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Manual handling problem identification in mining industry: an Ergonomic perspective

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Abstract

Ergonomics processes described in the literature have been associated mostly with manufacturing, financial, elec-tronics, and office settings where working conditions tend to be rather constant and repetitive. The information presented in this paper demonstrates, however, that an ergonomics process can also be implemented in a setting such as mining where working conditions frequently change and workers are periodically exposed to extreme conditions. This paper describes how to identify manual handling problem in one of Indonesian Coal Company at South Kalimantan Mine in 2015. The process of problem identification and the impacts of the process on working conditions at the mine using Job Discomfort Survey, Manual Handling Checklist and Sample Decisison Matrix (DM) are reviewed. Barriers overcome and lessons learned are also described. Quotes from Coal Company em-ployees are included in the document to add an ergonomic perspective. Other industries with working conditions similar to mining, such as construction and retail, may find this information useful. The uniqueness of decision matrix is that DM is the research instrument that collect baseline data from supervisor interviews, Nordic-questionnaire, incident data and management concerns becomes task analysis which consist of observations, video taping, discomfort intervention, task measurements which end up with identify risk factors. Scope of coal mining in this paper is crushing & sizing and barge loading, as we know that the overall scope of coal mining are: overburden stripping, coal mining, loading coal from rom stockpile to coal hauler, coal hauling, haul road, crushing & sizing, barge loading, coal barging, floating cranes, coal terminal. Finally, the contribution is to help, prevent or reduce the occurrence of lifting-related lower-back injuries

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Keywords: Manual handling; problem identification; mining industry; Ergonomic perspective

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1. Introduction

Coal mining continues to be an important source of musculoskeletal stress and injuries. The primary aim of the program described here was to reduce injury risks associated with manual tasks performed by miners [1]. Coal business process is started from Overburden stripping, coal mining, coal loading coal from the stockpile to hauler, coal hauling, crushing and sizing, barge loading, and ended up in coal barging. In coal mining industry, discrete-event simulation has been widely used to support decisions in material handling system (MHS) [2] while Bow-tie analysis combines aspects of fault-tree analysis and event-tree analysis to identify an initiating event [3].

Problem identification has also conducted in the 'minerals industry' as an overall descriptor for a group of activities related to mining (minerals extraction), ore/minerals processing and minerals transportation. This industry is a significant worldwide employer and major revenue earner; for example, in Indonesia. The minerals industry is present across virtually the whole globe, with some of the major mining areas being in Indonesia, Australia, Africa, North and South America, China, and India. Despite fairly recent declines, mining still occurs in much of Europe such as Poland, France and the UK. [4], [5]. Problem investigation also implemented elsewhere in mechanical and electrical system installation workers account for nearly 15% of 9.3 million building and construction workers in the United States in 2000. Mechanical installation workers install and service piping and heating, ventilation, and air conditioning (HVAC) systems. Piping system workers, which include plumbers, pipe fitters, and sprinkler fitters, install and service the piping systems in commercial, industrial, and residential structures [6]. The main elements of this industry include: a diverse group of people employed; a wide range of different jobs, tasks and roles; many different equipment manufacturers and suppliers; different worldwide mining companies; a wide range of national laws, regulations and guidelines; different procedures, rules, practices and cultures at individual mine sites; differences in the built environment and precise mining method used and uncertainties in the natural environment [4].

Scope of coal mining in this paper is Crushing & Sizing And Barge Loading, as we know that the whole scope of coal mining are: Overburden Stripping, Coal Mining, Loading Coal From Rom Stockpile To Coal Hauler, Coal Hauling, Haul Road, Crushing & Sizing, Barge Loading, Coal Barging, Floating Cranes, Coal Terminal as depicted in the following Fig. 1.

