Step change towards zero incidents in the chemical industry: Managing the human factor

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DEDICATION

This dissertation is dedicated firstly to God, *in whom we live, move and have our being;* and to my precious and loving wife, Mrs. Folakemi Manuwa, who has done no less than adding value to my life.

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ABSTRACT

Clearly, it is the short and long-term aspiration of workers within any safety-critical or high-hazard industry such as the chemical, oil and gas, rail or nuclear, to develop measures to prevent, avoid or reduce incidents.

Human factors are often cited as the initiator of error-events which leads to incidents in these high hazard industries, yet, either little or nothing is mentioned of them, or is being seen in a very narrow perspective. There are several case studies which illustrate how the failure of people or human errors at many levels within an organization, not just the operator on the front-line, but management, designers, and high level decision makers all led to the final outcome e.g. Chernobyl, Piper Alpha, etc.

The Human factors subject is a subject that most people are familiar with, but it seems to be poorly understood by many people. This subject actually provides powerful and practical principles for improving human performance, reducing hazards, improving safety and proactively preventing future incidents in all businesses where people are involved in planning, design and development, and operation.

This research was aimed at identifying the human factors elements which contribute primarily to incidents at Sasol Wax and finding best principles and practice in the industry for the integration and management of human factors. The research was accomplished by the following steps:

1. Developing an understanding of human factors.
2. Categorization of human factors.
3. Developing understanding of hazards and its identification methods.
4. Utilization of J. Reason's "Swiss cheese" accident model.
5. Quantification and weighting of human factors elements with the use of Questionnaires and the Health, Safety and Executive, UK, value system.

6. Evaluating and benchmarking the critical human factors elements at Sasol Wax against Sasol Technology, Sasol Solvent and Sasol Infrachem business units.

With Sasol Wax as case study for this research, human factors concerns evolved, and also performance gaps were identified during the benchmarking process. Recommendations, outlined in section 6.3 of this research, were made based on the conclusions drawn from the evaluations and benchmarking process.

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LIST OF ACRONYMS

Acronyms	Meaning
COMAH	Control of Major Accident Hazards
HAZOP	Hazard and Operability Studies
HF	Human Factors
HFE	Human Factors Engineer
HFE	Human Factors Engineering
HSC	Health and Safety Commission
HSE	Health and Safety Executive
HR	Human Resources
HR.P	Human Resources Personnel
JSA	Job Safety Analysis
MHSWR	Management of Health and Safety at Work Regulations
M.P	Maintenance Personnel
OHS	Occupational Health and Safety
OHSAS	Occupational Health Safety Assessment System
PDA	Potential Deviation Analysis
P.P	Production Personnel
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations
SHE	Safety Health and Environment
SH& E	Safety, Health and Environment
SHERQ	Safety, Health, Environment, Risk and Quality
S.P	Safety Personnel
SRAM	Safety Report Assessment Manual
UK	United Kingdom
US	United States

CHAPTER ONE

1.0 BACKGROUND

1.1 Introduction

The significance of occupational safety in chemical industries has been a very important issue in achieving productivity and an edge in the competitive world. It is also important to note that the most important asset a company has is its workers or employees because the workers are involved in, and interact with every aspect of the workplace including the technical systems. Workers safety is thus an integral part of the industry's economic sustainability and organizational development (Jukka Takala, 2001).

The occurrence of Work-related accidents and injuries can be considered as adverse effects of working in a chemical industry due to its high hazard work environment. Globally, it is estimated that about 50 workers get injured every minute of the 40-hour work week; and about 17 of these injured workers die each week (Publication of Loss Analysis and Accident Prevention, L.A.A.P Consultants, Inc.). This is alarming. More so, humans frequently play active roles in causing industrial failure and accidents through their shortcomings and fallibility (Hayim Granot, 1998); and these human errors can occur in every stage of industrial activity, not just during operations.

Truly, the purpose of economic activity in chemical industries is to increase the well being of workers and the business alike since it offers a means of livelihood for the workers and also a boost to the economy in terms of what is being produced according to the market demand. But if the working conditions are unsafe, with frequent cases of incidents, the workers wellbeing will be negatively affected; the national economy and social progress will be hindered, and it can also affect the performance of a company by increasing the company's expenses and lowering the profitability of workers (Arto Teronen, 2001).

The New York Times of November 8, 1997 reported that Nike, Inc., the world's largest retailer of athletic shoes came under severe criticism in 1997 over the working conditions of its over 350, 000 workers in its factories in Asia. Workers were required to work more than the maximum allowable

working hours, Personal Protective Equipment (gloves, masks) were not daily provided, and workers do not wear protective equipment even in highly-hazardous places where the concentration of chemical dust, fumes exceeded the standard allowable quantities. There were no trainings on proper handling of chemicals. Chemical releases led to an increased number of employees who had skin, throat and heart diseases. These affected the profitability of the company and the social progress of the workers.

In examining recent research conducted by safety professionals, Smith, S.L, 1995, put forward that an incident-free work environment creates a positive employee attitude, commitment, and a sense of awareness and responsibility. Such an environment also results in higher quality and lower total production costs due to decreased rework and scraps, lost time, workers' compensation and lost work days.

Thus whilst also maintaining the equipment and process standards achieved up to date in the chemical industry, organizations need to understand how human factors influence behavior and consequently safety performance, and how best to manage human factors since human errors are associated with almost every incident which occurs in the chemical industry (Gant, P.J *et al,* 2005).

1.2 Problem Statement and Substantiation

Much attention has not been given to the role human beings play in every stage and system in the chemical industry as much as it is given to improvements on designs, technologies and production output (Hayim Granot, 1998). This has resulted in a decrease in technical failures while human errors have steadily increased due to mismatch between the way that human beings think and work, and the design of the systems they have to work with (Ian Donald and Stephen Young, 1996).

It is essential to note that incidents involve people. According to a press release of January 2006 in the US, it is reported that approximately 96% of all workplace accidents are attributed to human error. Coincidentally, humans would always be needed in every aspect of the workplace.

Rasmussen, J, (1990) also expressed concern that no matter how big or complex today's technical systems become, they would always depend on human involvement in one way or the other for their safe operation. This then increases the level of maintenance of safety to be done in such complex systems and makes identification of human error as a cause in accidents increasingly important.

In its publication "Reducing error and influencing behavior" (Health and Safety Executive, 1999), it is stated that "*human factors is defined as environmental, organizational and job factors and human and individual characteristics that influence behavior at work in a way which can affect health and safety*".

The direct costs in terms of claims, medical costs, indemnity payments, and indirect costs in terms of a re-training, property damage, accident investigation, insurance, administrative costs, effect on environment and low morale, due to human error and failures as a result of not managing the human factor are very high.

The Piper Alpha disaster for example, not only involved the loss of one hundred and sixty seven lives, but was estimated to have cost over two billion dollars, which included seven hundred and forty six million in direct insurance payouts. Although the cost of smaller scale incidents which do not result in the loss of lives, damage to the plant or interrupted processes, are less easy to detect; it may be hidden in sick pay, increased insurance premium, or maintenance budgets (Lynn Fraser, 2007).

Successful management of human factors and control of risk involves the development of systems designed to take proper account of human capabilities and fallibilities since it is now widely accepted that the majority of incidents in the chemical industry generally are in some way attributable to human as well as technical factors in the sense that actions by people initiated or contributed to such incidents, or people could have acted better to avert them (Health and Safety Executive, 1989a).

Good human factors in practice is about optimizing the relationships between demands and capacities in considering human and system performance i.e. understanding human capabilities and fallibilities (Linda J., Tim A.W. Geyer, John Wilkinson).

To improve safety and therefore reduce undesired events requires designing of equipment, operations, procedures and work environment in such a way that they are compatible with the physical and cognitive capabilities and limitations of human beings. For a plant to be fully developed safety-wise, significant benefits must be provided to those who operate and maintain it. Therefore it is important to fully understand all aspects of the facility that influence the operator/maintainer performance. The evaluation and assessment of these aspects fall under the human factors domain (Simon Gitahi Kariuki, 2007).

In light of the above, the problem is that human factors management and consideration in the chemical industry has been poor, and this has reflected in many incidents ranging from near misses to fatalities. Some of these incidents and the outcome of investigations are discussed in section 2.6. Thus, human factor consideration from the planning stage, to design, to procurement, to operating and to maintenance in the chemical industry could possibly result in a step change towards zero incidents.

The contribution of this research to the ongoing efforts in achieving zero incidents in the chemical industry would be the development of world-class strategies and best practices that will ensure better management of human factors in the incident/accident process.

This research stands to benefit:

i. Any high hazard industry such as chemical, oil and gas (onshore and offshore), rail or nuclear, and their stakeholders including but not limited to operations managers, managers with health and safety responsibilities, employee safety representatives, industry regulator, human factors consultants, HSE advisors and specialists; in terms of human factor recognition, understanding and integration into safety management systems.

ii. Sasol Wax (a major business unit of Sasol Chemical Industry, South Africa), which will be used as a case study in its move towards achieving incidents-free work environment.

iii. The body of knowledge as a stepping stone for further research in human factors analysis and management in safety-critical or high hazard industries.

1.3 Research Aims and Objectives

The concern of this research is based on incident occurrences at Sasol Wax, as well as on the claim in a press release in the US that more than ninety percent of incidents in the chemical industry are largely influenced by human factors. Rasmussen, J., Reason, J., Hayim, G., to mention but a few, in their articles and journals on human factor involvement in the accident process, also attested to this fact.

It is the aim of this research to:

i. Investigate the human factors involvement in incident causations in the chemical industry,

ii. Review incidents which have occurred at Sasol Wax over a particular period,

iii. Examine the potential of anticipating likely sources of human error,

iv. Implement measures to prevent it, and

v. Develop best practices to be able to manage human factors.

The objectives of this research are to:

i. Improving organizational safety performance and enhancing the safety cultures and programs in the chemical industry, and

ii. Move towards zero incidents in a safety-critical industry like the chemical or process industry.

1.4 Research Outcomes and Deliverables

The research outcomes are a comprehensive knowledge and understanding of human factors in relation to the different phases of involvement in the chemical industry and in incident occurrences; and how its integration into safety management coupled with the capability to implement them, can improve health and safety performance.

The deliverables from this research as a whole are:

i. Human factors understanding and categorization.
ii. Human factors assessment results using an adapted Health, Safety and Executive, UK, weighting and value system.
iii. Principles and best practices for enhanced human factor management in the chemical industry derived from the benchmarking process.
iv. A framework outline that demonstrates the hierarchy of human factors in the incident/accident process.

The research covers largely errors classified as mistakes or oversights. Acts of calculated disrespect or disregard to laid-down rules and procedures like sabotage are not part of the research. Although focus is on the chemical industry, other high hazard and safety-critical industries like the oil and gas, rail, nuclear, aviation, etc, which bears similar conditions and information to the area of focus, were used as well.

1.5 Method of Investigation

1.5.1 Analysis of literature and sources of Information

For the purpose of this research, the following sources of information were used to carry out the literature survey:

i. Library sources
ii. Human psychology texts
iii. Internet sources: use of search engines like Google, yahoo, ixquick, copernic, metacrawler, etc.

iv. Journals and Publications
v. Related thesis'
vi. Personal interviews and consultations
vii. Safety handbooks, posters, and encyclopedia
viii. Texts on human error, human reliability and ergonomics
ix. Health and Safety regulations documents
x. Incident records at Sasol Wax
xi. The South African Health and Safety Legislation (Occupational Health and Safety Act).

1.5.2 Empirical Investigation and Verification

The empirical investigation for this research was done using the case study approach (Sasol Wax as case study) where recorded incidents at Sasol Wax were reviewed; and then data on human factor issues gathered from the use of questionnaires and interviews carried out, will be collated and analyzed.

1.6 Dissertation Outline

The subsequent chapters of this research shall be structured as follows:

A detailed literature review of human factors, the essentials of human error, chemical industry accidents attributed to human error, and also the health and safety regulations guiding human factors in the chemical industry was presented in chapter two.

Chapter three introduces hazards and its identification methods in the chemical industry. An accident model that explains the relationship between hazards, the human involvement, and incidents/accidents was also presented.

The empirical investigation methods, research instruments used, and the validation process also formed part of chapter three. The analysis and discussion of the results of chapter three were carried out in chapters four and five.

Further analysis of the results of chapter three took place in chapter five. The benchmarking method and process was presented in this chapter as well.

Finally, in chapter six conclusions was made based on the results of the analyses, and recommendations were made based on conclusions drawn.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Until recently, there has been the mindset among engineers and other technical professionals, particularly in the area of safety and reliability analysis, that human factor consideration is not a major issue. Not until in the 1970s when human error became identified as a frequent cause of things going wrong. One of the pioneers in the new emphasis called it a "socio-technical problem" (Hayim Grant, 1998).

From an analysis carried out in the Aviation industry of causal factors which contributed to a situation in which the safety of aircrafts were compromised, results show that approximately 98% of incidents in UK airspace during 1997 were caused by human error (Sandom Carl, 2002).

In a similar light from the report of Sandom, most of the incidences which have occurred over the years in the chemical industry have also put the blame on human error because humans often get injured and damage is done in one way or the other to equipment or environment which humans interact with, and are meant to control. But the obvious truth is that humans cannot be automated like equipment, and if humans must contribute less to unwanted events, designed systems should be able to prevent mistakes or human failure from happening.

Paradoxically, we live in a complex world to be able to achieve our safety targets with such a very simple solution as mentioned above (UK Parliament of Science and technology Postnote, 2001). We live in a world where systems design and/or manufacture of systems is most often done in a geographical area that is different from where it is to be put into operation or made use of.

Since it is certain that human errors will be made, it is also possible to reduce human failure or error in the chemical industry by careful application of human factor management practices that will focus on how the chances of these errors happening are reduced, the checks and controls are put

into place, and the impact of any failure or error that happens is minimized (UK Parliament of Science and technology Postnote, 2001).

The following are summaries of reported incidents in the chemical industry prepared by Nickleby HFE Ltd for Health and Safety Executive 2004. The incidents reflect lack of consideration of human factors, and they could have been potentially avoided if good human factor management practices had been adopted.

Incident 1: Use of wrong plug types

Notes from the incident report

A gas leak from a wellhead valve manifold occurred because a fusible plug, which was not designed to withstand high pressures, had been fitted instead of a blanking plug. Subsequent review found that blanking plugs had often been used in situations where fusible plugs were required.

Points to note

- Fusible and blanking plugs were stored together and are easily mistaken
- Fusible plugs are identified by a spot of paint, color coded by the failure temperature. The paint is easily scratched off.

What could reasonably have been expected in design of the well head manifold?

- To recognize that the blanking plug is a critical feature in avoiding gas release.
- To recognize the critical role of the human in ensuring the correct type of plug is fitted.
- To recognize the potential for human error.
- To ensure that the importance of using the correct type of plug was reflected in training material and procedures
- To recommend that different types of plugs are clearly perceptually distinct.
- To explore the possibility that fitting could be designed in such a way that it would not be possible to fit the wrong type of plug

- To discuss with suppliers the possibility of designing plugs to support the design solution.
- To provide prompts and reminders as part of the design of the manifold.

Would good practice in Human Factors have helped to avoid the incident?

Yes, provided the plug type was identified as being a critical element during Hazard Identification.

- An analysis of maintenance tasks should have identified the task as being potentially critical.
- Understanding of the wider context of use should have recognized the potential for error in selecting or fitting the wrong type of plug.
- An operability trial would have identified the possibility of confusion.

Incident 2: Thread tape fitted the wrong way round

Notes from the incident report

A hydraulic leak was detected coming from a 3/4 inch supply fitting to the masthead valve actuator. Two hundred litres of oil had run into the sea. The investigation team found that the 3/4 inch fitting had been assembled wrongly, as the thread tape used had been applied the wrong way round. This made the tape come off the thread and gather in the bottom of the fitting, which in turn did not allow for a good seal.

Points to note

- The incident investigation identified the contributory causes as lack of knowledge, and inadequate maintenance.
- The root cause was considered to be inadequate training and competence.
- Thread tape is understood to be in widespread use in many industries.

What could reasonably have been expected of the design team?

- The design team could have realized that avoidance of a leak was critically dependent on a simple operator task, with clear error potential.
- Be aware that the thread tape required in the design solution would only have been effective if fitted the correct way.
- Recognize the potential for human error and assume that at some point in time, the individual fitting the tape might be tired, distracted or simply make a mistake.
- Design-in additional protection to avoid the risk of oil release, or base the design on a different fitting which does not depend on correctly fitted tape.
- Provide clear and easily interpreted indications on the valve about the importance of applying the thread tape the correct way round.

Would good practice in Human Factors have helped to avoid the incident?

Yes.

- Consideration of maintenance tasks would have identified the potential for human error in applying the thread tape
- As thread tape is in widespread use, investigation of operational experience would probably have indicated that operators are well aware of the fact that thread tape is frequently incorrectly fitted.

Being aware of the fact that most systems in the chemical industry are safety critical, which typically relies on people, procedures and equipment so as to function safely within the operational environment, it is therefore necessary for the industry to allocate as much safety assurance efforts to human factor contributions to the workplace as much as it is given to technical issues.

2.2 HUMAN FACTORS DEFINED

As it has been explained in section 2.1, various reports indicate that humans are a major cause of incidents or accidents in the chemical industry since virtually every engineering system will require human intervention to some extent. It is worth noting at the this point that the human failure being

discussed in this study, is not just direct mistakes by operators and maintainers, but it also includes man-made errors from failed designs, as well as the role of the work environment, the organization or the management's failure played towards the occurrence of the human error leading to an incident.

In the human error management process for the chemical industry, the human factor approach needs to be used, so as to understand how best to manage the current situation and achieve safety improvements in this area. "*Human factors, also called ergonomics, is concerned with improving the productivity, health, safety and comfort of people, as well as ensuring effective interaction between people, the technology they are using, and the environment in which both must operate*" (Meshkati, 1991).

Human factors as also explained by Dr Ron McLeod, 2004, are concerned with taking proper account of the characteristics and abilities of people with focus on safety in their work environment. It is concerned with minimizing potential incidents particularly in high risk work environments.

2.3 HUMAN FACTORS CATEGORISED

The practical classification of the whole human factors domain is very challenging because the human factors field is wide, and different authors have approached it in different ways because what may be obtainable in the human factors area in the chemical industry may not be applicable in other high hazard industries (Kariuki, S.G, 2006).

From the 1999, 2001 and 2005 editions of the UK Health Safety and Executive and other human factors documents reviewed, the human factors which are considered to have the highest influence on people performance and incident rate in the chemical industry are categorized into the following four groups:

I. Culture/working Environment
II. Organization/Management Systems
III. People

IV. Facilities/Equipment

The International Association of Oil and Gas Producers of UK's article on Human Factors, *a means of improving HSE performance,* pointed out the major human factors elements which fall under the four broad human factors categories listed above. The human factors elements under each human factors category are explained below:

2.3.1 Culture/Working environment

2.3.1.1 Social and Community values

Social value is you, each person in a community. The truth is that everyone in a community or group has inherent value and worth merely because they exist. Culture simply put, is defined as shared values and beliefs among a group of people (Uttal, B, 1983). There is also a corporate culture which entails the values and standards of behavior that specifically reflects the objectives of the organization (http://en.wikipedia.org/wiki/Organizational_culture).

When people's personal, intrinsic value is recognized in a corporate organization, it fosters a better working environment. Conversely, when that value is not shared or recognized, then the working environment becomes dissatisfactory.

Chemical industries today have the challenge of ensuring that their company culture recognizes the intrinsic values of those of their employees, contractors and subcontractors e.g. religious activities, etc. The relationships that work best according to a human factors article are those that foster strong, compatible cultures.

2.3.1.2 Communication flow within an organization

Communication, both written and verbal can be critical in maintaining safety. This can include emergency communications, general communications in the form of safety information, communications between team members or between different teams during operations or maintenance work, or receiving information by direct perception.

2.3.1.3 Organizational changes

The chemical industry faces continuous pressure to change in order to meet its business objectives in a competitive world. Organizational changes such as reducing staff numbers, combining departments or changes in roles and responsibilities are usually not analyzed and controlled as thoroughly as plant, process or technology changes (HSE, 2005). The HSE explained further that if any change is to be carried out and such a change is not properly conceived or implemented, it can have a negative impact on safety as well as the management of major hazards.

2.3.1.4 Language

Language may contribute to incidents occurrence in a situation where operating and safety procedures are written in a language that is not well understood. According to Hendrikse and McKinney, 2000, English was not the official language of the end user population, and that the use of both English and the official indigenous language was initially being contemplated. This would have resulted in too high a financial cost if all instructional materials, equipment labeling and safety material had to be printed in both languages. Although English is universally accepted now, but it is still a difficulty for many who their first, second or even third language is not English.

2.3.1.5 Geography

Location or layout of a facility is also a very important consideration in the chemical industry. It is very important that the topology of a place where a facility is cited does not negatively impact on the workers as to affecting their safety.

2.3.1.6 Climate

Comparing the climate between developing countries and industrialized countries, one would see that there are vast differences. The climates range from extremely hot and humid to cold and dry. Work places designed for cold environments have different insulation and ventilation requirements than those designed for hot climates which are important considerations in terms of safety when

designing buildings and personal protective clothing and equipment for use in developing countries or in a different region.

2.3.1.7 Management support of safety values

Safety values are a major element in determining an organization's safety behavior and performance (Pedro, M. & Sergio, M.). According to the Parliamentary office of Science and Technology Postnote, when we put together individual and group values, attitudes, competences and patterns of behavior that establishes the style and proficiency of an organization's health and safety programs, they all make up a safety culture. Errors are common in settings where safety values are minimally upheld. Poor safety culture contributed to major incidents which will be discussed in the later part of this chapter.

2.3.2 Organization/Management Systems

2.3.2.1 Quality of operating procedures/work practices

Procedures are actually safe ways of doing things after they must have been considered and decided upon. Written procedures may include checklists, decision aids, diagrams, flow-charts and other types of job aids.

According the HSE 2005, problems with procedures and work practices are linked to numerous incidents in the chemical industry. Kariuki, S.G., noted that when assumptions are made rather than following a complete and correct procedure, then problems are sure to occur. Such assumptions could be that an operator could complete the task using "common sense" even when the procedure steps are given in the wrong sequence. At other times, such procedures could be inadequate, or equipment is changed requiring a different procedure, but the procedures are not changed.

2.3.2.2 Job Safety Analysis

This is essentially the assessment of work activities and the workplace in other to establish whether adequate precautions are in place or not. In an analysis like this, work methods are reviewed, and potential hazards in the workplace are identified as a step to controlling the possible risks involved (OHSAS 18001, 2002).

The job safety analysis (JSA), when carried out, can be a way whereby there is regular contact between workers and their supervisors on health and safety matters. It can also assist in carrying out complete incident investigations.

2.3.2.3 Clear Interfaces

The interactions between humans and systems in the chemical industry have been frequently identified as major contributors to poor operator performance (HSE 2005). It is through this human-system interface that the operator knows what is actually going on in the process associated with the system, and he will then know what decision is to be taken. So the proper and safe decision taken will be a function of the human capabilities and the clarity of the interfaces.

2.3.2.4 Clear Responsibilities and Accountability

Very often, top management will be more involved in the management of anything related to finance, and will often delegate the responsibility for quality assurance or other safety management systems, at least to allow themselves the chance to get on with running the business. This thinking will not actually promote safety if safety is not the business. If there must be step change towards zero incidences in the chemical industry, then everyone from top to bottom at the workplace must be responsible and accountable to safety management.

2.3.2.5 Risk Management

The risks associated with the chemical industry are in proportion with its rapid growth and development. Apart from their usefulness, chemicals have their own inherent properties and hazards. Some of them can flammable, explosive, toxic or corrosive etc.

