one metre distant. In such cases, workers in a noisy environment cannot hear each other when conversing at normal auditory tones.

Measurements can be carried out for statutory purposes, assessing personal noise exposures, identification of noise sources, noise mapping or for checking the effectiveness of prevention measures. Measurement methods and equipment vary

depending on the type and the reason for the measurement being undertaken. A person who has received adequate training in noise measurement techniques should always undertake such noise measurements.

Because of the noted adverse health effects, workers should not be exposed to noise levels of more than 90dB(A) for eight hours per day in terms of Zimbabwean health and safety statutory requirements (Factories and Works General Regulations, 1976). To this end, noise prevention and control measures should be put in place at workplaces. These measures include environmental noise control, control of noise at source, reduction of noise transmission and provision of ear protection devices to exposed workers.

1.2 Statement of the problem

Studies in Sub-Saharan Africa have indicated noise to be one of the prominent health and safety hazards in small-scale industries including motor vehicle repair workshops (panel-beating), metal fabrication, wood working and hammer millers (Atambo G 1995,Rongo L 2004 and Yisa A.M 2005).

In the past fifteen years Zimbabwe has seen a major growth of the small to medium scale sector which has come to be recognised and acknowledged by government as a major contributor to the National Gross Domestic Product and a growing employer of labour (Business Chronicle, 2005). Small-scale grinding mills in urban areas and rural business centres have also mushroomed as part of this growing economic sector.

Although it is known and accepted that noise is one of the most ubiquitous occupational stressors, no studies have been carried out so far in Zimbabwe to collect scientific data on prevailing noise levels in the small-scale industrial sector. As such, not much is known about noise levels, exposures and impacts in this industry hence the need for this study.

1.3 Aims and Objectives

1.3.1 Aim of the Study

The study describes occupational noise exposure in small-scale grinding mills in the Bulawayo area from October 2003 to June 2005.

1.3.2 Specific Objectives of study

i) To describe noise levels in 27 small-scale grinding mills in Bulawayo from 2003 to 2005.

ii) To identify major sources of noise in small-scale grinding mills.

iii) To compare prevailing noise levels in small-scale grinding mills with the national and international Occupational Exposure Limits of 90dB(A) and 85dB(A) respectively.

iv) To recommend noise preventative and control measures.

1.4 Definition of Terms

Sound: Any pressure variation (in air, water or other medium) that the human ear can detect.

Noise: unwanted or unpleasant sound.

A-weighted sound pressure level dB(A): a sound pressure level (noise) frequency weighting electronic circuit which sensitivity is nearly the same as that of the human ear, and is used to estimate ear damage potential of any noise.

Equivalent continuous a weighted sound pressure level: (LAeq) refers to A-weighted sound pressure level in decibels, determined over a time interval T. Equivalent Continuous A-weighted sound pressure level determined over 10 minutes is expressed as LAeq, 10 minutes.

Max P: the maximum noise peak level in the elapsed measurement time.

Hearing conservation: the prevention or minimisation of noise-induced hearing impairment by the control of noise through engineering methods and the implementation of hearing conservation procedures.

Small-scale sector: Small scale units producing and distributing goods and services and employing up to 10 workers.

Time weighted average (TWA): a time weighed average level or concentration of a hazard for a normal 8 hour work day and a 40 hour work week to which nearly all workers may repeatedly be exposed to every day without any adverse health effects.

Occupational Exposure Standard: a health based workplace standard to protect workers from adverse exposures (**e.g. TLVs, STELs, TWAs**).

Tinnitus: a ringing, roaring or hissing sound in one or both ears.

Hearing zone: a 0.10 metre spherical diameter surrounding the head.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Small-Scale Enterprises

There is no standard definition of what constitutes a small-scale industry. Some common definitions that have been used by various countries or organisations are based on the number of workers in the establishment, their coverage by occupational health legislation, the type of industry, the level at which the enterprises are managed or the size of their capital investment.

The International Labour Organisation (ILO) defines small-scale enterprises as "very small-scale units producing and distributing goods and services and consisting largely of independent, self-employed producers which are for the most part, unregulated and unrecorded in official statistics with little access to organised markets, formal credit training or public services amenities (ILO Encyclopaedia, 1998)".

According to Rongo (2004), small-scale enterprises are broadly conceived as very small-scale private units employing less than 10 persons and involved in the production of goods and services for sale in both rural and urban areas (Rongo, 2004). For purposes of this study, small-scale grinding mills were defined as those employing up to 10 workers.

According to the ILO, small-scale enterprises often operate on small profit margins that are achieved at the expense of their workers in terms of hours of work, intensity

of workloads and exposure to occupational health and safety hazards (ILO Encyclopaedia, 1998). As a result, most small-scale enterprises have a short life span and are very mobile, changing premises to cut costs and survive.
Small-scale enterprises are highly employment-intensive and even in industrialised countries, they offer employment to the workforce that is no longer employed by formal industries and otherwise would be unemployed (Rantanen et al, 1994).

2.2 Emergence of small-scale sector in Zimbabwe

The political and economic challenges Zimbabwe has faced in the past fifteen years have resulted in a marked decline in the country's economic performance, with reduced outputs in the agricultural sector (the economy's backbone), coupled with shrinkages in the mining, manufacturing and tourism industries. This resulted in reduced foreign currency inflows and in an increase in the country's inflation rate that has now reached four digits. This has seen the closing down, the down sizing and even the relocation of companies from the country with consequent loss of employment (Central Statistical Department Report, 2001/2002).

The growing numbers of these unemployed persons, including school leavers coming into the employment market have turned to the small-scale sector for employment and sustenance. Over the years, the small-scale sector in Zimbabwe has grown and has assumed increased national economic significance in terms of employment creation and it's contribution to the national fiscus. In 2000, the Reserve Bank of Zimbabwe estimated that the small-scale sector was employing

around 3.8 million people and had contributed an estimated 15% to the Gross Domestic Product (RBZ Weekly Economic Highlight, June 2000).

The small-scale sector in Zimbabwe now covers all sectors of the economy. In 2000, agriculture was the largest informal sector employer, employing about two million people or 56% of the sector. The mining sector employed 10% with the manufacturing sector accounting for 28% of the total small-scale sector employees (RBZ Weekly Economic Highlight, June 2000). In recognition of this emerging sector's importance to the national economy, the government has set up a fully-fledged Ministry of Small and Medium-Scale Enterprises Development to spearhead the growth of this industry and enhance it's contribution to the country's Gross Domestic Product (Business Chronicle, 1 March 2005).

Despite its growing importance and significance to the nation's economy, information about the occupational health status, problems and needs of this sector or industry is still inadequate. However, several studies have been carried out in sub-Saharan Africa, including Zimbabwe on occupational health risks in the small-scale sector.

2.3 Occupational Health and Safety Problems of Small Scale Enterprises (SSEs)

Studies in less developed and newly industrialised countries show that the occurrence of hazards and their severity in SSEs may be exceptionally high compared to large formal enterprises (Rantanen et al, 1994).

A study by Dr. Renee Lowenson in 1998 on small-scale enterprises in Zimbabwe established that they faced many occupational health and safety hazards similar to those found in the formal sector. These included poor housekeeping, poor lighting, noise, long hours of work, poor workplace design and exposure to hazardous chemicals (Lowenson, 1998). Noise, dust and heat problems were found in 58% of the manufacturing sector's small-scale enterprises covered in the study (Lowenson, 1998). Only 5% of the enterprises provided any form of personal protective clothing and equipment (PPC & E) for their workers.

A survey carried out in 1995 by Helen G. Atambo in Jua Kali industries (which are informal small-scale industries operating in undesignated areas under temporary and makeshift shelters in Kenyan urban centres), established that workers in these Jua Kalis were exposed to a concoction of health and safety hazards including physical, chemical, biological, psychosocial and ergonomic hazards (Atambo G. 1995).

Another study by Dr. Larama Rongo on occupational exposures and health problems in small scale industry workers in Dar es Salaam, Tanzania, revealed that workers in such small-scale industries as garages, metal workshops, hammer millers and wood workshops were exposed to excess noise, dust, metallic fumes (from welding and soldering) and exposure to chemicals during the handling of chemicals (Rongo 2004).

