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# **An Environmental Risk Assessment of the Creosote Bleedings at the Howick Pole Yard.**

By

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As the candidates supervisor I have / have not/ approved this thesis/ dissertation for submission

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## ABSTRACT

Many local authorities are major polluters and are ignoring each and every rule in the book. Raw sewerage is dumped in to rivers and the Vaal River is already a national health threat. Pollution of land, air and water is a common consequence by large corporations capable of causing harm to humans and other living organisms. Research on the pollution of these key natural resources is required to understand cumulative impacts, so as to take measures of precaution to minimize such pollution and reduce its consequences. Risk Assessments are therefore encouraged to identify and explore in quantitative terms, the types, intensities and likelihood of undesired consequences related to the risk of pollution. This study has identified a potential risk from creosote bleedings at Eskom pole yards and aims to explore the probability of such occurrences cumulatively so as to identify precautionary measures at the forefront of this problem to develop effective contingency plans. Soil samples were collected systematically and analysed for polycyclic aromatic hydrocarbons (PAH), a component of creosote that preserves wood. Studies have indicated that concentrations of this preservative beyond acceptable limits can impact negatively on natural resources especially water and soil. The laboratory analysed data indicates that the soil samples collected from the Howick Pole Yard were contaminated with PAH beyond the threshold values. The severity of the contamination, as determined by the application of the Risk Assessment tool, indicates that mitigation measures are essential.

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## Declaration- Plagiarism

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Signed \_\_\_\_\_

Shamaine Thulasaie

## **ABBREVIATIONS AND ACCRONYMS**

**ASGISA-** Accelerated and shared growth initiative

**CO<sup>2</sup>** - Carbon dioxide

**DEAT-** Department of Environmental Affairs

**DWAF-** Department of Environmental Affairs

**EIA-** Environmental impact assessment

**ERA-** Environmental Risk Assessment

**FAO-** Food and Agricultural Organization

**GEAR-** Growth, employment and Redistribution

**Ha-** Hectare

**IUCN-** International Conservation Union

**KZN-** KwaZulu Natal

**NEMA-** National Environmental Management Act

**NGO's** – non government organizations

**PAH-** Polycyclic Aromatic Hydrocarbons

**PCB-** Polychlorinated Biphenyl

**RDP-** Reconstruction and Development Programme

**SA** - South Africa

**SABS-** South African bureau of standards

**SANS-** South African National Standards

**SAWPA-** South African Wood Preservation Association

**TNC-** Transnational Corporations

**UNEP-**United Nations Environment Programme

**UNFCC-** United Nations Framework Convention on Climate Change

**USA-** United States of America

**WOCAT-** World Overview of Conservation Approaches and Technology

# CHAPTER ONE

## INTRODUCTION AND PROBLEM CONTEXTUALIZATION

### 1.1 Preamble

Humanity and their existence impact on ecosystems as a result of their dependence on natural resources such as air, water and soil for survival. During the past century science has begun to demonstrate to what extent humanity and ecosystems are inter-dependent. One such example of this lies in the continued extinction of animal and plant species around the globe from over-exploitation by humans which ultimately results in deterioration of human health. It is noted that the destruction of one species results in the possible destruction of a food chain that eventually impacts on people. African traditionalists, in general, state that healing plants which were previously in abundance have now become extinct. This, among others, has increased global concern about the balance between human life and ecosystems (UNEP, 2003).

Warnings, with respect to the impacts of humans on the environment were sounded as early as 1972, at the United Nations Conference on the Human Environment held in Stockholm, Sweden. Governments, since then have signed many environmental agreements and treaties, such as the Rio Convention in 1992 and United Nations Framework Convention on Climate Change (UNFCCC) in 1997, which aim to address related environmental, social, and economic problems. Despite these actions, human population is currently increasing by 77 million a year, (UNEP, 2003) and over consumption and pollution is rising steadily. This rapid population growth has subsequently led to rapid deforestation, loss of plant and animal habitats, soil erosion and loss of productive cropland as well as water and air pollution.

Relationships between humans and nature are, and have always been complex. But contemporary relations and their manifestations, such as acid rain, urban air pollution, deforestation, thinning of the upper atmospheric ozone layer, endangered species, threats to biodiversity, and the prospect of global warming,

among others, confirm the existence of fundamental problems within a socio-economic-environmental relationship (Brown *et al*, 2001). The demands and activities by people are stressing the limited natural resources and interfering with natural habitats. Some degradation problems such as the destruction of the Earth's ozone shield have accumulated to become truly global in scope; while others such as acid rain on crop fields are more regional (Berg *et al*, 1995). The proliferation of invasive alien species has in some instances upset the delicate balance of nature. Apart from displacing the natural flora and therefore impacting negatively on biodiversity, these invaders also use up more water than the better-adapted indigenous flora in a particular habitat. They also intensify wild fires, should these occur. In South Africa for example, 198 plant species have been declared weeds and invaders. The most widespread offending species in the eastern region of South Africa is *Chroemolaena Odorata* (Triffid Weed), and *Melia azedarach* (Syringa). Large areas of natural habitats have now been replaced by these invasive plants after their first introduction in the early 1800's into these habitats by humans (Gardner, 2005).

Industrial accidents, due to human activities can be catastrophic to the environment. In 1989, 53 million liters of oil from the Exxon Valdez super-tanker spilled into Alaska's Prince William Sound, a habitat for salmon, sea otters, seals, sea birds and the great white shark. This incident brought to the forefront that no area on Earth however remote and pristine is safe from the impacts of human activity. The impacts of the spillage includes the deaths of 250,000–500,000 seabirds, 5,000 sea otters, approximately 12 river otters, 300 harbour seals, 250 bald eagles, and 22 orcas, as well as the destruction of billions of salmon and herring eggs. Sea otters and ducks also showed higher death rates in the years that followed, partially because they ingested prey from contaminated soil and from ingestion of oil residues on hair (Gardner,2005). This left a permanent mark on the environment and changed society's understanding of the impacts of industrial activities on the environment.

Development and the environment share an inextricable relationship in that developments that have triggered transformations in the socio-economic-environment interrelationships include accelerating technological advances; changes in sources of energy; industrialization and its dispersal; commercialization of agriculture and the decline of more traditional forms of agriculture; growing economic differentiation of countries and populations as well as the growing globalization markets (Yeld, 1997).

Evidently, more people are using a significant amount of resources with greater intensity than at any point in human history. Reports from scientific research provided to the Food and Agricultural Organization of the United Nations confirm the per capita availability of world grains, which make up 80 percent of the world's food, has been declining for the past 15 years due to population demand. More than 99 per cent of the world's food supply comes from land, while less than 1 per cent is from oceans and other aquatic habitats. The continued production of an adequate food supply is directly dependent on ample fertile land, fresh water, energy, plus the maintenance of biodiversity. At present, fertile cropland is being lost at an alarming rate. For instance, nearly one-third of the world's cropland (1.5 billion hectares) has been abandoned during the past 40 years because erosion from over-usage and increased human activity has made it unproductive. The pressure for agricultural land accounts for 60 to 80 percent of the world's deforestation. Specifically, about 87 percent of the world's fresh water is consumed or used up by agriculture and, thus, is not recoverable (Gardner, 2005).

Additionally, the quality of freshwater resources based on the ecological and chemical content of the Worlds Rivers and streams has declined by up to 80% in the last 50 years (<http://www.ecological-aquaculture.co.uk>). Global population in 1970 was 3.6 billion and in 2007 the number of people on the planet was 6.6 billion ([http://en.wikipedia.org/wiki/World\\_population](http://en.wikipedia.org/wiki/World_population)). Over a 30 year period, the world population doubled, thus requiring more food, water, shelter and energy

supplies, creating increasing demands on natural resources. Biodiversity at the local, regional and global levels are all showing signs of stress with a rapid decline in the number of species (UNEP, 2001). Increasing pressure on the environment is the result of, on one hand, increasing affluence; that is, more consumption, pollution and waste, and on the other persistent poverty; that is, lack of resources and the technology to use them, and the lack of power to change these circumstances (UNEP, 2001).

Developed countries have economic systems based on continuous, self sustaining economic growth and high standards of living (Yeld, 1997). Developing countries are those which have not achieved a significant degree of industrialization relative to their populations, and which have a low standard of living (Peer, 1999). Developed and developing countries contribute significantly to environmental degradation either through wasteful, extravagant lifestyles, or chronic poverty (Yeld, 1997). The United States, a world renowned developed country with 5 percent of the world's population, consumes 25 percent of the world's petroleum resources. The US also contributes to 30.3 percent of the CO<sup>2</sup> emissions in the world ([www.inconvenienttruth.co.za](http://www.inconvenienttruth.co.za)). In developing countries, where rural families comprise the majority of the population, land represents a fundamental asset and it is a primary source of income, security, and status. But almost half of these rural families (some 230 million households) either lack any access to land or a secure stake in the land they till due to the imbalances created from first world influences. As a result, acute poverty, and related problems of hunger, social unrest, and environmental degradation persist. Soils in these communities have been over-utilized, and are unusable for crop production. These rural communities use wood for heating and paraffin for lighting that gives rise to air pollution and loss of indigenous vegetation (Yeld, 1997).

This understanding of an imbalance has been articulated in consensus documents negotiated at a series of global meetings convened in the 1990s. The result was that internationally, the United Nations Conference on Environment and Development (UNCED) proclaimed the concept of Sustainable Development as a workable objective globally. This was backed by the World Summit on Sustainable Development (WSSD) convened in Johannesburg, South Africa in 2002 (UNEP, 2003). In September 2002, the member states of UNEP further signed the Millennium Development Goals (MDG's) that further emphasized and committed the international committee to view human development and poverty reduction as the highest priority (Eskom, 2004). The need to enforce sustainable development was thus further emphasized.

Sustainable Development which can be defined as, 'development that ensures the existing natural resources are used in a way that would benefit those alive today as well as those to come in the future' (Brundtland Report, 1989) is the key to find the balance to meet social needs and environmental preservation so that the natural resources we enjoy today can be available for future generations. Poverty eradication, changing consumption and production patterns and protecting and managing the natural resource base for economic and social development are overarching objectives and the essential requirements for implementing sustainable development ([www.johannesburgsummit.co.za](http://www.johannesburgsummit.co.za)).

South Africa was placed in the unique situation to apply the principles of sustainable development after a legacy of Apartheid and colonialism. South Africa's transition to democracy in 1994 created new and daunting challenges. Among these challenges was the need for government to meet the basic housing, education, health and employment of its developing third world component, while maintaining the capacity of the natural environment to support this development in the long term (Eskom, 2004).