Risk management has to do with the identification, evaluation, selection and implementation of actions in a bid to reduce the risk to property, human health and the environment.

2.3.2.6 Safe Working Practices

This involves observing basic safety and emergency procedures, and it encompasses the skills, knowledge and attitudes to maintain a safe working environment.

2.3.2.7 Leadership and Compatible Organizational Goals

Management's leadership styles, supervision, as well as its corporate goals have been identified as significant organization factors affecting incidents in the chemical industry.

Management is all about planning and allocating work, making decisions, monitoring performance and compliance, providing leadership, facilitating, communication and teamwork, and ensuring workforce involvement in other to achieve its corporate goals. As a result of poor leadership or supervision in many chemical industry organizations today, senior managers can be said to also influence health and safety culture of such organizations (HSE 2004).

2.3.3 People

2.3.3.1 Stress and Fatigue

Fatigue is a state of tiredness or exhaustion and it arise from excessive working time or poorly designed shift patterns. This perceived state of tiredness is caused by prolonged or stressful exertion. It results in slower reactions, reduced ability to process information, memory lapses, absent-minded slips, lack of attention etc. According to the HSE 2005, this type of condition lead to errors and incidents, and it is often the root cause of major accidents.

2.3.3.2 Training Systems

Training processes and systems takes time and money, but it is essential if the organization wants to increase employee safety awareness and the commitment to the creation of an injury-free workplace (Ansari, A., 1997). The skills and know-how that a worker requires to be able to cope with the job is provided through training. A good training system is supposed to compliment other good safety structures and systems. Inadequate training, theoretical training without

commensurate practical exposure, lack of training and post-training evaluations to determine if skills have been acquired are a problem to safety in the chemical industry.

2.3.3.3 Workload and shift schedule

Workload, shifts and overtime can negatively affect the way tasks are carried if not properly organized. When this situation is not well organized, fatigue and stress sets in, and alertness is affected. According to Kariuki, S.G, there is 15% rise in incidents that happen in evening shifts (i.e. 4pm until midnight), and 20% rise in incidents that happen in night shift (i.e. midnight until 8am) in relation to the amount of incidents which happen during morning shifts.

2.3.3.4 Behavioral Safety

Behavioral safety involves the definition of safe/unsafe behaviors, observation of behaviors in the workplace by management or employees, and feedback/reinforcement of behaviors. Behavioral safety is based on the premise that a significant proportion of accidents are primarily caused by the behavior of front line staff. Although these behaviors may be largely the result of attitudes, it has been shown that changing behaviors first is more effective (HSE, 2007).

In a work environment where there are both contract and permanent employees, the contract employees are likely to have less positive behaviors than the permanent employees (Sharon Clarke, 2002). According to Sharon Clarke, contract or temporary workers appear less interested in safety behaviors like manual handling, housekeeping, use of correct PPE and tools, working at heights, etc., compared to the permanent workers. And this has resulted in many incidences involving the temporary workers than the permanent workers in the chemical industry.

Behavioral safety brings about increased visibility of management in the workplace, the workforce and management talking to each other about safety, increased employee engagement in safety, managers/supervisors may improve their safety leadership and also learn to think about human factors (Anderson, M.2004).

2.3.3.5 Attention/Motivation

This is based on the positive satisfaction that psychological growth provides. The presence of factors such as responsibility, achievement, recognition, and possibility for growth or advancement will motivate and satisfy people. And this state tends to direct a person's mind towards the organizational goal.

2.3.3.6 Physical and Mental Fitness

The physical, mental and intellectual abilities of a worker are a very important consideration in safety issues. Based on physical and mental workload, if work capacity, staff strength, and abilities of people are lower than workload, then safety is bound to be compromised and risks of incidents are high (Rabiul Ahasan, 2002). Thus it is necessary tasks match individuals capabilities.

2.3.4 Facilities/Equipment

2.3.4.1 Ergonomics

This is involves how work stations, work processes, tools, equipment, are designed with safety procedures and measures in place, in a way which fits the individual worker and enhances efficiency and productivity. Poor ergonomics will make the work place prone to frequent incidents.

2.3.4.2 Design

According to the HSE, the design of control rooms, plant and equipment can have a large impact on human performance. When systems design is carried out in the absence of feedback from its potential user, it is likely to increase the chance that the users will not be able to interact correctly with the systems.

Also inadequate design of controls and also inconsistencies in design will lead to errors particularly during emergency situations.

2.3.4.3 Maintenance and Reliability

Cost-effective maintenance plans and processes which continuously safeguards plant, processes and equipment is very important for workers in the chemical industry. If the plant, process or equipment is safe to work with, then the probability of incidents occurrence is lowered. Active support and cooperation of all people involved in this process is also very vital.

2.3.4.4 Physical layout of facilities and Sites

It is essential to plan a layout or site in such a way that it reduces the risk to the barest minimum possible when installations, operations, testing, maintenance, modification, repair or replacement is being carried out. This can be appropriately taken into account from the plant design stage by which the human interaction with the facility, as well as its reliability would have been taken into account.

2.3.4.5 Noise, Lighting, Toxics, Radiation

These are environmental conditions which can affect the performance of a worker. Noise of over 90 decibels from machineries, insufficient lighting, pollutant sources and radiation sources will affect communication, perception and the human body system negatively and also result in risk conditions (Kariuki, S.G).

Other environmental conditions which could pose as risks are vibration, temperature, humidity, wind, and air quality.

2.4 HAZARD IDENTIFICATION IN THE CHEMICAL INDUSTRY

Generally, a hazard is considered to be a situation or risk, which has the potential of creating harm or which eventually leads to incidents when triggered by humans. The incident could range from a *near miss* (an unplanned event which did not result in injury, illness or damage – but had the potential to do so) to *fatality* (casualty or loss of live) in the field of safety in the chemical industry (Paul Baybutt, 2003). This is depicted in Figure 2.1.

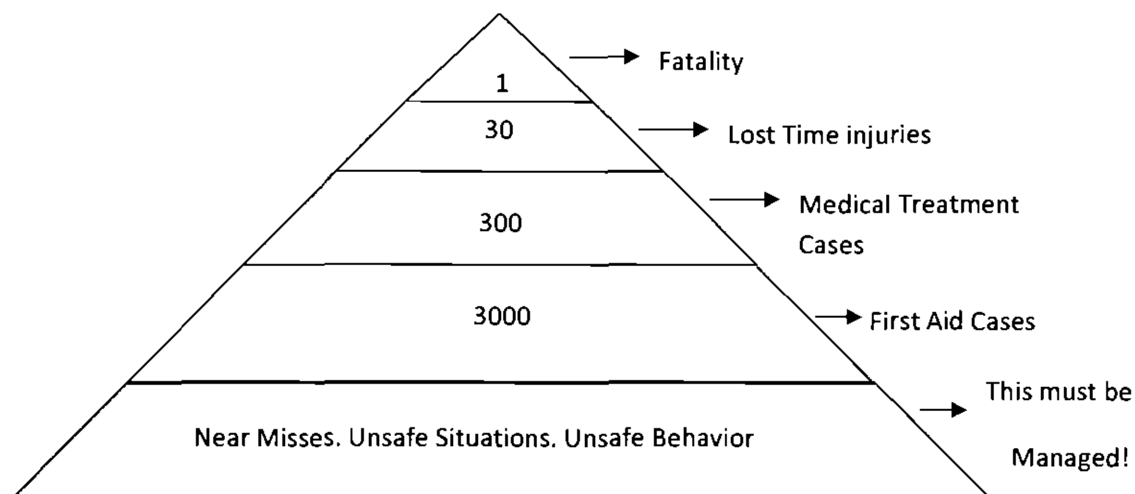

Figure 2.1: The Hazard Pyramid

The conclusion drawn from the ratios in Figure 2.1 is generally known as the *iceberg theory*. It implies that if for example there is oil spill on the floor (Hazard), then for 3000 persons that slips and sustains bruises as a result of the spill, will all require first aid treatment; 300 out of these may fall and sprain the elbow and will require medical attention; 30 out of these may slip and break the leg which becomes a major incident with lost time injuries; and there may be a case of fatality in which a person falls over an object and breaks the neck.

This theory thus shows that the risk to have a fatality is dramatically reduced if one manages the less severe incidents as small incidents, like near misses, small accidents and unsafe behaviors and conditions have a risk-reducing effect on all classes of incidents.

Hazards in the chemical industry may be chemical, electrical, physical, mechanical, fire/explosion or health hazards or a combination of these. At Sasol Wax, a combination of these hazards is present. For example, from Sasol's Group SH& E report of February 2007, it was reported that at Sasol Wax, a heat exchanger failed due to thermal expansion of wax in the shell side. Similar failures occurred on two other wax lines. Although no injury was reported during this incident, it was a case of chemical, electrical, mechanical and health hazards because the hot wax could be released and inflict serious burns on anybody nearby.

Thus hazard identification explores what could give rise to a situation that could lead to an incident. According to an article on Hazard Identification & Risk Assessment by BURGOYNE Consultants UK, understanding hazards and carrying out hazards identification as well as the assessment of risk are a fundamental requirement of the chemical industry. And that the requirement is a very essential part of the South African Occupational Health and Safety Act of 1993, the Irish Safety, Health and Welfare at Work Regulations of 1993, and of the UK Management of Health and Safety at Work Regulations of 1999.

Hazard identification should therefore be viewed, not as a drain on resources to attain a position of minimum legal compliance, but as a fundamental chemical industry business activity which is a proactive way of preventing or managing the occurrence of incidents, and also enhancing sustainability of the chemical industry business, as well as its corporate and social responsibilities.

2.5 CATEGORIES OF HAZARD IDENTIFICATION METHODS

The chemical industry uses a variety of hazard identification methods. The applicability and feasibility of a particular method depends on the nature of the process under study as well as a company's particular preference.

The hazard identification methods have been divided into four categories by the Health and Safety Laboratory (An Agency of the HSE, 2005); depending on the area in which they are predominantly applied (refer to Table 3.1 for definitions).

i. **Process hazards identification:** HAZOP, 'what if?' Analysis, CHA, PHA, FTA, CCA, Pre-HAZOP, FIHI, Checklists, CEX, MOSAR, GOFAR, Matrices, and IHA.

ii. **Hardware hazards identification:** Safety audit, FMEA, Function FMEA, FMECA, Mop, Maintenance Analysis, Sneak analysis, Block Diagram, SRA, Vulnerability, and DEFI.

iii. **Control hazards identification:** CHAZOP, Structured English, Structured language, SADT, State-transition Diagrams, Petri-nets, and GRAFCET.

iv. **Human hazards identification:** Task analysis, HTA, AEA, HRA, Pattern search method, and PHEA.

Details about the different hazard identification methods or techniques can be obtained from the Health and Safety Laboratory document of the HSE (HSL/2005/58) and other relevant literatures as cited in my references; but some widely-used methods from each category will be briefly described, but with emphasis on the human-related aspects since this research is focused onto human factors.

Table 2.1: Acronyms of hazard identification methods.

Acronym	Full Title
HAZOP	Hazard and operability study
CHA	Concept hazard analysis
CSR	Concept safety review
PHA	Preliminary hazard analysis
FTA	Fault tree analysis
CCA	Cause-consequence analysis
Pre-HAZOP	Pre-hazard and operability study
FIHI	Functional integrated hazard identification
CEX	Critical examination of safety systems
MOSAR	Method organized systematic analysis of risk
GOFA	Goal oriented failure analysis
IHA	Inherent hazard analysis
FMEA	Failure mode and effect analysis
Func. FMEA	Functional failure mode and effect analysis
FMECA	Failure modes, effects, and criticality analysis
Mop	Maintenance and operability study
Block diagram	Reliability block diagram

SRA	Structural reliability analysis
Vulnerability	Vulnerability assessment
CHAZOP	Computer hazard and operability study
Struc. English	Structured English
Spec. language	Specific language
SADT	Structured analysis and design techniques
State-transition	State-transition diagrams
GRAFCET	Graphe de commande etat-transition
HTA	Hierarchical task analysis
AEA	Action error analysis
HRA	Human reliability analysis
Pattern search	Pattern search method
PHEA	Predictive human error analysis

2.6 REVIEW OF SOME HAZARD IDENTIFICATION METHODS

2.6.1 Process hazards Identification

2.6.1.1 HAZOP

Hazard and operability studies (HAZOP) is the most commonly used method to identify and evaluate potential hazards in a process plant and to identify operability problems that could compromise the plant's ability to achieve design intent (Mary Kay O'Connor, 2006).

This systematic analysis method requires a detailed source of information for the design and operation of a process, such as current process flow diagrams (PFDs), process and instrumentation diagrams (P&IDs), detailed equipment specifications, flow charts, and for batch/semi-batch processes an operating guide, to produce maximum detail.

To produce a comprehensive evaluation of the process, a number of guidewords (typically no, not, none, more, less etc) are combined with process variables (flow, temperature, pressure, pH, level, etc), the resultant conditions are assessed in terms of potential negative safety consequences and existing safeguards.

2.6.1.2 FTA

Fault tree analysis (FTA) is a graphical representation of the combination of faults leading to a predefined undesired event. The method provides a deductive method for determining causes of the focused event (top event). By using Boolean logic gates (AND, OR) to relate equipment failure and human error, a FTA generates system failure logic models (Mary Kay O'Connor, 2006).

2.6.1.3 FMEA

The purpose of the Failure mode and effect analysis (FMEA) is to identify potential hazards associated with a process by investigating the failure modes for each process item, and their effects on a system or plant.

According to the Mary Kay O'Connor process safety document (Mary Kay O'Connor, 2006), human operator errors are usually not included in FMEA, but the effects of an operational mishap are often indicated by the process or equipment failure mode. And as such this method is not efficient for systems where complex logic exists in the equipment.

2.6.1.4 FMECA

The Failure modes, effects, and criticality analysis (FMECA) also uses the same methodology as FMEA described above, but it goes further in the determination of the severity of the effect, and also the evaluation of the frequency of the effect caused by the failure.

The severity of the failure is generally classified as being in the range of complete loss of capability with loss of life, to negligible effect on success with no injuries; while for the evaluation, the previous data for similar processes is examined (HSE 2005).

2.6.1.5 CHAZOP

The increased use of computers within safety systems allows significant hazards to occur due to their mal-operation since many of their operations share the use of the same component.

Computer hazard and operability study (CHAZOP) is based on the methodology used in HAZOP and is applicable to computers. It is used to identify potential flaws and weaknesses of computer and instrument control systems by reviewing how the system deviates from design intents. It goes through the programmable electronic systems building up a detailed view of how the system is intended to work, and what will happen if they fail.

2.6.1.6 AEA

When complex tasks are split until they become individual tasks according to hierarchy, in terms of its goals, operations and plans, a tree structure is thus produced, with the most complex task on top and the simplest on the bottom. Each step of the task is then analyzed to identify all the errors which the human operators can commit, and their effects on the process can be evaluated.

Action error analysis (AEA) can easily identify hazards produced by single actions, though for large processes it is impracticable to attempt to identify hazards occurring from more than one wrong action (HSE 2005).

2.6.1.7 HRA

Human reliability analysis (HRA) is used to quantify the human errors. According to the HSE, 2005, this analysis is performed by assessing a number of stages which includes:

I. Definition of the system failures of interest,
II. Listing and analysis of the related human operations,
III. Estimation of the relevant error probabilities,
IV. Estimation of the effects of human errors on the system failure rate, and
V. Recommendation of changes to the system and the recalculation of the system failure probabilities.

This method according to the HSE allows complex task to be analyzed and assessed in detail and can produce an overall probability of human error while the task is being performed; but besides being time consuming, the method is specifically tailored to assess human errors in performing tasks, and cannot be easily applied to other areas of the process.

2.6.1.8 PHEA

The predictive human error (PHEA) analysis method splits complex tasks until they become individual tasks according to hierarchy, and then systematically analyze them for:

I. Task type,
II. Error type,
III. Task description,
IV. Consequences,
V. Recovery, and
VI. Error reduction strategy.

Though this method has similar limitation as the HRA, but it assesses the consequences of the hazards as well as the human errors if they occur within the process.

A summary of the suitability of different hazard identification methods to phases of projects as given by the HSE is as shown in Table 3.2.

Table 2.2: Suitability of Hazards Identification methods to phases of project.

	Concept	Process	Design	Commissio-ning	Operation	Modifica-tion	Decommi-ssioning
HAZOP	X	X	Y	Y	Y	Y	Y
What if	O	O	Y	Y	Y	Y	Y
CHA	Y	Y	O	X	X	X	X
PHA	Y	Y	O	X	X	X	O
FTA	O	O	Y	Y	Y	Y	Y
CCA	O	O	O	Y	Y	Y	Y
Pre-HAZOP	Y	Y	O	X	X	X	X

Standards	Y	O	O	O	O	O	O
FIHI	X	O	Y	Y	Y	Y	Y
Checklists	O	O	Y	Y	Y	Y	Y
CEX	X	X	Y	Y	Y	Y	Y
MOSAR	X	X	O	Y	Y	Y	Y
GOFA	X	X	O	Y	Y	Y	Y
Matrices	O	Y	Y	O	O	O	O
Inherent	O	Y	Y	O	O	O	O
Safety Audit	Y	Y	Y	Y	Y	Y	Y
FMEA	X	X	Y	Y	Y	Y	Y
Func. FMEA	X	X	Y	Y	Y	Y	Y
FMECA	X	X	Y	Y	Y	Y	Y
Mop	X	X	Y	Y	Y	Y	Y
Maintenance	X	X	Y	Y	Y	Y	Y
Sneak Analysis	X	X	Y	Y	Y	Y	Y
Block diagram	X	X	Y	O	O	O	O
Structural	X	X	Y	O	O	O	O
Vulnerability	X	X	Y	O	O	O	O
DEFI	X	X	Y	O	O	O	O
CHAZOP	X	X	Y	Y	Y	Y	Y
Struc. English	X	Y	O	X	X	X	X
Spec. English	X	Y	O	X	X	X	X
SADT	X	Y	O	X	X	X	X
State-transition	X	Y	O	X	X	X	X
Petri-nets	X	Y	O	X	X	X	X
GRAFCET	X	Y	O	X	X	X	X
Task analysis	X	X	Y	Y	Y	Y	Y
HTA	X	X	Y	Y	Y	Y	Y

AEA	X	X	Y	Y	Y	Y	Y
HRA	X	X	Y	Y	Y	Y	Y
Pattern search	X	X	Y	Y	Y	Y	Y
PHEA	X	X	Y	Y	Y	Y	Y
Safety review	Y	O	X	X	X	X	X
Y = most suitable;			O = suitable;		X = not suitable		

2.7 ESSENTIALS OF HUMAN ERROR

Human error and human factors are often used by people interchangeably which sometimes create confusion. As described earlier, human factors has to do with environmental, organizational, job, task attributes and system design, as well as human characteristics that influence behavior and affect health and safety.

But when due to or lack of a human action, there is failure in performing a specified task or a forbidden task is performed either intentionally or unintentionally, which could have negative impact on people, plant, process or property, it is termed human error (B.S. Dhillon & Y. Liu, 2006). In essence, human error consideration is embedded in human factor analysis.

The fallibility of humans makes human error an inevitable part of all human endeavors, and it may occur in the whole range of stages involved in the chemical industry and even in all organizations (David W. Gillingham *et al)*. Thus, the managerial challenge is to manage human error.

2.7.1 Human Error categorized

2.7.1.1 Active Errors

These are errors made by individuals on the frontline like operators. Rasmussen, J. 1990, classified these errors into **three performance levels** which are:

- Skill based,
- Rule based, and
- Knowledge based.

At the **skill based level**, tasks are carried out routinely based on one's skills and regular practice, and people are often very good at this. At the **rule based level**, stored rules are applied in most of the situations. There are pre-packed solutions which are to be able applied for most of the problems. The responsible persons are usually trained for this. At the **knowledge based level**, trial and error in arriving at solutions usually take place. And this occurs when a person has repeatedly failed in finding a solution using known methods. Good solutions are sometimes produced, but there is also the fear element of getting things wrong.

Active errors are further classified by Rasmussen as:

I. **Unintentional Errors:**

- **Slips/lapses** are actions that were not as planned and they occur in familiar tasks which people carry out without too much need for conscious attention. For example, forgetting to open or close a valve, or opening or closing the wrong valve or doing it at the wrong time. These errors are skill-based.

- **Mistakes** are errors of judgment or decision-making. In this case, a person does the wrong thing believing it to be right. Sometimes mistakes could also be intentional. These errors are both rule-based and knowledge-based.

- **Mismatches** occur when people are asked to carry out tasks which are difficult or impossible for anyone, physically or, more often mentally. They could be overloaded with tasks or asked to go against established habits. The human errors which occur here can be skill-based, rule-based or knowledge-based.

II. **Intentional Errors:**

- **Violations** differ from the above in that they are intentional errors, although they may be well-meaning. For example, taking a shortcut, non-compliance with procedures termed unnecessary or deliberate deviations from the rules or procedures, and they usually result from an intention to get the task done despite the consequence.

Violations may be a **routine type** in which breaking the rules has become the person's normal way of working within the group; **exceptional type** which occurs often when things go wrong unexpectedly. The person breaks the rule even though he is aware of taking a risk but with the mindset that the benefits outweigh the risks; **situational type** in which the rules are broken due to factors dictated by the worker's immediate work space or environment, or working under pressure due to time, workload, unavailability of the right equipment or extreme weather conditions; **sabotage** which ranges from outright vandalism by a de-motivated employee to terrorism.

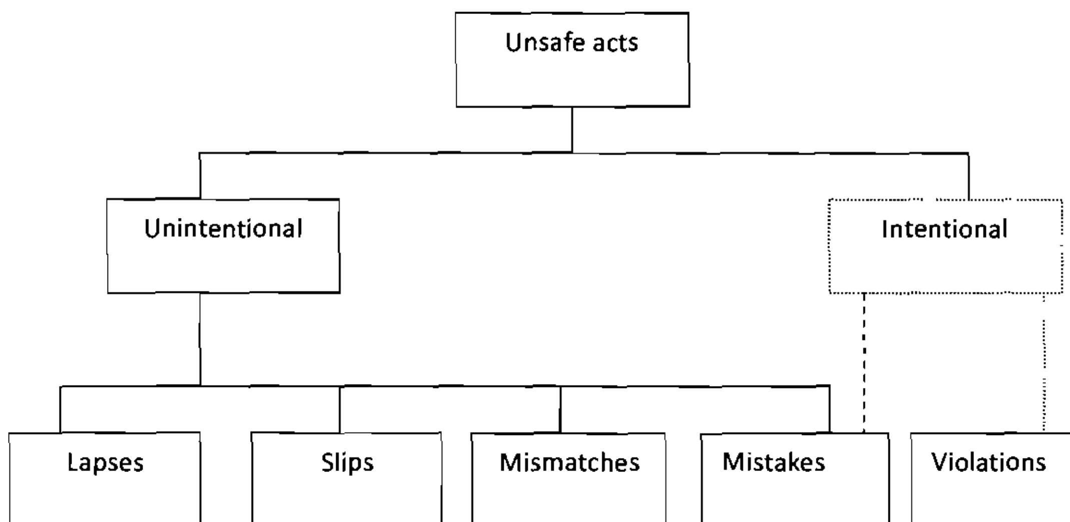

Figure 2.2: Types of human Error

The likelihood of these human errors is determined by the condition of some factors which influences the performance of a worker, such as distraction, time pressure, workload, competence, morale, noise levels and communication systems. Given that these factors influencing human performance can be identified, assessed and managed, potential human errors can also be predicted and managed (HSE, 2005).