In an ergonomic study carried out in Minna, the capital of Niger State in Nigeria, 20 randomly, selected small-scale grain mills were assessed for ergonomic compliance

in various areas, which included man-machine and human dimensions, temperature and noise. The results of the noise measurements taken at operators' ear-level ranged from 83.4dB(A) to 110.3 dB (A) (Yisa G.M. 2005). The noise levels measured in the mills were higher than the recommended value of 80dB(A). In some of the mills, communication was so hampered by the noise levels that sign language became the mode of communication between the operators and the clients.

2.4 Noise as an Occupational Health and Safety Problem

Noise, one of the hazards identified in the various studies carried out in small-scale enterprises including grinding mills, is recognised as one of the most ubiquitous of all occupational hazards, although not necessarily the most dangerous (African Newsletter on Occupational Health and Safety, 1992).

In the United States of America, more than 9 million workers are exposed to daily average A – weighted noise levels of 85dB(A) (ILO Encyclopaedia, 1998). The United States of America's Department of Labour estimates that 19.3% of workers in the manufacturing sector are exposed to levels of noise above 85dB(A) and 53.1% to levels above 80dB(A) (ILO Encyclopaedia, 1998).

According to Rantanen et al, noise is evidently the most common physical factor to which workers in numerous different activities such as construction; manufacturing, mining and transportation are exposed to. Levels of 100 to 120 dB(A) are not uncommon (Rantanen et al 1994). More than 50% of workers, particularly in industrialised units in developing countries and 10 to 20% of workers in industrialised

countries may be exposed to noise levels in excess of 85dB(A) (Rantanen et al, 1994). The noise levels are higher in less developed countries (including Zimbabwe) as engineering controls are not used as widely as in developed nations and the machinery used in their industries tends to be older. In these developing countries, hearing protection is often poor or none-existent and as a result, prevalence of noise-induced hearing loss at the level of 30% has been reported (Revente B.R., 1992). No collated scientific data on noise levels, noise exposures and incidence and prevalence of noise-induced hearing loss on Zimbabwean industries is available.

2.4.1 Health Effects of Noise

The adverse health effects of noise exposure include noise-induced hearing loss or impairment (NIHL), tinnitus, interference with speech communication, annoyance, headaches, high blood pressure, fatigue etc. Noise has also been shown to play an important role on work performance. Studies have shown that workers in high-noise environment have more lost-time accidents and are less productive than those with lower noise exposures (Schutte P.C. 2005).

Of all the adverse effects of noise exposure, noise induced hearing loss or impairment is the most well - known and probably the most serious, especially occupationally. Although noise-induced hearing impairment is very common, it is often underrated because there are no visible effects and, in most cases no pain. There is only a gradual, progressive loss of communication with colleagues, families, friends, and a loss of sensitivity to sounds in the environment. The severity of the hearing impairment depends on the level and frequency of noise, the duration of

exposure and the susceptibility of the individual (SIMRAC 2001). Intense noise or long stays in a noisy environment can lead to permanent reduction of hearing sensitivity caused by damage to the sensory organs of the inner ear (Brúel and Kjaer 1986). This type of hearing damage can never be repaired, thus the critical need to prevent it from occurring. In South Africa, hearing loss is one of the leading reported occupational conditions. Claims for noise-induced hearing loss received by the Compensation Commissioner between 2000 and 2002 were as follows:

- 1701 cases or 46.3% of all received cases in 2000
- 1785 cases or 55.3% of all received cases in 2001
- 2191 cases or 58.5% of all received cases in 2002

(Compensation Commissioner Annual Reports 2000 / 2).

2.4.2. Measurement of Noise

Measurement of sound provides definite and objective means of describing and assessing noise to enable the determination of noise-level thresholds which may be deleterious to human health, thus permitting appropriate corrective measures to be taken (Brúel and Kjaer, 1984). Noise measurements can be carried out for various purposes including;

- the assessment of personal noise exposure
- for statutory purposes
- for the identification of noise sources
- for noise mapping
- for checking the effectiveness of prevention / control measures.

Measuring methods and equipment used vary depending on the purpose for which measurements are being undertaken. Personal noise exposure can be evaluated by the use of noise dosimeters or A-weighted integrated sound level meters (Di Nardi, 1998). Personal noise dosimeters are more suitable for measuring noise exposure in cases where the noise levels fluctuate or when the worker moves around frequently during the work shift (OSHA, 1998). The noise dosimeter is convenient as it fits into a worker's pocket and the read-out is directly in percentage dose (Harrington et al 1998). Where the noise is more than 100%, it means the daily TWA of 90 dB (A) has been exceeded (see Table 2.1 below). The integrated sound level meter can also be used to determine noise levels, to identify the sources of noise and to evaluate whether there are noise peaks (NIOSH, 1998). Noise measurements should always be based on a rational sampling strategy and the accuracy of the measurements should be ensured by the use of instruments that have been electro-acoustically calibrated at 12-months intervals by an accredited laboratory (SABS 083:1996). Reports and certificates of such calibration should be maintained.

Table 2.1. Conversion from percent noise exposure or dose to 8 hour TWA sound level

Dose or Percent	Time Weighted Average dB(A)
50	85.0
60	86.3
70	87.4
80	88.4
90	89.2
100	90.0
110	90.7

Assumes 5dB exchange rate and 90Db Threshold Limit Value

2.4.3. Prevention and Control of Noise

The outcomes of the noise measurement provide a sound basis for the planning and implementation of noise control and prevention measures. The purpose of any noise control programme is two-fold: -

- to prevent the hazard of permanent hearing damage.
- to improve employee comfort and work efficiency.

Noise control and prevention measures include the following:

- elimination of noise sources, processes or operations.

- substitution of noise generating processes by none-noise generating processes (i.e. welding for riveting).
- at source noise reduction.
- controlling noise transmission through the workplace.
- improving machinery maintenance procedures.
- use of hearing protection devices by exposed personnel. (Schutte P.C. 2005).

All these principles are encompassed in well-designed Hearing Conservation Programmes.

2.4.4. Legal Limits

Noise is one of the few workplace stressors for which Occupational Exposure Limits (OELs) have been gazetted in Zimbabwean health and safety statutes. According to the Factories and Works (General) Regulations of 1982, the maximum Time-Weighted Average (TWA) noise exposure for an 8-hour day and 40 hour week should not be more than 90dB(A) (Factories and Works Regulations, 1976). Progressive legislation internationally has however placed this TWA noise exposure limit at 85dB(A) e.g. NIOSH and South Africa (Noise Induced Hearing Loss Regulations, 2003).

2.5 Rationale of study

The ubiquitousness of noise as an occupational hazard and the seriousness of this hazard (its adverse health effects) have been well documented in various studies. Studies in sub-Saharan Africa have identified noise as one of the prominent health and safety hazards in small-scale industries. Zimbabwe has over the past fifteen years seen a major growth of the small to medium scale sector, which has now been recognised as a major contributor to the National Gross Domestic Product as well as a growing employer of labour. However, no studies have been carried out to evaluate the extent and magnitude of this problem in this fast growing sector. Therefore, the aims of this study are: to determine and describe the prevailing noise-levels in small-scale grinding mills by analysing measurement results collected from 27 grinding mills in the Bulawayo area from 2003 to 2005, to identify common sources of noise in these grinding mills and compare the collected noise measurements to statutory occupational exposure limits, thus adding to scientific knowledge.

CHAPTER THREE

METHODS AND MATERIALS

3.1 Introduction

In this chapter, the materials and methods used in carrying out this study are described. The study design, study population and sampling strategy are discussed. The noise measurement equipment and methods are described including all the ethical considerations affecting the study. The chapter closes with an outlook of data analysis.

3.2 Study design

This study was a retrospective descriptive study of results from a cross-sectional noise survey carried out in small-scale grinding mills from October 2003 to June 2005 in the Bulawayo area.

3.3 Study population and sample

The study population were all the small-scale grinding mills in the Bulawayo area employing 10 or fewer workers in their operations. A list of such small-scale mills was generated from the City of Bulawayo's License Register and from the membership register of the Bulawayo Chapter of the Small-Scale Millers Association.

It should however be appreciated that the generated list is not complete and representative of all the small-scale grinding mills in Bulawayo as millers are not all necessarily members of the Small-Scale Millers Association, nor are they all licensed by the City of Bulawayo. Typical of small-scale entrepreneurs, several could be operating illegally and unregistered.