As we know Overburden Stripping is removing top sand of coal, ROM Stockpile is Raw Of Material Stockpile, Coal Hauling is transportation of coal, Haul Road is road for transporting coal, Crushing & Sizing is smashing coal into expected size, Barge Loading is loading coal into ship, Coal Barging is arranging coal in a stack, Floating Cranes is a crane which located on the river or sea, and Coal Terminal is port for coal. In this paper we choose to study on Crushing & Sizing and Barge Loading because in that area there are many manual-handling activities to be identified.

2. Definition

2.1. Manual handling

Manual handling of objects in an industrial setting has been a significant concern to occupational health professionals who attempt to prevent injury. Tasks that demand frequent and heavy lifting are associated with an in-creased risk of low back pain and MSDs. [7]. Musculoskeletal disorders (MSDs) are injuries or pain in the body's joints, ligaments,, muscles, nerves, tendons, and structures that support limbs, neck and back. MSDs are degenerative diseases and inflammatory conditions that cause pain and impar normal activities.

2.2. Problem identification

Problem identification has already conducted in the 'minerals industry' as an overall descriptor for a group of activities related to mining (minerals extraction), ore/minerals processing and minerals transportation. [4]

2.3. Minerals Industry

The 'minerals industry' is an overall descriptor for a group of activities related to mining (minerals extraction), ore/minerals processing and minerals transportation [4]. The main elements of this industry include : a diverse group of people employed; a wide range of different jobs, tasks and roles; many different equipment manufacturers and suppliers; different worldwide mining companies; a wide range of national laws, regulations and guidelines; different procedures and cultures at individual mine sites and differences in the built environment and precise mining method used.