2.7.1.2 Latent Errors

These are human errors which are as a result of the work environment and this includes those who are not in the frontline or in the direct control interface e.g. initial planners, designers, managers

and high level decision makers. Latent errors are sometimes overlooked, but they can lie dormant within the system for a long time waiting for the trigger of frontline operator error to set an incident or accident in motion (Hayim Granot, 1998).

By understanding the environmental factors more likely to induce an erroneous activity, and also taking into account the influences such erroneous activity can have on people, it should be easier to establish ways of reducing the problem.

2.8 HUMAN FACTORS VIEW OF ACCIDENT CAUSATION

Accident or incident is seen as that occurrence in a negative sequence of events that produces unintended injury, death or property damage (HSE, 2002).

Accidents are actually caused by *active failures* or *latent conditions* or the combination of both, which can lead to human error or violations. These two situations have been explained in section 2.7. From this, it will be seen that what might appear like a simple active failure is often actually a result of latent conditions. So simply blaming the individual will not help prevent future occurrences where the latent conditions still apply.

Very often in the chemical industry, it is the operator or the supervisor that are blamed for incidents, perhaps for failing to follow the rules. Managers fail to see that they also make incidents to happen when they ignore a rule in order to maintain output. Often the rules they break are not written down but are merely "accepted good practice" which becomes a latent condition.

According to Kletz, T.A., 2001, the operator is the last line of defense against poor management, poor design, faulty maintenance, poor facility/equipment and an unsafe work environment. So it is poor strategy to rely on the last line of defense. Contributing to this, Reason, 1990, expressed that the part of the operator is usually that of adding the final garnish to a lethal brew whose ingredients have already been long in the cooking.

It can also be shown from Reason's Swiss Cheese Accident Model shown below that for an accident or incident to occur; there must be a conjunction of oversights and error across all the different levels within organization. The model also shows that the chances of an incident occurring can be made smaller by narrowing the windows or incident opportunity at each stage of the process.

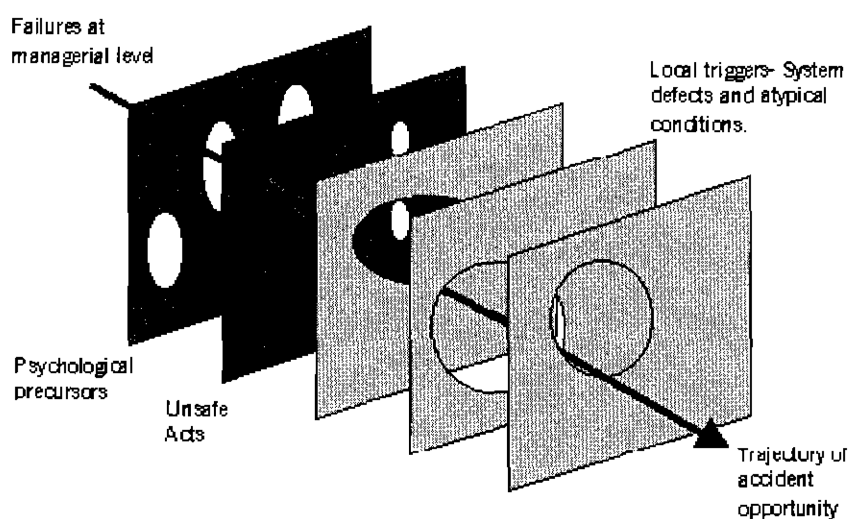

Figure 2.3: Reason, J., Swiss cheese model of accident causation (2000).

According to Reason, the Swiss cheese model shows a trajectory or trail of accident opportunity and its penetration through several types of defensive system.

The combined chances of an accident occurring are very small, as the holes in the various defense systems must all line up. Some are active failures of human or mechanical performance, and others are latent conditions, such as management factors or poor system design. However, it is clear that if steps are taken in each case to reduce the defensive gaps, the overall chance of accident or incident will be greatly reduced.

2.9 HUMAN FACTORS AND MAJOR INCIDENTS IN THE CHEMICAL INDUSTRY

A "major incident" means an occurrence of catastrophic proportions, resulting from the use of plant or machinery, or from activities at a workplace (OHSA, 1993).There is quite some number of

incidences where human errors have led to major incidents or accidents in the chemical industry and these have resulted in injuries, loss of lives and damage to properties. The following cases will show how the failure of people at many levels within an organization caused or contributed to the accidents. Not just the operator on the frontline alone, but management, designers, and high level decision makers all led to the final outcome.

Table 2.3: Some illustrative major incidents and the associated human factor elements
(Julie Bell & Nicola Healy, 2006, HSE 2005).

Incident	Date	Consequences	Human factor contribution and other causes
Union Carbide Bhopal, India *Chemical processing*	December 4, 1984	The plant released a cloud of toxic methyl isocynate. Death toll was approximately 3800 and over one quarter of the city's population was affected by the gas.	The leak was caused by a discharge of water into a storage tank. This was the result of a combination of operator error, poor maintenance, failed safety systems and poor safety management
Piper Alpha, North Sea *Offshore*	July 6, 1988	167 workers died after a major explosion and fire on an offshore platform.	Formal inquiry found a number of technical and organizational failures. Maintenance error that eventually led to the leak was the result of inexperience, poor maintenance procedures and poor learning by the organization. There was a breakdown in communications and the permit-to-work system at shift changeover and safety procedures were not practiced sufficiently.

Texaco Refinery, Milford Haven *Chemical processing*	July 24, 1994	An explosion on the site was followed by a major hydrocarbon fire and a number of secondary fires. There was severe damage to process plant, buildings and storage tanks. 26 people sustained injuries, none serious.	The incident was caused by flammable hydrocarbon liquid being continuously pumped into a process vessel that had its outlet closed. This was the result of a combination of: an erroneous control system reading of a valve state, modification which had not been fully assessed, failure to provide operators with the necessary process overviews and attempts to keep the unit running when it should have been shut down.
BP, Grangemouth *Petroleum refining*	June 10, 2000	Three incidents occurred within a two-week period: power distribution failure, steam main rupture and fire on catalytic cracker unit. Serious process interruption but no serious injuries. All incidents had the potential to cause major accidents.	The key findings of the Human Factors team explained why, notwithstanding the high standards set by BP; those standards were not always implemented and met consistently over each part of the Complex. The consequences of a non-unified management structure and differences resulting from the three historical business streams operating at the Complex, in large part provided a compelling explanation of the incidents which occurred. There was also a lack of monitoring of major hazard performance at the Complex.
Flixborough Nypro (UK)	June 1, 1974	A large explosion occurred and 28 workers were killed and further 36 suffered injuries.	A plant modification occurred without a full assessment of the potential consequences. Only limited calculations were undertaken on the integrity of the bypass line. No calculations were undertaken for the dog-legged shaped line or for the bellows. No drawing of the proposed modification was produced.

Table 2.3 illustrates that humans are prone to making errors. However, examination of all the facts in the above incidents suggests that several parts which make up the human factors, such as poor design, poor maintenance, equipment failures, organizational failures and human fallibility, usually combine in different proportions to produce the end result.

But going further, it is very important that human factors issues and human error occurrences be managed considering the value of life and property that is involved when such incidents occur in a high-hazard industry like the chemical industry.

2.10 CURRENT REGULATORY FRAMEWORK ON SAFETY AND HUMAN FACTORS IN THE CHEMICAL INDUSTRY

The **Health and Safety Commission/Executive** are UK regulatory bodies responsible for ensuring that risks encountered in the workplace are properly controlled. These regulatory bodies apply to work places in Great Britain and other countries where health and safety practices are adopted. It helps other industries discover specific legislation that applies to their industry and also provide links to organizations that can offer advice and guidance on legislation.

The Parliamentary Office of Science and Technology Postnote of June 2001 explains that the Health and Safety Commission (HSC) ensures that the health, safety and welfare of persons at work are secured, and that the environment including other humans are also protected against risks arising out of work activities. It also oversees the work of the Health and Safety Executive (HSE) which includes inspection of workplaces, investigation of accidents and ill health, enforcement of good standards, publication of guidance etc. Laws and regulations administered by the HSE include:

The Health and Safety at Work Act 1974: according to the Postnote, this is the foundation stone of British health and safety law. That it sets out general duties which employers have towards employees and members of the public, and also duties which employees have to themselves and

to each other. The principle of "*so far as reasonably practicable*" is used in the Act to qualify duties of employers and employees at the workplace that the degree of risk in carrying out a task needs to be measured against the time, trouble, cost and physical difficulty involved in taking measures to avoid or mitigate it.

Management of Health and Safety at Work Regulations 1992 (MHSWR) explains more clearly what employers are required to do to manage health and safety under the Act. They require employers to conduct a risk assessment and adapt company safety policy accordingly.

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR) explains that employers are to work-related accidents, diseases and dangerous occurrences. These will include deaths, major injuries, or any other injury that leaves the employee off work for three days or more, any work-related disease and any dangerous near miss.

Occupational Health and Safety Amendment Act 181 of 1993, Labor Relations Act 66 of 1995 also provides for the health and safety of persons at work and for the health and safety of persons in connection with the use of plant and machinery; the protection of persons other than persons at work against hazards to health and safety arising out of or in connection with the activities of persons at work; to establish an advisory council for occupational health and safety; and to provide for matters connected therewith.

Control of Major Accident Hazards Regulations 1999 (COMAH) applies mainly to the chemical industry. The regulation according to Linda J. Bellamy *et all*, 2006, requires that companies have all measures necessary to control the risks and inspectors are required to take a risk based approach to inspection. More specific human factors guidance can be got from Inspectors Toolkit (Health and Safety Executive 2005) and the COMAH Safety Report Assessment Manual (SRAM) criteria used in COMAH safety report assessment (Health and Safety Executive, 2006).

South African Regulations affecting the Chemical Industry: In South Africa, key legislations which apply to the chemical industry are the following:

- Explosives Act of 1956
- Hazardous Substances Act No. 15 of 1973
- Hazardous Chemical Substances Regulations (1995) of the occupational Health and Safety Act No 85 of 1993
- Mine Health and Safety Act 29 of 1996.

Regulations pertaining to the chemical industry can be divided into three areas:

I. **Safety in the work place**

In the work place, occupational health and safety act is exercised to protect workers exposed to or who work directly with chemicals. Regulations that are applied are: Regulations on hazardous substances, regulations on emergency response and regulations on specific substances like lead and asbestos.

II. **Consumer protection**

For the protection of consumers, the foodstuffs, cosmetics and disinfectant act is employed. The hazardous substances act regulates the labeling and advertisement of foodstuffs and it regulates the use of certain chemicals in food and cosmetics.

III. **Environmental protection**

Environmental protection is regulated by the environmental conservation act of 1989. The act regulates waste disposal and management, air quality management, water pollution prevention and conservation, as well as environmental impact assessment in South Africa.

Good regulatory frameworks (OHS Act, legislative instruments, guidance) are already in place with the aim of eliminating risks to health and safety so far as reasonably practicable, and then preventing incidences or accidents occurrences in the chemical industry. But unfortunately, incidences which range from minor to major still occur with a large percentage due to human errors or failures! The aim of this research is to investigate the human involvement in incidents occurrences and then provide best industry practices and approaches to managing human factor issues in the chemical industry.

CHAPTER THREE

3.0 EMPIRICAL INVESTIGATION

In chapter one, the objectives of this dissertation was presented; which is to discover the role human factors play in chemical industry incidents, and then to develop measures to further manage the human involvement since humans are inherently fallible and errors are inevitable. The overall aim is to improve on safety and also move towards zero incidents in a high hazard industry like the chemical industry.

In chapter two, relevant books, journals, articles and ideas of different authors about human factor issues as well as human error influences on incidents/accidents occurrences in the chemical industry were reviewed and presented.

This chapter focuses on experimental investigation of human factors integration and management in the chemical industry with Sasol Wax as the case study. This, as explained in chapter one will be done by:

I. Reviewing the incidents which have occurred at Sasol Wax over a particular period.

II. Collecting and analyzing data via questionnaires and interviews at Sasol Wax.

3.1 Overview of Incidents at Sasol Wax and the associated Human Factor elements

As a result of the recent migration to a new system administration protocol (SAP system), the researcher was only able to obtain Sasol Wax incidents recorded between July 2007 and Feb 2008, from the SH&E department of Sasol Wax. The incidents which occurred at Sasol Wax during this period that imparted negatively on the workers, with the human factor contribution to their occurrence, are illustrated in *table 3.1*.

	Incident description	**Date**	**Consequence**	**Human factor contribution**
1	While two employees were moving mobile scaffold next to parked Isotainer, a set of wheels came off causing the scaffold to topple over on top of Ronal	26/10/2007	One of the employees sustained bruising on his legs and left shoulder	This was as a result of poor maintenance.
2	While maintenance technician was carrying out an inspection on the slabbing room sump strainers he slid the sump cover open to view the strainers. He then stepped onto the cover which tilted downwards and his right leg slipped off into the sump and the cover then fell back into place against his leg.	1/11/2007	Contact on the cover of the sump with right leg resulted in contusion injury to the shin of the leg. Fall from elevation resulted in right hand wrist being twisted/sprained.	This was a result of not following safe work practice procedures.
3	While service providers were removing asbestos sheets from the warehouse roof one of the sheets slipped from the hands of the person on top of the roof and landed on the person on the ground.	14/11/2007	Laceration to left leg just below the knee.	This was a result of not following safe work practice procedures and not having eyes on task.
4	A Process Controller was busy cleaning the spray drum when his hand was caught between the scrapers and the drum	22/11/2007	Serious injury was sustained to his right hand with a likely amputation of ring and middle finger tips	This was the result of not following the right procedure, and poor job safety analysis
5	A scaffolding builder was leaning over a hot wax line to tighten an H-clamp on a scaffold.	5/12/2007	He sustained second degree burn wounds to his chest (R)	This was a combination of poor job safety analysis and poor ergonomics by management.
6	While the maintenance artisan was re-installing a flow meter that was removed for rechecking, a wax plug was ejected and he was struck with hot wax in the face and neck	5/12/2007	1st degree burn wounds to his face and neck and second degree burns to his eyelids nose	This was a result of the combination of poor job safety analysis and poor reliability of process equipment due to poor maintenance.
7	Person was busy filling the measuring vessel with liquid wax. When the wax overflowed into the container below the overflow line, it splashed upwards.	2/1/2008	Burn wounds on persons Neck and Face	This was a combination of unsafe working condition, poor job safety analysis and poor reliability of process equipment.
8	Person hit small finger on left hand with hammer while loosing bolts on bottom dome sieve heads.	15/1/2008	Person was taken to medical station for treatment	The person did not have eyes on task. Not following procedures.
9	A truck driver was busy covering a load with canvas over the top of the trailer and then he slipped and fell.	24/1/2008	Potential fatality, soft tissue in injury in his leg.	The driver wore a wet canvass which made him slip and fall to the ground. This was an unsafe act.
10	An employee was walking to get his timesheet from another employee. He walked headlong into a closed glass door.	1/2/2008	Upon hitting the glass door, he sustained a small cut on his upper lip.	He thought the right side of the closed glass door was opened and walked into it. This was a result of poor design by management and the employee not having eyes on path.

Table 3.1: Sasol Wax Incidents resulting in Occupational Injuries with the associated human factor contribution.

As illustrated in *Table 3.1*, human factors played a significant role in all of the incidents investigated. The researcher identified a series of common contributory factors preceding the incidents, both from the perspective of the management and the injured person. These included:

- Poor perception of risks by workers.
- Complacency on the part of staff in working safe and according to procedures.
- Complacency on the part of management in putting adequate measures in place to ensure a safe work environment.
- Lack of ownership of safety responsibilities.
- Lack of comprehensive maintenance tasks.
- Lack of staff supervision.
- Inadequate job safety analysis.
- Poor communication between staff.

If these critical issues had been identified and effectively controlled prior to the incidents, it is likely that the momentum of events leading to the incidents would have been neutralized, thus preventing the occurrence of the incidents.

3.2 Data Gathering and Collection on Human Factors at Sasol Wax

The methods of empirical investigation used for this research includes the following data sources:

I. Questionnaires (as compiled by the author of this research)
II. Personal interviews and discussions

3.2.1 Questionnaires1&2

The Questionnaire (Questionnaire1) on human factors and its influence on incidents causation were designed in order to understand the views of different categories of employees working at Sasol Wax about the human factors subject.

Their views are essential so as to have an overview of the knowledge base and practice of human factors management, which can also be comparable to similar chemical business units in the Sasol organization. This will also help to compare what is obtainable and practicable in a real situation in this part of the world with theory.

A complimentary Questionnaire (Questionnaire2) was designed as well. It addresses top human factors issues in the chemical industry as identified by the Health Safety and Executive, UK, from various researches, intermediaries, consultations and inspections it made. This Questionnaire will be used to benchmark Sasol Wax human factors management with other business units within the Sasol organization, as well as the international standard in this field of study.

After the survey, the views would be merged together and analyzed in the next two chapters. The sample population for this survey using the first Questionnaire includes production operators, maintenance personnel, planners, safety officers, engineers and managers.

The complimentary Questionnaire (Questionnaire2), in addition to the above sample population, includes research and development personnel in the Sasol organization, since the benchmarking process will span over different business units within the Sasol organization. In the cause of this research, the target population for the Questionnaires would be referred to as *research community*.

Questionnaire1 consists of five different parts namely:

- PART 1: RESPONDENT'S INFORMATION
- PART 2: HUMAN FACTORS BACKGROUND
- PART 3: WORKING CONDITIONS, HEALTH AND WELL BEING
- PART 4: HUMAN FACTORS CATEGORIES
- PART 5: HUMAN FACTORS ELEMENTS

Each part of Questionnaire1 has sub-questions, some of which are also illustrated in tables. Questionnaire1 would require on average, about sixty minutes completing.

Questionnaire2 addresses the top ten human factors issues of the chemical industry which have been identified internationally. The top ten factors are *Organizational change, Staffing arrangements and workload, Training and competence, Fatigue from shift work and overtime, Ergonomic designs, Work and Safety critical procedures, Safety culture, Communications and interfaces, Integration of human factors into risk assessment and investigations, and Maintenance error* (HSE, 2002).

The complimentary Questionnaire thus seeks to evaluate how the above key factors assessed or managed in Sasol Wax and other business units. The sub-questions for this Questionnaire were developed inline with the above key factors.

3.2.2 Design of the Questionnaires

In the design of the Questionnaires, existing and available Questionnaires from the scientific databases were sought. However, some of the Questionnaires published in open literature do not sufficiently cover the information intended to cover the scope of this research.

The format of the Questionnaires and the questions were done in a way as to present an understanding of human factors, assess the general well being of the respondents, and present the human factors categories and elements and also solutions to managing human factors in the chemical industry with reference to Sasol Wax.

The following suggestions by Kari L. Davis, 2001, were used during the development of the Questionnaires for this research:

- The Questionnaire should be spread out,
- By putting more than one question on a line will cause some respondents to miss the second question altogether,
- The Questionnaire should contain brief introduction and clear instructions where applicable,
- Ambiguous words or statements that could confuse respondents should be avoided,

- Avoiding bias questions which have a tendency of encouraging the respondents to support a particular point of view. (pp. 78-79).

The Questionnaires for this research begin with a clear title which shows the main subject of the survey, a brief introduction of the subject, the aim of the survey, and a clear instruction on how to fill the Questionnaires.

In Part 1 of Questionnaire1, the respondents are required to tick the box which gives brief information about their gender, age, employment type and work area.

Part 2 has three options of 'yes', 'no' or 'to some extent' in which the respondent is required to tick the option that best describes his or her background knowledge of human factors.

Part 3 has five options of 'to a very large extent', 'to a large extent', 'somewhat', 'to a small extent', or 'to a very small extent', in which the respondent is required to tick the option which best, describes his or her well being in the organization.

In Part 4 and 5, the Likert Scale was used. The respondents are required to rate the human factors categories and elements with variables such as 'least important', 'important', 'moderately important', 'highly important', or 'extremely important'.

In the computation of responses for parts 4 and 5,

- 1 would represent the *'least important'* variable,
- 2 would represent the *'important'* variable,
- 3 would represent the *'moderately important'* variable,
- 4 would represent the *'highly important'* variable, and
- 5 would represent the *'extremely important'* variable.

According to Kari L. Davis, 2001, the Likert Scale format is valuable because it is unambiguous and the researcher can easily judge the relative strength of the respondents.

The performance factors and measurement from the Human Factors Assessment Validation study by the HSE, 2004, has been adapted to develop the parameters for Questionnaire2, and the questions are intended to determine how human factors issues are assessed and managed in the sampled business units.

Questionnaire2 comprises majority of 'yes' or 'No' answer options with a total of eighteen questions which would require on average, about twenty five minutes completing.

Space was also provided at the end of Questionnaires1&2 for respondent's comments about the subject of the survey and also the structure of the Questionnaire.

3.2.3 Objectives of the Questionnaires

The Questionnaires were aimed at the following:

- To know the diverse views of the research community about human factors in relation to the chemical industry.
- To discover the human factors involvement in incident/accident causations in the chemical industry with Sasol Wax as a case study.
- To discover other like sources and causes of human error.
- To determine how the core or top human factors issues are assessed and managed, as a basis for benchmarking.
- Finding the best practices that will further improve organizational safety performance through human factors consideration and management.

3.2.4 Pre-test and validation of the Questionnaires

After the development of the Questionnaires, they were first sent to the research supervisor, Professor Harry Wichers for his comments and reviews. He made some grammatical corrections to it and then recommended that few copies be made and given to some selected people within and outside Sasol Wax in a way of pre-testing and validating the Questionnaires.

This approach afforded the researcher the opportunity to obtain further inputs and ideas about the survey, and then to add such inputs to the Questionnaires before printing more copies to cover the research community.

The researcher delivered Questionnaire1 to the following respondents at Sasol Wax business unit:

I. A senior safety officer,
II. An instrumentation & control section manager,
III. A mechanical section/shutdown coordinator,
IV. A production operator,
V. A maintenance planner, and
VI. Sasol Wax operations manager.

Questionnaire2 was also delivered to the same respondents of Questionnaire1 and to other business units as:

I. Sasol Technology,
II. Sasol solvent,
III. Environmental and risk engineering, and
IV. Sasol Infrachem business units.

The testing process revealed unanticipated problems with question wording and answer options, which were appropriately corrected in the final copies to be given out to the larger research community.

Nevertheless, the pre-test respondents expressed good understanding of the context in which the questions were written, and that the Questionnaires sufficiently addresses the major issues in their business units.

Additional feedback from the above respondents about the Questionnaires was a lot positive. One of the respondents said the Questionnaires and its subject are "simple and sensible", another commented "well done" for the Questionnaires' development and its aim, another said it is a good

research area which will contribute to the safety initiatives of the Sasol organization, and the others simply said it was "good".

Nothing was cloudy about the subject presented in the Questionnaires, and there were no further inputs from the respondents after corrections arising from the pre-test process had been made to the Questionnaires. The Questionnaires1&2 are shown in Appendices A and B respectively.

From the feedback it became evident that the Questionnaires covered broadly the research subject and will achieve its research aims and objectives.

More so, the factors under consideration in the Questionnaires have been validated from many researches, consultations, intermediaries and inspections made by the Health, Safety and Executive http://www.hse.gov.uk/humanfactors/index.htm. A go-ahead was then given by the research supervisor to distribute more copies to cover the intended research community.

3.2.5 Selection of Sample Size

Ideally, a whole population of a research community should have a say in a survey that affects its organization since a survey that includes all workers will always provide a more precise picture. But this is only achievable if all workers are office-based staffs and have the same schedule, and can all be reached by a common means.

For this research, the researcher conducted the survey randomly among the research community in which the paper questionnaires were delivered by hand (manually) to every respondent. Limited number of Sasol workers had internet access and as such email surveys could not be used to complement the paper surveys.