From the above two sources, an initial list of 33 grinding mills was drawn up. All 33 were visited and noise measurements carried out as part of routine workplace assessments from October 2003 to June 2005, a period of 20 months.

For purposes of this study, the following inclusion and exclusion criteria were set.

Inclusion criteria: Grinding mills in the Bulawayo area employing 10 or fewer workers.

Exclusion criteria: Grinding mills employing more than 10 workers and grinding mills employing 10 or less workers **but** located outside the Bulawayo area.

After the application of the inclusion / exclusion criteria, 6 grinding mills were disqualified, leaving a total of 27 grinding mills whose results were used in this survey.

3.4 The grain milling process

Grain goes through several steps and processes to be prepared for human consumption. In the unconventional small-scale grain milling, the process includes sieving where the grain is sieved with use of a wire-mesh screen to remove dust, stones, pieces of wood and other extraneous matter. This is virtually a manual process. From here, the grain goes into the de-hulling machine where the husks of the grain are removed. The grain can then be further sieved using mechanical sievers. This step is optional and many small-scale grinding millers skip it. The de-husked grain is then fed into the grinding machine where it is milled to the required grade. The milled grain is then packaged into packs of varying size and weights, normally 5kgs, 10kgs and 20kgs, which are sealed (sown) before being dispatched. The conventional milling process involves many more intricate steps than mentioned above.

The majority of small-scale grinding mills consist of one open room in which all the processing machinery viz: de-hullers, grinding machines and packing area are located. All the milling operations in essence take place in one room. The de-hulling and grinding operations take approximately 10 minutes per load (bucket), which are repeated throughout the day.

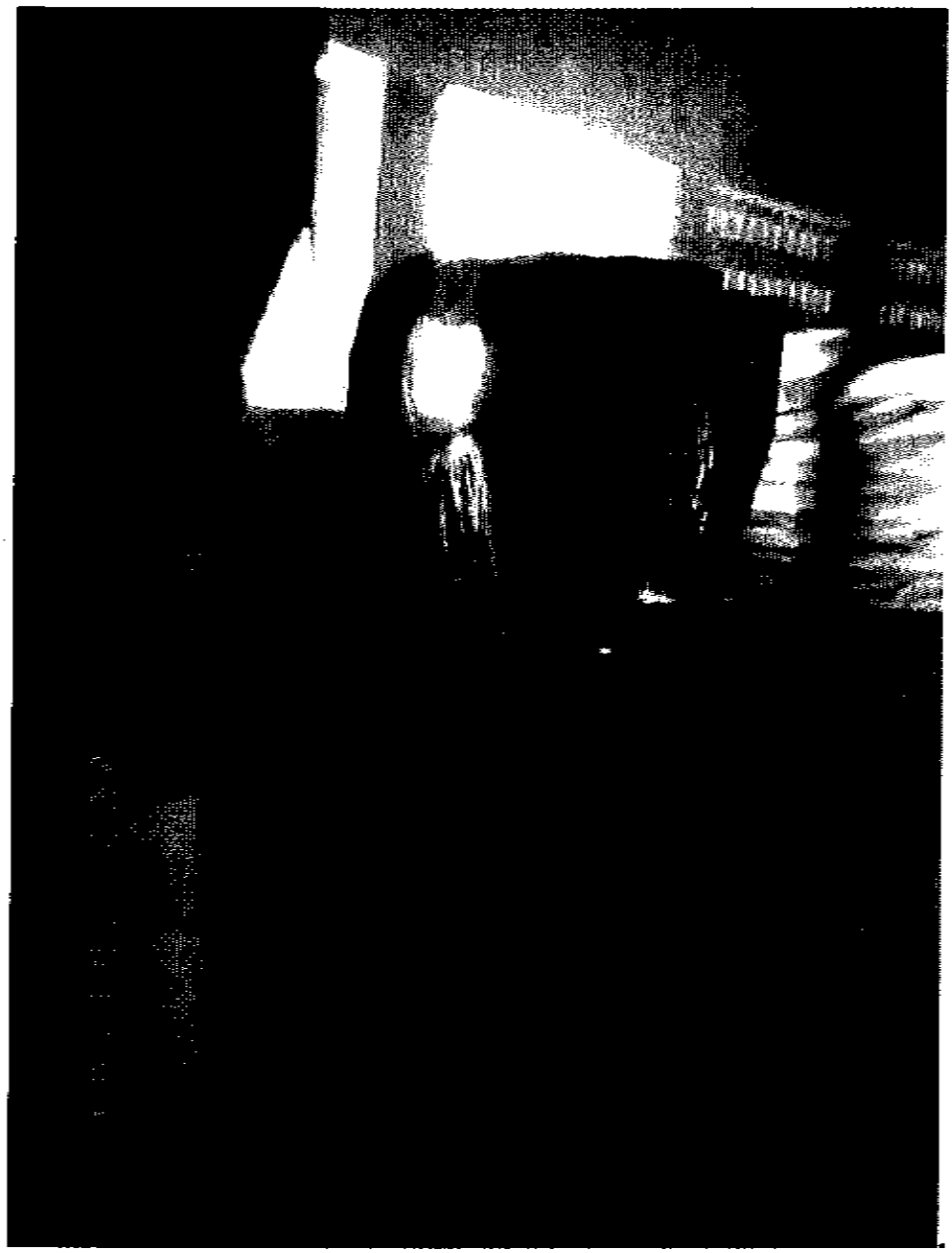

Fig 3.1 Typical grinding and de-hulling machines mounted in small-scale grinding mills

3.5 Noise measurements

The noise measurements were carried out by the Principal Researcher from October 2003 to June 2005. The noise measurements were done following the International Standard ISO 2204's survey method. The noise measurements were done using a Type 2 Sound Level Meter. A Type 2 Integrating Sound Level Meter is useful for measurements of short-term sound pressure measurements and non-steady state or intermittent noise, to determine the noise levels, to identify the sources of noise and to evaluate whether there are any noise peaks.

The instrument used for the study was a Brúel & Kjaer Integrated Sound Level Meter, Model 2237, serial no. 2255207 calibrated with the assistance of a Brúel & Kjaer Sound Level Meter Calibration System B & K 9600 cal 2237 on 24th October, 2000. A copy of the calibration certificate is attached (Appendix C). Further, the sound level meter was calibrated before and after each and every measurement using a Brúel and Kjaer calibrator Model 2237. At each grinding mill, noise measurements were taken for the various milling machinery or equipment found in these mills. At most mills, such equipment or machinery included de-hulling machines, grinding machines and packaging machines (stitching machines). The noise levels for each machine were measured separately with all other machines switched off. Noise measurements were taken for 10 minutes duration in each case to cover the de-husking or milling cycle. The following measurement parameters were noted:

i) LAeq – equivalent continuous sound level, which is the A-weighted sound pressure level in decibels determined over time interval T. Because the milling cycles are about 10 minutes long, the LAeq 10 minutes or equivalent continuous A-weighted sound pressure level determined over 10 minutes was used..

ii) Max P – peak sound pressure level.

All results are in decibel (dB (A).

The noise could not be characterised in terms of its frequency, as the Type 2 Integrating sound level meter does not have the capacity to do frequency analysis.

The noise measurements were made at an average distance of the operator from the milling machinery and at ear level within the monitored employee's hearing zone with the sound level meter's microphone directed towards the noise source. All measurements were done during regular working hours.

At each grinding mill where noise measurements were done, the following information and details were routinely captured: -

- Trading name
- Location/Address
- Number of employees
- Milling machinery or equipment installed
- LAeq 10 equivalent continuous level
- Max P- peak sound pressure level.
- Shift duration
- Noise control measures available/PPC issued.

3.6 Data analysis plan

Data were analysed to show the distribution of noise measurements. The sample mean, sample variance, sample standard deviation and sample range were calculated. Measurements from the grinding machines, de-hulling machines and packaging were analysed to determine whether there were was any similarity in the noise levels from various milling equipment or operations and whether they complied with national and international OELs. This was achieved through analysis of variance (ANOVA) and Fisher's test statistic. The test was done at 5% level of significance.

The results of the analysis will be used to identify the grinding mill equipment or activity producing the loudest noise between the grinding machines, de-hulling machines and packaging machines.