South Africa's first world component has been responsible for some major environmental degradation, such as air pollution in some areas of Gauteng and in parts of Mpumalanga. These areas can be compared to the heavily polluted areas of industrial Eastern Europe. South Africa's developing Third World component is mainly as a result of the former policies of apartheid and colonialism, which have been responsible for huge environmental destruction. Soil erosion, in areas such as the former "homelands" of Kwa-Zulu Natal and Transkei through overcrowding and overgrazing is one such example. This developing component has also been responsible for other forms of environmental degradation, demonstrated by significant air pollution in the townships because of the burning of firewood and poor quality coal, for heating and cooking (Yeld, 1997).

South Africa possesses a treasure of biological diversity as a result of the wide range of climatic conditions and many variations in topography e.g. narrow coastal plain, steep escarpment and large plateau. More than 20 300 species of flowering plants occur in South Africa. One of the six most significant concentrations of plants in the world is the Cape Floral Kingdom, with its distinctive fynbos vegetation, in the south west Cape. In total 243 mammals are also found in this region. There are 17 threatened species in South Africa, including the black rhino, pangolin and giant golden mole. The riverine rabbit, roan antelope and wild dog are endangered species. Two mammals have become extinct: the blue antelope and the quagga (Strydom, 2004). South Africans' are now faced with the responsibility to preserve this genetic, species and ecosystems diversity on behalf of the global community while it simultaneously has the responsibility to reconstruct and develop on behalf of its people. The challenge to find the balance is thus considerably heightened as achieving a just and equitable future requires more than just political democracy; there is also a huge demand on the country's limited resource base as development initiatives are implemented (Yeld, 1997).



Between 1994-2000, much effort within the framework of the Reconstruction and Development Programme (RDP) and later Growth Employment and Redistribution (GEAR) went into the design and implementation of government initiated programmes intended to redress past and present inequalities. In 1994, the government adopted the Reconstruction and Development Programme (RDP) as a policy framework to guide it in transforming South Africa from a divided society to one that provides equal opportunities for all its citizens. The main principles of the RDP were to meet the people's basic needs, such as housing, water and electricity; developing the country's human resources; building the economy; and democratising state institutions and society. In 1996 the ANC adopted the GEAR macroeconomic strategy for rebuilding and restructuring the economy in line with the main principles of the RDP (Strydom, 2004).

Electricity is known to be the basis of industrial development, the force behind transportation, heating, cooling, lighting and various day-to-day needs. Electricity provision is therefore central to achieving the environmental, social, and economical goals of sustainable development. The provision of electricity leads to job creation, and a subsequent increase in disposable income in a community. The supply of electricity can lead to a decrease in the harvesting of firewood with resultant biodiversity implications, and a decrease in respiratory diseases due to the reduction of biomass burning. The relative efficiency of using electricity will reduce the overall emission of pollutants and lead to an improved quality of life. As such, electricity provision was a key focus area in the above government initiated programmes, and Eskom the electricity parastatal was tasked to provide a stable electricity supply to meet these programmes (Eskom, 2000).

The South African government, local municipalities and Eskom expressed their commitment in 1994 to electrify 2, 5 million households by the year 2000 of which 1.75 million were to be electrified by Eskom. In order to meet the target, Eskom electrified an annual average of 300 000 households from 1994 onwards and at

the end of 1999, Eskom met and exceeded this target. The effective implementation of the electrification programme was made possible by the commitment and participation of a number of bodies, including government, business, academic institutions and NGOs. These bodies later developed the Accelerated and shared growth initiative for South Africa (Asgisa) (No 25088. Gov Gazette, 2003). ASGISA is the 2006 government led initiative and its objectives are to promote economic growth and halve the rate of unemployment and subsequent poverty by 2014

President of SA, Mr. Thabo Mbeki has pledged access to electricity by 2012 for all South Africans in his parliamentary speech in 2006 (No 25062. Gov Gazette, 2006). This was aimed at meeting the aims of Asgisa and the Millennium Development Goals. According to available statistics there are 12,13 million households in South Africa requiring electricity of which 8,7 million have been electrified at the end of 2005 ([www.eskom.co.za](http://www.eskom.co.za)). This has brought the level of electrification in the country to about 72%. The number of rural households electrified countrywide has risen from 12% in 1994 to 52% in 2005. Electricity generation, transmission and generation is required to achieve successful electrification through the various different technical infrastructures. The generation, transmission and distribution of electricity, however, frequently have negative environmental consequences such as air pollution, water pollution, wildlife interactions with powerlines resulting in bird collisions, giraffe electrocutions, stakeholder clashes in obtaining servitudes and soil erosion (Eskom, 2000). The focus in this report however will be on the impacts of creosote bleedings from wooden poles.

In accordance to South Africa's legal requirements, Eskom Distribution undertakes an Environmental Impact Assessment (EIA) for site specific distribution projects above 33kV and performs an environmental screening for all electrification projects. The EIA conducted for electricity distribution is used to determine an environmentally sound route to build electrical infrastructure while it

may on the other hand overlook other possible environmental impacts. Such examples include, *inter alia*, alien vegetation invading servitudes where vegetation has been removed and creosote bleedings at pole yards from wooden poles that is needed for electricity distribution. Each of the above factors mentioned on an accumulative level can pose major concerns to the receiving environment.

To provide access of electricity to the people, overhead powerlines are used to transport the electrical current from the source of generation, to the point of usage. A servitude is then required to build this infrastructure and sometimes traverse past virgin habitats and creates an ecological niche for alien species. Soil degradation is also an associated environmental problem with powerline development, as large trucks that are used to transport material contribute to rapid soil degradation. In addition wooden utility poles are required for the building of these overhead lines. These poles are covered with a preservative known as creosote that contains hydrocarbons. While EIA's and specialist studies are conducted to ensure that negative impacts on the powerline route are minimized, these studies do not look at impacts that are caused from creosote bleedings and this has created the rationale for this study.

Hydrocarbons that include, phenol and polycyclic aromatic hydrocarbons (benzo (a) pyrene and benzanthracene) (MSDS Suprachem, 2007) are used to manufacture creosote. These hydrocarbons are also found in oil. Oil compounds and other related hydrocarbons pose a serious pollution problem, when released into the environment. These compounds, apart from posing a fire hazard, also have the ability for just one litre of oil to contaminate in excess of a million litres of water (Brown *et al*, 2001). Oil may rapidly penetrate certain soil types, which may lead to extensive soil degradation as well as groundwater and surface water contamination. The National Water Act (Act 36 of 1998) states that, *inter alia*, "hydrocarbons should not touch the soil or water, and if they do- they shall be removed immediately." Therefore as a result of its hydrocarbon contents,

creosote in large quantities is highly toxic to the environment. Growing concern has arisen after increasing creosote bleeding has been observed at Eskom Distribution wood-pole storage yards recently. These bleedings in large quantities can contribute to significant soil contamination.

## **1.2 Problem Contextualization**

Eskom, South Africa's energy parastatal, apart from ensuring the energy requirements of the country, had also been challenged with the daunting task of electrifying 1.75 million households during 1994-2000, with the greatest need of 500 000 being in Kwa-Zulu Natal (Eskom, 2000).

Between the years 2000-2006 Eskom completed 400 000 electrification projects (Eskom, 2007). Wooden utility poles, essential for these projects are used to build powerlines up to a voltage of 33kV. These poles are required to be treated for long term sustainability and maintenance of the line as well as for safety reasons. If wooden poles that are used to hold conductors carrying high voltages of electricity supply, are not preserved for long term sustainability, the likelihood of electrocutions and fire hazards will occur repeatedly and place utility companies continuously in financial and legal risks (Eskom, 2004). In South Africa therefore, the treatment of timber is protected by the National Forests Act of 1998.

By design the chemicals used to protect wood, must be toxic to the target organisms that feed on wood, but they may also affect non-target organisms (Winn, 2005). Eskom Distribution currently uses approximately 2.2 million wooden utility poles per annum nationally (Eskom, 2007). To achieve one of the objectives of Asgisa, Eskom is required to provide electricity to thousands of people who were previously deprived of this basic need. Eskom Distribution has the final responsibility to take the electricity to the customers by building the infrastructure to technically support electricity provision. It is therefore likely that

there will also be a considerable increase in the number of utility poles required as population demands increase. Kwa-Zulu Natal, where electrification is needed the most requires between 300 000 - 500 000 poles annually (Eskom, 2005).

With the increasing demand for electrification targets- manufactures have been placed under tremendous pressure to supply wooden poles. The quality of the poles therefore became the subject of concern as poles were arriving damp with increased quantities of creosote bleedings. This was noticeable at the Eskom Distribution warehouses in Marburg, Vryheid, Empangeni and Howick in the Kwa-Zulu Natal region. This raised environmental concern, as increased creosote bleedings could potentially result in contamination of soil and sub-surface water.

In 2000, Eskom had purchased 2.2 million wooden poles. South Africa's telecommunications parastatal, Telkom purchased a further 12 million wooden poles; while Durban Municipality purchased approximately 260 000 treated wood poles that were used for urban electricity provision (ESI Africa, 2000). These numbers indicate the magnitude of demand for wooden utility poles. Furthermore, to increase added pressures, the Department of Water Affairs and Forestry then introduced a bill that proposed a virtual embargo on the areas that can be put on afforestation ([www.sawpa.co.za](http://www.sawpa.co.za)). This was positive from an environmental perspective, but placed even further pressure on timber growers to produce quality products.

In the year 2001, treated wooden poles were failing by collapsing on the field as a result of termites feeding on them. Electrical infrastructure were collapsing and resulting in electricity outages. Eskom faced negligence claims associated with wooden utility pole failure amounting to R15 million. Telkom's claims, for similar problems amounted to R18 million. In 2000; Eskom's insurers suspended their

cover of Eskom MV (medium voltage) lines until the utility completed a full inspection on them. The standards governing the specification of poles and field inspections remained the key to improve the current situation (ESI Africa, 2000).

The South African Wood Preservation Association (SAWPA) was under no illusion that with South Africa's increasing energy demands, Eskom would revert to importing its timber needs with a synthetic alternative. Research was thus undertaken to save the South African timber industry and one of the criteria under review was the specifications governing creosote manufacture ([www.sawpa.co.za](http://www.sawpa.co.za)). During this review, environmental concerns heightened as increased recognition of the polycyclic aromatic hydrocarbons used in the creosote manufacture was brought to the forefront. This created an ideal pretext for the current investigation.

The South African National Standards (SANS) 10005 also sets out specifications on how treatment facilities should store wooden utility poles after treatment which was absent previously. This is primarily due to the surface water run-off from timber preservation facilities that can cause unacceptable levels of copper, chromium, arsenic and polycyclic hydrocarbons to enter water bodies from soil penetration or contaminated sedimentation dams which may result in uncontrolled discharges to water bodies (Environmental Compliance Report, 2002). While these specifications applied primarily to timber preservation manufactures, this study will provide recommendations with respect to other storage facilities that can contribute to environmental degradation. Eskom Distribution in Kwa-Zulu Natal will be used as a case study for this investigation.