Nevertheless, the random sampling method used by the researcher provides a statistically valid way to gather data (HSE User Manual, 2002). According to the HSE, It allows you to take results from the sample and make use of them as best estimate of what represents the views of the whole

workforce. Although the larger the sample, the more precisely it would reflect the target population; however, the rate of improvement in the precision also decreases as the sample size increases (http:www.surveysystem.com/sdesign.htm). In addition, numerous duplication of responses also set in when using a larger sample size (HSE User Manual, 2002).

The following sample size was thus considered adequate by the researcher:

- **Questionnaire1** = 75
- **Questionnaire2** (complimentary Questionnaire)
  - Sasol Wax = 28
  - Sasol Technology = 27
  - Sasol Solvent = 21
  - Sasol Infrachem = 25

3.2.6 Personal Interviews and Discussions

The questions for the personal interviews were extracts from the Questionnaires drawn from all parts. The discussions were also centered on the focus of the research. These afforded the research community to air their own views about incident happenings, human factor issues as well as some other safety-related factors applicable to a high hazard industry like the chemical industry. The interviewees' views as well as the outcome of discussions held were also analyzed together with the results and findings from the Questionnaires.

The research community for the interviews and for completing the Questionnaires were the same since some respondents preferred discussing the research issue rather than creating time to fill out the questionnaires due to a busy schedule, while some other respondents have difficulty in reading/writing but could express themselves verbally. But an individual was not interviewed personally if he or she has been given a Questionnaire. The aim of conducting personal interviews was to complement the objectives of the Questionnaires.

CHAPTER FOUR

4.0 QUESTIONNAIRE FINDINGS, ANALYSIS AND DISCUSSION

4.1 Data Analysis

Questionnaire1

The number of employees at Sasol Wax, Sasolburg as at June 2008 when this survey was carried out stands at 382 (Marinder Beyer -Sasol Wax HR, 2008).

Sasol Wax Sasolburg is a wax production work-environment, and as such production plants are in continuous operation. Production workers basically work on shift basis, while all the other workers are day workers with some selected people from maintenance group staying on "standby" to attend to any high priority maintenance problem that occur "after hours".

The surveys were tracked as they were received from individuals. The anticipated amount of feedback from the *research community* using Questionnaire1 was thus put at 10%. But out of over 70 Questionnaires sent out for the survey, 65 usable Questionnaire1 responses were received which indicates: (65÷382) x 100% ≈ 17% feedback.

4.2 Presentation of findings

From Sasol Wax Sasolburg employees' database, about 80% are made up of both production and maintenance personnel, with the remaining 20% as human resources/administrative employees and SHE representatives.

For easy analysis of the findings, the author has divided the Sasol Wax Sasolburg employees into four broad categories which are:

I. **Production personnel:** comprising of the production operators, production engineers, production planners and production managers.
II. **Human resources personnel:** comprising of the financial, administrative and logistic personnel

III. **Maintenance personnel:** comprising of the instrumentation, electrical and mechanical artisans, technicians, engineers, planners and managers.

IV. **Safety personnel:** comprising of the SHE representatives, managers and specialists.

4.2.1 Breakdown of Questionnaire1 Responses

The responses received by each of the four categories mentioned above with respect to the total of 65 responses received from the Questionnaire1 are: Production Personnel (43%), Maintenance Personnel (36%), Safety Personnel (12%) and Human Resources (9%). *The results obtained from Questionnaire1, with the researcher's particular interest in the questions that cover the Questionnaire aim, are the ones presented in tables 4.0 to 4.11.* The measure of importance given to each human factor major category and elements by all the respondents and the author are presented in *table 4.12*.

Production Personnel

Table 4.0: Respondents background view about Human Factors

Questions	*Yes (%)*	*No (%)*	*To some extent (%)*	*Total (%)*
Do you understand the subject of human factors and how it contributes to incidents in the chemical industry?	*93*	*0*	*7*	*100*
Do you know that more than 90% of incidents in the chemical industry are caused by human failure either directly or indirectly?	*93*	*3.5*	*3.5*	*100*
Do you think much consideration is given to human factors issues in the organization where you work now?	*36*	*28*	*36*	*100*
Do you have a Human Factors Engineer (HFE) or Human Factors Specialist in the department or section where you are currently working?	*0*	*100*	*-*	*100*

Table 4.1: Respondents wellbeing at work

Questions	Very Satisfied (%)	Satisfied (%)	Unsatisfied (%)	Not relevant (%)	Total (%)
Are you satisfied with your work prospects in your current organization?	14	54	28	4	100
Are you satisfied with the physical working conditions of your current organization?	7	50	43	0	100
Are you satisfied with your normal net salary (take home pay)?	0	14	75	11	100

Table 4.2: Respondents rating of Human Factors Major Categories and elements

Categories	Least Important (%)	Important (%)	Moderately Important (%)	Highly Important (%)	Extremely Important (%)	Total (%)
Culture/Working Environment	11	21	28.5	28.5	11	100
Organization/Management Systems	3.5	36	18	14	28.5	100
People Characteristics	0	21	36	32	11	100
Facilities/Equipment	3.5	21.5	32	21.5	21.5	100

Human Resources Personnel

Table 4.3: Respondents background view about Human Factors

Questions	*Yes (%)*	*No (%)*	*To some extent (%)*	*Total (%)*
Do you understand the subject of human factors and how it contributes to incidents in the chemical industry?	*83*	*0*	*17*	*100*
Do you know that more than 90% of incidents in the chemical industry are caused by human failure either directly or indirectly?	*83*	*0*	*17*	*100*
Do you think much consideration is given to human factors issues in the organization where you work now?	*17*	*17*	*66*	*100*
Do you have a Human Factors Engineer (HFE) or Human Factors Specialist in the department or section where you are currently working?	*0*	*100*	*-*	*100*

Table 4.4: Respondents wellbeing at work

Questions	Very Satisfied (%)	Satisfied (%)	Unsatisfied (%)	Not relevant (%)	Total (%)
Are you pleased with your work prospects in your current organization?	0	83	17	0	100
Are you pleased with the physical working conditions of your current organization?	0	83	17	0	100
Are you pleased with your usual take home pay?	0	50	50	0	100

Table 4.5: Respondents rating of Human Factors Major Categories and elements

Categories	*Least Important (%)*	*Important (%)*	*Moderately Important (%)*	*Highly Important (%)*	*Extremely Important (%)*	*Total (%)*
Culture/Working Environment	*0*	*0*	*17*	*33*	*50*	*100*
Organization/Management Systems	*0*	*50*	*17*	*33*	*0*	*100*
People Characteristics	*0*	*17*	*0*	*50*	*33*	*100*
Facilities/Equipment	*17*	*0*	*0*	*0*	*83*	*100*

Maintenance Personnel

Table 4.6: Respondents background view about Human Factors

Questions	Yes (%)	No (%)	To some extent (%)	Total (%)
Do you understand the subject of human factors and how it contributes to incidents in the chemical industry?	87	0	13	100
Do you know that more than 90% of incidents in the chemical industry are caused by human failure either directly or indirectly?	96	0	4	100
Do you think much consideration is given to human factors issues in the organization where you work now?	39	22	39	100
Do you have a Human Factors Engineer (HFE) or Human Factors Specialist in the department or section where you are currently working?	0	100	-	100

Table 4.7: Respondents wellbeing at work

Questions	Very Satisfied (%)	Satisfied (%)	Unsatisfied (%)	Not relevant (%)	Total (%)
Are you pleased with your work prospects in your current organization?	9	74	17	0	100
Are you pleased with the physical working conditions of your current organization?	9	78	9	4	100
Are you pleased with your usual take home pay?	0	56.5	43.5	0	100

Table 4.8: Respondents rating of Human Factors Major Categories and elements

Categories	Least Important (%)	Important (%)	Moderately Important (%)	Highly Important (%)	Extremely Important (%)	Total (%)
Culture/Working Environment	0	17	22	39	22	100
Organization/Management Systems	0	26	17	26	31	100
People Characteristics	4	9	43	35	9	100
Facilities/Equipment	0	22	13	35	30	100

Safety Personnel

Table 4.9: Respondents background view about Human Factors

Questions	Yes (%)	No (%)	To some extent (%)	Total (%)
Do you understand the subject of human factors and how it contributes to incidents in the chemical industry?	87.5	0	12.5	100
Do you know that more than 90% of incidents in the chemical industry are caused by human failure either directly or indirectly?	100	0	0	100
Do you think much consideration is given to human factors issues in the organization where you work now?	62.5	0	37.5	100
Do you have a Human Factors Engineer (HFE) or Human Factors Specialist in the department or section where you are currently working?	0	100	-	100

Table 4.10: Respondents wellbeing at work

Questions	Very Satisfied (%)	Satisfied (%)	Unsatisfied (%)	Not relevant (%)	Total (%)
Are you pleased with your work prospects in your current organization?	12.5	75	12.5	0	100
Are you pleased with the physical working conditions of your current organization?	25	62.5	12.5	0	100
Are you pleased with your usual take home pay?	0	37.5	62.5	0	100

Table 4.11: Respondents rating of Human Factors Major Categories and elements

Categories	Least Important (%)	Important (%)	Moderately Important (%)	Highly Important (%)	Extremely Important (%)	Total (%)
Culture/Working Environment	0	12.5	12.5	25	50	100
Organization/Management Systems	0	0	0	50	50	100
People Characteristics	0	12.5	25	25	37.5	100
Facilities/Equipment	0	0	0	62.5	37.5	100

Respondents

Production Personnel

Human Factors Categories and Elements	Author	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Average	Standard Deviation
Culture/working Environment	4	5	4	5	5	2	3	3	2	2	3	3	4	4	4	4	2	3	3	4	4	4	1	1	3	1	3	2	3.11	1.19
Management Systems	5	4	4	4	5	2	5	5	2	2	3	5	3	5	3	5	2	3	3	2	4	5	2	2	4	1	2	2	3.30	1.30
People characteristics	4	4	4	5	4	2	3	3	3	2	3	3	4	2	4	4	3	3	4	5	3	4	2	4	3	2	4	3	3.33	0.88
Facilities/Equipment	4	4	4	4	3	2	5	5	2	2	3	5	3	3	3	4	3	5	4	3	2	4	1	3	3	2	5	5	3.41	1.15
CULTURE/WORKING ENVIRONMENT																														
Social and community values	3	4	1	5	2	2	1	1	2	4	2	1	3	3	3	3	2	3	3	3	2	3	3	1	1	3	2	2	2.41	1.05
Communication flow within an organization	3	4	2	5	5	2	5	5	4	5	2	5	4	4	2	3	2	3	4	5	2	3	1	4	2	5	2	5	3.52	1.34
Organizational changes	4	3	1	4	3	1	3	3	3	4	3	3	4	3	4	3	2	3	4	3	3	4	2	3	2	4	1	4	2.96	0.94
Language	3	4	2	4	3	3	5	5	2	5	4	4	4	4	4	3	2	3	3	3	4	4	4	4	1	4	5	5	3.63	1.04
Geography	3	2	1	2	1	3	4	4	2	2	3	4	1	3	4	3	2	3	4	2	2	3	4	1	1	4	2	4	2.63	1.11
Climate	3	1	1	2	1	3	4	4	2	2	3	4	1	4	4	3	2	3	3	1	2	3	3	1	2	3	4	4	2.59	1.12
Management support of safety values	5	5	2	5	5	1	5	5	4	5	4	5	4	5	3	4	4	3	3	4	5	5	4	1	2	4	4	5	3.93	1.24
Safety culture and policy	5	5	3	5	4	2	5	5	4	5	4	5	3	4	4	3	4	2	2	4	3	5	3	1	2	5	5	5	3.78	1.22
MANAGEMENT SYSTEMS																														
Quality of operating procedures	4	5	3	4	5	2	5	5	4	5	4	5	4	3	3	4	4	3	4	3	4	4	4	3	3	4	5	3	3.89	0.85
Job safety analysis	3	5	3	4	5	1	5	5	4	5	4	5	4	4	4	4	4	2	2	3	3	4	4	4	3	4	5	4	3.85	1.03
Staffing arrangements	4	4	3	4	3	2	5	5	3	5	3	5	4	5	4	4	3	2	3	4	2	3	3	1	3	5	3	4	3.52	1.09
Clear interfaces between human and systems	4	4	3	5	3	2	4	5	3	5	3	4	4	3	4	3	3	2	3	4	3	4	3	5	3	3	4	4	3.56	0.85
Labels and Signs	2	5	2	4	4	2	4	5	5	5	4	4	4	3	5	5	3	2	4	2	3	4	4	5	4	4	5	5	3.93	1.04
Documentation	2	2	2	5	4	2	3	5	5	5	3	3	4	4	5	3	3	2	4	3	4	4	4	4	3	3	5	5	3.67	1.04
Clear responsibilities and accountability	4	4	4	4	4	2	4	5	4	5	3	4	4	5	4	3	3	2	4	5	3	4	3	4	3	4	5	5	3.85	0.86
Risk investigation and management	5	5	2	5	5	1	5	5	5	5	4	5	4	4	3	3	3	2	3	4	3	4	3	5	3	5	5	4	3.89	1.15
Safe and quality work practices	4	5	2	5	4	1	5	5	5	5	3	5	4	4	4	3	4	3	4	5	4	3	4	4	3	5	4	4	3.96	1.02
Leadership style and supervision	4	4	3	5	4	2	5	5	5	5	2	5	4	5	2	3	2	2	4	4	4	4	3	4	3	4	4	4	3.74	1.06
Management's corporate goals	4	4	3	5	5	2	3	5	3	5	4	3	4	5	3	3	2	2	4	3	3	4	4	5	2	3	4	5	3.63	1.04
PEOPLE CHARACTERISTICS																														
Stress and Fatigue	3	5	2	4	3	2	4	4	2	4	2	5	4	4	4	3	4	2	4	2	3	4	2	5	3	5	4	5	3.52	1.09
Training and competence	4	5	3	5	5	1	5	5	2	4	2	5	4	4	2	4	3	4	4	3	5	4	3	5	4	5	5	5	3.93	1.17
Workload	3	4	2	4	4	2	3	3	1	4	2	3	5	3	3	4	2	4	4	2	4	4	4	4	3	4	5	5	3.41	1.05
Shift work and overtime	3	5	2	3	2	2	3	5	3	4	3	3	5	3	3	2	3	3	4	2	2	4	4	3	3	5	4	5	3.33	1.04
Safety behaviour	3	5	3	5	3	1	4	5	4	4	4	4	4	4	4	4	2	4	3	4	3	4	4	3	3	5	5	5	3.81	0.96
Motivation	3	5	3	5	4	2	5	3	3	5	2	5	4	4	3	3	2	4	4	5	5	5	2	1	5	4	5	4	3.78	1.22
Skills and knowledge	4	5	3	5	5	1	5	5	2	5	4	5	3	3	4	5	3	4	4	3	4	4	3	1	3	4	5	4	3.78	1.19
Literacy/Education	3	5	3	4	3	2	4	3	2	5	4	4	3	3	3	4	2	3	3	2	2	4	3	2	2	5	5	5	3.33	1.07
Personal protective equipment	5	5	3	3	5	2	5	3	5	5	4	5	5	3	5	5	2	4	2	2	5	5	5	1	3	5	4	5	3.93	1.30
Manual handling	3	5	2	3	4	2	5	3	3	3	4	5	4	3	4	3	2	4	4	5	2	4	3	3	2	4	4	4	3.48	0.98
Physical and mental fitness for duty	4	5	2	4	4	2	5	3	2	5	3	5	4	3	4	5	2	3	4	3	4	4	5	4	2	5	4	5	3.74	1.10
FACILITIES/EQUIPMENT																														
Ergonomics	4	4	4	5	4	3	3	3	2	5	4	3	4	4	3	3	3	3	4	3	2	4	3	4	2	5	4	4	3.52	0.85
Design of controls	4	5	3	5	4	3	3	3	2	4	3	5	4	4	4	2	2	3	3	3	4	3	3	4	2	4	4	4	3.44	0.89
Field control panels and displays	4	4	3	4	4	1	3	4	2	4	3	5	4	4	2	3	1	3	3	2	3	3	3	1	2	4	4	4	3.07	1.07
Maintenance and Reliability	4	3	4	4	4	4	5	5	2	5	3	5	4	3	4	3	1	4	4	4	3	4	3	3	3	5	4	4	3.70	0.95
Physical layout of facilities and Sites	3	2	3	5	4	2	5	5	3	4	3	3	4	3	3	3	2	3	3	3	2	4	3	4	4	4	4	5	3.44	0.93
Accessibility	3	2	3	5	4	2	4	2	2	4	3	4	4	3	4	4	2	3	3	3	3	4	2	4	3	5	4	4	3.33	0.92
Noise	3	4	2	5	2	2	5	4	2	4	2	5	3	4	4	4	2	4	3	1	2	5	3	5	1	3	4	4	3.30	1.27
Vibration	3	2	3	5	1	2	3	4	2	4	2	3	3	4	4	3	2	4	4	2	2	4	3	3	1	3	4	5	3.04	1.09
Lighting	3	4	3	5	3	2	3	4	5	5	4	3	4	4	4	4	2	4	3	1	2	4	3	3	1	4	5	5	3.48	1.16
Toxics	3	3	2	5	2	3	5	4	3	2	3	5	4	2	2	5	2	4	2	2	3	3	3	4	3	4	5	5	3.33	1.14
Radiation	3	2	3	5	1	2	5	4	2	1	2	5	4	3	3	4	4	4	3	1	2	3	2	1	3	5	5	5	3.11	1.40
Temperatures	3	3	2	5	3	2	3	4	1	1	2	3	4	3	4	3	3	4	2	1	2	3	3	3	2	4	5	5	2.96	1.16
Tools	4	5	3	5	4	3	3	4	2	2	4	3	4	3	4	3	2	4	2	3	2	3	3	4	2	4	5	5	3.37	1.01
																														1.08

Human Resources Personnel

Human Factors Categories and Elements	1	2	3	4	5	6	Average	Standard Deviation
Culture/working Environment	3	5	3	4	4	4	3.83	0.75
Management Systems	2	5	3	4	2	4	3.33	1.21
People characteristics	4	2	4	5	4	5	4.00	1.10
Facilities/Equipment	4	1	4	4	4	4	3.50	1.22
CULTURE/WORKING ENVIRONMENT								
Social and community values	4	1	4	2	4	4	3.17	1.33
Communication flow within an organization	4	5	4	3	3	5	4.00	0.89
Organizational changes	4	5	4	3	3	5	4.00	0.89
Language	4	1	4	3	5	3	3.33	1.37
Geography	4	1	4	3	2	3	2.83	1.17
Climate	4	1	4	3	2	3	2.83	1.17
Management support of safety values	5	5	5	4	5	5	4.83	0.41
Safety culture and policy	5	5	5	4	5	5	4.83	0.41
MANAGEMENT SYSTEMS								
Quality of operating procedures	5	5	5	5	2	5	4.50	1.22
Job safety analysis	3	5	5	5	4	5	4.50	0.84
Staffing arrangements	4	5	5	4	3	5	4.33	0.82
Clear interfaces between human and systems	5	2	4	3	3	5	3.67	1.21
Labels and Signs	5	1	5	3	5	5	4.00	1.67
Documentation	5	1	4	3	4	4	3.50	1.38
Clear responsibilities and accountability	5	5	5	5	4	5	4.83	0.41
Risk investigation and management	5	5	5	5	4	5	4.83	0.41
Safe and quality work practices	5	3	4	4	5	5	4.33	0.82
Leadership style and supervision	5	5	4	4	4	5	4.50	0.55
Management's corporate goals	5	5	4	4	4	5	4.50	0.55
PEOPLE CHARACTERISTICS								
Stress and Fatigue	4	1	5	5	5	5	4.17	1.60
Training and competence	4	5	5	5	5	5	4.83	0.41
Workload	5	3	5	4	5	5	4.50	0.84
Shift work and overtime	5	3	5	3	5	5	4.33	1.03
Safety behaviour	5	4	5	5	5	5	4.83	0.41
Motivation	4	5	5	5	4	5	4.67	0.52
Skills and knowledge	5	5	5	5	5	5	5.00	0.00
Literacy/Education	4	4	5	4	4	3	4.00	0.63
Personal protective equipment	5	5	5	5	5	5	5.00	0.00
Manual handling	5	3	5	3	4	5	4.17	0.98
Physical and mental fitness for duty	5	3	5	5	5	4	4.50	0.84
FACILITIES/EQUIPMENT								
Ergonomics	4	3	5	3	4	5	4.00	0.89
Design of controls	5	3	5	3	3	5	4.00	1.10
Field control panels and displays	3	3	4	3	3	5	3.50	0.84
Maintenance and Reliability	5	4	5	4	3	5	4.33	0.82
Physical layout of facilities and Sites	5	3	5	4	3	4	4.00	0.89
Accessibility	5	3	5	4	3	5	4.17	0.98
Noise	5	3	4	3	5	5	4.17	0.98
Vibration	5	3	5	3	5	3	4.00	1.10
Lighting	5	3	5	4	5	5	4.50	0.84
Toxics	5	3	5	4	5	5	4.50	0.84
Radiation	5	3	5	3	5	5	4.33	1.03
Temperatures	5	3	4	3	5	3	3.83	0.98
Tools	5	3	4	4	5	5	4.33	0.82
								0.88