The data was also analysed to indicate whether or not noise levels were above national Time-Weighted Average – Occupational Exposure Limit (TWA-OEL) of 90dB(A) and the internationally recommended level of 85dB(A). The results will be used to determine compliance with national statutory limits (TWA-OEL) and international standards by the small-scale milling industry and also identify any potential Noise-Induced Hearing Loss cases from this sector.

The data was also analysed to assess noise exposure periods (work shift) and presence of noise control measures.

3.7 Ethics and confidentiality

Ethics approval for the study was granted by the University of Witwatersrand's Human Research Ethics Committee (Medical) on 26th June, 2006; reference number: PC-J/444/dsk/10es (see Appendix B) as the focus of the research was mainly the analysis of secondary data and no human subjects were involved.

Names and locations of the grinding mills were not released. Only pooled data analysis results were presented.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the analysed results of the study are presented and discussed. The data are first simply described and its distribution characterised. Analysis of variance (ANOVA) is used to examine and describe the relationship of noise-levels between grinding machines, de-hulling machines and packaging. The mean noise levels from the various milling operations are then compared with Zimbabwean and International Statutory Occupational exposure limits of 90dB(A) and 85dB(A) respectively through the use of frequency tables. Implications of these results are then discussed.

4.2 Description of statistics

A total of 83; 10 minutes LAeq (equivalent continuous A-weighted sound pressure levels) and 83 max P (maximum peak sound pressure levels) measurement results from 27 grinding mills were available for analysis during this study. The overall results are presented in table 4.1. The LAeq measurement figures were analysed and presented for this study, as the noise from the grinding operations is intermittent in its nature. LAeq measurements were therefore selected for data analysis because LAeq characterises noise from fluctuating or intermittent sources better than Max Peak measurements. The data were analysed to determine sample mean values, sample variance, sample standard deviation and range among other variables, for each of the four milling processes, viz.- de hulling, grinding and packaging.

Table 4.1 Results of noise survey in 27 small-scale grinding mills

GRINDING MILL	NO OF EMPLOYEES	SHIFT DURATION	PPC USE	DE-HULLER dB(A)		GRINDING MACHINE dB(A)		PACKING MACHINE dB(A)		SIEVER dB(A)	
				Laeq	Max	LAeq	Max	LAeq	Max	LAeq	Max
1	10	9 hours	None	94.3	96.1	96.7	97.5	84.3	84.9		
2	6	10 hours	None	94.9	96.1	97.3	97.7	89.1	91.0		
3	7	9 hours	None	92.9	93.5	93.7	95.2	86.1	89.2		
4	7	9 hours	None	96.1	97.9	95.5	96.3	82.4	83.0	85.1	85.5
5	10	9 hours	None	92.6	93.0	94.2	95.1	87.0	87.7		
6	10	10 hours	None	92.1	93.0	98.7	101.2	85.3	86.1		
7	6	9 hours	None	96.7	97.2	97.9	99.3	92.0	92.5		
8	4	8 hours	None	96.5	97.4	93.4	94.0	92.1	92.9		
9	3	8 hours	None			98.7	100.3	93.2	94.8		
10	10	9 hours	None	93.1	93.6	94.7	95.3	89.7	92.0	88.0	90.1
11	10	10 hours	None	94.6	95.2	95.9	96.7	92.5	93.1		
12	9	10 hours	None	94.2	97.8	94.7	96.9	82.8	84.1		
13	10	9 hours	None	89.2	91.4	93.1	95.0	82.0	82.7	83.3	83.5
14	5	9 hours	None	97.2	97.9	96.9	97.1	89.1	90.7		
15	9	11 hours	None	94.3	97.1	92.6	93.9	87.4	88.3		
16	7	9 hours	None	92.0	92.9	89.7	91.5	81.2	83.5		
17	5	10 hours	None	97.8	101.1	102.5	105.6	92.3	95.2		
18	7	10 hours	None	95.7	97.0	98.2	99.2	91.6	93.1		
19	7	9 hours	None	92.4	92.9	94.1	94.5	88.7	92.0		
20	5	10 hours	None	93.7	95.1	94.6	95.3	89.3	92.3		
21	8	10 Hours	None	94.8	96.2	91.9	92.3	87.6	89.2		
22	3	9 hours	None	97.3	99.1	101.2	103.5	92.5	96.6		
23	6	8 hours	None	95.5	96.1	92.7	93.6	87.4	90.9		
24	7	10 hours	None	93.7	94.9	95.4	97.1	90.3	92.5		
25	7	9 hours	None	97.6	99.1	95.8	96.7	92.7	93.5		
26	7	9 hours	None	95.2	95.9	96.1	98.0	89.7	91.3		
27	10	9 hours	None	92.5	93.7	94.1	94.6	81.6	82.0		

In calculating the sample mean noise levels or average sound pressure levels (in dB), first of all, the average sound pressure in Pascals (Pa) was calculated. The sound pressure level of the average sound pressure was determined using the following formula:

$$\text{Average Lp} = 10 \log_{10} (1/n \sum_{1}^{n} 10^{L}P_n/10) \quad \text{(Di Nardi, 1998)}$$

Noise levels ranged from 81.2dB(A) to 101.2dB(A). The results are presented in table 4.2.

Table 4.2 Description of 10-minute mean noise measurements from 27 small-scale grinding mills

	De-hullers dB(A)	Sievers dB(A)	Packing Machines dB(A)	Grinding Machines dB(A)
Sample size	26	3	27	27
Sample mean	95.4	86.3	89.9	96.2
Sample variance	4,33	5,62	14,50	7,93
Standard deviation	2,08	2,37	3,81	2,825
Range	8.6	4.7	12.0	12.8

The mean noise levels varied from 86.3dB(A) (C.1: 79.6 to 91.4dB(A) for sieving machines to 96.2dB(A) (C.1: 94.5 to 96.7dB(A) for grinding machines. The sample mean values for grinders and de-hullers were almost the same (i.e. 96.2dB(A) and 95.4dB(A). However, grinding machines were marginally nosier than de-hulling machines. The standard deviations indicated a larger variance in the noise measurements for packaging (3.8) and the least variance from de-hulling machines (2.08).

Figures 4.1 and 4.2 show the distribution of the mean and maximum noise levels from the 27 small-scale grinding mills.

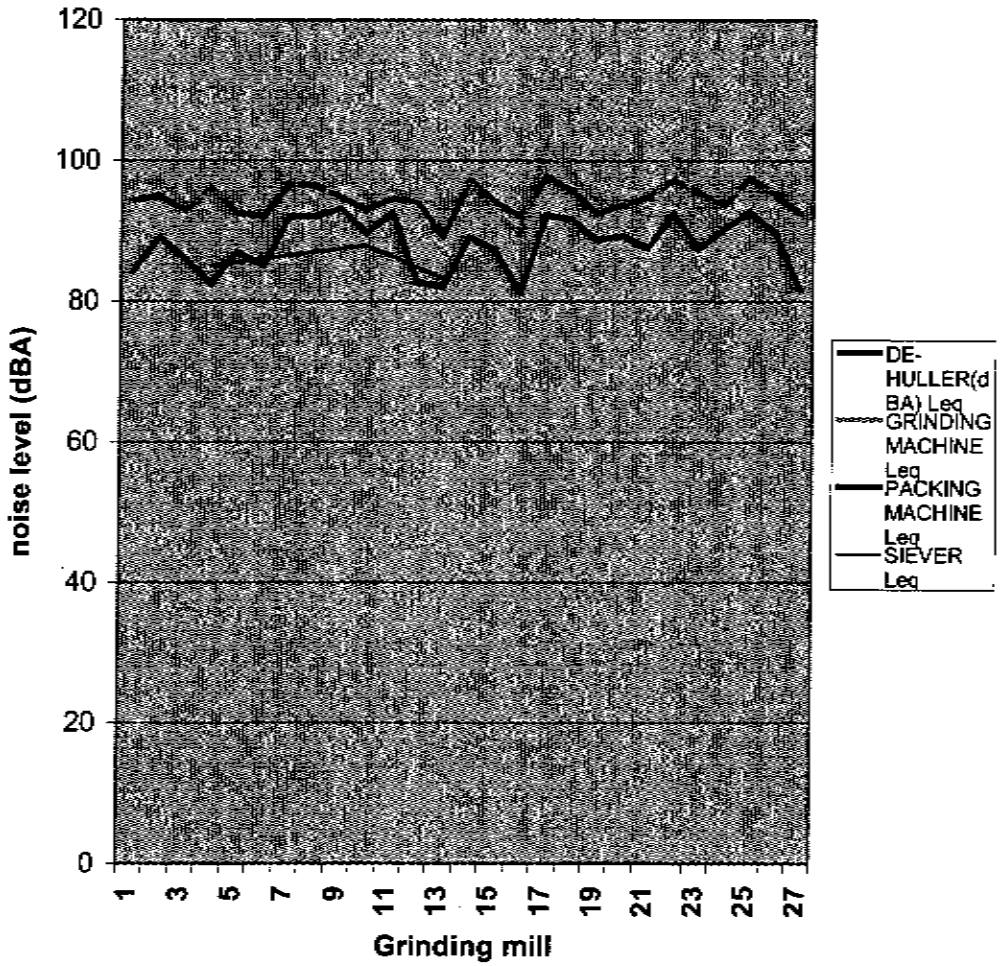

Fig. 4.1 Combined line graph showing the distribution of mean noise levels from 27 grinding mills