After leaving the respective treatment facilities, wooden utility poles are generally transported and stored temporarily at respective storage warehouses at the different utilities that use creosote poles. At Eskom Distribution in Kwa-Zulu

Natal, these poles are stored at one of the four warehouses before they are sent to the respective sites where they are utilized in powerline construction. At the pole-yards increasing quantities of creosote have been observed. The one assumption is that manufactures are speeding up the coating process and drying times of the manufacture process to meet demands and earn added income. The other is that the timber is still green after being felled young and not absorbing the creosote (Eskom, 2000). These combined reasons indicate that the problem however remains in that larger quantities of creosote are being exposed to the environment *via* bleedings. This study, apart from reviewing the above, will investigate further explore the possibility of soil contamination from these creosote bleedings. If soil contamination is proven, possible measures to mitigate soil pollution will be reviewed. In addition, this study paves the way for further research into investigating reasons for the recent increases in creosote bleedings.

### **1.3 Aim and Objective**

**1.3.1 Aim of the Study:** An investigation using the Environmental Risk Assessment tool to determine the environmental impacts of creosote exposure from creosote bleedings on soil, during wooden pole storage - a case study of the Eskom Distribution Eastern Region, Howick Pole Warehouse.

#### **1.3.2 Objectives of the Study:**

- ❖ To investigate by means of a Risk Assessment, if creosote bleedings at Eskom's Howick Wood Pole Yard is resulting in significant soil contamination from the presence of polycyclic aromatic hydrocarbons constituents entering the soil.
- ❖ To determine the occurrence of PAH on soils at the Howick Pole Yard by submission of soil samples for laboratory analysis.
- ❖ To provide additional information on the limited research currently available on creosote bleedings and its impacts in South Africa, so as to motivate for stringent regulations in the storage of creosote.
- ❖ To investigate and forward recommendations on how to minimize accumulative soil contamination from creosote bleedings, so as to enforce effective environmental management from wooden pole storage.

**Null Hypothesis:** Creosote bleedings does not result in soil contamination at the Howick Pole Yard.



## 1.4 Chapter Sequence

The opening chapter brings the reader into perspective of the drive for sound environmental management globally, narrowed down to the South African scenario. Issues that motivated the need for this research are explained. This introductory chapter also highlights the aims and objectives of the study.

Chapter two comprises of the literature review and forms an extensive part of this report. It describes how the environment is essential to life and the impacts of environmental degradation. Environmental problems that start locally, in time have potential to become global. South African environmental issues are brought into perspective with the focus being on soils in South Africa. The South African legislation pertaining to pollution is elaborated and the problem of creosote on wooden poles is investigated further with a literature review on the impacts of hydrocarbons, a component in creosote, on the receiving environment.

Chapter Three highlights the site-specific case study, *viz.* Howick Pole yard. It, apart from providing a description of the study area, also reviews methods and techniques in research. The chosen technique of investigation will be described in detail.

The focus in Chapter Four will be on the analysis of the results obtained from the implementation of the methodology described in the previous chapter.

The contents of the fifth and final chapter will be on discussion. Recommendations are provided and the chapter ends with an overall conclusion.

## **1.5 CONCLUSION**

Environmental Management is now accepted as not just 'nice to have", but an integral part of an organisations systems and practices. Therefore while Eskom Distribution provides service delivery, it is important for the organisation to also review potential impacts that can cause environmental degradation. In order to contribute towards sustainable economic and social development, Eskom has declared commitment to the continual improvement of its environmental performance (Eskom, 2000). As such this provides an opportunity for researchers to investigate any possible environmental impacts by the organization and forward recommendations. This is in keeping with continually improving environmental management of such corporate organizations.

Creosote has a long history of successful use as a wood preservative, but polycyclic aromatic hydrocarbons (PAH's) in this preservative have raised environmental concerns ([www.sawpa.co.za](http://www.sawpa.co.za)). This thus places Eskom Distribution at a potential risk, as wooden utility poles are preserved with creosote. A risk assessment is the procedure in which the risks posed by inherent hazards involved in processes or situations are estimated either quantitatively or qualitatively (Williams, 1999). Reviewing related literature is the the first step in the application of qualitative risk assessment which will occur in the following chapter before enforcing a quantitative risk assessment in chapter three.

## **CHAPTER TWO DEGRADATION OF SOIL: A THEORETICAL REVIEW**

### **2.1 Introduction:**

Concern has been expressed over the leaching of wood preservatives from timber, into the environment globally ([www.sawpa.co.za](http://www.sawpa.co.za)). The widespread use of wood preservatives has fostered the need for detailed information on the movement and the environmental impact of such compounds. Creosote components such as polycyclic aromatic hydrocarbons are known to migrate and permeate within treated wood and into the surrounding soil. Although some recent studies have examined such leaching, detailed information is still limited on the environmental impact of these compounds. Research in this regard has thus been prompted by the International Research Group on Wood Preservation through their consultants ([www.sawpa.co.za](http://www.sawpa.co.za))

With South Africa's transition to democracy in 1994, increasing powerline construction was necessary to meet the country's electricity demands from a previous backlog during the apartheid regime. This process required the use of increasing numbers of wooden utility poles preserved by creosote to build electrification infrastructure. At the Eskom pole storage warehouses, increasing quantities of creosote bleedings were observed recently. The reason for this was that poles received more recently are still moist as manufacturers' fast track drying processes in their struggle to meet the new demand for poles. As such, the ideal pretext was created to investigate further the environmental impacts from creosote bleedings on the physical environment in this South African context. The conservation of the physical environment contributes to great economic, aesthetic and ethical value, particularly since air, water and soil are life sustaining factors (Yeld, 1997). Any possible degradation of soil, air and water must be monitored, investigated and limited.

## **2.2 Environmental degradation affecting the bio-physical environment**

More than a decade ago, three of the world's most influential environmental agencies- The International Conservation Union (IUCN), World Wide Fund for Nature (WWF) and the United Nations Environment Programme (UNEP)- jointly published the World Conservation Strategy in which they cautioned that humanity had no future unless nature and natural resources were utilized wisely or conserved. Despite impressive technological advances and inventions, people remain intimately connected to nature and the natural life supporting systems: air, water and soil. For Humans to survive the fertility and productivity of the planet must be guaranteed (Yeld, 1997).

While environmental awareness was promoted *via* treaties and conferences such as the Ramsar convention in 1971, United Nations conference on the Human environment and Convention of Prevention of marine dumping in 1972 and World charter for Nature in 1982; there were also huge setbacks on the actual implementation of sound environmental management, due to reasons elaborated below. Increasing environmental problems included greater global pollution, ozone depletion, acid rain, and rainforest losses, while in many areas there was worsening human poverty and diseases such as kwashiorkor (Berg *et al*, 1995).

Historically, environmental degradation has occurred as a result of the following factors: Firstly, the past two decades have seen human numbers increase exponentially and this was accompanied by the rapid deterioration of the quality of natural resources that humans depend on. People have altered, degraded and destroyed the landscape on a vast scale, driving species and even whole communities to the point of extinction (Wilcove *et al* 1998). The first noticeable effects of human activity causing rapid extinction rates can be seen in the elimination of large mammals from Australia and North and South America at the time humans first colonized these continents many thousand years ago. Shortly after humans arrived 74% of the megafauna – (mammals weighing more than 44kg) in these areas became extinct. These extinctions were probably caused

directly by hunting and indirectly by burning, clearing forests and the spread of introduced diseases. On all continents there is extensive record of prehistoric human alterations and destructions of habitat that coincides with a high rate of species extinctions. Based on the available evidence the best estimate is that 85 species of mammals and 113 species of birds have become extinct since the year 1600. While these numbers initially may not seem alarming, the trend to these extinction rates is upward, with a dramatic increase in extinctions having occurred in the last 150 years due to population growth and rapid industrialization (Berg *et al*, 1995). The extinction rate for birds and mammals was about one species every decade during the period from 1600 to 1700, but rose to one species every year during the period from 1850-1950. This figure showed continuous growth in the late 1980's (Smith *et al*, 1993).

The major threats to biological diversity that result from human activity are habitat destruction and degradation, habitat fragmentation, (including pollution), global climate change, invasion of exotic species and increased spread of diseases (Willcove *et al* 1998). While the phenomenal growth in population contributes to environmental degradation, there is however other factors that contribute to the decline in biodiversity such as new technologies being able to extract more raw materials from the earth, in a shorter timeframe and chronic poverty among developing countries that over-utilize natural resources in their quest to survive. Unequal usage of natural resources is another contributing factor. Although in most instances, greater numbers of people result in more consumption, in other instances, particularly in developed countries, affluent lifestyles contribute to the exploitation of natural resources. Each year, the average citizen in America uses 43 times more petroleum products and 386 times more paper products than the average citizen in India (WRI, 1994). India's population size however, was calculated to comprise of 1,095,351,995, while the USA comprised of 298,444,215 people demonstrating a detectable imbalance on the usage of natural resources ([www.geohive.co.za](http://www.geohive.co.za)). America's over consumption creates a huge stress on natural resources and such unequal distribution of resources

often occurs even within individual countries. People have sub-divided into first and third world components.

The above trend was actually established by the creation of transnational corporations (TNC's). These are companies that do business and have investments in more than one country. TNC's are mainly from developed countries and are large corporations engaged in a wide range of activities including food, agriculture, mining and manufactured food (TUNZA, 2003). With only 500 companies accounting for two-thirds of the world's trade, TNC's are one of the main driving forces behind the global economy. Since TNC's are driven by profit, their activities have often been harmful to the environment (Krebs *et al*, 1999). These industries affect the environment by consuming one third of the world's energy, emitting large quantities of carbon dioxide and are responsible for producing more than two billion tonnes of solid waste and 338 million tonnes of hazardous waste annually (TUNZA, 2003). Moreover, because the world's economic system is currently based on consumption and growth, industries must continue growing and extract more resources in order to be considered profitable. This industrial trend continues to add more stress on the environment.

Environmental degradation may also result from the application of pesticides, herbicides and chemicals and unintended industrial by-products. These products once released can persist in the natural environment for a long time and migrate over long distances. Some of these pollutants can become volatile in warm air, which means that they evaporate and can be transported by air. When they reach cooler areas, they condense into gas or solid particles and snowflakes. Due to high solubility in fat, these particles can be stored in human and animal tissues. One such example of a persistent organic pollutant is the Polychlorinated Biphenyls (PCB) that was widely used as a coolant in transformers and later discovered to be a persistent pollutant that does not biodegrade. Polar regions are currently suffering from pollutants that were produced thousands of kilometers away, again demonstrating the world-wide impact of pollution

(TUNZA, 2003). This also re-enforces the need to maintain a healthy balance between the environment and development.