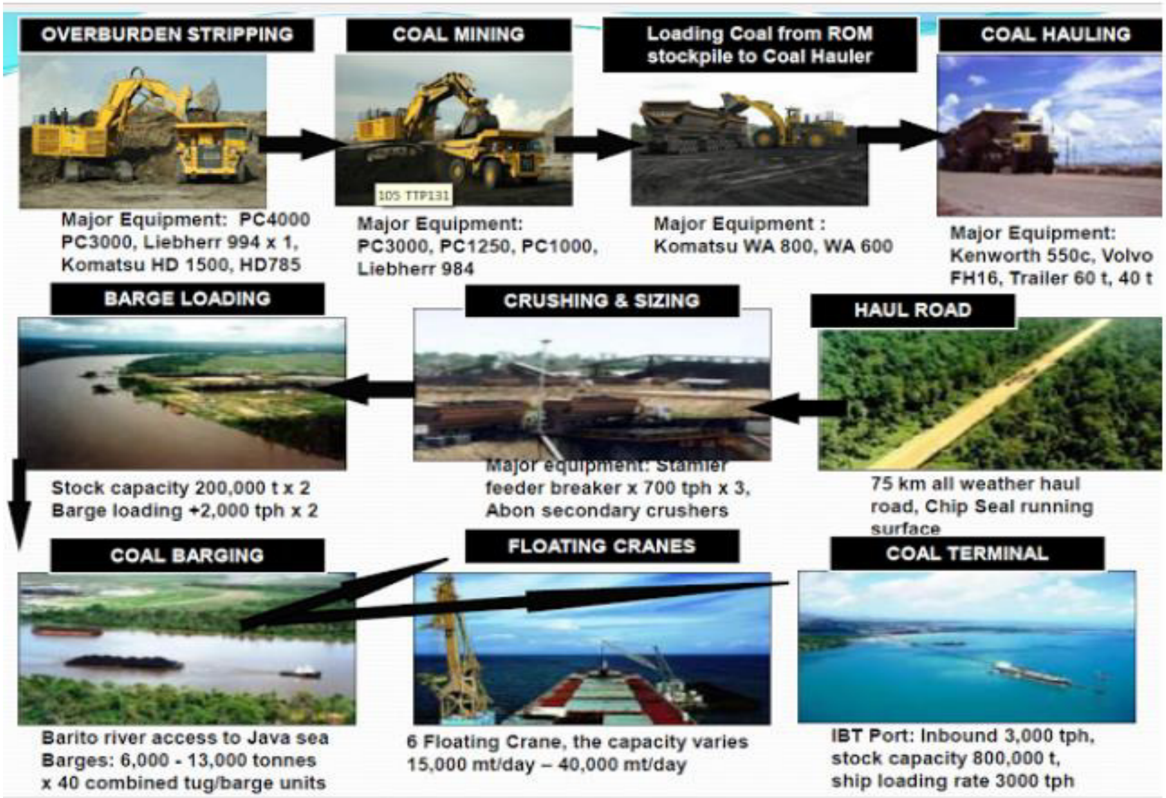


Fig. 1. Coal mining operation. Scope of coal mining investigated is Crushing & Sizing and Barge Loading

2.4. Ergonomics

Ergonomists [8], [9] study people and how they operate equipment in the home, in commerce, and in factories, in activities. It stands to design products and also design jobs. More specifically, they design products, designing jobs, material-handling systems, machine-tool interfaces, workplace layouts, process-control interfaces, machine tool layouts, training programs, interviews, human performance predicting systems, safety and health programs, for undesirable environments, communication systems, wage administration, and programs for personnel selection and placement.

3. Methodology

This section provides a general overview of the methodology.

The data collection activities at site were slightly and necessarily different. Fig. 2 represents what the team considers to be one useful strategy for assessment of MSD injury risk. This assessment leads to (1) selecting work activities that would be good candidates for further study, (2) working with mine site personnel to better define the MSD injury risk for specific tasks, and (3) exploring ideas for improving the work process.

To establish a baseline team used a combination of data collection tools: (1) incident data, (2) Nordic Questionnaires, (3) first-line supervisor interviews, and (4) management concerns. The overall intent of gathering baseline data was to form a picture of relative MSD injury risk by work activity. To accomplish this, the team used both qualitative and quantitative data collection tools. This met two objectives: (1) it helped the team learn more about the mining technology, process, and conditions present, and (2) it allowed the team to collaborate with workers, front-line supervisors, and management to develop an objective and structure for selecting work tasks.