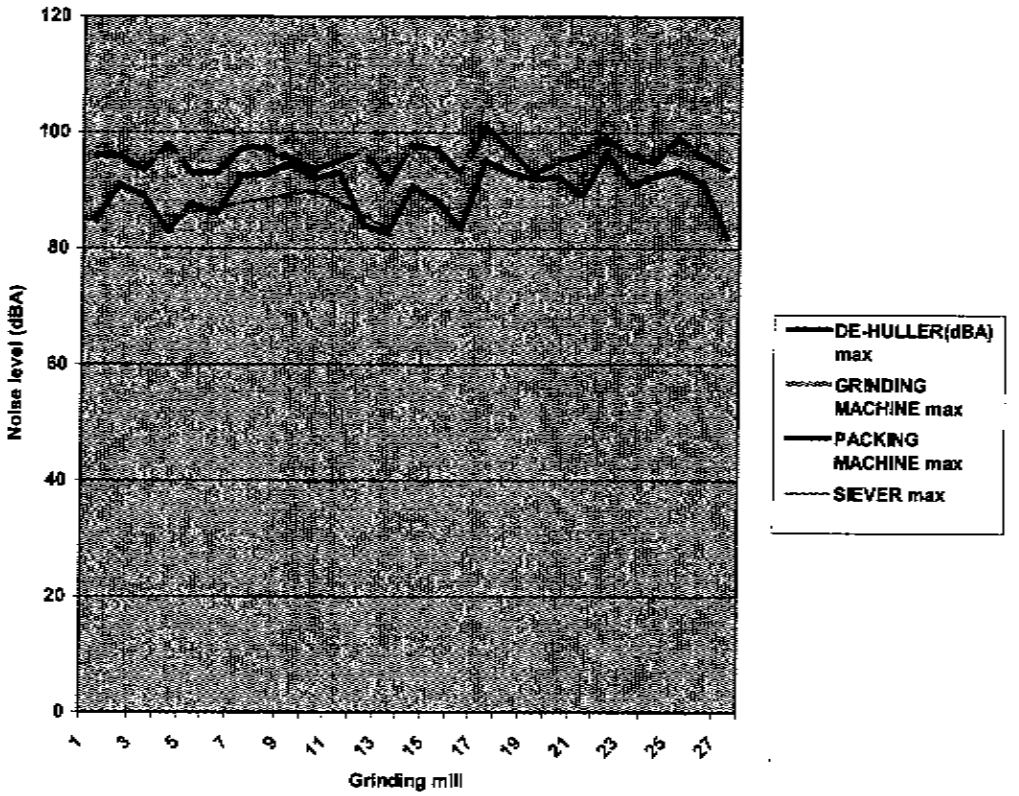

Fig. 4.2 Combined line graph showing the distribution of maximum noise levels from 27 grinding mills

Both mean and maximum peak noise readings from grinding machines and de-hulling machines were generally higher with peaks of over a 100dB(A) being recorded. Noise levels for sieving machines were the lowest (all below 90dB(A). The noise patterns for both the LAeq and max P graphs were similar.

4.3 Analysis of variance

Analysis of variance or ANOVA was used in this study to compare and to determine whether there were any significant differences between the measured noise exposure levels from the four different milling processes or equipment, viz: de-hulling machines, grinding machines, sieving machines and packaging. The basic assumption or hypothesis for the analysis was that there is no significant difference between the above mentioned noise measurements; the alternative hypothesis being that there is a significant difference. The results of ANOVA are presented in table 4.3

Table 4.3 One-way ANOVA noise readings treatment results table

Source	Df	ss	ms	F
Treatment	3	1017,94	339,32	38,15
Error	79	702,74	8,90	
Total	82	1720,69		

$\alpha = 0,05$; $F^{3}_{79} = 3,34$

Where: α = level of significance

df = degrees of freedom

ss = sum of squares

ms = mean squares

F^{3}_{79} = critical value selected

F = Fisher's test statistic

From the One-way ANOVA table:

$F(38,1446) > F^{3}_{79}(3.34)$

The null hypothesis was therefore rejected in this case and it was concluded that there are differences in the noise levels between the grinding machines, de-hulling machines, sievers and packaging at 5% level of significance.

4.4 Do noise levels comply with statutory exposure limits?

According to Zimbabwean legislation, the Occupational Exposure Limit (OEL) for noise exposure over an 8-hour working period is 90dB(A) (Factories and Works regulations). However, international organisations like ILO, ISO, NIOSH and even South Africa nearby have recommended an 8-hour OEL of 85dB(A). Where there is a noise exposure problem, 80dB(A) is the noise level at which hearing conservation programmes are supposed to be initiated. This is known as the Action Level (WHO, 1980).

Compliance of the noise levels of each of the grinding mills' four processes with national and international OELs and the Action Level was analysed. The results are presented in table 4.4.

Table 4.4 Compliance of LAeq noise measurements with a) Action Level-80dB (A), (b) International OEL-85dB (A), and (c) Zimbabwean OEL- 90dB (A)

Milling Process	Sample Size	Mean Noise Levels dB(A)	<80dB(A) (%)	<85dB(A) (%)	<90dB(A) (%)
De-hulling machines	26	95.4	0	0	3.9
Grinding machines	27	96.2	0	O	3.7
Packaging	27	89.9	0	22.3	66.7
Sieving machines	3	86.3	0	33.3	100

All the LAeq noise measurements from all the four milling processes were above the Action Level of 80dB(A) as compliance was 0%. 22.3% of packaging operations and 33.3% for sieving machines complied with the international OEL of 85dB(A). However, none (0%) of the measurements from grinding and de-hulling machines complied with this standard.

For the national (Zimbabwean) OEL, only 3.9 % of the de-hulling machines and 3.7% of grinding machines had noise measurements below the OEL of 90 dB (A). The majority (over 96.2%) failed to comply with the national statutory requirements for noise exposure. However, 66.7% of packaging operations and 100% of sieving machines complied with the national OEL.

Generally, noise measurements for de-hulling and grinding machines failed to comply with both Zimbabwean and international OELs for noise exposure. Sieving and packaging operations were in compliance with Zimbabwean OEL, but not fully compliant with the international OEL of 85dB(A).

4.5 Exposure periods

The results of the exposure periods of workers in the 27 grinding mills are presented in the frequency table 4.5.

Table 4.5 Frequency table showing the length of shifts worked by employees in the 27 grinding mills

Length of shift (hrs)	Frequency of mills working length of shift	%
8	3	11,11
9	14	51,90
10	9	33,33
11	1	3,70

N = 27

From the above table, the majority of employees worked 9-hour shifts (51,9%) and 10-hour shifts (33,33%). Only 11,11% worked the normal 8-hour shift. Long work shifts increase the exposure of grinding mill employees to noise from the milling operations.

4.6 Exposed population

A line graph was used to describe the distribution of employees in small – scale grinding mills, refer to figure 4.3.