Maintaining a healthy environment means preserving all of its components, *viz*: ecosystems, communities, species and genetic variation in good condition (Yeld, 1997). For each of these components, initial threats can lead to complete loss; hence research on any potential hazards that poses a potential threat to the environment is encouraged to enforce sound environmental management. The major threat to biological diversity identified thus far globally is habitat loss, and the most important means of protecting biological diversity is habitat preservation. Habitat loss includes habitat destruction, habitat damage associated with pollution and habitat fragmentation (Berg *et al*, 1995).

Habitat loss in South Africa must be avoided at all costs as this country has one of the world's greatest diversity of plant and animal species, and is home to many species found no-where else in the world (Rina, 1996). A total of 4,849 plant species are found in the 112,000 square kilometers of the Succulent Karoo, and almost half of these live nowhere else in the world. The Cape Floristic Region, located at the bottom of the southern tip of South Africa, encompasses an entire floral kingdom. The area has the highest concentration of plant species per unit area compared to any other place in the world, with more than 8,000 known varieties. The majority of these species are found nowhere else in the world (Berg *et al*, 1995). To manage this wealth of ecology, it is important that environmental, political, social and economic issues are inextricably connected. This was indeed recognized in the 1994 South African constitution, which included a section on environmental rights for every citizen under section 24. A healthy environment has great economic, aesthetic and ethical values to a country (Berg *et al*, 1995). However, in South Africa terrestrial resources are rapidly disappearing due to conversion of natural habitat to farmland, forestry, human settlement, and industrial development. Degradation of vegetation and

soils is also a widespread problem in South Africa. This in turn will further heighten the problems associated with loss of South Africa's rich biodiversity.

Considering good quality soil is identified as one of the crucial natural resources to preserve South Africa's rich biodiversity, it is important to encourage research on any potential areas that can contribute to degrade soil quality. Possible soil contamination from creosote bleedings on soil is one such example. Research can contribute significantly to minimize the rapid biophysical degradation by identifying possible problems and seeking mitigation measures.

Environmental degradation as previously discussed has several different factors that contribute to it. The most subtle and universal form of environmental degradation is environmental pollution. Common causes of pollution are pesticides, chemicals and sewage released by industries and human settlements, emissions from factories and automobiles, and sediment deposits into the ground creating cumulative impacts on soil quality and water bodies. Although much environmental pollution are sometimes highly visible and dramatic, as in the case of for example the massive oil spills and the 500 oil well fires that resulted from the Persian Gulf War, it is the subtle unseen forms, or overlooked pollution levels that are probably the most threatening, primarily because they are so insidious (Gorlach, 2004).

Scientists have therefore embarked on increased research and investigation on subtle forms of environmental degradation by virtue of the application of conducting risk assessments. These risk assessments are conducted worldwide as a proactive tool before new products are released into the market and wherever possible contaminants are identified. With such a concerted effort made at all levels to address the problems of land degradation, it can be anticipated that there will be a reduction in acidified, saline, polluted, eroded and otherwise degraded soils, minimizing habitat loss and its associated environmental problems. It is necessary to investigate the potential impacts of soil contamination and degradation through external agents as soil is an



important natural resource in the world. Degrading quality of soils occurs when soil is sterilized by salts, poisoned by chemicals, sapped dry of nutrients and blown away by wind.

Soil is just as important as plants, animals, rocks, landforms, lochs and rivers. It influences the distribution of plant species and provides a habitat for a wide range of organisms. It controls the flow of water and chemical substances between the atmosphere and the earth, and acts as both a source and store for gases such as oxygen and carbon dioxide in the atmosphere. Soils not only reflect natural processes but also record human activities both at present and in the past. They are therefore part of our cultural heritage. The modification of soils for agriculture and the burial of archaeological remains are good examples of this (Smith, 1988). The importance of soil will be elaborated in detail below.

### **2.3 The importance of soils**

There is growing concern that a decline in long-term soil productivity is already seriously limiting food production in the developing world, and that the problem is getting worse. Human survival is linked to food security and as such is linked to productive fertile soil. Humans use about 8.7 billion hectares of land worldwide. About 3.2 billion hectares are potentially arable, of which a little less than half is used to grow crops. The remaining 1.7 billion hectares of potentially arable land, along with most non-arable land, function as pasture, forest, and woodland. Recent global studies state that soil degradation is widespread and the overall pace of degradation has accelerated in the past 50 years. Productivity has declined substantially on approximately 16 percent of agricultural land in developing countries, especially on cropland in Africa and Central America, pasture in Africa, and forests in Central America (Toepfer, 2003).

Almost 75 percent of Central America's agricultural land has been seriously degraded as has 20 percent of Africa's and 11 percent of Asia's. Assuming that land loss continues at current rates, an additional 150 to 360 million hectares

would go out of production by 2020. The fifty seven developing countries of the world of which the majorities are in Africa are characterized by high population pressure on arable land that range between one to ten million hectares. In view of this, these countries need to take into consideration not only soil protection but also developing long term programmes to enhance the quality of these vulnerable lands. Poor quality soils have low potential to produce economic yield. In developing countries food security, particularly in Africa, is threatened (Gorlach, 2004).

The world's land area covers a total of more than 140 million square kilometers, which is slightly under one third of the Earth's surface (Toepfer, 2003). Land which is largely made up of soil is an important support system for plant and animal life. Soils are also home to an amazingly large number of different organisms. In fact, scientists believe that there are probably more individual species living below ground than above the surface. Worms, beetles, caterpillars, ants and larger animals like moles are all examples of soil creatures. However, just one teaspoon of soil will also contain up to several million protozoa (probably the simplest form of animal life), bacteria, algae and nematodes (microscopic worm-like animals). Many of these species are vital to the proper functioning of soils ([www.seafriends.org](http://www.seafriends.org)).

Soil plays an important role in producing most of our food, timber and fibers for our clothing. Soil is the median for agriculture (both commercial and subsistence). It also provides a base for our homes, our industry and many of our leisure activities. In spite of this dependence, soil is often treated as if it is an inexhaustible resource and over the years human activities have deteriorated the quality of soil by actions such as increased cultivated areas and chemical additions into soil resulting in soil quality deterioration. Without a range of soils there would be an absence of many different habitats, plants and animals. In other countries, the United States and the Netherlands are good examples, the view that soils are worthy of conservation in their own right is rather more

advanced. Both of these countries have specific legislation to protect soils ([www.seafriends.org](http://www.seafriends.org)). Direct impacts of soil degradation are changes in soil functions, while indirect impacts are effects on the ecosystems and humans by change in population size, human health, change in biodiversity, forest health and productivity and contamination of surface and ground water (Gorlach, 2004).

Soil organisms contribute a wide range of essential services to the sustainable function of all ecosystems. These organisms act as the primary driving agents of nutrient cycling and regulate the dynamics of soil organic matter. In addition soil organisms play a role in modifying soil physical structure and water regimes, enhancing the amount and efficiency of nutrient acquisition for vegetation and enhancing plant health. These services are not only essential to the functioning of natural ecosystems but constitute an important resource for the sustainable management of agricultural systems. Agricultural security is what provides human population with food for survival. The sustained use of the earth's land and water resources - and thereby plant, animal and human health - is dependent upon maintaining the health of the living biota that provide critical processes and ecosystem services (Toepfer, 2003).

Previous agricultural productions has largely ignored the vital soil management component and have only now realized the mis-management of soil biota could play a vital role in destroying soil quality and health. This will impact negatively on achieving the goals of agricultural production, food security and sustainable land use and land resources management. Given escalating population growth, land degradation and increasing demands for food, achieving sustainable agriculture and viable agricultural systems are critical to the issue of food security and poverty alleviation. Maintaining soil quality results in the following economic, environmental and social benefits ([www.sawpa.co.za](http://www.sawpa.co.za)):

**Economic benefits:** Soil biological management reduces input costs by enhancing resource use efficiency (especially decomposition and nutrient cycling, nitrogen fixation and water storage and movement). Less fertiliser is used when nutrient cycling becomes more efficient and less fertiliser is leached from the rooting zone. Fewer pesticides are needed where a diverse set of pest-control organisms is active. As soil structure improves, the availability of water and nutrients to plants also improves. Cash production is also available for export and more revenue for the country's economy (Pimentel, 1997).

**Environmental protection:** Soil organisms filter and detoxify chemicals and absorb the excess nutrients that would otherwise become pollutants when they reach groundwater or surface water. The conservation and management of soil biota help to prevent pollution and land degradation, especially through minimising the use of agro-chemicals and maintaining/enhancing soil structure (Pimentel, 1997).

**Food security:** Soil biological management can improve crop yield and quality, especially through controlling pests and diseases and enhancing plant growth. Below-ground biodiversity determines resource use efficiency, as well as the sustainability and resilience of low-input agro-ecological systems, which ensure the food security of much of the world's population (Pimentel, 1997).

For the greater part of human history soil has literally formed the basis of all economic activity. Classical economic thinkers included soil, along with capital and labour as one of the three basic production factors. In 1798, Thomas Malthus provided the first economic theory of soil utilization and degradation; arguing that human population growth and economic growth would eventually be restricted by scarcity of fertile soil (Gorlach, 2004). In Africa, the main source of economic activity is agricultural production. Declining soil quality thus not only means less food can be grown but also the production of cash crops for export is endangered. High population growth in Africa, aggravated in some instances by migration of large numbers of people, due to pressure on land for subsistence

farming and political factors (such as the case in South Africa), have reduced the capacity of land to sustainably support Africa's agricultural needs. Stats presented to the Food and Agricultural Organisation (FAO) in 1992 showed that there is between 0.28 and 0.52 hectares per person of cultivated land. The table below demonstrated the amount of land that has degraded across the globe, in millions of hectares. This figure has increased even more over the years.

**Table 2.1 Soil degradation in the world in 1992 (million ha).**

<b>CONTINENT</b>	<b>Areal extent of soil loss (million ha)</b>	<b>Agent of Erosion</b>	<b>Areal extent of soil loss (million ha)</b>
<b>Africa</b>	497	<b>AFRICA</b>	
<b>Asia</b>	748	<b>Water erosion</b>	222
<b>South America</b>	243	<b>Wind erosion</b>	187
<b>North and Central America</b>	158	<b>Chemical</b>	70
<b>Europe</b>	219	<b>Physical</b>	18
<b>Australia</b>	103		
<b>TOTAL</b>	1964		

(Source: Isric, 1992)

This thus resulted in international concern on soil degradation in Africa and the World Overview of Conservation Approaches and technology (WOCAT) was initiated in 1992 to assess Africa's soil degradation and promote measures to manage soil quality. The key to restoration and enhancing soil fertility is the collective responsibility of many parties including government, non-government organisation and all stakeholders in the food production process (Barbier, 1997). The natural erosion of soil has been exacerbated by human activities. Such examples include: Physical degradation such as compaction from overgrazing and water-logging. Chemical degradation such as pollution from industrial waste

and Biological degradation from biomass burning and depletion of vegetation cover.