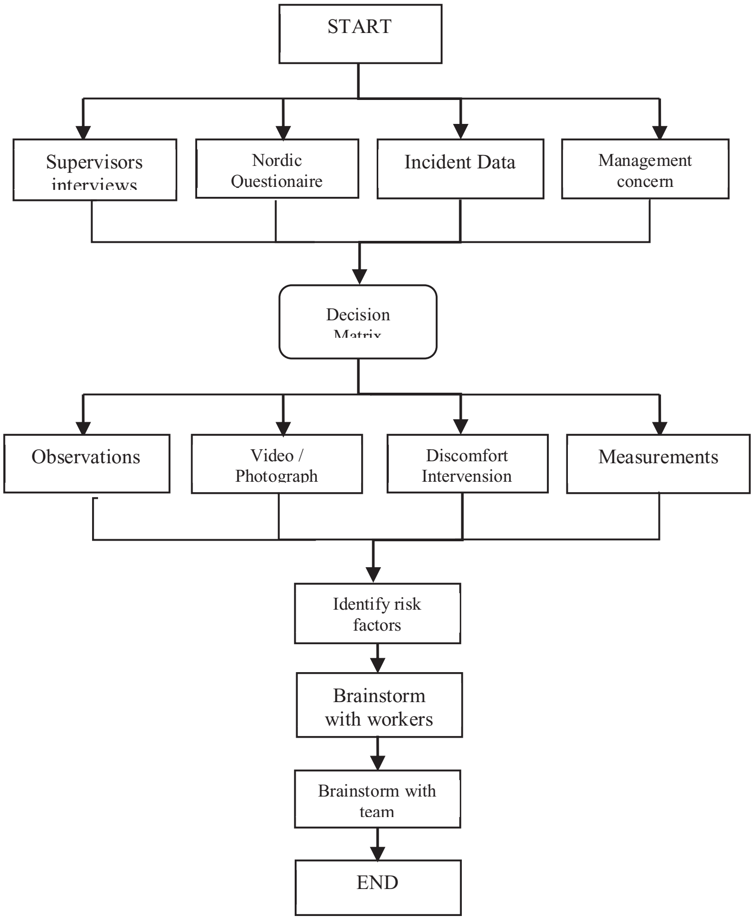


Fig. 2. Overall study of problem identification strategy

- **Incident Data**

At least 6 months of incident data were obtained. This included any available information about incidents involving (1) medical treatment, and (2) injuries that were reportable to the Occupational Safety and Health Administration. Incident data were summarized using spreadsheet software. The summary organized the incident data by job classification and accident type (e.g. caught, sprains/strains). Incident rates by job classification were prepared.

- **Nordic Questionnaire**

Employee input was requested via response to a general discomfort questionnaire—the Nordic Questionnaire. These data were gathered to identify musculoskeletal aches and pains existing within the working population. The goal was to have as much of the workforce as possible fill out a questionnaire. Employees were asked to complete the questionnaire after a brief overview of the instrument and reasons for its use by a safety representative from the mine team member. The Nordic Questionnaire can be found in appendix A.

- **Supervisor Interview Guide**

The team prepared a set of interview questions to obtain relevant information from first-line supervisors. These interviews, conducted took about 20 minutes during Manual Handling Training. The purpose was to learn about the variety, scope, and context of work performed at the mine site and to obtain insights about the jobs and work tasks that the front-line supervisors believed to be the most physically demanding.

- **Management Concerns**

As part of the field work, management was asked to identify work activities that they thought warranted further study to reduce MSD injury risk.

- **Job Selection**

Baseline data were used to identify work activities considered for further study. Several factors were considered in selecting a task, but a key factor was evidence of significant MSD risk factor exposure. Tasks selected for additional study did not necessarily have the highest (within each site) risk factor exposure. The extent that each type of data (i.e., the incident data, Nordic Questionnaire, supervisor interviews, and management concerns) was used varied based on the constraints encountered at each site. However, across all four sites, the mine's incident data were thoroughly examined and management concerns were clearly identified.

- **Task Analysis**

Specific tasks that exposed workers to significant MSD risk factors were identified for each candidate job. Using job descriptions obtained from supervisor interviews, team interviewed, and observed work tasks. Team members observed and identified a set of risk factors along with relevant measurements of worksite dimensions, force exertions, and the size and weights of tools and work pieces. Finally, workers' views of their physical job stress were obtained using a Body Part Discomfort Interview Guide developed by the evaluation team.

- **Body Part Discomfort Interview Guide**

Workers were interviewed to identify symptoms of discomfort and work activities that contribute to discomfort. The interview guide inquired about body part discomfort and workers' thoughts about the most physically demand-ing aspects of their work. The interview guide was based on concepts from the general form of the Nordic Ques-tionnaire. The goal was to identify tasks that workers believed were most likely to cause physical discomfort and why they are hard to perform.

Task analysis results were used to identify a list of demanding tasks. Following reviews with mine management, target tasks were chosen for final evaluation to develop ideas for improvement. A target task is a work activity with evidence of significant potential for MSD risk factor exposure.

- **Brainstorming**

The team examined all available data to identify risk factors. This information was presented at brainstorming sessions to members of the mine work groups. The aim was to discuss targeted work activities and identify health and safety issues, with emphasis on understanding the risk factors and discussing practical ideas to reduce risk factors in order to make the activities less physically demanding.

Following the mine brainstorming sessions during Manual Handling Training, a session was held with a diverse group of team. Videotapes / photographs were reviewed by the team to trigger a discussion of possible risk factors and to review the findings of the mine site evaluation team. Special emphasis was placed on notes taken from the brainstorming sessions conducted at the mine site. The aim was to examine the key issues identified and further develop or add to the ideas to improve how the target work tasks are performed. The risk factors identified and general ideas for job improvement were discussed at the training session.