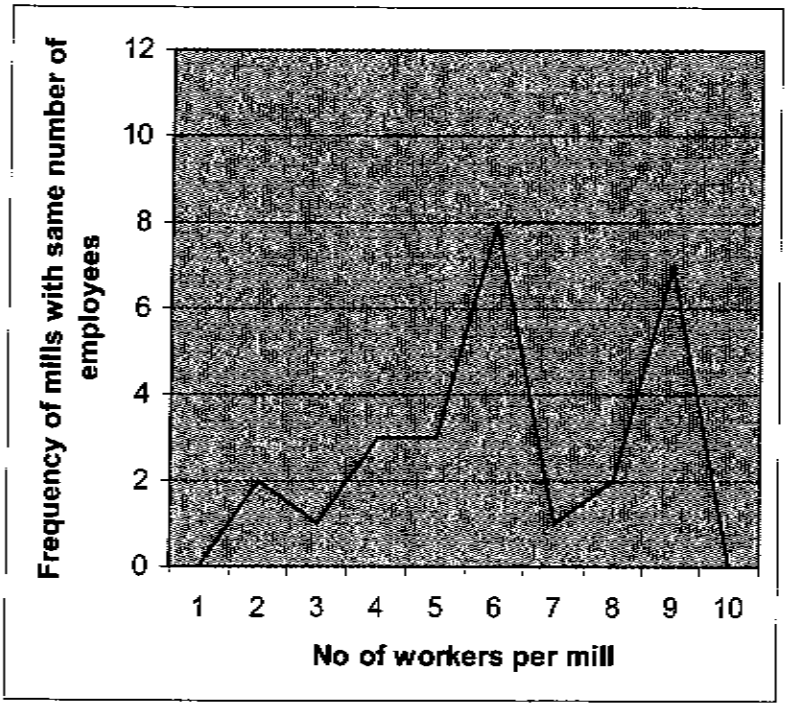

FIG. 4.3 Line graph showing the distribution of employees in the 27 small-scale grinding mills

The various grinding mills employed a total number of workers ranging from 3 to 10. Over 50% of the grinding mills however employed more than 7 employees with 29.63% of the mills employing 7 workers and 25.93% employing 10 workers. All 195 employees in the 27 grinding mills covered in this study were exposed to high noise levels with de-hulling and grinding machine operators exposed to the highest noise levels.

4.7 Existing noise controls

Of the 27 grinding mills covered in this study, none (0%) had any form of control measures (including basic personal protective equipment) in place to protect employees from exposure to noise. See table 4.6

Table 4.6 Frequency table showing provision of noise control measures in 27 grinding mills

Personal protective equipment provided	Sample size	%
Yes	0	0
No	27	100

CHAPTER FIVE

DISCUSSION AND LIMITATIONS

5.1 Discussion

The aim of this study was to describe noise levels from small-scale grinding mills in the Bulawayo area. The study was specifically meant to identify the major sources of noise in these grinding mills and to compare the prevailing noise levels with national and international OELs of 90dB(A) and 85dB(A) respectively.

Several studies undertaken in various parts of sub-Saharan Africa have demonstrated that small-scale enterprises face mounting challenges on the occupational health and safety front. Previous studies by Dr. R. Lowenson in Harare, Zimbabwe (1998), H.G. Atambo in Nairobi, Kenya (1995) and Dr. L..M. Rongo in Dar es Salaam, Tanzania (2004) identified some of these occupational health and safety problems as being exposure to excess noise, chemical fumes, dust, poor lighting, manual handling and long hours of work. Another ergonomic study on small-scale grinding mills by M.G.Yisa in Minna, Niger state of Nigeria found that operators of these mills were exposed to noise levels above 80 dB(A).The results of this study established that workers in small scale grinding mills in Bulawayo are exposed to noise levels significantly in excess of the Zimbabwean statutory OEL-TWA of 90dB(A) and the internationally recommended exposure standard of 85dB(A). The mean noise level for grinding machines was 96.2dB(A) and for de-hulling machines was 95.4dB(A). This was higher than the mean noise level of 88.09dB(A) from the Minna, Nigeria study. The mean noise level for packaging machines, although in compliance with the Zimbabwean OEL-TWA at 89.9dB(A) was still in excess of the international noise exposure standard of 85dB(A). The Minna, Nigeria study did not specifically cover

packaging operations, so it is not possible to compare these. All four grinding operations i.e. de-hulling, grinding, sieving and packaging had noise readings in excess of the Action Level of 80dB(A). It has been established that exposure to average noise levels exceeding 80 dB(A) over an 8-hour working day can cause permanent hearing damage (NIOSH,1998).

The major sources of noise in grinding mills were found to be grinding machines and de-hulling machines. With mean noise levels of 96.2dB(A) and 95.4dB(A), there was no significant difference between the two machine types at 5% level of significance. In cases where the grinding and de-hulling machines are operated simultaneously (as is often the case on busy days), the resultant noise exposure is expected to double up to about 98dB(A). This is based on the premise that noise from two equally intense sound sources operating together produce a sound level which is 3dB higher than the one alone (Brúel and Kjaer, 1986). The mean noise level of 88.dB (A) for packaging was mostly due to background noise from grinding and de-hulling machines.

Over 85.2% of employees in grinding mills worked shifts longer than the recommended 8-hour shifts on which OEL-TWA exposure standards are based. Only 3 mills (11,11%) worked 8-hour shifts. The majority (51.9%) of the mills worked 9-hour shifts and 37.7% of the mills worked shifts longer than 10 hours. In both Lowenson (1998) and Atambo (1995) studies, long hours of work were found to be one of the major occupational health and safety problems facing small-scale enterprises.

The extent of hearing loss or hearing impairment depends on the level and frequency of the noise, the duration of the exposure and the susceptibility of the

individual exposed (ILO, 1998). Noise exposure level normalised to a nominal 8-hour working day and time-weighted average (TWA) 8-hour equivalent noise exposure are the preferred parameters for quantifying noise exposure for both risk assessment and occupational hygiene monitoring purposes (Occupational Health Review, 2004).

The daily noise dose (Lep,d) of an employee is an important parameter to measure when assessing personal noise exposure where the noise levels fluctuate. The daily noise or Lep,d is a function of both noise levels and the length of time for which each level exists over the working day (Harrington et al 1998).A nomogram can be used to compute the daily noise dose (Lep,d). Based on these shifts, the applicable daily noise dose (Lep,d) from grinding machines becomes 94.5dB(A) for the 10-hour shift (see appendix D and E).

The legal requirement is that employees must not be directly exposed to noise over the statutory time-weighted average limit (Factories and Works General regulations, 1976). ISO standards require that the time spent in a noise environment be halved for each 3dB increase in noise level above the set TWA limit (Brüel and Kjaer, 1986). Where the 8-hour TWA limit is set at 90 dB (A) as in Zimbabwe, then at 93dB(A), the time allowed will be 4 hours, at 96dB(A), 2 hours and at 120 dB (A), only 30 seconds can be allowed. Therefore, at noise levels of 94.5dB(A), the recommended "safe" exposure period should not be more than 4 hours (see table 4.7)

Table 5.1 Noise exposures equivalent to 90dB(A) for 8 hours based on 3dB(A) exchange rate (from Harrington J.M. et al – Occupational Health 1998)

Limiting dB (A)	Maximum duration of exposure
90	8 hours
93	4 hours
96	2 hours
99	1 hour
102	30 mins
105	15 mins
108	7 mins
111	4 mins
114	2 mins
117	1 min
120	30 sec

None of the 27 grinding mills covered in this study provided any form of noise control, reduction or protection measures for their employees, despite the fact that the employees were exposed to noise levels in excess of the OEL-TWA (90dB) and for periods longer than the recommended 8 hours. This is consistent with Rantanen et al's study findings that in developing countries, hearing protection is often poor or none- existent.

Therefore, the occupational noise exposure assessment of small-scale grinding mills clearly indicates that workers in this sector are exposed to noise levels in

excess of both international and national occupational exposure standards (OES) and for longer periods than the reference exposure periods (8hours) on which OES are based on. Despite this excessive exposure, no noise control, reduction or prevention measures are being implemented by the mill owners to protect their exposed employees. The implications on resultant noise-induced hearing loss cases from a combination of the above-mentioned factors are a serious cause for concern, requiring further studies.

The results of this study go a long way to confirm the results of other studies carried out in small-scale enterprises in Kenya (Atambo 1995), Tanzania (Rongo 2004) and Nigeria (Yisa 2005) which established that employees in this sector were exposed to a litany of occupational hazards including excessive noise levels with no protection offered.