Natural erosion wears soil down and washes it into the continental margins. Tectonic plates push it underneath continents, where it is homogenates and melts. Magma cauldrons rise up through the continental crust, bringing rocks of various types to the surface. Rocks weather slowly to produce soil of varying qualities. In the top soil, where the soil organisms live, the nutrients relevant to life are retained and all others are lost by leaching. Top soils all over the world have very similar compositions, which are often very different from their bed rocks. Nutrients are carefully cycled between the plants above and the soil organisms beneath the surface. As a rule, the soil contains much more living biomass than the plants above it. Nutrients are cycled many times before they are lost. Erosion and leaching slowly diminish the top soil but in natural ecosystems, the rate of loss equals that of formation (Toepfer, 2003). The climate determines many of the soil's processes, its fertility and its properties. This natural process however, has been altered with human development over the years.

Land degradation will then result due to the loss of biological or economic productivity of soil. Examples of some human activities contributing to soil loss include unsuitable agricultural use, poor soil and water management, removal of natural vegetation, poor irrigation practices and pollution (TUNZA, 2003). Such activities requires being monitored and researched, so as to manage effectively and derive measures to reduce accelerated degradation, which will result in several consequences, such as the shortage of good quality food supplies and habitat loss for species. This in turn can contribute to global food shortages and mass species extinctions.

The direct causes of land degradation are mainly:

- **Deforestation:** Forest land is now being utilized for arable land, pasture, urban use, logged area, or wasteland. Deforestation is a consequence of removal of trees without sufficient reforestation, and results in declines in habitat and biodiversity, wood for fuel and industrial use.
  
- **Overgrazing and over-cutting:** Overgrazing occurs when plants are exposed to livestock grazing for extended periods of time, or without sufficient recovery periods. It reduces the capability of the land and causes desertification and erosion. Overgrazing is also seen as a means of enhancing the spread of invasive plants. Overcutting refers to the large volumes of trees and vegetation that is removed leading to forest fragmentation, soil loss and biodiversity loss.
  
- **Shifting cultivation:** is an agricultural system in which plots of land are cultivated temporarily and then abandoned. This system often involves clearing of a piece of land followed by several years of wood harvesting or farming, until the soil loses productivity.
  
- **Agricultural mismanagement of soil and water resources:** These include examples such as non-adoption of soil and water conservation practices, improper crop rotation, use of marginal land, insufficient and excessive use of fertilizers, chemical additions into the soil and over-pumping of groundwater.

The indirect causes of land degradation are mainly:

- **Accelerating population increases:** the population increases created additional stress on the land for food production, land for housing, transportation systems and other human needs for survival

- **Land shortage:** Land shortage and poverty, in combination, lead to non-sustainable land management practices, and subsequent causes of degradation. Poor farmers have little choice but to clear forest, cultivate steep slopes without conservation, overgraze rangelands and make unbalanced fertilizer applications, thereby a decline in land capability. Land degradation then lead to reduced productivity: a lower response to the same inputs or, where farmers possess the resources, a need for higher inputs to maintain crop yields and farm incomes. This has the effect of increasing land shortage still further, thus completing the cycle (Figure 2.1).
  
- **Short term or insecure land tenure:** For rural communities, land represents a fundamental asset: it is a primary source of income, security, and status. But almost half of these rural families (some 230 million households), either lack any access to land or a secure stake in the land they till. As a result, acute poverty, and related problems of hunger, social unrest, and environmental degradation persist. Farmers will be reluctant to invest in measures to conserve land resources if their future rights to use these resources are not secure
  
- **Poverty and economic pressure:** Poverty results in land degradation as poor people cannot afford to maintain the quality of soil. Small land holdings lead to severe economic pressures on farmers, to obtain sufficient food and income to meet immediate needs. Because of such pressure in the short term, labour, land and capital resources cannot be spared to care for the land, for example green manuring or soil conservation structures. This is also the underlying reason for two other direct causes noted above, improper crop rotations and unbalanced fertilizer use. In former times, most farmers accepted the situation into which they were born, even if it was one of relative poverty. Modern

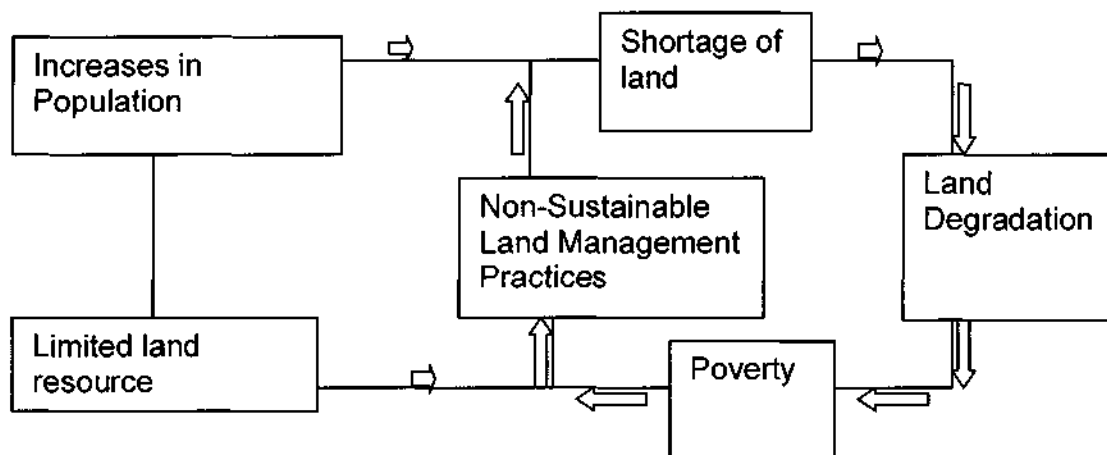


communications and influence have led to greater aspirations and consequent requirements for income, thus increasing economic pressures.

**Figure 2.1 Causal Nexus among land resources, population, poverty and land degradation**

The causes identified above are generally interrelated as described in the figure below:

Continuous increases in population results in shortage of land. This gives rise to non-sustainable land use, resulting in poverty and soil degradation. Limited land resources also, results on shortage of land. Once again, non-sustainable land use occurs which contributes to poverty and soil degradation. The cycle is ongoing as indicative in the causal nexus diagram below.



(Barbier, 1997)

Apart from soil degradation impacting on reducing food security, it can also negatively impact on bodies of water. Although soil and rock are compressed by tremendous forces, there are nonetheless gaps and cracks that have been interconnected by flowing water. One would have expected that water, being three times lighter than rock, is pushed up as sediments and rocks are pushed down by their own weight, so that free water cannot exist at depth. However, as can be observed in limestone Karst systems, water can exist deep down to 300 m and perhaps even deeper ([www.seafriends.org](http://www.seafriends.org)). Thus chemicals added to soil have the potential not only to reduce soil quality, but also can filter and impact on sub-surface water.

#### **2.4 Soils in South Africa**

It is estimated that South Africa loses an estimated 500million tons of topsoil annually through soil erosion. Approximately 81% of the total land area of South Africa is farmed of which roughly 70% is suitable for grazing. Overgrazing and erosion already leads to land degradation which is a South African national concern ([www.deat.co.za](http://www.deat.co.za)) and therefore any additional factors that might escalate the level of soil degradation must be prevented. Only then can a sustainable and equitable future be achieved through a healthy natural environment which supplies raw materials, absorbs and treats waste products and maintains water, soil and air quality (South African Yearbook, 2000/2001).

South Africa falls within the relatively little known third world major soil region of the world. This region covers the mid latitudes of both sides of the equator, between humid tropics and high altitudes. South Africa is dominated by very shallow soils. This is as a result of the combination of parent materials and very low, inefficient rainfall which limits soil production (Laker, 1999).

Approximately 35% of SA receives enough rain for dryland crop production. However, SA only has 13% (14 million ha) of arable land. Of this 3% is considered high potential land. Using the international norm of 0.4 ha of arable

land is required to feed one person, it is apparent that statistically SA should only be producing food for 35 million people. In mid 2007, statistics on SA population was approximately 47.9 million ([www.southafrica.info.co.za](http://www.southafrica.info.co.za)). Accelerated degradation occurs when the human carrying capacity of the land is exceeded. A characteristic of most South African soil is that it is extremely vulnerable to various forms of degradation and have low resilience. Thus even the smallest mistake in land use planning and land management can be devastating (Laker, 1999).

Soil erosion in the southern region is primarily subject to considerable spatial and temporal variation. The type of processes operating within an area are determined by the substrate conditions, climatic- geographic history, the time over which particular processes have operated, and land management practices. The result is considerable variability in geomorphic effects of soil erosion, both within and between morphic climatic conditions (Garland, 1987). These factors thus contribute to regional levels of soil erosion.

The total area affected in South Africa by pollution is much smaller than those affected by other types of degradation, such as erosion by water and soil compaction. The direct affects of soil pollution however are big, especially on long term soil fertility and human health. Mitigation on polluted soil is always necessary for long term sustainability (Laker, 1999).

## **2.5 PAH Contamination**

One possible contaminant identified to degrade the quality of soil further is PAH. PAH is found in oil, and other chemicals such as creosote. International studies from the Johns Hopkins University in the USA, Technical University of Denmark, and Institute for Environmental Technology and Analytical Chemist Laboratory in Paris among others have proved that PAH contamination has the potential to degrade soil ([www.sawpa.co.za](http://www.sawpa.co.za)).

Creosote bleedings, one example of PAH contamination can result in degradation of soil quality *via* sub-surface soil erosion and infiltration. Subsurface pollution has been considered the consequences in terms of the chemical leaching of material through the soil and regolith cover (Garland, 1987). In the event of creosote bleedings being spilled over soil surface, this will be further spread by the process of sub-surface erosion. Infiltration can also occur as a result of rainfall. Water has the likelihood to penetrate the soil, absorbing certain hydrocarbons and transporting this to the water table, which could further result in, ingestion by other organisms.

Therefore, mitigating creosote exposure to the natural environment will contribute to effective environmental management of a hazardous substance. Implementing environmental management is an emerging trend, both internationally and in South African jurisprudence. Courts of law and legislation are playing an important role in enforcing legal requirements for industries (Eskom, 2005). Environmental management is a legal requirement in South Africa in accordance to specific environmental legislation.