4. Results

To construct a decision matrix using mine incident data, Nordic Questionnaire responses, and supervisor interviews for identifying work groups appropriate for further evaluation. For each source of data, a subjective ranking of "low," "medium," or "high" was given by consensus of the NIOSH evaluation team. Each ranking for a work group was relative to other groups at the site. A ranking of "high" would not indicate a high risk level for injury; it would indicate that the comparison measure(s) for the given data type was high when compared to other work groups at that site.

For each work group, an incident ratio was calculated to provide a relative estimate of incident risk. A work group incident ratio significantly above the site-wide incident ratio was given a "high" rating. A work group incident ratio significantly below the site-wide incident ratio was given a "low" rating.

Work group discomfort was evaluated by comparing the number of body parts reported and the number of reports of discomfort for similar body parts. Work groups reporting higher than the site-wide average numbers of body parts and high percentages of workers with discomfort for a body part(s) were given a "high" rating. Work groups reporting lower than the site-wide average numbers of body parts and low percentages of workers with discomfort for a body part(s) were given a "low" rating

If a supervisor identified a work group as having physically demanding work, it was considered for a "high" or "medium" rating. Supervisor comments were evaluated for key characteristics of physical stress. The degree of physical stress was based on common physical risk factors, which include forceful exertions, heavy lifting, awkward postures, repetitive motions, and jolting or jarring. If any single or combination of risk factors was described to exist at a significant level, a rating of "high" was given. Work groups not identified by a supervisor were given a "low" rating.

For scoring purposes, a rating of "high" was given 3 points, "medium" was given 2 points, and "low" was given 1 point. One additional point was awarded if management expressed concern regarding a particular work group. Work groups having the highest scores were deemed suitable for further evaluation. Wiehagen and Turin [10] provide a more detailed discussion of how the decision matrix can be used to identify jobs that could be suitable for ergonomic evaluation. Table 1, table 2, table 3 show decision matrix, rating of body discomfort by work area, and decision matrix for selecting tasks, respectively.

Table 1 explain Decision Matrix. Table 2 describe the rating of body discomfort by work area. Results of the decision matrix are shown in Table 3. The ranking procedure identified three areas with a score of 8 or higher: mechanic (9), plant production (8), and crusher (8). Tables 3 summarize information gathered for the specific tasks studied at the surface coal mine. Ideas to reduce risk factors were developed based on brainstorming sessions with those who had a stake in the task, i.e., those who performed the task, supervisors, safety representatives, and engineering and maintenance staff. Management personnel facilitated the brainstorming sessions. The ideas for improvement are not listed in any particular order with regard to likelihood of successfully reducing risk factor exposure. These ideas are unique to this mine site and the tasks observed and should not be generalized to all mine sites.

Table 1. Decision matrix

Work group	No. of employees	Incident data	Nordic questionnaire	Supervisors interviews	Management concern	Final score
Supervisors	4	Low	Medium	Low	Yes	5
Loader operators	3	Medium	Medium	Medium	Yes	6
Mechanics	3	High	High	High	Yes	7
Water truck operators	1	Low	Medium	Low	Yes	5
Laborers	2	Low	Medium	High	Yes	5
Welders	3	Low	High	Medium	Yes	6

Table 2. Rating of body discomfort by work area

Work area	Above average ratings	Below average ratings
Maintenance	Knee, ankles	Neck, shoulder, low back
Electric	Upper back	None
Welder plant	Shoulders, low back	Elbows, hips, knees, ankles
G A	None	All
Plant operator	Upper back	None
Plant ledman	Elbows, upper back, knee, ankle	None
Plant support project	None	All
Conditional monitoring	None	All
Mekanik	Shoulders, elbows, upper back	None
Civil maintenance	Elbows, upper back, knee, ankle	None
Mekanik plant	Shoulders, low back	Elbows, hips, knees, ankles
Operation production	Neck, upper back	None
Stock pile management	Stomach	All
Production supervisor	None	All
Welder	Shoulders, low back	Elbows, hips, knees, ankles
Logistic warehouse & receiving	Shoulders, low back	All
Operator plant	Low back, knee, ankle	None
Operation	Low back, knee, ankle	All