Maintenance Personnel

Human Factors Categories and Elements	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average	Standard Deviation
Culture/working Environment	4	4	3	4	4	5	4	3	2	2	2	5	3	2	5	5	4	4	3	3	4	5	4	4	3.67	1.01
Management Systems	3	3	2	4	5	4	4	3	2	5	2	4	5	2	5	5	4	5	3	2	5	4	2	5	3.67	1.20
People characteristics	3	3	3	4	4	3	5	3	1	3	2	3	4	3	4	4	3	4	3	2	5	4	4	5	3.42	0.97
Facilities/Equipment	4	4	2	4	5	3	4	3	5	5	2	2	5	4	4	4	2	5	3	2	5	5	4	4	3.75	1.11
CULTURE/WORKING ENVIRONMENT																										
Social and community values	3	3	3	4	4	5	4	3	1	4	3	2	3	2	4	4	3	3	3	1	4	2	4	1	3.04	1.08
Communication flow within an organization	2	4	3	4	5	4	4	3	3	4	3	4	4	4	5	4	2	4	3	1	5	5	4	4	3.67	1.01
Organizational changes	1	3	3	4	5	3	3	3	1	4	3	4	4	4	4	2	3	4	2	1	3	4	4	3	3.13	1.08
Language	1	4	2	3	5	3	4	3	5	3	1	4	4	2	2	2	2	3	3	2	4	2	4	4	3.00	1.14
Geography	2	3	2	4	4	2	4	3	1	3	1	1	3	2	2	2	1	2	3	1	4	2	4	2	2.42	1.06
Climate	3	3	2	4	3	4	3	3	1	2	2	1	3	1	2	4	2	2	4	2	4	2	4	1	2.58	1.06
Management support of safety values	2	4	2	5	5	5	4	3	2	5	1	5	4	4	5	5	2	5	3	3	5	5	2	5	3.79	1.35
Safety culture and policy	3	4	3	5	5	5	5	3	2	5	1	4	4	4	5	5	3	5	3	2	5	5	4	5	3.96	1.20
MANAGEMENT SYSTEMS																										
Quality of operating procedures	3	3	3	4	5	4	5	3	1	5	2	5	5	2	5	3	4	4	2	2	4	5	3	4	3.58	1.21
Job safety analysis	4	3	2	4	5	3	4	3	2	5	1	5	5	4	3	4	3	5	2	4	5	5	4	4	3.71	1.16
Staffing arrangements	1	3	2	3	4	3	5	3	2	4	1	5	5	2	4	3	2	3	2	1	4	2	1	1	2.75	1.33
Clear interfaces between human and systems	1	3	2	4	4	3	4	3	1	4	1	5	5	4	4	3	4	4	2	1	4	4	3	4	3.21	1.25
Labels and Signs	3	4	2	4	5	3	5	3	2	3	2	5	5	4	5	3	4	4	2	2	4	4	4	3	3.54	1.06
Documentation	1	3	2	4	5	3	5	3	2	4	1	5	5	4	5	3	2	4	2	2	4	3	1	4	3.21	1.35
Clear responsibilities and accountability	4	3	2	4	5	5	5	3	2	5	1	5	4	4	4	3	4	4	2	1	5	5	3	4	3.63	1.28
Risk investigation and management	1	3	2	4	5	5	5	3	2	5	1	5	4	3	5	4	5	5	2	2	5	5	2	5	3.67	1.46
Safe and quality work practices	3	3	3	4	5	5	5	3	2	5	2	5	4	2	5	4	4	4	2	2	4	5	4	5	3.75	1.15
Leadership style and supervision	1	3	2	5	4	5	5	3	1	4	1	5	5	4	4	4	3	5	2	1	5	4	4	3	3.46	1.44
Management's corporate goals	3	3	2	3	5	5	4	3	2	4	1	5	5	4	4	4	2	4	2	2	5	5	4	3	3.50	1.22
PEOPLE CHARACTERISTICS																										
Stress and Fatigue	2	3	3	4	5	4	5	2	2	5	1	3	3	1	4	4	1	3	2	1	5	5	4	5	3.21	1.44
Training and competence	3	4	3	4	5	4	5	2	2	5	3	5	5	4	4	2	1	4	2	1	5	5	5	5	3.67	1.37
Workload	3	3	3	4	5	4	5	2	2	5	1	5	5	4	4	2	2	3	2	1	5	4	5	4	3.46	1.35
Shift work and overtime	4	4	3	4	5	4	4	2	2	4	2	4	4	1	4	2	1	4	2	2	5	3	1	1	3.00	1.32
Safety behaviour	3	3	3	5	5	5	5	2	2	5	3	4	5	3	5	2	5	5	2	2	5	4	4	5	3.83	1.24
Motivation	1	3	3	5	4	5	5	2	2	4	1	5	5	5	4	2	2	4	2	1	5	5	5	3	3.46	1.50
Skills and knowledge	3	4	3	4	5	4	5	2	2	5	2	4	5	3	5	3	4	4	2	1	5	5	3	4	3.63	1.21
Literacy/Education	1	3	3	4	5	3	5	2	2	5	2	4	4	2	4	3	3	4	2	1	5	5	3	4	3.29	1.27
Personal protective equipment	4	4	3	4	5	3	4	2	5	3	2	5	4	2	4	2	5	5	2	3	5	5	4	4	3.71	1.12
Manual handling	1	3	2	3	4	3	3	2	2	3	2	5	4	3	3	2	5	4	2	2	5	3	3	2	2.96	1.08
Physical and mental fitness for duty	4	4	2	4	5	5	4	2	2	3	2	5	5	1	3	2	2	4	3	1	5	5	4	3	3.33	1.34
FACILITIES/EQUIPMENT																										
Ergonomics	3	4	2	4	4	4	5	2	5	4	1	4	4	4	4	4	4	4	3	2	5	5	4	3	3.67	1.05
Design of controls	2	3	2	4	4	3	5	3	5	4	2	4	4	2	4	4	3	4	3	1	5	5	5	4	3.54	1.14
Field control panels and displays	1	3	3	3	4	3	5	3	3	3	2	3	5	2	3	2	3	3	3	1	4	4	5	4	3.13	1.08
Maintenance and Reliability	1	4	3	3	4	3	5	2	5	5	2	2	5	2	3	2	4	5	3	2	4	4	4	4	3.38	1.21
Physical layout of facilities and Sites	3	4	2	3	4	4	5	3	2	4	1	3	4	3	3	4	3	4	2	1	4	4	3	3	3.17	1.01
Accessibility	2	4	2	4	4	4	5	2	2	4	2	2	5	4	4	4	5	4	2	1	4	4	4	3	3.38	1.17
Noise	3	3	3	4	5	3	5	2	1	4	2	1	4	2	4	2	2	4	3	2	4	5	4	3	3.13	1.19
Vibration	1	3	3	4	5	3	3	2	1	3	2	1	4	1	3	2	2	4	2	2	4	5	4	3	2.79	1.22
Lighting	3	3	5	5	5	3	4	2	4	4	2	3	4	1	3	2	4	4	3	3	4	5	4	3	3.46	1.06
Toxics	1	3	5	4	5	3	5	2	1	4	2	2	4	2	4	2	2	4	2	2	4	5	4	4	3.17	1.31
Radiation	1	3	3	4	5	2	5	2	3	4	2	1	4	1	4	2	1	4	2	3	4	5	4	4	3.04	1.33
Temperatures	3	3	3	4	4	3	4	2	1	4	2	1	4	1	3	2	4	4	2	2	4	5	5	4	3.08	1.21
Tools	4	3	1	4	5	4	5	2	2	4	2	2	4	2	3	4	5	5	3	3	4	5	3	4	3.46	1.18
																										1.20

Safety Personnel

Human Factors Categories and Elements	1	2	3	4	5	6	7	8	Average	Standard Deviation
Culture/working Environment	5	5	2	4	4	5	4	3	4.00	1.07
Management Systems	4	5	4	5	5	5	4	4	4.50	0.53
People characteristics	5	4	2	4	3	5	5	3	3.88	1.13
Facilities/Equipment	5	5	4	4	4	4	5	4	4.38	0.52
CULTURE/WORKING ENVIRONMENT										
Social and community values	5	5	2	4	3	4	2	3	3.50	1.20
Communication flow within an organization	5	5	2	4	3	5	2	3	3.63	1.30
Organizational changes	4	4	4	5	3	4	3	3	3.75	0.71
Language	3	4	1	5	4	4	5	3	3.63	1.30
Geography	2	4	2	3	3	3	4	3	3.00	0.76
Climate	4	4	2	3	3	3	4	3	3.25	0.71
Management support of safety values	5	5	5	5	4	4	5	3	4.50	0.76
Safety culture and policy	5	5	5	5	4	3	5	3	4.38	0.92
MANAGEMENT SYSTEMS										
Quality of operating procedures	5	5	5	5	3	4	4	3	4.25	0.89
Job safety analysis	5	5	5	5	4	4	5	3	4.50	0.76
Staffing arrangements	5	5	2	4	4	4	4	3	3.88	0.99
Clear interfaces between human and systems	5	5	4	4	3	3	5	3	4.00	0.93
Labels and Signs	5	5	4	5	3	3	5	3	4.13	0.99
Documentation	5	5	5	5	4	3	5	3	4.38	0.92
Clear responsibilities and accountability	5	5	5	5	3	3	5	3	4.25	1.04
Risk investigation and management	5	5	5	5	3	5	5	3	4.50	0.93
Safe and quality work practices	5	5	4	5	3	3	5	3	4.13	0.99
Leadership style and supervision	5	5	3	4	3	3	5	3	3.88	0.99
Management's corporate goals	4	5	5	3	3	3	5	3	3.88	0.99
PEOPLE CHARACTERISTICS										
Stress and Fatigue	5	5	2	4	4	4	3	4	3.88	0.99
Training and competence	5	5	5	5	3	4	3	4	4.25	0.89
Workload	5	4	2	4	1	4	3	4	3.38	1.30
Shift work and overtime	5	4	4	4	2	3	3	4	3.63	0.92
Safety behaviour	5	5	5	5	4	5	5	5	4.88	0.35
Motivation	5	4	2	3	2	5	5	3	3.63	1.30
Skills and knowledge	5	5	4	4	2	4	4	5	4.13	0.99
Literacy/Education	5	4	2	4	3	3	5	3	3.63	1.06
Personal protective equipment	5	5	4	3	5	4	5	5	4.50	0.76
Manual handling	5	5	4	5	5	3	3	3	4.13	0.99
Physical and mental fitness for duty	5	5	3	5	4	3	3	3	3.88	0.99
FACILITIES/EQUIPMENT										
Ergonomics	4	5	1	4	4	3	3	5	3.63	1.30
Design of controls	5	5	2	4	4	3	3	3	3.63	1.06
Field control panels and displays	5	5	2	4	4	3	3	3	3.63	1.06
Maintenance and Reliability	5	5	3	5	4	3	3	3	3.88	0.99
Physical layout of facilities and Sites	5	5	3	4	3	3	3	3	3.63	0.92
Accessibility	5	5	3	5	4	3	4	3	4.00	0.93
Noise	5	5	4	5	4	3	4	3	4.13	0.83
Vibration	5	5	4	5	5	3	4	3	4.25	0.89
Lighting	5	5	4	5	5	3	4	3	4.25	0.89
Toxics	5	5	3	5	5	3	5	3	4.25	1.04
Radiation	5	5	4	5	5	3	5	3	4.38	0.92
Temperatures	4	5	4	4	4	3	5	3	4.00	0.76
Tools	5	5	5	5	5	3	4	4	4.50	0.76
										0.94

Table 4.12: Respondents Weighting of the Human Factors Major Categories ar

4.3 Analysis of Findings

Analysis of the findings comprises the charts drawn from the raw data obtained from the Questionnaires1 responses. The representation of the data using charts is aimed at giving a graphical analysis of the displayed results.

As a result of the four categories in which the respondents were grouped into as well as the different types of responses to the different questions of Questionnaire1, the Microsoft excel format was used to develop a PivotTable for the data which provides ease of drop-down menus.

4.3.1 Respondents Background View about Human Factors

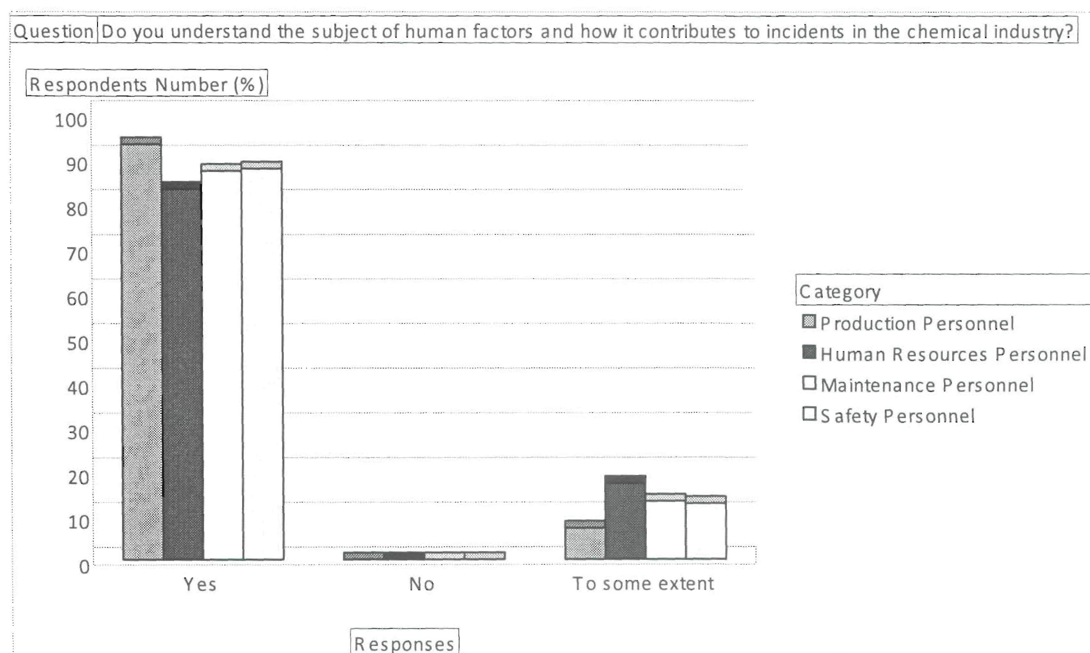

Figure 4.1.1: *Background view about human factors (HF understanding)*

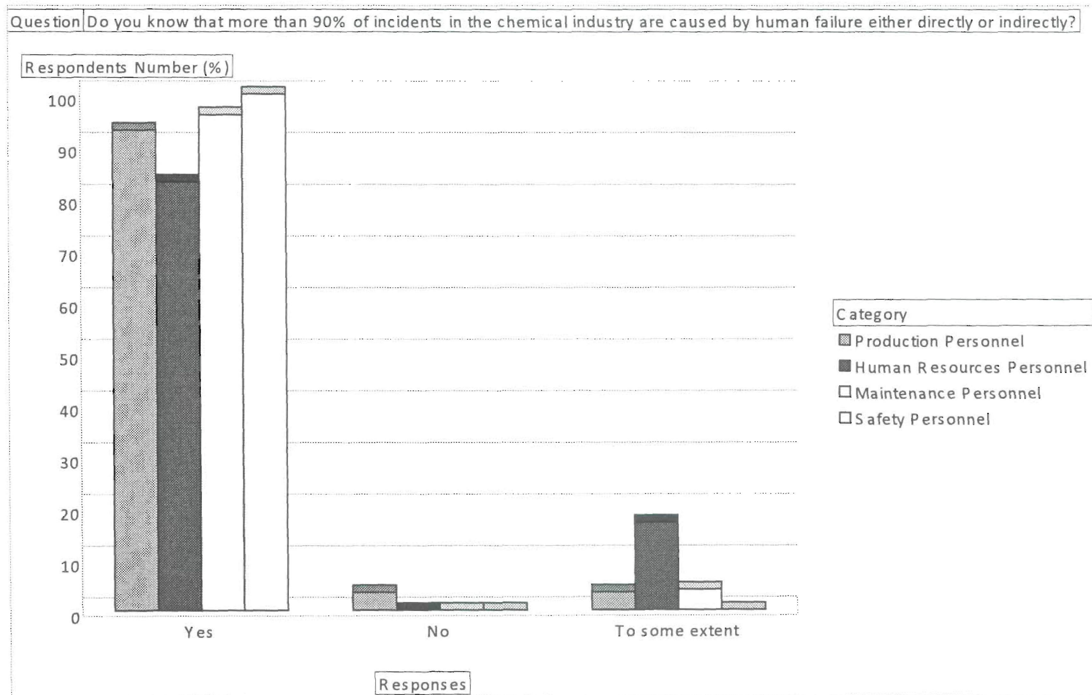

Figure 4.1.2: *Background view about human factors (HF influence)*

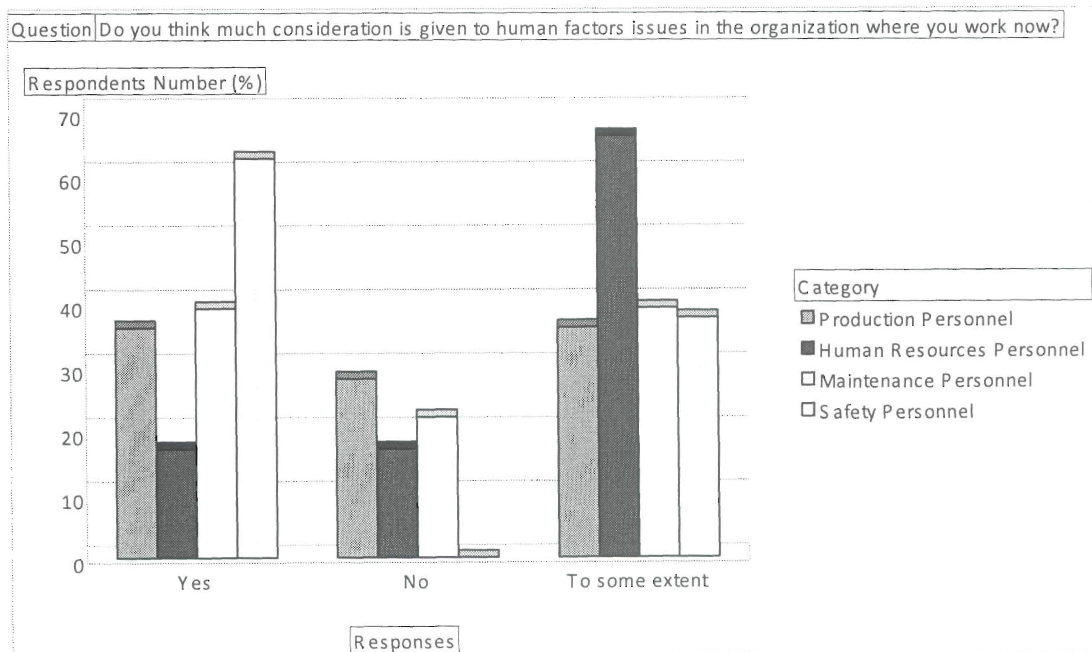

Figure 4.1.3: *Background view about human factors (HF consideration)*

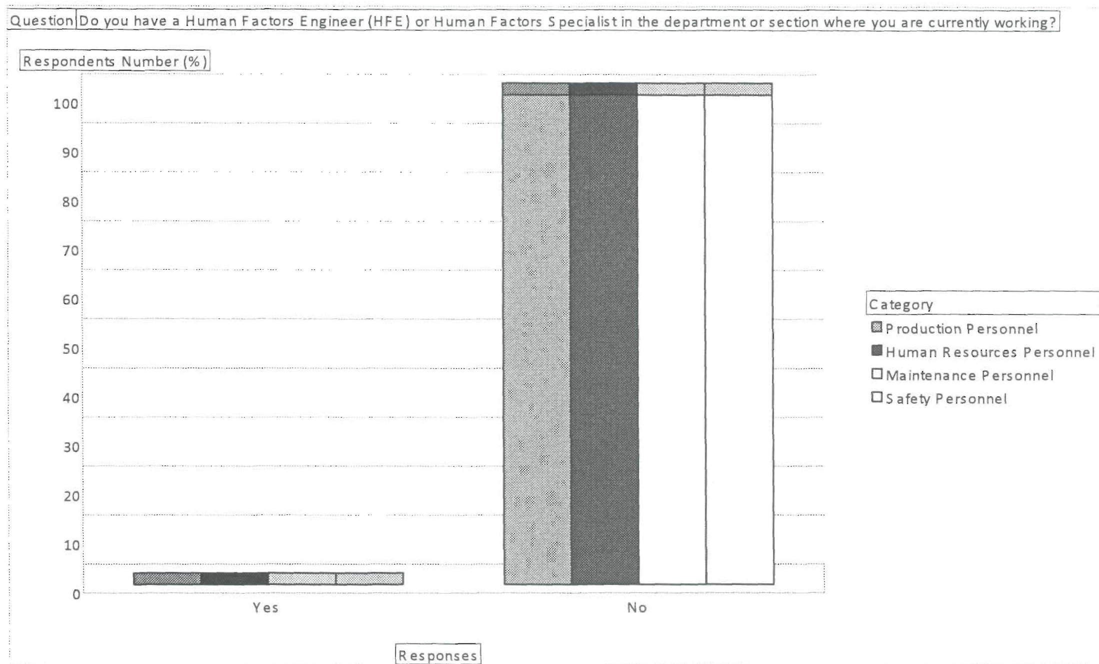

Figure 4.1.4: *Background view about human factors (HF specialist)*

4.3.1.1 Discussion of the Findings on the Respondents Background View about Human Factors

It can be seen from Figure 4.1.1 that a large number of the respondents have a good understanding of human factors issues in the chemical industry with the production personnel having the highest percentage. This could be due to the fact that the production personnel are the people who actually do the supervision and day to day running of the chemical plant (http://en.wikipedia.org).

Averages of 88 and 12 percent of the respondents both have a good and fair understanding of human factors. This indicates that none of the respondents are novices in human factor issues in the chemical industry. This is thus a plus to human factors management in Sasol Wax.

Figure 4.1.2 also indicates a very high knowledge by the respondents, of the role human factors play in the occurrence of incidents in the chemical industry. Safety personnel records the highest in

terms of the background knowledge about human factors which could be due to the fact that their day to day activities are basically safety, health and environmental issues, and as such are more abreast with the causes and occurrence of incidents in the work environment.

A very small number of production personnel who could probably be new to the chemical industry or the organization, are not aware of this fact. It can be understood that the human resources personnel may not necessarily carry out duties which are directly related to chemical operations. This thus makes them not so much aware of the fact.

In figure 4.1.3, and based on the overall understanding of the subject of human factors by the respondents, the different responses for the categories show that much consideration is not being given to human factors at Sasol Wax. This can be seen from the fact that the percentage of the respondents that indicated "no" together with the percentage who indicated "to some extent" outweighs the percentage that indicated an outright "yes". This then gives rise to the fact that the organization places more attention to other issues while giving less attention to human factors management and integration, else more than fifty percent would have indicated "yes".

As can been seen from figure 4.1.4, the presence of a human factors engineer or specialist is non-existent at Sasol Wax. This is one of the contributing factors to chemical industry incidents because of the lack of specialists or engineers in the human factors field who can define how process operations will integrate people and technology so as to improve human safety, plant safety and productivity (Greg A. Jamieson, 2008).

4.3.2 Respondents Wellbeing at Work

Figure 4.2.1: *Wellbeing at Work (Work prospects)*

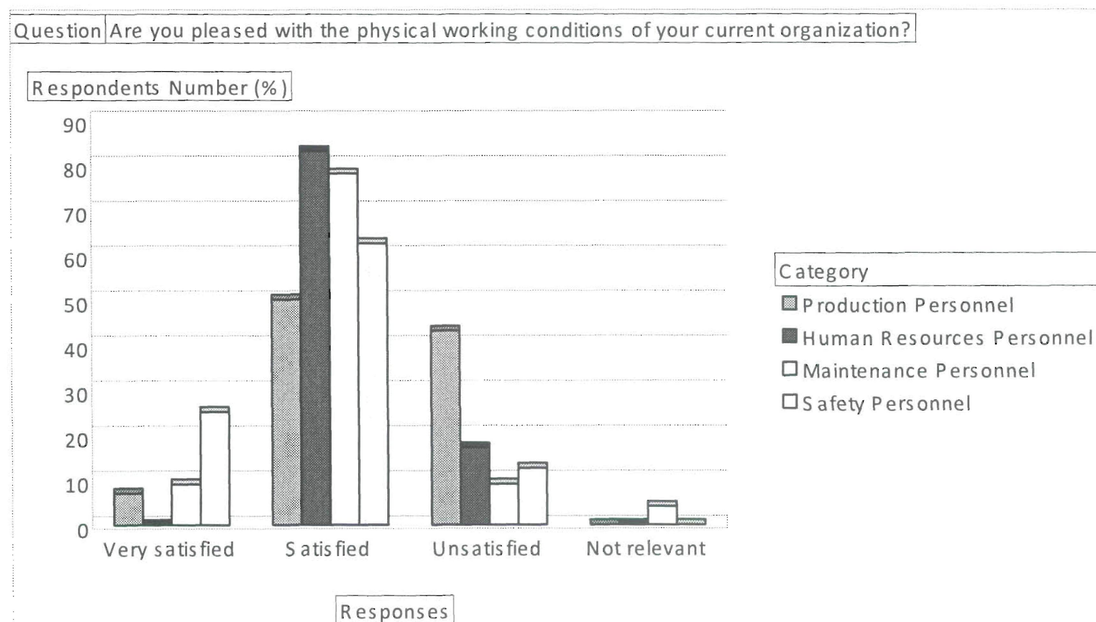

Figure 4.2.2: *Wellbeing at Work (Working conditions)*

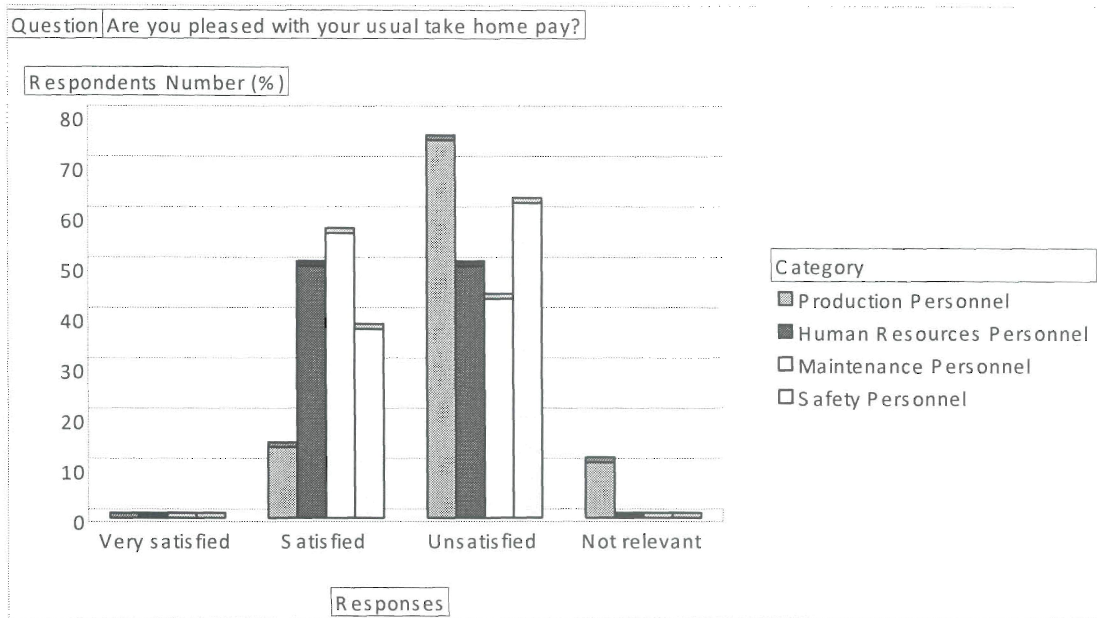

Figure 4.2.3: *Wellbeing at Work (Take home pay)*

4.3.2.1 Discussion of the Findings on the Respondents Wellbeing at Work

Going by the respondents feedback indicated in figures 4.2.1, 4.2.2 and 4.2.3, it is evident that the human resources personnel are better satisfied and have good working conditions compared to the other personnel categories in the same organization.