## **2.6 South African Legal requirements**

Environmental Management is a multidisciplinary process that forges the path between finding the balance between development and the environment (Knoll, 2005). An emerging trend that started in the 1990's both internationally and in the South African jurisprudence, is that the courts of law are playing an increasingly important role in advancing the principles of sustainable development. This is particularly so in situations where the components of sustainable development find manifestation in competing constitutionally guaranteed rights, as is the case in South Africa ( Eskom, 2005).

There are many definitions and views about what constitutes the environment. However, one of the more inclusive definitions is the one contained in S.A. law,

viz. Environment: the surroundings within which humans exist and that are made up of:

- a) *The land, water and atmosphere of the earth;*
- b) *Micro-organisms, plant and animal life;*
- c) *Any part or combination of (a) and (b) and the interrelationships among and between them; and*
- d) *The physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being.*

An important aspect of environmental law is the liability for clean-up following pollution or degradation of the environment. The basis of this requirement lies in the Constitution, but rehabilitation obligations also arise under the National Environmental Management Act 107 of 1998 and the National Water Act 36 of 1998.

The constitution guarantees the right to an environment that is “not harmful to human health and well-being” and to have the environment protected from, among other things, pollution and ecological degradation (section 24(b)). The duty to take reasonable measures to uphold this right is binding on the state and natural and juristic persons (section 8(2)).

The constitution obligation, referred to above is entrenched in NEMA. It imposes a “duty of care” in relation to the environment which requires that:

*Every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or insofar as such harm the environment is authorized by law or cannot reasonable be avoided or stopped, to minimize and rectify such pollution or degradation of the environment. (Section 28(1)).*

The categories of people upon whom the duty to take reasonable measures is imposed is very wide and includes an owner of, a person in control of, or a person who has the right to use land or premises where significant pollution is likely. Section 28 of NEMA include, but are not limited to, obligations to contain or prevent the movement of pollutants.

The two important general features of NEMA is the emphasis on the notion of Sustainable Development which endorses the definition and analysis offered by the Brundtland report and South Africa's transition to democracy with its socio-economic implications (Fuggle & Rabbie, 1997). NEMA outlines a number of more specific ways to take these ideals forward. The underlying reason for this is that South Africa's domestic legislation needed to reflect its international obligations under international treaties to which it is a party of (Judges, 2000). The preamble to NEMA makes it clear that one of the purposes of the Act is to establish a framework that will promote the progressive fulfillment of section 24 of the Constitution. Furthermore, the interpretation and implementation of NEMA must be guided by the National Environmental Management Principles set out in NEMA, section 2 (Govender, 2005).

Minimizing spread of pollution is further backed by the National Water Act 36 of 1998. It imposes a duty of care similar to that contained in section 28 of NEMA in relation to the pollution of water resources (section 19). It also specifies the reasonable measures required as a result of this duty of care, which include requirements to contain or prevent the movement of pollutants; eliminate any source of the pollution; and remedy the effects of the pollution. The South African National Standards complement South African legislation by providing set criteria that businesses must abide by, in keeping with meeting the requirements of legislation. SANS 10005 is the standard set out to provide for the management of treatment plants that have potential to cause massive pollution.

## **2.7 SANS 10005**

South Africa Bureau of Standards (SABS) is a statutory body that was established in terms of the Standards Act, 1945 (Act No. 24 of 1945) and continues to operate in terms of the latest edition of the Standards Act, 1993 (Act No. 29 of 1993) as the national institution for the promotion and maintenance of standardization and quality in connection with commodities and the rendering of services ([www.sabs.co.za](http://www.sabs.co.za)). SABS was reviewed and succeeded by the South African National Standards which provide the various standards for implementation in South Africa. A Standard is a published document which lists specifications and procedures established to ensure that a material, product, method or service is fit for its purpose and perform in the manner it was intended for. Standards define quality and establish safety criteria. Conformance to standards ensures quality and consistency. In South Africa our standards enhance competitiveness and provide the basis for consumer protection, health, environmental and safety management ([www.sabs.co.za](http://www.sabs.co.za)).

In South Africa, the treatment business news announced in 2005 that compulsory requirements were impending, requiring the construction and operation of creosote treatment plants. This resulted in the revised SANS that was adopted in late 2005 and contained requirements that all plants responsible for treating timber complies with the code of practice covering the construction, use of correct equipment and their operational procedure (i.e.: SANS 10005). The release of SANS 10005 occurred on 23 June 2006 and the standard is now SANS 10005:2006- *The Preservative Treatment of Timber*. The requirements are drawn up against a background of health, safety and environmental considerations and government pressure for the treatment industry to have its own compulsory operational standards. Plants are required to be audited by SANS accredited auditors to obtain a certificate of compliance.

The Standard (SANS 10005) contains the following provisions:-

- Details of allowable timber preservatives;
- Hazard conditions for timber;
- Solvents used for timber preservatives;
- The preparation of timber for treatment;
- The various treatment processes;
- The use of preservative-treated timber;
- Handling and safety of preservative-treated timber;
- Treatment plant conformity requirements; and
- Normative references, including preservatives and preservative treated products.

During the revision of this standard, many additional environmental concerns were triggered from management of creosote treated wood ([www.sawpa.co.za](http://www.sawpa.co.za)). Temporary storage of utility poles preserved with creosote was one possible concern due to the possible creosote bleedings. This concern was heightened, after the new electrification programmes were implemented demanding more creosote poles which were recently observed to being delivered very moist.



## **2.8 Creosote:**

Creosote is a wood preservative consisting mainly of aromatic hydrocarbons obtained by distillation of coal tar. It is used to preserve wood products such as utility poles and fence posts.

In South Africa, creosote is the only oil-borne preservative which has been used, with or without a waxy oil additive. Creosote is a heavy duty preservative which is toxic to most fungi and insects. It does not alter the dimension of the wood during treatment and is highly water repellent making it an excellent wood preservative. Creosote treated wood is not subject to water leaching. Its water repellency gives it excellent weathering characteristics. Creosote treated wood usually has a characteristic odour. It is usually black and may through 'bleeding' exhibit black deposits on the wood surface ([www.sawpa.co.za](http://www.sawpa.co.za)).

It is known that wood pole creosote treatment facilities are characterised by odourous fumes. The composition of the fumes has not been investigated in detail in South Africa and concerns have been expressed that the hazardous compounds in the fumes may have adverse effects on human health. The more direct concern though is the potential to contaminate soil and subsequent pollution of sub-surface water.

The Department of Environmental Affairs and Tourism (DEAT), has identified PAH as a compound of potential concern contributing to the hazard profile list. Since creosote consists primarily of PAHs, the toxicity and fate of many of the components of the mixture are therefore similar to PAH ([www.deat.co.za](http://www.deat.co.za)).

Biotransformation by microbes is primarily the process by which creosote constituents are degraded in soils, surface water and possibly ground water. The mixture is relatively stable and persistent in the environment. The half life data however, are not available. Among the more volatile constituents of creosote are the cresols in its phenolic fraction. These materials comprise only about one percent of the creosote weight, but it is the cresol components that give creosote

its distinctive medicinal odour and its resin-like properties. Creosote is classified as carcinogenic on the basis of some of the PAHs as well as the benzene component (Lewis, 1996).

There are 13 classes of hazard identification, with some further subdivided into numbered divisions (e.g.: class H4.1, H4.2). For example, classification H4.1 means that the waste is in division 1 of class 4; and that the waste exhibits "flammable solids" characteristics. Creosote has a hazard classification of H4. The Material Data Safety Sheet of creosote can be found in Appendix I in this report.

### **2.9 Health effects of Creosote**

Environmental degradation is often linked to subsequent health effects. Creosote contamination is also linked to negative health consequences. Long-term exposure to low levels of creosote, especially direct contact with the skin during wood treatment or manufacture of coal tar and creosote-treated products has resulted in cancer of the scrotum and skin. Animal studies have also shown skin cancer from exposure to coal tar products ([www.sawpa.co.za](http://www.sawpa.co.za)). It has also been noted that eating food or drinking water contaminated with creosote may cause a burning in the mouth and throat as well as occasional stomach pain. If one touches creosote directly, skin may turn red and become irritated with blisters and sores ([www.sawpa.co.za](http://www.sawpa.co.za)). Further studies in animals have shown birth defects in the young of mothers exposed to high levels of creosote during pregnancy, but no similar studies have been performed on humans (Ben, 2000).

Creosote may dissolve with rainfall and move into the ground water through the soil. Less dense creosote chemicals stay near the top of water and can be ingested by animals, thus has the potential thereby to enter the food chain ([www.sawpa.co.za](http://www.sawpa.co.za)). Despite the long history of creosote industrial use, there is relatively little data on the migration of PAH from creosote into the surrounding environment. It is generally assumed that the quantities of PAH entering the

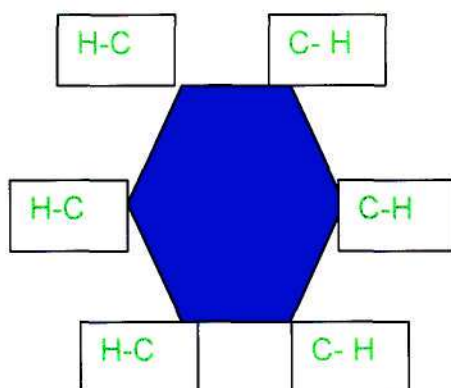
environment from treated wood in service are relatively small. The available evidence, however is limited, inconclusive and sometimes conflicting (Xiao, 2000). The limited quantities of PAH from wood is also changing as a result of the recent observations from Eskom wood pole yards that demonstrate significant increases in bleedings.

### **2.10 Polycyclic Aromatic Hydrocarbons:**

Polycyclic aromatic hydrocarbons (PAHs) are a group of different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances that include tobacco or charbroiled meat. PAHs are usually found as a mixture containing two or more of the different compounds, such as soot ([www.sawpa.co.za](http://www.sawpa.co.za))

PAH are components of crude and refined petroleum and coal. Oil spills are a major source of PAH in freshwater and marine environments. Combustion of organic materials in fires or in internal combustion engines also produces PAH which are released to the environment in exhaust particulates and in solid residues (ash). Concern about PAH in the environment arises from the fact that many of them are quite persistent and some are known to be potent carcinogens in mammals.