Plant operation	None	Elbows, hips, knees, ankles
Plant production	Elbows, hips, knees, ankles	None
Mekanik sopir	Low back, hips, knees, ankles	None
Maintenance & control	Shoulders, low back	Elbows, hips, knees, ankles
Electric maintenance	Neck, Low back	Elbows, hips, knees, ankles
HSE	Stomach	None
Dozer operator	Head, neck, low back	Hands, knee, ankle
GA Clerk	None	Low back, elbows, knees, ankles
Mechanic maintenance	Upper back, low back	Shoulders, elbows, knee, ankle
Operation clean up	Low back	None
Maintenance welder	Hips	Low back, neck
Maintenance plant	Shoulders, elbows, upper back	None
Logistic Fuel Oil Grease Chemical	Shoulders, low back	Elbows, hips, knees, ankles
Logistic supervisor	Low back	Hands, knee, ankle
Administrasi	Hands, low back	Head, neck
Plant	Elbows, upper back, knee, ankle	Head, neck
Administrasi civ. Mtn	None	None
Production plan	Shoulders, upper back, knee, ankle	None
Camp maintenance	Hips	Low back, neck
Logistic	Shoulders, low back	Elbows, hips, knees, ankles
QHSE SPV	Neck, shoulders, upper back, hips	None

Data are collected using Material handling Checklist form and Body Part Discomfort Interview Guide (see Fig. 3 and 4) as well as Filling out BPD form during identification stage and manual handling activity in stock pile area (see Fig. 5 and 6).

Table 3. Decision matrix for selecting tasks

Work area	No. of employees	Incident data	Nordic Questionnaire	Supervisor interviews	Management concern	Final score
Electrical:						
Maintenance	28 (10%)	Medium	Low	Medium	Yes	4
Operators	45 (20%)	Medium	Medium	Medium		5
Mechanic:						
Maintenance	7 (03%)	Low	High	Medium	Yes	5
Operators	24 (10%)	Medium	High	High		8
Plant production:						
Maintenance	4 (02%)	Low	Low	Medium	Yes	6
Operators	13 (05%)	High	Low	Medium		8
Hopper:						
Maintenance	32 (13%)	High	Medium	Medium	Yes	5
Operators	51 (21%)	High	Medium	High		7
Crusher:						
Maintenance	7 (03%)	Medium	Medium	Medium	Yes	6
Operators	14 (06%)	Medium	High	Medium		9
Secondary Crusher:						
Maintenance	7 (03%)	Medium	Medium	Medium	Yes	5
Operators	13 (05%)	Low	High	High		7

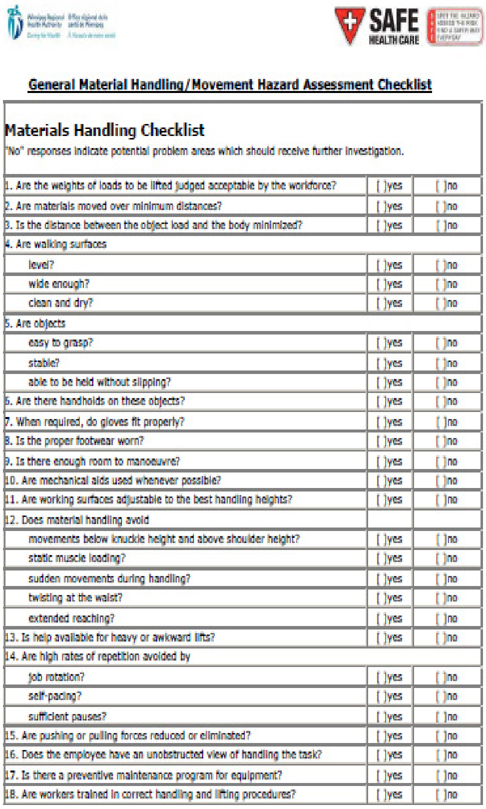
5. Conclusion

This phase focused on identifying MSD risk factors using qualitative and quantitative data. The tools used to assess work tasks were effective for quickly identifying risk factors. Brainstorming sessions made workers more aware of risk factor significance.