5.2 Limitations of the study

i) The sample size for this study (at less than 30) was rather small and might not be fully representative of the small-scale grain milling industry nationwide.
ii) The standard reference calibration for the equipment used for noise measurements was three (3) years old at the commencement of the study in 2003. It is important that all equipment used in such measurements should be correctly calibrated to ensure accuracy and validity of results. However, due economic problems, annual standard calibrations of the equipment (as required by SABS 083:1996) could not be done. To maintain some measure of accurateness and ensure validity of the data, daily field calibrations using an acoustic calibrator (Bruel and Kjaer calibrator Model 2237) were done before and after all measurements. Although the sound level meter could have been 'out of

specification', I do not believe that any resulting measurement error would have been large enough to make a significant impact on the overall findings and subsequent conclusions arrived at in this report.

iii) Measurements for this survey were once off for each work- station covering one,10 minutes milling cycle and might therefore not accurately characterize exposure levels over a longer 8 to 11 hour working day for 6 days a week. Variables to consider include the breaks between the milling cycles, possible breakdown of milling equipment, periods when there was no grain to mill and worker movements about their workstations. All these invariably affect the exposure periods and levels .The use of dosimeters (if available) over a full shift would have given a more accurate assessment. However, when making measurements to determine whether the acceptable limit is exceeded, it is not normally necessary to measure the sound level during the entire shift. Assessment may be based on the sample periods that are typical of the working day (Department of Employment, UK.1972).

In spite of the limitations noted above, this study does provide useful information regarding the excessive exposure to occupational noise and the absence of preventive measures against noise exposure for employees of small-scale industries as typified by small-scale grinding mills. However, future longitudinal follow-up studies to give a more comprehensive picture of noise exposures in other small-scale enterprises need to be carried out. Further studies to explore consequent noise induced hearing loss (NIHL) and to give a general idea of the caseload or magnitude of potential NIHL claims to be compensated can be warranted.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

6.1.1 The mean equivalent noise levels obtained for de-hulling machines were 94.5dB(A) with standard deviation of 2.08 and 95.5dB(A) with standard deviation of 2.81 for grinding machines. Therefore, in small-scale grinding mills, the major sources of noise are the de-hulling machines and grinding machines.

In cases where these machines run simultaneously, there is approximate doubling of sound energy. Since 95.4dB(A) + 96.2dB (A) sums to 99dB(A).

6.1.2 Small-scale grinding mills failed to comply with national and international OES for noise exposure with over 96.2% of noise levels from grinding and de-hulling machines found to exceed the Zimbabwe national time-weighted occupational exposure limit for noise of 90dB(A) and the internationally recommended exposure standard of 85dB(A).

6.1.3 According to NIOSH, exposure to average daily noise exposure of 90dB(A) over a 40 year working lifetime results in a 29% estimated excess risk of incurring material hearing impairment (NIOSH, 1998). Material hearing impairment in this case is defined as an average of the Hearing Threshold Level at 500Hz, 1000Hz and 2000Hz that exceeds 25dB. Therefore, employees in grinding mills daily exposed to noise levels in excess of 95.5dB(A) have over 29% risk of developing noise-induced hearing loss.

6.1.4 Despite the evident risk of employees from this sector developing noise-induced hearing loss, no preventative or control measures have been put in place to protect the workers.

6.1.5 There is therefore need to put in place innovative, comprehensive preventive measures to address this situation.

6.2 Recommendations

In addressing the identified noise exposure problem in small-scale grinding mills, emphasis should always be on preventative measures, followed by noise exposure control measures. Protective measures e.g. hearing protective devices, should be the last resort. The following are some of the recommended preventative, control and protective measures that can be implemented.

6.2.1 When purchasing new grinding mill machinery or replacing older equipment, entrepreneurs should select grinding and de-hulling machines with lower noise ratings. Unfortunately, most milling machinery manufactured locally (in Zimbabwe) does not display noise ratings, as this is not yet a legal requirement.

6.2.2 Government, through responsible ministries and statutory bodies e.g. National Social Security Authority, need to put in place comprehensive legislation and noise regulations to include such pertinent issues as mandatory risk assessments to identify noisy operations, measuring noise levels, health surveillance (pre-employment, periodic and exit audiometric testing), preventative control measures, training, use of hearing protection devices etc. The legislation should also include the mandatory display of noise

ratings on all machinery manufactured, imported or sold in Zimbabwe to enable clients to make informed decisions when purchasing machinery (van Niekerk, 2005).

6.2.3 Reducing the power of the electric motors and diesel engines used to run the milling machinery. This results in the reduction in the speed of the motor and in the amount of energy communicated to the vibrating surfaces of the machines. This consequently reduces the noise generation and emission by the mills. Currently most of the mills are powered by 15 horsepower electric motors or 18 horsepower diesel engines.

6.2.4 The milling machines should be mounted on vibration isolating or damping materials like rubber, instead of bolting the machines directly onto the concrete floors as was the case with all machines observed. The reduction in the vibration transmitted to the floor enables the live-load allowance for vibration to be reduced by as much as 75% (ILO Encyclopaedia, 1988). The reduction of shock loading within the machine can actually increase its useful lifespan.

6.2.5 The interior of the grain feeding hoppers for both grinding and de-hulling machines can be coated with resilient materials such as synthetic rubber to reduce noise when grain is fed or poured into the hoppers. The height at which grain is poured into hoppers can also be reduced. This reduces the impact energy of the grain on the surface of the hopper and consequently reduces the noise produced.

6.2.6 Sound reflecting or absorbing materials can be used to reduce the noise reaching the operators. However, to be able to select the

appropriate controls, there is need to further characterise the noise from the grinding mills by carrying out frequency analysis (which was not done in this study). High frequency noise is more directional and can be reflected. Barriers or reflective surfaces can therefore be used to protect workers. Low frequency noise on the other hand has large wavelengths and is not easily reflected. It can however be reduced by the use of absorbent materials on walls. Absorbent materials should not pose a fire risk or health hazard though. (Department of Employment, 1972)

6.2.7 Noisy operations viz. de-hulling and grinding should be separated from packaging that is a generally low noise operation. The high and low noise areas need to be totally partitioned off by ensuring that partition walls go up to the roof and that there are a minimum of openings in the partition. This will ensure that packaging workers are not necessarily exposed to excess noise.

6.2.8 All machinery in grinding mills is to be regularly inspected and serviced by competent persons. Maintenance of such machinery includes lubrication/ greasing of moving parts and nipples, tightening of loose parts, replacement of worn parts. This reduces unnecessary friction and vibrations that are potential noise sources.

6.2.9 If it is not possible to reduce the noise to below 85dB(A), the possibility of avoiding excessive noise exposure of employees by reducing exposure duration should be considered. Some of the options for consideration include: -

- reducing the number of workers on a shift and increasing the number of shifts.
- reducing the length of the shifts so that workers are only exposed for shorter periods. (job rotation)
- provision of noise refuge at the workplace.

These are to be implemented in such a way that will not affect efficiency or reduce overall production (Okwulehie P.D. 1996).

6.2.10 All areas in the mills with noise levels in excess of 85dB(A) are to be designated as noisy areas and clearly marked as such. All employees in these areas are to be provided (free of charge) with appropriate and effective hearing protection devices able to attenuate the noise to below 85dB(A). The use of such hearing protection devices should be encouraged and enforced by the employers.

6.2.11 All workers exposed to noise levels in excess of 85dB(A) are to be sent for audiometric tests to check for the incidence and extent of any hearing threshold loss (temporary or permanent).

6.2.12 From the study, it appears both employers and workers do not appreciate the hazard posed by exposure to the prevailing high noise levels. Awareness raising amongst owners and workers is necessary so that they can have sufficient understanding of their particular noise environments and of the adverse health effects of excessive noise exposure in their workplaces. Hopefully this can result in positive behaviour changes by both parties.

6.2.13 Most of the small-scale millers are not financially stable to afford the required corrective measures. Government can assist by funding or

subsidising special programmes to routinely and regularly carry out risk assessments, noise measurements for milling premises and audiometric tests on over-exposed workers. Targeted training programmes to be also carried out for this and other similar small-scale industries.

6.2.14 This study provides useful baseline information or data regarding the excessive exposure to occupational noise and the absence of any preventive measures against noise exposure for employees as typified by small-scale grinding mills. The results provide a basis for further studies to give a more comprehensive picture of noise exposure in small-scale enterprises in general, to explore consequent noise-induced hearing loss from such exposures and to give a general idea of the case load or magnitude of potential noise-induced hearing loss claims to be compensated in the future.