With a critical look at Questionnaire1, only the personnel who are in managerial positions for all the categories seem to be satisfied and enjoying the conditions and prospects of their jobs as well as their remunerations. It also appears the production personnel are much more dissatisfied with their wages compared to the maintenance personnel.

Working with dissatisfaction also portends a hazard in a safety-critical work environment like the chemical industry and it furthermore could also result in a skills shortage in an organization (Dominique Besson *et al*, 1999).

Another issue which is a subject of another research is the placing of some employees of an organization on a contract-employment status for a very long time. Going by recent incident notifications at Sasol Wax, most victims of incidents are the production and maintenance personnel with a greater part of the number being contract employees. Unfortunately, none of the few contractor employees who was handed a questionnaire completed it. The researcher could only have interview with one contract employee.

4.3.3 Respondents Rating of Human Factors Major Categories and Elements

Table 4.1 has the computation of the data from questionnaire1. The first column has a listing of the human factor elements under the major categories, all of which have been explained in chapter two. The second column shows the rating of the human factors elements from the author or researcher's point of view, while the rating by the production, human resources, maintenance and safety personnel are in the next four columns.

Each of the respondents rating from 1 (least important) to 5 (most important) is indicated under the four personnel groups according to number of feedback received from each group.

The average for each personnel group with respect to the human factor element was computed horizontally. Using this average rating, the standard deviation from the author's rating was then computed horizontally as well. This standard deviation was computed in order to determine the extent to which each human factor major category and element deviated from the author's ratings. This was done for the four personnel groups and according to each human factors element.

Calculating the average of the standard deviations for each personnel group for all the human factors major categories and elements, vertically, gives results as:

- Production Personnel (1.08),
- Human Resources Personnel (0.88),
- Maintenance Personnel (1.20), and
- Safety Personnel (0.94).

With reference to the author's rating, the production and maintenance personnel both have average deviations greater than one. This is because these two categories are both directly involved in the operation and maintenance of the chemical facility.

The chemical industry involves a huge capital investment, and as such production is generally on a continuous basis. The continuous production processes thus makes the maintenance function an important part of the industry (R.H.P.M. Arts *et al*, 1998).

In recent times, mechanization and automation of chemical plants and facilities have also resulted in the reduction of production personnel while at the same time, increasing the capital employed in the production or chemical facility. As a result of this, the number of employees working in the area of maintenance increases. This can also be attributed to the average deviation by the maintenance personnel being very much greater than one.

The human resources and safety personnel recorded average deviation of less than one considering the fact that they are largely office workers. Hazards such as chemical, electrical, physical, mechanical, fire/explosion or health hazards have less impact on office personnel than those who are exposed to them daily, and whose jobs entail monitoring meter readings, opening and closing of valves, controlling heating and cooling equipment, starting up and shutting the plant as well as maintenance activities.

4.3.4 Human Factors Major Category Ranking at Sasol Wax

The standard deviations of the four personnel groups for the human factors major categories from the survey data as computed in *table 4.12* can be simplified as shown in *table 4.13*.

	Culture/Working Environment	**Management Systems**	**People Characteristics**	**Facilities/Equipment**
Production personnel	1.19	1.30	0.88	1.15
HR Personnel	0.75	1.21	1.10	1.22
Maintenance Personnel	1.01	1.20	0.97	1.11
Safety Personnel	1.07	0.53	1.13	0.52
Average Deviation	**1.01**	**1.06**	**1.02**	**1.00**

Table 4.13 Standard deviations of the human factors major Categories.

From *table 4.13,* the average of the deviations for the four personnel groups is presented in bottom row. This shows *'management systems'*, with the standard deviation averaging 1.06, as the top human factor issue at Sasol Wax. This is followed by 'people characteristic', 'culture/working environment' and the least as 'facilities/equipment'.

4.4 Outcome of Interviews and Discussions with Sasol Wax Employees

A contract and permanent employee were both approached at different times on June 20, 2008, to express their views on the reason why incidents and injuries still occur despite several safety measures and awareness at Sasol Wax. Their responses are:

Contract Employee: "pressure from management to get a job done and as such there is rush to complete tasks".

Permanent Employee: "experienced staffs shortfall due to poor motivation and career prospects. Low competence by new staffs as was also mentioned".

The responses from the contract and permanent employee showed a management system problem as well as people characteristics deficiency.

In a safety-critical work environment like Sasol Wax and other similar chemical business units, working under pressure posses risk to the employee carrying out the task as well as those around him. Employees should rather be encouraged to work carefully but smartly.

Furthermore, if there is little or no prospect and motivation in working in an organization, then the employee will be unsatisfied and will seek an opportunity to move over to another organization where the working conditions and wellbeing are satisfactory.

On the 22nd of August, 2008, a **discussion** was held with 19 Sasol Wax employees comprising a maintenance manager, plant foremen, a safety representative, planners, technicians and artisans, about the safety concerns and spate of incidents at Sasol Wax and other similar chemical business units within the Sasol organization.

The summary of the discussion was that the frequent incident occurrences and injuries can be attributed to the following factors:

1. Time – always in a hurry to get job done
2. Lack of competence to carry out tasks
3. Poor skills
4. Lack of knowledge of required safety rules and procedures
5. Lack of accountability and responsibility
6. Management too slow to act on deviations
7. Lack of discipline, and also unfairness in addressing disciplinary cases
8. Poor top-bottom communication
9. Blaming culture and lack of teamwork
10. Inadequate tools and improper usage of tools

Placing the above factors into the human factors major categories,

Culture/working Environment = numbers 8 & 9

Management Systems = numbers 1, 5, 6, & 7

People Characteristics = numbers 2, 3, & 4

Facilities/Equipment = number 10.

4.5 Overall Inference from Questionnaire1, Interviews and Discussions

It can be inferred from the presentation of the interviews and discussions that their outcomes substantiate the Questionnaire1 findings. That management system is the top human factors issue at Sasol Wax which is akin to other similar business units within the Sasol organization. This somewhat contradicts previous arguments (presented in chapters one and two), that 'individual' or 'people characteristics' is largely the cause of incidents in the chemical industry.

Elise and Sierra, 2006, also pointed out that although many researchers have attributed majority of incident causes to individuals, the actual majority of underlying causes are due to management systems which influence the individual directly or indirectly; and that management systems may be the most critical in considering human factors contribution to incidents in the chemical industry.

Agreeing with this inference, Reason, *Human Error,* 1990, adeptly pointed out that *"rather than being the main instigators of an accident or incident, operators tend to be the inheritors of system defects created by poor design, incorrect installation, faulty maintenance and bad management systems and decisions. Their part is usually that of adding the final garnish to a lethal brew whose ingredients have already been long in the cooking"*. And that operators being part of people characteristics element, are often 'set up' to fail by management and organizational failures.

Stephen Reinach and Alex Viale, 2005 in their accident/incident analysis and prevention journal explained that in a total of six incidents/accidents investigated in the rail industry in the US, a total of 36 probable contributing factors were identified. According to the investigation, all the operator errors had preconditions of management and organization factors influencing them.

Although from the findings from this research, management system has been deduced to be a leading factor, but all the human factors major categories are major issues which all require

consideration. The next step is to identify the key human factor elements for these human factors major categories which are top issues not just at Sasol Wax only, but also in other high hazard chemical business units and industries.

These factors have been identified by the HSE, and they form the structure and context of Questionnaire2 with which the findings at Sasol Wax will be benchmarked against other selected business units within the Sasol organization and industry standards in other to determine the performance gaps and optimize the current status of human factors integration and management. These are presented in the next chapter.

CHAPTER FIVE

5.0 BENCHMARKING THE MANAGEMENT OF HUMAN FACTORS AT SASOL WAX

"Benchmarking is a way of measuring a firm's strategies and performance against "best-in-class" firms, both inside and outside the industry. The aim is to identify best practices that can be adopted and implemented by the organization with the purpose of improving a company's performance" (Adapted from: Per V. Freytag and Svend Hollensen, 2001).

The essence of benchmarking the management or status of human factors issues in Sasol Wax against other business units and standards is not only as a problem solving process, but to also identify the highest standard of excellence in the field of human factors and then to make improvements necessary to reach those standards. This is also a way of identifying new ideas to meet the need of optimum safety and progress towards zero incidents (Dean Elmuti and Yunus Kathawala, 1997).

The benchmarking of the Sasol Wax human factors management is based on:

- Analysis of the top human factors elements contributing to incidents,
- Analysis of the performance levels of human factors management at Sasol Wax,
- Comparison of the performance level at Sasol Wax with other business units of Sasol and industry standards,
- Identification of performance gaps as the basis for improving human factors management and optimizing safety at Sasol Wax and similar chemical business companies.

5.1 The Benchmarking Process

The type of benchmarking to be adopted for this research is both the *internal* and *functional benchmarking system.*

Internal benchmarking entails benchmarking against the operations of similar companies or business units within a large organization. According to Dean and Kathalawa, this system "enables

the sharing of a multitude of information". And "the benefit of immediate gain comes from identifying the best internal procedures and being able to transfer them to other portions of the organization".

The *functional benchmarking* involves the measurement of one or more areas under evaluation, and then comparing these with similar measurements from other industry leaders with similar business operations, technology or standards. Performance gaps and best external procedures can also be realized from this which can be beneficial to the company or business unit being benchmarked.

The benchmarking process for this research will thus combine the methods and benefits of the two benchmarking systems in other to achieve the research aim of developing principles and best practices for enhanced human factor management in Sasol Wax and in other similar high hazard and safety-critical industries.

The benchmarking process will thus follow the following main stages:

1. Deciding the human factors issue at Sasol Wax to be benchmarked,
2. Evaluating the importance of the human factors issue to be benchmarked,
3. Determining the benchmarking partners,
4. Determining the benchmarking method,
5. Presentation of the benchmarking information,
6. Identifying performance gaps by comparing the "best-in-class" with Sasol Wax performance level,
7. Presentation of the benchmarking results,
8. Development of a framework outline that demonstrates the hierarchy of human factors management process at Sasol Wax.

According to Khurrum and Faizul, 1999, "the benchmarking process could be carried out in 33 steps or just five; however the essence remains the same". So the above steps are chosen to avoid complexity and to achieve the study aim.

From the findings and analysis made thus far, it can be deduced that the four human factors major categories are all major issues at Sasol Wax with incident tendencies, although management systems ranked highest. But the top human factors issues which spans over these four major categories will be evaluated.

5.1.1 Top Human Factors Parameters to be benchmarked

Since the human factors subject is an interaction between the four major human categories of *culture/work environment, management systems, people characteristics and facility/equipment,* the critical elements enumerated by the HSE, 2002, will be the top benchmarking factors at Sasol Wax.

The benchmarking factors listed below spans over the four major human HF categories. Whilst numbered, the factors according to HSE are not in priority order.

1. Organizational change
2. Staffing arrangements and workload
3. Training and competence
4. Fatigue from shift work and overtime
5. Ergonomic designs
6. Work and Safety critical procedures
7. Safety culture
8. Communications and interfaces
9. Integration of human factors into risk assessment and investigations
10. Maintenance error

5.1.2 Importance of the Top Human Factors Elements

The Health and safety executive (HSE, 1996 – 2006), after several researches, consultation with industry and intermediaries and inspection experiences have defined the importance of the top ten human factors issues facing the chemical industry, and also illustrated them with consequences as summarized in *table 5.1* below.

Issue	Definition	Consequences
1. Organizational change	Any change to the structure, population or distribution of roles and responsibilities of an organization that may impact safety. Can include one or a combination of: business re-engineering, downsizing, delayering, empowerment, multiskilling, outsourcing/contractorisation, and mergers, de-mergers and acquisitions.	Can include reduction in resources, competence or motivation to deal with: upsets and crisis, emergencies, maintenance and safety management system.
2. Staffing arrangements and workload		
3. Training and competence	The continuing ability of individuals and teams to perform reliably the safety related elements of their roles, responsibilities and tasks, and for this to be demonstrable.	Failure to perform to required level in delivery of safety-related or safety critical tasks, roles or responsibilities.
4. Fatigue from shift work and overtime	Impaired human reliability from fatigue.	Symptoms include loss of alertness, drowsiness, loss of patience. Errors include absentminded slips, memory lapses; 'losing the picture'; etc. Three Mile Island and Chernobyl included fatigued staff amongst the root causes.

5. Ergonomic designs	Integration of human factors at various stages of design, layout of plant or equipment, displays, controls, hardware, safer and more productive systems to aid human reliability, such that design is not just an engineering hardware issue.	Failure to incorporate human factors consideration leading to human error in operations or maintenance.
6. Work and Safety critical procedures	Selecting, designing and managing procedures in a way that assists human reliability.	Unreliability or dangerous performance of safety-critical tasks.
7. *Safety culture*	The product of individual and group values, attitudes, perceptions, competences, and patterns of behavior, whether just for safety or the wider organization, that determine the commitment to, and the style and proficiency of, an organization's safety management.	Safety culture is widely believed to be directly related to safety performance (i.e. the frequency and/or probability of accidents).
8. Communications and interfaces	Reliable and accurate communication of safety-critical or safety-related information, for example between control room and field operators, between operators within a shift and at shift hand-over.	Risks from lack of or inaccurate, information.
9. Integration of human factors into risk assessment and investigations	Positioning human factors at the core of design, development, operation and investigation so that human factors are embedded in the activity throughout the life cycle.	Higher operational costs, poor usability and a higher cost of adding human factors later.
10. Maintenance error	Human errors in maintenance that lead to immediate or latent unsafe conditions.	Can include loss of process integrity, or failure in service or on demand of plant and equipment.

Table 5.1: Summary of the Importance of the top ten human factors issues (Adapted from HSE).

5.1.3 The Benchmarking Partners

Sasol Wax, which has production and marketing operations in South Africa, Europe, UK and America, and is a world leader in the production and supply of waxes, petroleum jellies and liquid paraffin derived from Ficher-Tropsch and oil-refinery feedstock to customers worldwide; will be benchmarked internally against:

1. **Sasol Technology,** which manages Sasol organization's research and development, technology innovation and management, pilot plants design and operation, process safety, risk and environmental engineering services, occupational health and hygiene, and project management portfolios.

2. **Sasol Solvent,** which has plants in South Africa and Germany and supplies alcohols, ketones, esters, acrylic acid esters, ethyl acetate, ethers, propionic acid, acetic acid and mining chemicals to customers worldwide.

3. **Sasol Infrachem,** which provides a services platform for reforming natural gas and providing utilities, infrastructure and site support at the Sasolburg complex.

(The above information has been adapted from Sasol's publication: "Sasol facts, 07 & 08". Further details can also be found on Sasol's website: www.sasol.com).

Sasol Wax will also be benchmarked externally against the ***Health and Safety Executive (HSE) of the UK,*** which are regulatory bodies that sponsors research, inspects work places, investigates accidents and ill health, enforces good standards, publishes guidance, promotes training and advices industries and governments on all aspects of health and safety legislation (http://www.hse.gov.uk).

5.1.4 The Benchmarking Method

For each of the elements explained in *table 5.1,* the HSE, in the 'Human Factors Assessment Model Validation Study' report of 2004, has defined the relative priority, in terms of weightings or value system that is associated with each element. This value system will also be adapted for this

benchmarking process because it is not ambiguous, and it makes the evaluation process less tedious with ease of analysis and inference.

Weightings

The validation model mentioned above, integrated in it a weighting scheme to reflect the relative importance of each of the element of *table 5.1*. The value system is the weightings of 1, 2 and 10 described by the HSE as follows:

- A weighting of 1 meaning that the element is a basic component of good practice in human factors. That these elements will not of themselves ensure that human factors effort delivers the expected impact, though they each make an important contribution.
- A weighting of 2 meaning that the element is of more than basic importance but is not in itself sufficient to achieve the best practice.
- A weighting of 10 meaning that the element is considered extremely important, and is an indispensable condition for achieving best practice in Human Factors.

Key HF Elements	Basis for Assessment	HSE Weighting
1. Organizational change	**1.1** The business unit recognizes that changes in its structure or job functions could affect safety negatively.	10
2. Staffing arrangements and workload	**2.1** The business unit ensures that staffing arrangement and workload do not affect safety negatively.	1
	2.2 The business unit clearly defines the expected manpower, the way it is likely to be organized and supervised, and also the allocation of roles and responsibilities and expected shift patterns.	1
3. Training and competence	**3.1** The business unit provides opportunities for its employees to acquire competences so as to perform well in their responsibilities.	2
	3.2 The business unit ensures that it s employees have adequate SHERQ training related to their work environment and areas of responsibilities	2

4. Fatigue from shift work and overtime	**4.1** The business unit recognizes the employees who at anytime may have to work overtime.	1
	4.2 The business unit considers the fact that fatigue could result from long hours of work and that such employees need some hours or time off work to rest after such long hours of work.	2
5. Ergonomic designs	**5.1** The business unit recognizes that projects and plant design need to consider the role of the human in the operation and maintenance or how the equipment or facilities impact on the operators and maintainers.	10
	5.2 The business unit recognizes the importance of a well organized work environment which has high reliability of safety to the human.	10
6. Work and Safety critical procedures	**6.1** The business unit makes available necessary safety procedures required by the employees.	1
	6.2 The business unit ensures the provision of adequate training on safety-critical procedures to its employees.	2
7. Safety culture	**7.1** The business unit recognizes that everyone must be jointly committed to safety.	10

8. Communications and interfaces	**8.1** The business unit ensures clear and accurate communication through proper channels.	1
	8.2 The business unit ensures the involvement of the employees in the day to day issues that bothers on safety and operational excellence.	2
9. Integration of human factors into risk assessment and investigations	**9.1** The business unit carries out proper investigations of incidents, putting all the factors surrounding the incident into consideration.	2
	9.2 The business unit recognizes the consideration of human factors during risk assessments, PDA's, HAZOP's, investigations, plot plan and model reviews.	10
10. Maintenance error	**10.1** The business unit ensures human safety by carrying out potential hazard analysis before maintenance work is done on any critical equipment.	10

Table 5.2: Top Human Factors Assessment and Weighting Framework.

Assessment Method

The method for carrying out the assessment involves the researcher or assessor coming to a judgment on whether the business units under consideration satisfy the basis for the assessment according to the adapted value system described and presented in *table 5.2,* using the responses from the *complimentary Questionnaire (Questionnaire2).* The calculated percentage of responses by Sasol Wax and the benchmarking partners from the complimentary Questionnaire are presented in Appendices C, D, E, and F.

For each of the elements, the author applies a **rating of 1, 2 or 3** according to the value system as follows:

1. Not satisfied (highest percentage responses being ≤ 45%):
   The researcher is confident that from the information available and basis of assessment, the element **has not** been met.

2. Unsure (highest percentage responses being 46-65%):
   The researcher is unsure or has insufficient information according to the basis of assessment to make a definite judgment one way or the other.

3. Satisfied (highest percentage responses being 66% and more):
   The researcher is confident from the information available and basis of assessment that the element **has** been met.

Calculation of the Assessment Scores

The summary score is calculated across all the 10 key HF elements of *table* 5.2. Once the researcher has formed a judgment on each element according to the basis of assessment, the ratings of each business unit is combined to produce an overall assessment score as follows:

- For each key HF element, the researcher's rating of 1, 2 or 3, is multiplied by the weighting corresponding to the basis of assessment for that particular element. For example, if the researcher is "satisfied" from the information provided by the respondents that assessment "**1.1**" under "organization change" *(table 5.2)* had been met, he would give a rating of 3. Multiplying this by the relevant weighting of 10 gives a weighted score of 30 for that particular assessment under the organization change HF element.

- The scores for each business unit are then summed across all 10 HF elements. This total figure is normalized by dividing it by 231. This number (231) is the total weighted score that would be achieved if the researcher was satisfied that all the basis of assessment under all the elements had been achieved (i.e. all were rated 3).

Interpretation of the Assessment Scores

In interpreting the scores of the assessment, the validation study by the HSE stated that the closer the score is to 100%, the better the assessment.

The validation study was quick to also point out that the aim of this evaluation method is not to simply produce scores, but for organizations to use this method to benchmark themselves against what might be considered good and best practice. It thus provided a means of interpreting ranges of the assessment scores in terms of five levels of *human factors capability* as shown in *table 5.3.*

Level	HF Assessment score	Description
5	91% or more	Best Practice.
4	76 – 90%	Good Practice achieved, towards Best Practice.
3	66 – 75%	Good Practice.
2	46 – 65%	Some elements of Good Practice achieved, but not enough to be confident that it will be applied consistently.
1	45% or less	Definitely not following Good Practice.

Table 5.3: Interpretation of HF Assessment Scores (Adapted from the HSE, 2004).

According to the HSE in the HF assessment validation report, "an important challenge has been to ensure that the assignment of scores to levels of capability is credible, meaningful and useful in terms of the conclusions drawn about the capability of the organization being assessed". This will thus reflect the fact that over the 10 key HF elements assessed, organizations or business units will inevitably be better at some than others.

The *human factors capability* levels further described by the HSE are:

Level	Title	Level description
5	Optimized	This level typifies "best practice' within the industry. There is clear organizational commitment to improving the human contribution to safety that goes beyond minimum HSE expectations. HF processes are well integrated into the way the organization does business. Monitoring of HF processes forms part of the organization's normal business practice.
4	Managed	This level typifies "good practice' within the industry. There is clear organizational commitment to improving the human contribution to safety that goes beyond minimum HSE expectations. HF processes are well integrated into the way the organization does business, but there may not be sufficient monitoring and feedback across the organization to ensure the processes are carried out to best effect.
3	Defined	Commitment to HF is sufficient to meet minimum HSE expectations. The organization does have its own procedures for ensuring effective implementation of HF processes. There are few feedback mechanisms for the improvement of HF processes across the organization.
2	Repeatable	No established policy or processes but the organization has a record of carrying out HF activity, and can repeat what it has done before, at least within projects. The organization does not plan ahead or track what has been done.
1	Initial	Consideration of the human contribution to safety is conducted in an ad hoc, unsystematic way, usually only as a response to specific incidents. In general, these organizations are only beginning to be aware of the need to consider HF

Table 5.4: The HF Capability Levels (Adapted from the HSE, 2004).