Observations of work tasks and interviews with workers performing those tasks suggested that handling heavy and awkward objects, forceful arm and shoulder exertions, and working in awkward postures were common to mine site. Tasks requiring a significant amount of manual work involving upper extremity and low-back activity were found. Tables 1 through 3 indicate that awkward postures and forceful exertions are the most common MSD risk factors observed within and across the mine site.

These identification stage were very useful as they generated ideas to reduce risk factors—or make the work pro-cess less physically demanding and less difficult. The sessions also offered an opportunity for the team to meet with workers and offer comments and feedback on their work process and methods. Discussions were aided by the use of videotapes/photographs of workers performing the target tasks. In some cases, workers were surprised at the amount and extent of bending and twisting while handling heavy objects. From this problem identification, it can reduce discomfort in manual handling for each department in the Mining Industry

Appendix A



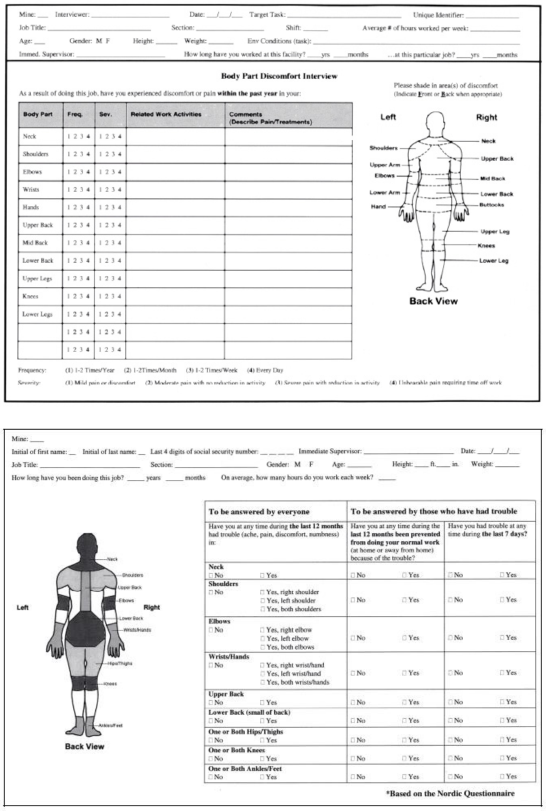
General Material Handling/Movement Hazard Assessment Checklist

Materials Handling Checklist

"No" responses indicate potential problem areas which should receive further investigation.

1. Are the weights of loads to be lifted judged acceptable by the workforce?	[ ]yes	[ ]no
2. Are materials moved over minimum distances?	[ ]yes	[ ]no
3. Is the distance between the object load and the body minimized?	[ ]yes	[ ]no
4. Are walking surfaces		
level?	[ ]yes	[ ]no
wide enough?	[ ]yes	[ ]no
clean and dry?	[ ]yes	[ ]no
5. Are objects		
easy to grasp?	[ ]yes	[ ]no
stable?	[ ]yes	[ ]no
able to be held without slipping?	[ ]yes	[ ]no
6. Are there handholds on these objects?	[ ]yes	[ ]no
7. When required, do gloves fit properly?	[ ]yes	[ ]no
8. Is the proper footwear worn?	[ ]yes	[ ]no
9. Is there enough room to manoeuvre?	[ ]yes	[ ]no
10. Are mechanical aids used whenever possible?	[ ]yes	[ ]no
11. Are working surfaces adjustable to the best handling heights?	[ ]yes	[ ]no
12. Does material handling avoid		
movements below knuckle height and above shoulder height?	[ ]yes	[ ]no
static muscle loading?	[ ]yes	[ ]no
sudden movements during handling?	[ ]yes	[ ]no
twisting at the waist?	[ ]yes	[ ]no
extended reaching?	[ ]yes	[ ]no
13. Is help available for heavy or awkward lifts?	[ ]yes	[ ]no
14. Are high rates of repetition avoided by		
job rotation?	[ ]yes	[ ]no
self-pacing?	[ ]yes	[ ]no
sufficient pauses?	[ ]yes	[ ]no
15. Are pushing or pulling forces reduced or eliminated?	[ ]yes	[ ]no
16. Does the employee have an unobstructed view of handling the task?	[ ]yes	[ ]no
17. Is there a preventive maintenance program for equipment?	[ ]yes	[ ]no
18. Are workers trained in correct handling and lifting procedures?	[ ]yes	[ ]no