**Figure 2.2:** Representation of PAH Atom by a chemist (Baird, 1995)



When multiple units of benzene are fused together in more than one ring, the polycyclic aromatic hydrocarbons are formed on the sides of the hexagon, such that a single carbon atom participates in bonding in more than one ring. This results in the formation of polycyclic aromatic hydrocarbons (PAH's). There are many different types of PAH compounds. According to Baird (1995), "benzo (a) pyrene is one of the common by-products of the incomplete combustion of fossil fuels." It has caused cancer in test animals and therefore has potential to cause cancer in humans.

PAH's generated in the production of coal tar have been found in sediments and fish internationally. They tend to accumulate in fatty tissues of fish. According to Baird: pg 11 (1995), "the PAH's that are the most potent carcinogens possess a 'bay region' formed by the branching in the benzene ring sequence: the organization of carbon atoms as a bay region which imparts a high degree of biochemical reactivity to the PAH". PAH's are not necessarily carcinogens themselves, but when they are adsorbed on the surface of particles, or when

they are transformed by metabolic reactions in the body, the actual cancer – causing species is produced (Xiao, 2000).

When PAH is released from a large area, such as an industrial plant, or from a drum or dripping as in the case of creosote bleedings from wood-pole storage, it enters the environment as a chemical emission. This emission known as a release does not always lead to human exposure. One may be exposed to a chemical only when one comes into contact with the chemical. Exposure to PAH be will be dependant on the dose (how much), the duration (how long), the route or pathway of exposure (breathing, eating, drinking, skin contact) as can be determined *via* a Risk Assessment (Antegana, 2001).

Very little information is available on the individual chemicals within the PAH group. Most of the information available is for the PAH group as a whole. Although the health and environmental effects of the individual PAH's are not exactly alike, the following 15 are considered as a group:

- **Acenaphthene:** Acenaphthene has been shown to produce nuclear and cytological changes in microbial and plant species. Results of acenaphthene mutagenicity studies in microorganisms and carcinogenicity study are negative. Despite the negative results, acenaphthene is a polycyclic aromatic hydrocarbon (PAH), a class of chemicals that contain carcinogens; the carcinogenic potential of acenaphthene is of great concern. The concern is that acenaphthene bonds other PAH particles and together they pose problematic (<http://ec.europa.eu/health.html>).
- **Acenaphthylene:** Like most PAHs, acenaphthylene is used to make dyes, plastics and pesticides. Also a possible carcinogen due to its characteristic to bond other PAH particles (Morrel *et al*, 1999).

- **Anthracene:** One of the most common ways anthracene can enter your body is through breathing contaminated air. It can get into your lungs when you breathe and caused lung infection. If one works in a hazardous waste site where PAHs are disposed, it is likely to breathe anthracene and other PAHs. Eating or drinking food and water that are contaminated with anthracene is also harmful. Exposure can also occur if your skin comes into contact with contaminated soil or products like heavy oils, coal tar, roofing tar or creosote where PAHs are found. Once in your body, anthracene can spread and target fat tissues. Target organs include the kidneys, liver and fat which can be infected (Morrel *et al*, 1999)
- **Benzo (a) pyrene:** A common compound of PAH is benzopyrene, a known carcinogen and also an ingredient in cigarette smoke. Benzopyrene is suspected to be a major factor in lung cancer (Morrel *et al*,1999)
- **Benzo (b) flouranthene:** Although there are natural sources of benzo[b]flouranthene emissions (e.g., volcanic activity), anthropogenic sources are the most important to air pollution. Considering only its physical removal processes, the lifetime of benzo[b]flouranthene due to particle dry deposition is expected to be about ten days. This on its own has not proven to be a carcinogen, but its characteristic to bond other PAH particles is of concern (Morrel *et al*, 1999).
- **Benzo (ghi) perylene, Benzo (k) flouranthene, Benz (a) anthracene:** Benzene is a known carcinogen and has been classified as a Group A carcinogen of medium potency by the US EPA and a Group 1 carcinogen by the International Agency for Research on Cancer (IARC). Benzene particles make up the composition of Benzo (ghi) perylene and therefore are hazardous. Benzene also has hematological effects and is mutagenic. The major effect of long-term exposure to benzene is on the blood.

Benzene causes harmful effects on the bone marrow and can cause a decrease in red blood cells leading to anemia (Morrel *et al*, 1999).

- **Chrysene:** There is a large body of evidence supporting an excess risk of lung cancer in workers exposed to mixtures of chrysene and other PAH (<http://eied.deh.gov.au/atmosphere.html>)
- **Flouranthene:** Flouranthene can cause skin irritation, eye irritation and liver enzyme induction (<http://eied.deh.gov.au/atmosphere.html>)
- **Flourene:** Flourene has not been extensively studied, and its effects are largely undetermined. It is considered non-carcinogenic, but is a liver enzyme inducer (<http://eied.deh.gov.au/atmosphere.html>).
- **Indeno (1, 2, 3-cd) pyrene:** Indeno [1, 2, 3-cd] pyrene, a crystalline solid with a chemical formula of C<sub>22</sub>H<sub>12</sub> and a molecular weight of 276.3, (PAH). There is no commercial production or known use of this compound. Indeno [1, 2, 3-cd] pyrene is found in fossil fuels and occurs ubiquitously in products of incomplete combustion (IARC, 1983) and has been identified in soils, groundwater, and surface waters at hazardous waste sites (ATSDR, 1990). No absorption data were available for indeno [1, 2, 3-cd] pyrene; however, its ability to be structurally-related to most common PAHs, primarily benzo[a]pyrene, it would be expected to be absorbed from the gastrointestinal tract, lungs, and skin (EPA, 1991).
- **Phenanthrene:** Phenanthrene primarily causes skin damage, such as irritation, photosensitization, and allergic responses. Phenanthrene is only slightly toxic orally (<http://eied.deh.gov.au/atmosphere.html>)

- **Pyrene:** There are limited data on the toxicity of pyrene. Pyrene is a skin irritant and it may cause minor liver infection. It is considered non-carcinogenic (Morrel *et al*, 1999)
- **Naphthalene:** Naphthalene has a strong, but not unpleasant smell. Naphthalene is weakly attached to soil and pass through the soil into underground water. Naphthalene concentrations in water are reduced in water by bacteria and evaporate into the air. Naphthalene does not accumulate in the flesh of animals and fish and hence is not a carcinogenic agent. Instead, hemolytic anaemia (a condition involving the breakdown of red blood cells) is the primary health concern for humans exposed to naphthalene for either short or long periods of time ([www.eco-usa.net](http://www.eco-usa.net)).

These pure PAH's usually exist as colorless, white, or pale yellow-green solids. They however are always found in more one compounded together due to the chemical characteristics of the compound. The vast number of compounds of this important group, derived chiefly from petroleum and coal tar, are rather highly reactive and chemically versatile. The name is due to the strong and unpleasant odor characteristic of most substances of this nature.

PAH components do not occur alone in the environment, rather they are found as mixtures of two or more PAH's. They can occur either in air attached to dust particles, or in soil or sediments as solids (Baird, 1995).

### **2.11 Acceptable levels of PAH**

In order to analyze the results of soil analysis, it is important to note the acceptable levels of PAH in the environment. Internationally, this has been generally determined by the health department through the use of Health Risk Assessments. In Europe health risks were calculated based on a conservative approach, which meant calculating risks for the most sensitive receptors on-site,



i.e., children. A site exposure model was prepared by S Goel in 2006 for a contaminated site in India. As part of this conservative approach, the longest durations and frequencies of exposure that are likely in the long-term, and the highest contaminant levels on-site were chosen for risk calculations. The results of this model using a quantitative risk assessment indicated that the cancer risk due to exposure to PAHs alone was  $>10^{-4}$  based on maximum and average contaminant concentrations which equates to 10000  $\mu\text{g}/\text{Kg}$ . Soil should not contain any PAH contaminant at a concentration above 10000  $\mu\text{g}/\text{kg}$  (Antegana,2004).

In South Africa as well, PAH acceptable levels of contamination for oil spill clean-up is currently 10000 micrograms per kilogram. In the event of an oil spillage, remediation must be conducted such that contamination levels are brought to equal to or less than 10000  $\mu\text{g}/\text{Kg}$  (Antegana, 2004). This criterion will be used to assess PAH levels in this study from bleeding at the Howick Pole yard. The 10000  $\mu\text{g}/\text{Kg}$  serves as the maximum permissible concentration from creosote contamination.

The Department of Environmental Affairs in South Africa however, has created specific criteria for a few individual components of PAH, as described in their document on 'Minimum requirements for the handling, classification and disposal of Hazardous waste (Appendix II). Benzo (a) pyrene is among the specific list, where the acceptable level in the environment is 0.005 ppm or 50  $\mu\text{g}/\text{Kg}$ . Pyrene contamination level in the environment is 65ppm or 6500 $\mu\text{g}/\text{Kg}$ . Naphthalene has an acceptable level of 0.38ppm or 3800 $\mu\text{g}/\text{Kg}$  ([www.dwaf.co.za](http://www.dwaf.co.za)).

The remaining contaminants that combine to formulate PAH are given an acceptable risk level, whereby the contaminants are allocated acceptable levels based on the standard safety factor of 10000 $\mu\text{g}/\text{Kg}$  for the individual compounds. These compounds are however found in Dwaf's list of mutagens and

carcinogens and research is still ongoing to determine whether to apply specific criteria to these contaminants.

## **2.12 Wood Preservation**

Wood preservation promotes the conservation of indigenous forests by making timber plantations which aren't naturally durable, into effective substitutes for durable timbers from indigenous forests. It also reduces the volume of wood used by prolonging the service life of wood for many years ([www.sawpa.co.za](http://www.sawpa.co.za)).

The ability to penetrate wood with chemicals that are toxic to insects or fungi is largely dependant on being able to remove moisture, so that the preservative liquid can be added in its place. Thus wood must dry out first and then be coated with creosote and then must dry again. Some water soluble chemicals will move by diffusion to penetrate the wood sufficiently to protect it (Xiao, 1999).

Most preservatives, creosote included, will not pass through the cell wall membranes of wood and require pressure to push them deep into the wood. The depth to which penetration is achieved is dependant on density, chemical inclusions within cells, moisture content, cell types and techniques used. Essentially the science of wood preservation is the treatment of wood to give extended life service. This involves the placement, within the wood microstructure, of preservative chemicals which are antagonistic to wood destroying agencies. South African manufacturers use the kiln dry process and air drying. The process of kiln drying consists basically of introducing heat. This may be directly, using natural gas and/or electricity or indirectly, through steam-heated heat exchangers, although solar energy is also possible. The wood preservation industry is required to achieve certain levels of treatment quality and these are laid down in the forms of National standards.

The variety of chemicals and processes requires a corresponding range of environmental controls outlined in the standards. Environmental risks can be virtually eliminated if wood treatment manufacturers ensure that at the time of distribution, the surface of the products is dry and free from preservative deposits or exudates. Observations by Eskom, a key client of the wood preservation industry indicate that in the last decade wooden poles arriving at its wood pole yards are moist with subsequent occurrence of bleedings.