5.1.5 The Benchmarking Information

The benchmarking information based on Questionnaire2 findings from the *benchmarking partners* is shown in *table 5.5.* Sasol Wax, Sasol Solvent, and Sasol Infrachem business units achieved a *capability level* of 4 with assessment scores of 77%, 85% and 90% respectively, with Sasol Wax having the weakest score on the range having that capability level. But Sasol Technology business unit achieved a *capability level* of 5 with an assessment score of 91%.

5.1.6 Identified Performance Gaps

The performance gaps identified at Sasol Wax when compared to the 'best practice' and 'good practice achieved' from the assessment presented in *table* 5.5 are in:

- Organizational change
- Staffing arrangements
- Fatigue from shift work
- Ergonomic designs
- Communication
- Work procedures.

Table 5.5: The Benchmarking Information

Key HF Element		Basis for Assessment	*Weight*	Sasol Wax		Sasol Technology		Sasol Solvent		Sasol Infrachem		Max Possible Score
				Rating	Score	Rating	Score	Rating	Score	Rating	Score	
1.	Organizational change	1.1	10	2	20	3	30	2	20	3	30	30
2.	Staffing arrangements	2.1	1	2	2	3	3	3	3	3	3	3
		2.2	1	1	1	2	2	2	2	1	1	3
3.	Training and Competence	3.1	2	3	6	3	6	3	6	3	6	6
		3.2	2	3	6	3	6	3	6	3	6	6
4.	Fatigue from shift work and overtime	4.1	1	1	1	1	1	1	1	1	1	3
		4.2	2	3	6	3	6	2	4	3	6	6
5.	Ergonomic designs	5.1	10	1	10	3	30	2	20	2	20	30
		5.2	10	2	20	3	30	3	30	3	30	30
6.	Work and Safety Critical Procedures	6.1	1	1	1	1	1	1	1	1	1	3
		6.2	2	3	6	3	6	3	6	3	6	6
7.	Safety culture	7.1	10	3	30	3	30	3	30	3	30	30
8.	Communication and Interfaces	8.1	1	2	2	2	2	2	2	2	2	3
		8.2	2	1	2	1	2	2	4	1	2	6
9.	Integration of human Factors into Risk Assessment and Investigations	9.1	2	2	4	2	4	1	2	2	4	6
		9.2	10	3	30	3	30	3	30	3	30	30
10.	Maintenance error	10.1	10	3	30	2	20	3	30	3	30	30

Total			177	209	197	208	231
HF Assessment Score (=Total/231)%			77	91	85	90	

5.1.7 Presentation of the Benchmarking results

The analysis of the results obtained from the above HF assessment and performance gaps identified will be organized into four parts:

- A brief summary of each business unit
- Discussion of issues which were common among the four business units
- Lessons learned and applicable human factors framework
- Application of human factors to a new project (a Case study).

5.1.7.1 Overview of each Business Unit

In all four business units and in compliance with good human factors, health and safety management, Sasol's organization health and safety strategy is its commitment to eliminating all incidents and work to world class safety standards. And as such, Sasol recognizes that all accidents can be prevented and consider safety as the first priority in planning any task (Pat Davies-Sasol CEO, 2005).

Sasol Wax

The review of Sasol Wax is based on some documents accessed on Sasol's website, the researcher's experiences while working at Sasol Wax as well as the information from the respondents. Clarification of some of the materials and information was possible through brief discussions with some of the unit's employees and safety managers.

Sasol Wax as a business unit is clearly aware of the need to take account of human factors issues and safety during organizational changes such as business re-engineering, transition management, staffing, downsizing, empowerment, multiskilling, outsourcing or contractorisation. There was how ever little indication from the sources of information that when these or similar changes are carried out, that safety in terms of human factors are adequately considered.

At the background, this business unit has a fair understanding of what human factor is. This is evident in some safety guidelines in *root cause analysis techniques* for accident/incident investigation being followed, PDAs', HAZOPs being carried out, SHERQ trainings, safety plans, programs and procedures being developed as well as safety awareness being given to employees. Although the human capability in carrying out tasks is often not addressed.

From the researcher's evaluation, the drive at Sasol Wax appears to be 'production', with less consideration to how facility sites, equipment or layout affect humans. Hazards are also well identified and the selection and designing of procedures is good but workers are either not well communicated to about the procedures related to their areas of responsibilities or some simply do not know where to find them; and as such may not always follow procedures which will assist human reliability.

In summary, the importance of human factors issues and practice is recognized by Sasol Wax. From the HF assessment, Sasol Wax achieved a score of 77% (see table 5.5). This represents a level 4 capability. There were elements of good HF processes being well integrated into the way the business unit does its business, but there may not be sufficient monitoring and feedback in every business area to ensure the processes are carried out to best effect. And as such it still has to work towards best practice.

Sasol Technology

The review of Sasol Technology is based on some documents accessed on Sasol's website and the information from the respondents. This was followed up by some discussions with some of the unit's employees.

Sasol Technology as a business unit has a reasonably mature awareness of the need to integrate human factors into design, development and operations. Although the unit is the part of the organization which handles risk and environmental engineering as well as occupational health and safety issues in partnership with SHERQ departments in other business units, there is no evidence

of having Human Factors Specialists. The health, safety and environmental officers and engineers appear to be responsible for issues of safety.

Nevertheless, information available to the researcher shows that human factors activities at Sasol Technology can be regarded as 'best practice' even though a senior employee of the business unit pointed out that the way humans will perceive or react too issues in the work environment may not be adequately represented during design. But that it aspires to control the resulting risks through design of fail-safe systems where possible.

From the HF assessment, Sasol Technology achieved a score of 91% (see table 5.5). This represents a level 5 capability. This level typifies 'best practice' within the industry and HF processes are well integrated into the activities of this business unit.

Sasol Solvent

The review of Sasol Solvent is based on some documents accessed on Sasol's website and the information from the respondents. This was followed up by some discussions with some of the unit's employees as with Sasol Technology.

Although no explicit reference to human factors was made, there was evidence from the information gathered by the researcher which indicates that Sasol Solvent recognizes the contribution of humans to safety in all its business activities.

The business unit makes attempt at managing changes as well as health, safety or environmental concerns with consideration to human-related issues. Although it has got some few drawbacks in facility layout, and like the other business units, in the area of mental fatigue or stress which could increase the risk of incident occurrences.

Nevertheless, information available to the author shows that human factors activities at Sasol Solvent can be regarded as 'best practice' even though an employee of the business unit pointed

out that the way humans will perceive or react too issues in the work environment may not be adequately represented during design.

From the HF assessment, Sasol Solvent achieved a score of 85% (see table 5.5). This represents a level 4 capability as with Sasol Wax, but Sasol Solvent is higher up the range of 'good practices' achieved towards best practices. In addition to the good HF processes and elements of good practice by Sasol Solvent, there is also greater commitment to improving the human contribution to safety.

Sasol Infrachem

The review of Sasol Infrachem is based on some documents accessed on Sasol's website and the information from the respondents. This was followed up by some discussions with some of the unit's employees as with Sasol Technology and Sasol Solvent.

Information available to the researcher indicates that Sasol Infrachem recognizes the human contribution to safety in all areas of its business unit and has got a reasonably mature awareness about human factors integration like Sasol Technology, but with no explicit reference to human factors too.

Although ergonomics in terms of facility layout is a little bit of an issue at this business unit, which appears to be peculiar in the organization, Sasol Solvent still passes for a high level of 'good practices' with a HF assessment score of 90% (see table 5.5). This is also a level 4 capability with good HF processes in place and elements of good practice achieved towards best practice.

5.1.7.2 Observation

To some extent, the following observations were common among the four business units reviewed.

Training and Competence

The business units recognize the importance of training and as such provide opportunities to their employees to attend training and development courses, and to also acquire competences in their areas of responsibilities.

Safety Culture and Values

Observation by the researcher as regards this show that all four business units have virtually all categories of their workers being committed to safety. The workers recognize that all accidents/incidents can be prevented and also consider safety as the first priority in planning any task. And that everyone, individually and collectively in teams are all accountable for their own safety and the safety of others around them.

Hazard Identification Process

All the business units adopt formal hazard and operability studies (HAZOP) processes. Although this is designed to be carried out when a design is essentially complete, potential deviation analysis (PDA) is being adapted from this so that problems that were not catered for in the design stage can be appropriately addressed in the operational stage. These hazard identification processes have the intent of human factors recognition in them.

Risk Assessment

The business units carry out risk assessments in the workplace on existing operational activities in compliance with occupational health and safety regulations. This represents the likelihood of the occurrence of incidents in inherent hazard areas.

5.1.7.3 Lessons Learned and the Human Factors Framework

Considering the above observations that cut across the four business units, all reportable incidents can be assumed to be investigated. Results are expected to be used to improve human factors awareness, trainings, and procedures and where necessary to implement fail-safe facilities that is less dependent on human reliability.

The results of safety sessions and reviews, as well as experiences from the work environment, and lessons learnt from maintenance and production operations are rich and valuable sources of information for preventing incidents to humans and equipment, as well as in general health ,safety and environmental issues if well implemented.

From the information available to the researcher from these evaluations, there appears to be a significant opportunity to further improve on human factors management and integration in Sasol Wax in the areas of organizational change, staffing arrangements, shift work, ergonomics, communication and work procedures.

The human factors framework was based on Reason's 'Swiss Cheese' model of accident causation described in section 3.3 of chapter three of this study. Reason, a prominent British psychologist showed in the Swiss cheese model how a trajectory or trail of hazard or accident opportunity can penetrate through several types of defensive system and result in losses or adverse events.

Reason, made a distinction between *latent failures* and *active failures* in the model. The latent failures are expressed as pre-conditions for 'unsafe acts' while the active failures are expressed in the 'unsafe acts'. These latent failures may lie dormant within the system for a long time waiting for active failures by the frontline operator to trigger the latent failures which may result in incidents.

Latent failures are revealed in organizational changes, staffing arrangements and workload, training and supervision, design, procedures, organizational culture and development, communications, safety management systems; while active failures could show up in the direct

failures by operators due to individual characteristics of competence, fatigue, maintenance errors and mistakes which according to Reason are often influenced by the latent failures.

The human factors framework is outlined as: Management Systems, People Characteristics, Culture/Working Environment and Facilities/Equipment and is represented in the relationship shown in figure 5.1.

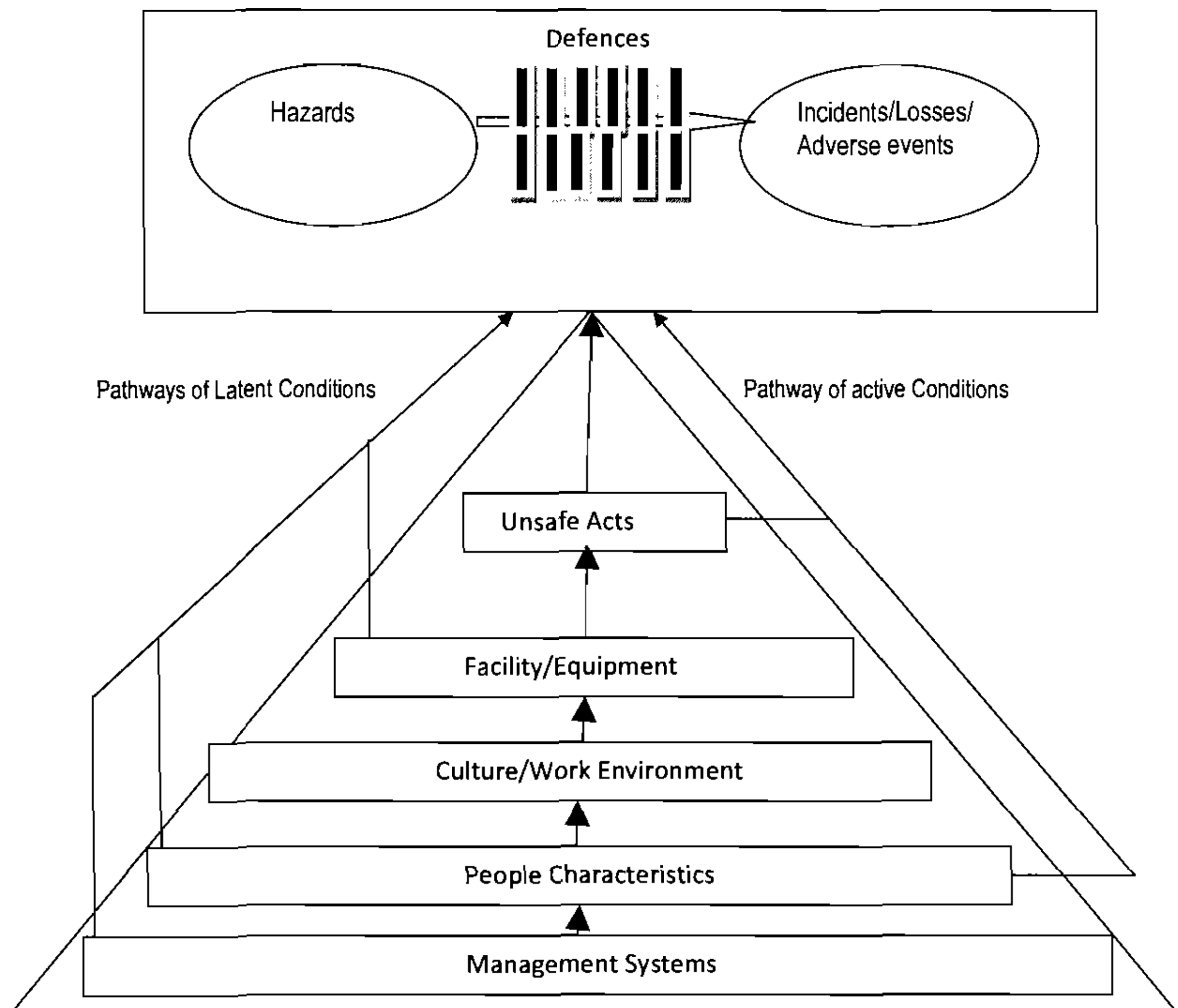

Figure 5.1: A framework outline of Human Factors.

The system shown in Figure 5.1 allows us to identify and examine a wide range of latent and active failures that contribute to incidents at Sasol Wax and in similar safety-critical or high-hazard

industries. The components of the system have been extensively discussed in chapter two of this study and further analyzed in chapter five in terms of their consequences and weights.

In brief, the upper part of Figure 5.1 shows the failure events such as the hazards, defences (safety barriers or controls), and the incidents. The lower part of Figure 5.1 shows the pre-conditions or developments from management systems which influence the culture/working environment and facility/equipment, and then combine with natural human tendencies to produce unsafe acts. From the Swiss cheese model, these unsafe acts may create holes in the defences, and then incidents become inevitable.

Figure 5.1 may not really portray the way the various human factors components interact with one another, but changes in any part of the system surely affects other parts. When all the components of the overall system are functioning well together, they collectively serve as a set of barriers or defences to prevent incidents. But when weaknesses exist within the components of the different parts of the system, and they align, it then results to adverse events or incidents.

However, it is apparent that if steps are taken in each element of the system, the overall chance of incidents will be greatly reduced. Organizational planning can lessen the latent failures at the management level, psychological failings can be minimized by planning and paying attention to the task that are required of workers in the work environment and unsafe acts can be reduced by a good quality interface design.

Although the Swiss cheese model was originally developed for accident investigation and has been widely adapted in the military and aviation sectors, it also finds application in the chemical industry, and can also be used as a predictive and management tool (Martin Sconbeck, 2007).

5.1.7.4 Application of Human Factors to a new project (a Case study)

The case study presented here is derived from the International Association of Oil and Gas Produces bulleting, 2007.

The owners of a large-scale onshore and off-shore development agreed to incorporate human factors engineering (HFE) into the base design and philosophy of a new operation.

Action

With senior management endorsement, HFE professionals helped to produce a human factors programme based on seven key principles.

1) Involve HFE early in the project
2) Assign an HFE champion
3) Locate capability in engineering departments
4) Base programme on accepted HFE design standards
5) Involve an HSE professional in appropriate tasks
6) Design facilities either to eliminate or minimize human error and to mitigate errors that may occur
7) Extend influence of HFE beyond facility design

Implementation

With the approval of an "HFE champion", work instructions outlining HFE expectations were issued to project staff. Technical staff training started immediately. HFE professionals were included as part of the engineering team.

Impact

Component rearrangements (relocation of heat exchangers, orientation and elevation of large components, deluge pipe simplification) comprised the majority of HFE changes. Because these rearrangements were incorporated early in the design process, their cost was minimal.

Human factors also influenced procedures development, training, labeling and signage to enable efficient and effective training. The HFE programme introduced a number of standardized designs for the project, including a ladder design specifically covered by one of the HFE guides.

Results

Project HFE costs reflect personal charges only. HFE driven design changes were considered design development. The original estimated cost for the HFE programme was 0.07 percent of the facilities budget. The actual HFE cost for this project was approximately half of the estimate."

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

The 'Human factors' subject as described in this research is a term which covers:

- The understanding of human capabilities.
- Application of this understanding into design and development of systems, processes, products and work environments.
- Good integration of the human factors programs.

In chapter one, a background introduction to the research was presented alongside the problem statement of the research. The specific aims of the research, the benefits, as well as the scope of the research were all presented.

Relevant literature review about the human factor subject was carried out in chapter two of this dissertation. The researcher presented a detailed review of the essentials of human error, the major categories of human factors and their elements, and also health and safety regulations guiding human factors issues in the chemical industry. As case studies, some major incidents which have occurred in the chemical industry as well as incidents specific to Sasol Wax were also reviewed.

Chapter three introduced the meaning of hazards, hazards peculiar to Sasol Wax and similar high-hazard industries, and their identification methods. The human involvement which eventually turns hazards into incidents and the relevance of the Swiss cheese model to the research area was also reviewed. This chapter also documents the empirical investigation. The research instrument, the research community, the design and validations of the Questionnaires, as well as the sampling size and process were presented.

Documented in chapter four are the findings and results from **Questionnaire1** and interviews/discussions carried out at Sasol Wax. Tabulations and charts were also used in illustrating the findings.

Chapter five illustrates the top human factors issues affecting safety-critical or high hazard industries, the benchmarking process, the benchmarking partners, and the findings from **Questionnaire2** given to the benchmarking partners with respect to the top human factors issues. The results of the findings were evaluated using the HSE's human factors framework, and were also weighted by using its value system.

Summaries of the previous chapters are made in chapter six. The overall conclusions are presented, and then recommendations are made for improvements and for further work in this research area.

6.2 Conclusions

This research was aimed at identifying the human factors which contribute the most to incidents at Sasol Wax, and also finding best principles and practices in the industry in human factors integration and management, which could enhance human performance and optimize safety.

The following conclusions can be drawn from this research:

1. Conclusions on the problem statement (*refer to section 1.2)*

Based on this research and from the findings and analysis presented in chapter four, human factors were involved in a significant proportion of the incident causes at Sasol Wax. This was due to less attention being given to human factors integration and management.

In addition, the four human factor major categories of *culture/working environment, management systems, people characteristics and facilities/equipment* all have influences on incidents at Sasol Wax.

2. Conclusions on the aims and objectives *(refer to section 1.3)*

The incidents reviewed at Sasol Wax by the researcher also showed that active failures by operators and maintainers trigger the incidents which more often than not, are due to latent errors *(refer to sections 2.4 & 2.6)*, and as a result, there were more human errors than technical failures.

3. Conclusions on the outcomes and deliverables *(refer to section 1.4)*

- The researcher presented a comprehensive explanation of human factors, their major categories and elements in chapter two of this dissertation. The Questionnaires developed were based on the human factors definitions and categorizations, and the validations and responses from the research community demonstrated a comprehensive knowledge and understanding of the human factors subject presented by the researcher *(refer to section 3.5.4)*. However, knowledge without its appropriate application may not give the expected results.

- A framework outline was developed as shown in figure 5.1 which presented the hierarchy of human factors issues at Sasol Wax. **Management Systems** ranked the major factor with the highest influence on error events *(also refer to section 4.5)*.

- The findings from the benchmarking process indicated that the performance gaps that exist in Sasol Wax are in the areas of organizational change, staffing arrangements, shift work, ergonomics, communication and work procedures.

Going further, safety in complex and safety-critical chemical work environment like Sasol Wax can be optimized by accounting for a wide range of human factors that impact on human performance directly and indirectly. The application of human factors knowledge about human strengths and limitations to the design and development of systems and work environment can have positive impact on the overall business operations of an organization.

In summary, human factors consideration and integration,

- Takes a wide range approach to safety and examines the whole workplace.
- Looks at the organization and management, tasks, responsibilities, procedures, communication system, workplace design, and the workforce.
- Does not just blame the worker and try to modify worker behavior.
- Understands that anyone in the system can contribute to human error or failure either directly or indirectly, including designers and managers.
- Recognizes that people will make mistakes and as such works to eliminate situations with likelihood of errors or failures.
- Aims to match plant, processes and procedures to human capabilities and limitations through effective training programs.
- Looks positively at physical, mental and behavioral issues like stress, fatigue and motivation.

In addition, human factors also try to:

- Allow for differences which occur among people.
- Remove potential or opportunities for errors or failures.
- Reduce the impact of failures even when they occur.
- Design "fail-safe" work systems into the operation.
- Match the job to the worker and not the worker to the job.

This study has thus added to the pool of evidence supporting the claim that humans account for more than 90% of incidents in the chemical industry with management systems being the lead factor rather than the blame of frontline operators and maintainers; and that human factors awareness, consideration and integration into the overall business activities in the chemical industry will further improve human performance, optimize safety and reduce incidents occurrences.

6.3 Recommendations

To achieve a step change in zero incidents at Sasol Wax and similar chemical business organizations and based on the conclusions arrived at from the research, the following principles and practices are recommended:

1. Promoting the awareness of human factor issues and their impact on the potential safety and efficiency in a chemical industry work environment through human factor programs. Such programs should be behavior-based safety programs which will focus more on proactively reinforcing the behavior necessary to complete a task safely, rather than accident-prevention programs which focus on determining the reasons for accidents that have already occurred. In the long run, the safe behavior becomes a habit, and then a lifestyle.

2. Seeking the opinions of your workforce and health and safety representatives, as well as the consciousness of the fact that the behavior of people in your organization will be affected by its culture and expectations, and the design of the work systems they are part of i.e. the management approach, the equipment, environment, reward systems (e.g. pay) etc, are important parts of the human factors process which should be done in order to identify issues and find workable solutions.

3. The goal of human factors engineering is to maximize the ability of an individual to operate and maintain a system or process at the required levels by eliminating design-induced difficulty and failures. And as such, a human factors engineer or specialist and possibly a human factors group who would work together with the health and safety representatives is recommended to be employed or engaged in the business units evaluated in this research as well as in similar chemical industries which do not have.

   The roles, effectiveness and impact of a human factors engineer or specialist in defining how current and future process operations will integrate people and technology in order to maximize human and plant safety as well as productivity, cannot be effectively handled by the health, safety and environment officers alone.

4. Building human factors into management systems, practices and standards through:

    - **Safety reviews:** this involves a continuous program of evaluating the safety and operability of sites and equipment through audits, checklists and possibly questionnaires which could be used to gather data on how process safety and plant operability can be improved.