Fig. 3. Material handling Checklist Form



Mine: ___ Interviewer: ___ Date: __/__/__ Target Task: ___ Unique Identifier: ___
Job Title: ___ Section: ___ Shift: ___ Average # of hours worked per week: ___
Age: ___ Gender: M F Height: ___ Weight: ___ Env Conditions (task): ___
Immed. Supervisor: ___ How long have you worked at this facility? ___yrs ___months …at this particular job? ___yrs ___months

Body Part Discomfort Interview

As a result of doing this job, have you experienced discomfort or pain **within the past year** in your:

Body Part	Freq.	Sev.	Related Work Activities	Comments (Describe Pain/Treatments)
Neck	1 2 3 4	1 2 3 4		
Shoulders	1 2 3 4	1 2 3 4		
Elbows	1 2 3 4	1 2 3 4		
Wrists	1 2 3 4	1 2 3 4		
Hands	1 2 3 4	1 2 3 4		
Upper Back	1 2 3 4	1 2 3 4		
Mid Back	1 2 3 4	1 2 3 4		
Lower Back	1 2 3 4	1 2 3 4		
Upper Legs	1 2 3 4	1 2 3 4		
Knees	1 2 3 4	1 2 3 4		
Lower Legs	1 2 3 4	1 2 3 4		
	1 2 3 4	1 2 3 4		
	1 2 3 4	1 2 3 4		

Please shade in area(s) of discomfort (Indicate Front or Back when appropriate)

Frequency: (1) 1-2 Times/Year (2) 1-2Times/Month (3) 1-2 Times/Week (4) Every Day
Severity: (1) Mild pain or discomfort (2) Moderate pain with no reduction in activity (3) Severe pain with reduction in activity (4) Unbearable pain requiring time off work

Mine: ___
Initial of first name: __ Initial of last name: __ Last 4 digits of social security number: __ __ __ __ Immediate Supervisor: ___ Date: __/__/__
Job Title: ___ Section: ___ Gender: M F Age: ___ Height: ___ ft.___ in. Weight: ___
How long have you been doing this job? ___ years ___ months On average, how many hours do you work each week? ___

To be answered by everyone	To be answered by those who have had trouble	
Have you at any time during **the last 12 months** had trouble (ache, pain, discomfort, numbness) in:	Have you at any time during the **last 12 months been prevented from doing your normal work** (at home or away from home) because of the trouble?	Have you had trouble at any time during **the last 7 days?**
Neck ☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
Shoulders ☐ No ☐ Yes, right shoulder ☐ Yes, left shoulder ☐ Yes, both shoulders	☐ No ☐ Yes	☐ No ☐ Yes
Elbows ☐ No ☐ Yes, right elbow ☐ Yes, left elbow ☐ Yes, both elbows	☐ No ☐ Yes	☐ No ☐ Yes
Wrists/Hands ☐ No ☐ Yes, right wrist/hand ☐ Yes, left wrist/hand ☐ Yes, both wrists/hands	☐ No ☐ Yes	☐ No ☐ Yes
Upper Back ☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
Lower Back (small of back) ☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
One or Both Hips/Thighs ☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
One or Both Knees ☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
One or Both Ankles/Feet ☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes

***Based on the Nordic Questionnaire**

Fig. 4. Body part discomfort interview guide

Fig. 5. Filling out BPD form during identification stage

Fig. 6. Manual handling in stock pile area

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