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APPENDIX A

List of statistical symbols used

n	-	sample size
Σ	-	sum
$\bar{X}$	-	sample mean
X	-	random variable
Y	-	random variable
S^2	-	sample variance
S	-	sample standard deviation
N	-	total sample size
μ	-	population mean
σ^{-2}	-	population variance
s^2_p	-	sample pooled variance
α	-	level of significance
t	-	student's t critical value
Tcalc	-	calculated test statistic value
H_0	-	null hypothesis
H_1	-	alternative hypothesis
F	-	Fisher's test statistic
df	-	degrees of freedom
ss	-	sum of squares
ms	-	mean square

subscripts

d - de-hulling machines

g - grinding machine

p - packaging machine

s - siever

APPENDIX B Ethics Clearance Letter

University
of the Witwatersrand,
Johannesburg

Human Research Ethics Committee (Medical)
(formerly Committee for Research on Human Subjects (Medical)

Secretariat: Research Office, Room SH3005, 10th Floor, Senate House • Telephone: +27 11 717-1234 • Fax: +27 11 339-5708
Private Bag 3, Wits 2050, South Africa

PC-J/444/dsk10es

27 June 2005

TO WHOM IT MAY CONCERN:

re: **Dingilizwe MAZIBUKO, MPH**
Title: Noise in small-scale grain grinding mills in Bulawayo (Zimbabwe)

This certifies that this project does not require clearance from the Human Research Ethics Committee (Medical).

The research is secondary data analysis and no human subjects are involved.

Yours faithfully

Professor Peter Cleaton-Jones
Chair: Human Research Ethics Committee (Medical)

copy: Anisa Keshav, Research Office, Senate House, Wits

The Brüel & Kjær Calibration Laboratory

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Fax: +4577412037

DANAK

Reg.Nr. 307

CERTIFICATE OF CALIBRATION

No.: CA001743

CALIBRATION OF:

Sound Level Meter :	2237	No :	2255207
Microphone :	4137	No :	2245320
Identification :			
Date of receipt :	23.Oct.2000		

CLIENT:

Cowi A/S
Parallelvej 15
2800 Lyngby
Danmark

Order No.:

CALIBRATION CONDITIONS:

Preconditioning:	12 hours at 23 °C.		
Environment conditions	Air temperature :	23 °C	± 3°C
	Air pressure :	101.3 kPa	± 3 kPa
	Relative Humidity :	50 % RH	± 20 % RH

SPECIFICATIONS:

The Sound Level Meter has been calibrated in accordance with the requirements as specified in IEC 651 and IEC 804 type 2 ,and vendor specific procedures.

PROCEDURE:

The measurements have been performed with the assistance of :
Brüel & Kjær's Sound Level Meter Calibration System B&K 9600 Cal2237 Version 16.09.1996

RESULTS:

A list of the performed (sub)tests is stated on page 2 of this certificate. Actual measurements are documented on worksheets.
The uncertainties of the references used and the test methods are registered at the DANAK (Dansk Akkreditering) and available on request, and all measurements and statements are based on a 95% confidence level.

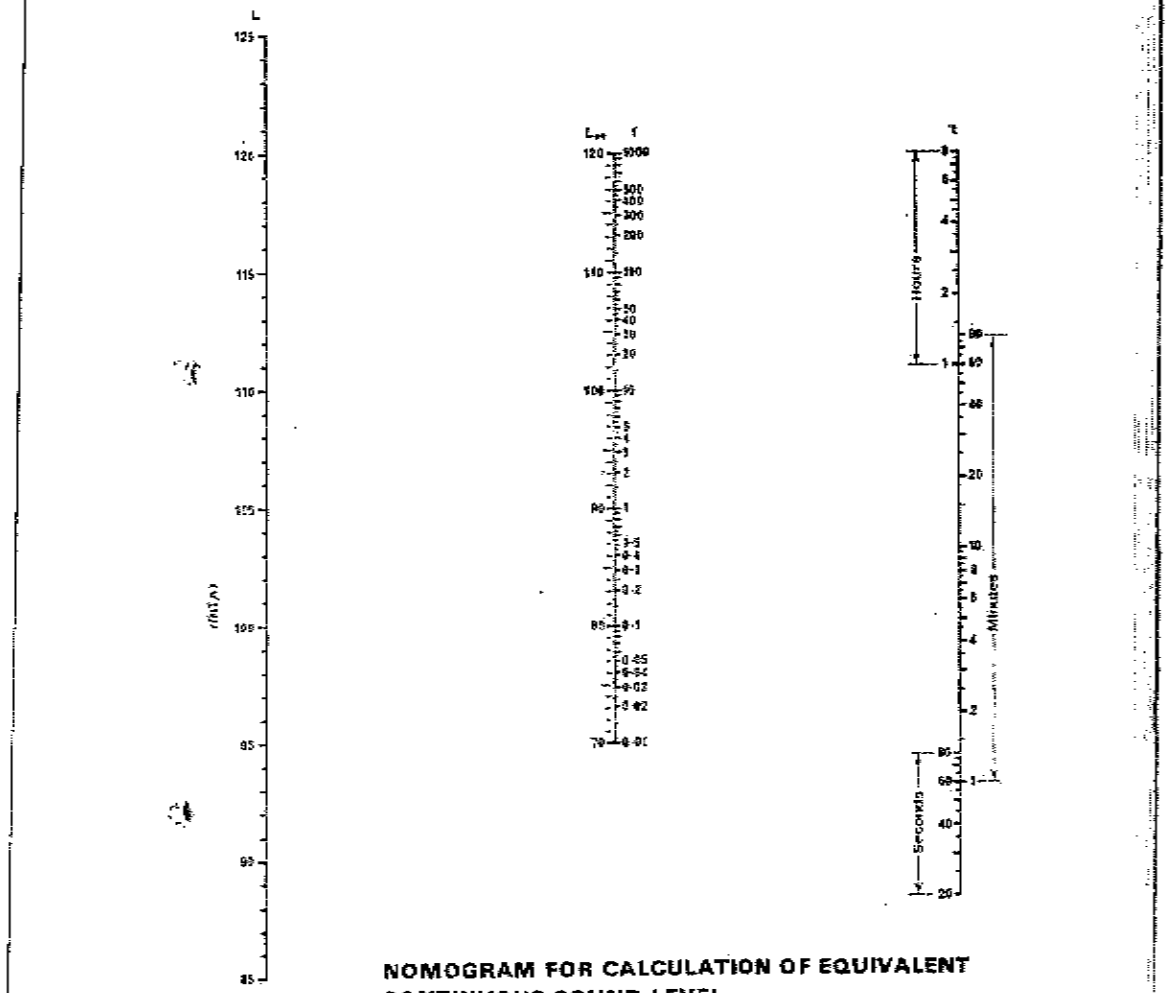
Date of Calibration : 24.10.2000 Certificate issued: 24.10.2000

Greta Koch
Calibration Technician

Approved signatory:

Peter Gaardsdal

Reproduction of the complete certificate is allowed. Parts of the certificate may only be reproduced after written permission.



NOMOGRAM FOR CALCULATION OF EQUIVALENT CONTINUOUS SOUND LEVEL

(1) For each exposure connect sound level dB(A) with exposure duration t and read fractional exposure f on centre scale.

(2) Add together values of f received during one day to obtain total value of f.

(3) Read equivalent continuous sound level L_{eq} opposite total value of f.

Fig. 1

APPENDIX D Nomogram for the calculation of $L_{EP,d}$

APPENDIX E

Calculation of $L_{EP,d}$ for grinding machine with mean noise-level of 96.2dB(A) using nomogram.

Calculation of 'f ' value for one, ten minute milling cycle at average noise level of 96.2dB(A):

- By connecting 96.2dB(A) and 10 minutes, gives fractional exposure 'f' value of 0.098.....**(1)**
- (In a 10-hour shift, about 30 ten minute milling cycles are completed).
- Total 'f' values for 30 milling cycles: 30* 0.098 = 2.94
- Reading $L_{EP,D}$ opposite total 'f' value of 2.94 = 94.8dB(A)....**(2)**

- Therefore, the $L_{EP,D}$ for the 10 hours shift (everything being normal) is **94.8dB(A).**