    - **Operating instructions:** this entails writing or documenting site guidance on operating instructions that has human factors consideration such as layout, accessibility, readability, and usability.

    - **Investigations with terms of reference:** this is the inclusion in the terms of reference for investigations on incidents the need for specific consideration of the relevant human factor causes particularly latent factors.

5. In the management of human factors, every aspect of the work system in terms of the job, work environment, the organization and the individual aspects and how they all contribute to the likelihood of failures, losses or adverse events, need to be considered.

    High hazard industries must begin by addressing human factors in relevant activities such as risk assessments, incident investigations, specifications, designs and procurements, and in relevant areas of day-to-day business activities such as health and safety culture, shift work, overtime etc.

6. Closing the performance gaps between "good practices" and "best practices" in the human factor issues such as:

    - **Organizational change:** this should be planned in a thorough and systematic way, and the direct or indirect effects of any proposed change on the control of hazards should be properly identified and assessed. It is also necessary to carry employees along during and after any change.

- **Staffing arrangements:** too much strain should not be placed on staffs in such a way that safety is compromised. Staffs should also be carried along with technology changes in terms of effective trainings.

- **Fatigue:** it is the employer's legal duty to manage risks from fatigue whether or not any employee is willing to work extra hours or prefers a particular shift pattern for personal or social reasons. A good practice on shift roster design takes account of shift types, length, period and social concerns.

- **Ergonomics:** designs and facility layouts should be evaluated against the requirements of the users. This can be done by involving target users and human factor specialists.

- **Communication:** a very important area of communication in the chemical industry work environment is shift handover. This should be made a priority, with proper procedures in place. Employees' communication skills should also be developed.

- **Work procedures:** these are agreed and documented ways of doing things safely. Work procedures should be made available to workers, and compliance with procedures should be encouraged through user participation. The workers should also be trained on the procedures.

In summary, "*applying good human factors early on is much more effective than trying to do so at the end, especially when designing new systems*" (HSE, 2002).

According to the HSE, "human factors consideration is not 'common sense', and it is not a stand-alone activity. Best practice is achieved when human factors are integrated into the entire lifecycle of the chemical industry projects or processes i.e. from conceptualization to full development to delivery and to operation".

6.4 Suggestions for further study

Suggested areas for further research are:

- Development of functional models which specifically address the management of human factors in the chemical industry.
- Investigation into impact of contractorisation or temporary employment on chemical industry safety from the human factors perspective.

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APPENDIX A

QUESTIONNAIRE1:

THE CONTRIBUTION OF HUMAN FACTORS TO WORK-RELATED INCIDENCES AT SASOL WAX

Brief Introduction:

Human factors include environmental, organizational and job factors, as well as human and individual characteristics that influence behavior at work in a way which can affect health and safety.

This Questionnaire is an academic survey to determine the major human factor issues which initiates human errors and which eventually leads to work-related incidents in the chemical industry. Sasol Wax will be used as a case study. The aim is to optimize human performance and reduce human failures with resultant decrease in work-related incidences.

Please tick the appropriate boxes and fill in the blank spaces where applicable.

Kindly note that your name or signature is **not** required on this Questionnaire.

PART 1: RESPONDENT'S INFORMATION

Gender: ☐ Male ☐ Female

Age: ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ Over 45

Employment type: ☐ Permanent ☐ Contractor/Service Provider

Work Area:
- ☐ Production operations
- ☐ Maintenance (Electrical, Mechanical, Instrumentation, etc.)
- ☐ Planning
- ☐ Safety
- ☐ Engineering & Design
- ☐ Managerial
- ☐ Others, *Please specify* ....

PART 2: HUMAN FACTORS BACKGROUND

1. Do you understand the subject of human factors and how it contributes to incidents in the chemical industry?

   Yes No To some extent

2. Do you know that more than 90% of incidents in the chemical industry are caused by human failure either directly or indirectly?

   Yes No To some extent

3. Do you have a Human Factors Engineer (HFE) or Human Factors Specialist in the department or section where you are currently working?

   Yes No I don't know Not Applicable

4. Do you agree that failed designs, organization culture, work environment, management failure and individual characteristics all play a role in initiating incidents in the chemical industry?

   Yes No To some extent

5. Do you think much consideration is given to human factors issues in the organization where you work now?

   Yes No To some extent

6. Do you think if human factors consideration is integrated into your organizational activities that there will be improvement in the safety record and reduction in incidents occurrences?

   Yes No To some extent

PART 3: WORKING CONDITIONS, HEALTH AND WELL BEING

1. Do you feel motivated and involved in your work?

   To a very large extent To a large extent Somewhat

   To a small extent To a very small extent

2. Do you receive all the information you need in order to do your work well?

   To a very large extent To a large extent Somewhat

   To a small extent To a very small extent

3. Is high priority given to further training of personnel, job satisfaction, work planning and good allocation of work in your department or organization?

   To a very large extent   To a large extent   Somewhat   To a small extent   To a very small extent

4. Are you pleased with your work prospects in your current organization?

   Very satisfied   Satisfied   Unsatisfied   Not relevant

5. Are you pleased with the physical working conditions of your current organization?

   Very satisfied   Satisfied   Unsatisfied   Not relevant

6. Are you pleased with your usual take home pay?

   Very satisfied   Satisfied   Unsatisfied   Not relevant

7. Are there enough employees at your place of work to get the job done?

   Much too many employees   Slightly too many employees   Just right
   Slightly too few employees   Much too few employees

PART 4: HUMAN FACTORS CATEGORIES

Please rate the following major categories of human factors according to their importance and how they contribute to human failure incidents at Sasol Wax.

	Least Important	Important	Moderately Important	Highly Important	Extremely Important
Culture/working Environment					
Management Systems					
People characteristics					
Facilities/Equipment					

PART 5: HUMAN FACTORS ELEMENTS

How would you rate the influence of the following elements of human factors with respect to the occurrence of incidents at Sasol Wax?

	Least Important	Important	Moderately Important	Highly Important	Extremely Important
CULTURE/WORKING ENVIRONMENT					
Social and community values					
Communication flow within an organization					
Organizational changes					
Language					
Geography					
Climate					
Management support of safety values					
Safety culture and policy					
ORGANIZATION/ MANAGEMENT SYSTEMS					
Quality of operating procedures					
Job safety analysis					
Staffing arrangements					
Clear interfaces between human and systems					
Labels and Signs					
Documentation					
Clear responsibilities and accountability					
Risk investigation and management					
Safe and quality work practices					
Leadership style and supervision					
Management's corporate goals					
PEOPLE CHARACTERISTICS					
Stress and Fatigue					
Training and competence					
Workload					
Shift work and overtime					
Safety behavior					

Motivation					
Skills and knowledge					
Literacy/Education					
Personal protective equipment					
Manual handling					
Physical and mental fitness for duty					
FACILITIES/EQUIPMENT					
Ergonomics					
Design of controls					
Field control panels and displays					
Maintenance and Reliability					
Physical layout of facilities and Sites					
Accessibility					
Noise					
Vibration					
Lighting					
Toxics					
Radiation					
Temperatures					
Tools					

Please give you personal comments about the Questionnaire: ....

....

....*Thank you.*

APPENDIX B

QUESTIONNAIRE2

BENCHMARKING THE MANAGEMENT OF HUMAN FACTORS IN SASOL BUSINESS UNITS.

Brief Introduction:

The human factors issue in the chemical industry is an interaction between *culture/work environment, management systems, people characteristics and facility/equipment.*

This Questionnaire is an academic survey to determine how human factor issues are assessed and managed in your business unit of Sasol to achieve an incident-free work environment.

Please answer questions by ticking the appropriate boxes.

Kindly note that your name or signature is **not** required on this Questionnaire.

1: Organizational changes

- Does your business unit make changes in its structure or job functions that could affect safety negatively?

  Yes   No   Not sure

- If the above answer is Yes, please specify any of such changes ....

2: Staffing arrangements

- Does the staffing arrangement and workload in your business unit affect safety negatively?

  Yes   No   Not sure

- Do you feel that the number of employees in your section, department or business unit is adequate?

  Yes   No   Not sure

3: Training and Competence

- Are the employees in your business unit performing well in their responsibilities?

  Yes   No   Not sure

- Do the employees in your business unit have adequate SHERQ training related to their work environment and areas of responsibilities?

  Yes   No   Not sure

4: Fatigue from shift work and overtime

- Do you or other employees in your business unit work beyond the maximum overtime hours?

  ☐ Yes ☐ No ☐ Sometimes

- Are you or other employees given time off work to rest after such long hours of work?

  ☐ Yes ☐ No ☐ Sometimes

5: Ergonomic Designs

- Do you think human factor consideration is integrated into plant design?

  ☐ Yes ☐ No ☐ Not sure

- Does the layout of your plant or work environment make it difficult to do your work?

  ☐ Yes ☐ No ☐ Not sure

6: Work and Safety Critical Procedures

- Do you think the employees in your business unit follow procedures when performing tasks?

  ☐ Always ☐ Most of the time ☐ Sometimes ☐ Never

- Are you trained on documented safety-critical procedures in your work area?

  ☐ Yes ☐ No ☐ Not sure

7: Safety Culture

- Who do you think is more committed to safety in your business unit, managers or workers?

  ☐ Managers ☐ Workers ☐ Both Managers and Workers

8: Communications and Interfaces

- Is the information you need to work safely communicated to you clearly and accurately?

  ☐ Always ☐ Most of the time ☐ Sometimes ☐ Never

- How often do employees of your business unit have scheduled communication and feedback sessions?

  ☐ Always ☐ Most of the time ☐ Sometimes ☐ Never

9: Integration of human factors into risk assessment and Investigations

- Is the employee who is directly involved in an incident always held responsible?

  ☐ Yes ☐ No ☐ Not sure

- Are human factors considered during risk assessments, PDA's, HAZOP's, investigations, plot plan and model reviews?

  Yes No Not sure

10: Maintenance Error

- Do you think potential hazard analysis is always carried out before maintenance work is done on critical equipment?

  Yes No Not sure

Please give your comments:

....

....

.... *Thank you.*

APPENDIX C

SASOL WAX QUESTIONNAIRE2 RESPONSES

QUESTIONNAIRE

BENCHMARKING THE MANAGEMENT OF HUMAN FACTORS IN SASOL BUSINESS UNITS.

Brief Introduction:

The human factors issue in the chemical industry is an interaction between *culture/work environment, management systems, people characteristics and facility/equipment.*

This Questionnaire is an academic survey to determine how human factor issues are assessed and managed in your business unit of Sasol to achieve an incident-free work environment.

Please answer questions by ticking the appropriate boxes.

Kindly note that your name or signature is **not** required on this Questionnaire.

1: Organizational changes

- Does your business unit make changes in its structure or job functions that could affect safety negatively?
  Yes, (17.9%) No, (64.2%) Not sure, (17.9%)
- If the above answer is Yes, please specify any of such changes ....

2: Staffing arrangements

- Does the staffing arrangement and workload in your business unit affect safety negatively?
  Yes, (39.2%) No, (42.9%) Not sure, (17.9%)
- Do you feel that the number of employees in your section, department or business unit is adequate?
  Yes, (32.1%) No, (64.3%) Not sure, (3.6%)

3: Training and Competence

- Are the employees in your business unit performing well in their responsibilities?
  Yes, (82.1%) No, (10.7%) Not sure, (7.2%)

- Do the employees in your business unit have adequate SHERQ training related to their work environment and areas of responsibilities?

  Yes, (78.6%) No, (14.3%) Not sure, (7.1%)

4: Fatigue from shift work and overtime

- Do you or other employees in your business unit work beyond the maximum overtime hours?

  Yes, (42.9%) No, (17.9%) Sometimes, (39.2%)

- Are you or other employees given time off work to rest after such long hours of work?

  Yes, (71.4%) No, (0%) Sometimes, (28.6%)

5: Ergonomic Designs

- Do you think human factor consideration is integrated into plant design?

  Yes, (42.9%) No, (39.2%) Not sure, (17.9%)

- Does the layout of your plant or work environment make it difficult to do your work?

  Yes, (35.7%) No, (53.6%) Not sure, (10.7%)

6: Work and Safety Critical Procedures

- Do you think the employees in your business unit follow procedures when performing tasks?

  Always, (25%) Most of the time, (67.9%) Sometimes, (7.1%) Never, (0%)

- Are you trained on documented safety-critical procedures in your work area?

  Yes, (75%) No, (14.3%) Not sure, (10.7%)

7: Safety Culture

- Who do you think is more committed to safety in your business unit, managers or workers?

  Managers, (10.7%) Workers, (10.7%) Both Managers and Workers, (78.6%)

8: Communications and Interfaces

- Is the information you need to work safely communicated to you clearly and accurately?

  Always, (50%) Most of the time, (35.7%) Sometimes, (14.3%) Never, (0%)

- How often do employees of your business unit have scheduled communication and feedback sessions?

  Always, (32.1%) Most of the time, (32.1%) Sometimes, (32.1%) Never, (3.7%)

9: Integration of human factors into risk assessment and Investigations

- Is the employee who is directly involved in an incident always held responsible?

  ☐ Yes, (17.9%) ☐ No, (50%) ☐ Not sure, (32.1%)

- Are human factors considered during risk assessments, PDA's, HAZOP's, investigations, plot plan and model reviews?

  ☐ Yes, (71.4%) ☐ No, (14.3%) ☐ Not sure, (14.3%)

10: Maintenance Error

- Do you think potential hazard analysis is always carried out before maintenance work is done on critical equipment?

  ☐ Yes, (75%) ☐ No, (14.3%) ☐ Not sure, (10.7%)

Please give your comments:

....

....

....*Thank you.*

APPENDIX D

SASOL TECHNOLOGY QUESTIONNAIRE2 RESPONSES

QUESTIONNAIRE

BENCHMARKING THE MANAGEMENT OF HUMAN FACTORS IN SASOL BUSINESS UNITS.

Brief Introduction:

The human factors issue in the chemical industry is an interaction between *culture/work environment, management systems, people characteristics and facility/equipment.*

This Questionnaire is an academic survey to determine how human factor issues are assessed and managed in your business unit of Sasol to achieve an incident-free work environment.

Please answer questions by ticking the appropriate boxes.

Kindly note that your name or signature is **not** required on this Questionnaire.

1: Organizational changes

- Does your business unit make changes in its structure or job functions that could affect safety negatively?

  Yes, (11.1%) No, (77.8%) Not sure, (11.1%)

  If the above answer is Yes, please specify any of such changes ....

2: Staffing arrangements

- Does the staffing arrangement and workload in your business unit affect safety negatively?

  Yes, (22.2%) No, (70.4%) Not sure, (7.4%)

- Do you feel that the number of employees in your section, department or business unit is adequate?

  Yes, (48.2%) No, (33.3%) Not sure, (18.5%)

3: Training and Competence

- Are the employees in your business unit performing well in their responsibilities?

  Yes, (74.1%) No, (11.1%) Not sure, (14.8%)

- Do the employees in your business unit have adequate SHERQ training related to their work environment and areas of responsibilities?

  Yes, (77.8%) No, (18.5%) Not sure, (3.7%)

4: Fatigue from shift work and overtime

- Do you or other employees in your business unit work beyond the maximum overtime hours?

  Yes, (11.1%) No, (59.3%) Sometimes, (29.6%)

- Are you or other employees given time off work to rest after such long hours of work?

  Yes, (66.7%) No, (18.5%) Sometimes, (14.8%)

5: Ergonomic Designs

- Do you think human factor consideration is integrated into plant design?

  Yes, (70.4%) No, (11.1%) Not sure, (18.5%)

- Does the layout of your plant or work environment make it difficult to do your work?

  Yes, (25.9%) No, (66.7%) Not sure, (7.4%)

6: Work and Safety Critical Procedures

- Do you think the employees in your business unit follow procedures when performing tasks?

  Always, (25.9%) Most of the time, (66.7%) Sometimes, (7.4%) Never, (0%)

- Are you trained on documented safety-critical procedures in your work area?

  Yes, (74.1%) No, (18.5%) Not sure, (7.4%)

7: Safety Culture

- Who do you think is more committed to safety in your business unit, managers or workers?

  Managers, (18.5%) Workers, (14.8%) Both Managers and Workers, (66.7%)

8: Communications and Interfaces

- Is the information you need to work safely communicated to you clearly and accurately?

  Always, (51.9%) Most of the time, (40.7%) Sometimes, (7.4%) Never, (0%)

- How often do employees of your business unit have scheduled communication and feedback sessions?

  Always, (18.5%) Most of the time, (63%) Sometimes, (18.5%) Never, (0%)

9: Integration of human factors into risk assessment and Investigations

- Is the employee who is directly involved in an incident always held responsible?

  Yes, (18.5%) No, (51.9%) Not sure, (29.6%)

- Are human factors considered during risk assessments, PDA's, HAZOP's, investigations, plot plan and model reviews?

  Yes, (88.9%) No, (3.7%) Not sure, (7.4%)

10: Maintenance Error

- Do you think potential hazard analysis is always carried out before maintenance work is done on critical equipment?

  Yes, (59.3%) No, (33.3%) Not sure, (7.4%)

Please give your comments:

....

....

....*Thank you.*

APPENDIX E

SASOL SOLVENT QUESTIONNAIRE2 RESPONSES

BENCHMARKING THE MANAGEMENT OF HUMAN FACTORS IN SASOL BUSINESS UNITS.

Brief Introduction:

The human factors issue in the chemical industry is an interaction between *culture/work environment, management systems, people characteristics and facility/equipment.*

This Questionnaire is an academic survey to determine how human factor issues are assessed and managed in your business unit of Sasol to achieve an incident-free work environment.

Please answer questions by ticking the appropriate boxes.

Kindly note that your name or signature is **not** required on this Questionnaire.

1: Organizational changes

- Does your business unit make changes in its structure or job functions that could affect safety negatively?

  Yes, (19%) No, (62%) Not sure, (19%)

  If the above answer is Yes, please specify any of such changes ....

2: Staffing arrangements

- Does the staffing arrangement and workload in your business unit affect safety negatively?

  Yes, (19%) No, (66.7%) Not sure, (14.3%)

- Do you feel that the number of employees in your section, department or business unit is adequate?

  Yes, (62%) No, (19%) Not sure, (19%)

3: Training and Competence

- Are the employees in your business unit performing well in their responsibilities?

  Yes, (71.5%) No, (19%) Not sure, (9.5%)

- Do the employees in your business unit have adequate SHERQ training related to their work environment and areas of responsibilities?

  Yes, (66.7%) No, (14.3%) Not sure, (19%)

4: Fatigue from shift work and overtime

- Do you or other employees in your business unit work beyond the maximum overtime hours?
  Yes, (23.8%) No, (38.1%) Sometimes, (38.1%)

- Are you or other employees given time off work to rest after such long hours of work?
  Yes, (52.4%) No, (23.8%) Sometimes, (23.8%)

5: Ergonomic Designs

- Do you think human factor consideration is integrated into plant design?
  Yes, (61.9%) No, (33.3%) Not sure, (4.8%)

- Does the layout of your plant or work environment make it difficult to do your work?
  Yes, (19%) No, (76.2%) Not sure, (4.8%)

6: Work and Safety Critical Procedures

- Do you think the employees in your business unit follow procedures when performing tasks?
  Always, (28.6%) Most of the time, (52.4%) Sometimes, (19%) Never, (0%)

- Are you trained on documented safety-critical procedures in your work area?
  Yes, (85.7%) No, (9.5%) Not sure, (4.8%)

7: Safety Culture

- Who do you think is more committed to safety in your business unit, managers or workers?
  Managers, (14.3%) Workers, (14.3%) Both Managers and Workers, (71.4%)

8: Communications and Interfaces

- Is the information you need to work safely communicated to you clearly and accurately?
  Always, (47.6%) Most of the time, (38.1%) Sometimes, (14.3%) Never, (0%)

- How often do employees of your business unit have scheduled communication and feedback sessions?
  Always, (47.6%) Most of the time, (38.1%) Sometimes, (9.5%) Never, (4.8%)

9: Integration of human factors into risk assessment and Investigations

- Is the employee who is directly involved in an incident always held responsible?

  Yes, (42.8%) No, (28.6%) Not sure, (28.6%)

- Are human factors considered during risk assessments, PDA's, HAZOP's, investigations, plot plan and model reviews?

  Yes, (66.7%) No, (9.5%) Not sure, (23.8%)

10: Maintenance Error

- Do you think potential hazard analysis is always carried out before maintenance work is done on critical equipment?

  Yes, (81%) No, (4.7%) Not sure, (14.3%)

Please give your comments:

....

....

....*Thank you.*

APPENDIX F

SASOL INFRACHEM QUESTIONNAIRE2 RESPONSES

BENCHMARKING THE MANAGEMENT OF HUMAN FACTORS IN SASOL BUSINESS UNITS.

Brief Introduction:

The human factors issue in the chemical industry is an interaction between *culture/work environment, management systems, people characteristics and facility/equipment.*

This Questionnaire is an academic survey to determine how human factor issues are assessed and managed in your business unit of Sasol to achieve an incident-free work environment.

Please answer questions by ticking the appropriate boxes.

Kindly note that your name or signature is **not** required on this Questionnaire.

1: Organizational changes

- Does your business unit make changes in its structure or job functions that could affect safety negatively?

  Yes, (0%) No, (100%) Not sure, (0%)

- If the above answer is Yes, please specify any of such changes ....

2: Staffing arrangements

- Does the staffing arrangement and workload in your business unit affect safety negatively?

  Yes, (4%) No, (88%) Not sure, (8%)

- Do you feel that the number of employees in your section, department or business unit is adequate?

  Yes, (36%) No, (60%) Not sure, (4%)

3: Training and Competence

- Are the employees in your business unit performing well in their responsibilities?

  Yes, (80%) No, (12%) Not sure, (8%)

- Do the employees in your business unit have adequate SHERQ training related to their work environment and areas of responsibilities?

  Yes, (92%) No, (4%) Not sure, (4%)

4: Fatigue from shift work and overtime

- Do you or other employees in your business unit work beyond the maximum overtime hours?

  Yes, (12%) No, (64%) Sometimes, (24%)

- Are you or other employees given time off work to rest after such long hours of work?

  Yes, (84%) No, (12%) Sometimes, (4%)

5: Ergonomic Designs

- Do you think human factor consideration is integrated into plant design?

  Yes, (60%) No, (28%) Not sure, (12%)

- Does the layout of your plant or work environment make it difficult to do your work?

  Yes, (16%) No, (72%) Not sure, (12%)

6: Work and Safety Critical Procedures

- Do you think the employees in your business unit follow procedures when performing tasks?

  Always, (40%) Most of the time, (52%) Sometimes, (8%) Never, (0%)

- Are you trained on documented safety-critical procedures in your work area?

  Yes, (96%) No, (4%) Not sure, (0%)

7: Safety Culture

- Who do you think is more committed to safety in your business unit, managers or workers?

  Managers, (20%) Workers, (4%) Both Managers and Workers, (76%)

8: Communications and Interfaces

- Is the information you need to work safely communicated to you clearly and accurately?

  Always, (56%) Most of the time, (40%) Sometimes, (4%) Never, (0%)

- How often do employees of your business unit have scheduled communication and feedback sessions?

  Always, (36%) Most of the time, (48%) Sometimes, (16%) Never, (0%)

9: Integration of human factors into risk assessment and Investigations

- Is the employee who is directly involved in an incident always held responsible?

  Yes, (20%) No, (56%) Not sure, (24%)

  Are human factors considered during risk assessments, PDA's, HAZOP's, investigations, plot plan and model reviews?

  Yes, (80%) No, (4%) Not sure, (16%)

10: Maintenance Error

- Do you think potential hazard analysis is always carried out before maintenance work is done on critical equipment?

  Yes, (72%) No, (16%) Not sure, (12%)

Please give your comments:

....

....

....*Thank you.*