### **2.13 Creosote Bleedings**

International studies on the rate of creosote bleedings, e.g.: American wood preservation tests E11, indicate that short term creosote bleedings, results are very aggressive compared to natural rain exposure and that the bleedings found in smaller samples are greater than the bleeding from a larger sample ([www.eco-usa.net](http://www.eco-usa.net)). For this study however, soil samples from the natural receiving environment will be investigated to understand the environmental impacts from natural environmental exposures at the Howick Pole Yard, in Kwa Zulu Natal, South Africa.

Generally the following factors contribute to the creosote bleeding phenomena.

- Wetting of wood and penetration of free water into the wood reduces space, surface wetting properties and type of exposure;
- Dissolving of preservative components from the chemical can lead to diffusion out of the cell walls (depends on preservative and temperature);
- Diffusion of preservative components to the wood surface (depends on the preservative, wood permeability, moisture content, temperature etc);
- Drying of wood, the interval of drying after treatment should be crucial to avoid excessive creosote bleedings (Xiao, 1999).

The review of literature pertaining to creosote bleedings and subsequent impacts reveals that research in the field is limited. Studies however, have been executed on the effects of the primary component of creosote viz: PAH. These studies include:

### ***2.13.1 PAH contaminated site in Perth***

Natural attenuation studies were carried out at the Eden Hill site in Perth, Western Australia, where a gasoline spill had contaminated soil with PAH and other soluble components. PAH chemicals are also used in the composition of creosote. Over a 7 year period, soil was sampled from transects and examined. Soil cores were recovered in the source regions to determine the vertical gasoline distribution and composition. A tracer test using deuterium-labeled contaminants was carried out within the plume to obtain direct estimates of degradation rates for PAH (Xiao, 2000)

Over the 7 year period, PAH from the above spill persisted in the environment. Eventually, after 7 years of microbial remediation, PAH was reduced to the acceptable level of 1000 ug/Kg. This case study proves that PAH which also found in creosote does persist in soils, and can therefore pose health threats to those who come into contact with the soil (Xiao, 2000)

### ***2.13.2 University of Patras publication on creosote loss***

In 1998 the University of Patras, Patra Greece published the rate of Creosote Loss. The study focused on the rate of losses of creosote from power transmission powerline poles. Three different categories of poles were included, i.e.: 11m light, 11m medium and 10m light. It was found on average the loss of creosote is 6.8% annually depending on the type of pole. The change in the retention of creosote can be expressed satisfactorily from the equation (Morrei *et al*, 1999):

$$Y = Y_0 \times e^{-b.t}$$

**Y<sub>0</sub>**= initial retention of creosote

**Y**=expected retention of creosote after t years

**t**= time of storage in years

**b**= constant

The creosote losses for the first year of storage were in order of 5-12 kg of creosote per cubic meter of poles. This study concluded that the quantity of creosote drained into the soil during one year of storage is high when compared to the amount of PAH allowed in soil of 10000 µg/Kg and can have a serious impact on the soil (Morrel et al, 1999).

### ***2.13.3 Key-stone species survival rate in PAH contaminated soils***

The earthworm is identified as the key-stone species in the soil fauna. Earthworms are involved in many sub-processes of life-support functions in the food chain (van Hesteren, 1998). Earthworms respond quickly to environmental disturbances and provide a lot of ecotoxicological information about their relationship with soil pollution.

Earthworms were placed in soils highly contaminated with PAH in California. The growth and survival of the earthworms were reduced at high PAH concentrations. Barely, carrots and tomato's were also planted in high PAH contaminated soils. Some of these plants showed cell damage (van Hesteren, 1998).

This study confirms that that highly contaminated PAH soils reduce the fertility of soils.

#### ***2.13.4 Environmental impacts of Conroe Creosote Company***

Conroe Creosote Company, a multi-million dollar operation was managed since 1944 in Montgomery. The site was taken over by the Montgomery County for non-payment of taxes in 1997 and left abandoned. After several cancer incidents of the residents around the site, the EPA was triggered to conduct tests in the area. The EPA report confirmed that large quantities of creosote had contaminated the soils in the area and even entered the nearby lake. Fish had harmful levels of PAH, PCB's and metals. A fish consumption warning was issued to all the people in the area and clean-up of the abandoned site was initiated. Up to 20 feet of soil had to be removed, to ensure removal of all cancer causing chemicals (<http://www.thebulletin.com>).

This study confirms that creosote contaminated soil in large quantities has the potential to cause huge environmental risks.

#### **2.14 Creosote's Environmental Risk**

Environmental Risk is the way of describing the possibility of an environmental accident (such as spills of wastes or chemicals polluting soil) occurring. Environmental liability is the threat that an environmental accident or disaster that may cause. For example a spill that occurs in a factory with no procedures to deal with spills will have a greater environmental liability in the eyes of an insurance company, than a company that does have emergency procedures in place. Environmental Risk Assessments are used to determine the impact of an environmental risk. Creosote as an environmental risk will be elaborated in the next chapter.

## **2.15 Conclusion**

As the world's population continues to soar, development continues to accelerate to meet the demands of the growing population. This development constantly impacts on the environment negatively, and thus mitigation has become essential during the implementation of development activities to promote environmental responsibility (Xiao, 2000)

Around the globe, in the absence of mitigation measures, biological communities that took millions of years to develop are being devastated by human actions. Vast numbers of species have declined rapidly as a result of excessive hunting, habitat destruction and an onslaught of pollution activities from human activities. Environmental pollution eliminates many species from biological communities even where the structure of the community is not obviously disturbed. Natural hydrological and chemical cycles have been disrupted by the clearing of land, and the addition of constituents to the biophysical environment resulting in massive pollution (Wilson, 2004).

Soils are one such important natural resource found in the environment that is vulnerable to massive pollution. Among the various roles that soil play to maintaining biodiversity, one its most important functions to human survival is food security. Soil requires to be managed, to promote essential living conditions for all organisms, *i.e.*: oxygen, water, carbon dioxide and other essential nutrients that are exchanged in the soil. In order to manage soil, data is required from researching possible contaminants. This study researches creosote as a contaminant by the application of the methodologies discussed in the next chapter.

## **CHAPTER THREE: STUDY AREA AND METHODOLOGY**

### **3.1 Introduction**

Research is a systematic and methodical process of inquiry and investigation that increases the knowledge and/ or solves a particular problem (Sekaran, 1992). The purpose of research can be summarized as the following: To review and synthesize existing knowledge, to investigate existing problems and situations, to provide solutions to a problem and to generate new knowledge. Research can be classified as, exploratory, descriptive, and causal and predictive (Gephart, 1999).

Exploratory research involves investigation of a problem or pending problem where there are few or no earlier studies. Descriptive research describes phenomena as they exist. Statistics generally apply to this research to quantify information. Finally causal or predictive research seeks to explain what is happening in a particular situation (Gephart, 1999).

Environmental management requires the use of detailed procedures and methodology. The environmental evaluation must be conducted using comprehensive protocols and fixed procedures to ensure the collection of the relevant data and the necessary documentation that is required to determine the respective objectives of the study (Berg *et al*, 1995).

There are a number of terms used to describe the two major research approaches. Two often used terms are quantitative and qualitative. Within management and organizational studies, the quantitative approach is seen as objective and relying heavily on statistics. Qualitative on the other hand is seen as subjective and preferring language and description rather than numerals and figures (Gephart, 1999). These distinctions are useful in recognizing the two approaches. They, however, do not portray the differing paradigms that underpin each approach and how these paradigms affect the research approach.



A paradigm provides a conceptual framework for seeing and making sense of the social world. According to Burrell and Morgan, (1979) "To be located in a particular paradigm is to view the world in a particular way." This becomes applicable in a research process, as the beliefs of the researcher will reflect in the way that the research is designed, and how data is collected and analyzed, and how the results are presented. A researcher is therefore required to identify his/her respective paradigm so as to identify his/her role in the research process. Quantitative and qualitative approaches to the research process are based upon differing assumptions that shape the whole research design and influence the role of the researcher. The six stages of the research process discussed below remain constant, however the basic belief of the researcher and his /her paradigm influence choices made within the research process.

### **3.2 The Research Process**

The actual process constitutes six steps; identifying the research topic, defining the research problem, determining how to conduct the research or the method, collecting research data, and analysis and interpretation of results (Burrell and Morgan, 1979).

Identifying a research topic is done by researching a broad need, and examining an area for research. Once this is done, the researcher will have to outline the research problem and state the rationale for the investigation. The literature review provides information on what other researchers have found and provides the basis for the researcher to work from. A sound literature review provides a basic conceptual framework to proceed further with the investigation by clarifying the research problem and identifying likely variables. In this study, the literature review helps the reader understand the background knowledge on the global environmental problems regarding land degradation, possible soil contaminants such as creosote, the South African legal framework, and what are the likely implications of creosote contamination on soil (Gephart, 1999).

The research strategy, a subset of research design, includes elements of data collection and interpretation and emerges from both the research purpose and question. Data collection entails the selection of a sampling procedure. Sampling is the process of selecting units (e.g., people, organizations) from a population of interest so that by studying the sample the researcher may fairly generalize about the population. In science there are two major approaches to how we provide evidence for a generalization. The first approach is the sampling model where one identifies the population size and draws a fair sample that is representative of the population targeted. The second approach is proximal similarity model or external validity model where a researcher identifies different general contexts and develops a theory about which contexts are more and less associated to the study. One uses this method and maps out the degree of proximal similarity among various contexts with a methodology like concept mapping (Creswell, 1994).

The sampling frame entails listing of the accessible population from which the researcher draws a sample or the procedure that the researcher follows as the actual basis for random or non-random sampling. Random sampling, also known as probability sampling, occurs when every combination of items from the frame, or stratum, has a known probability of occurring, but these probabilities are not necessarily equal. With any form of sampling there is a risk that the sample may not adequately represent the population but with random sampling there is a large body of statistical theory which quantifies the risk and thus enables an appropriate sample size to be chosen (wikipedia.org). To conduct a random sample, the population size and a source of random numbers is required. Computer programs such as Excel and Minitab generate random numbers, and alternately random numbers are found in a table of random digits. Numbers are organized into numbered rows and columns. The researcher decides non-purposively to start at specific row, specific column. If for example a sample of ten was to be taken from a class of 200. The researcher would choose a starting point of row one column four and write down three digit numbers from the table.

This process will continue until ten applicable units from 0-200 are chosen (Johnston, 1991). The simple random sample is further sub-divided into cluster random sampling, stratified random sampling and so on.

Systematic sampling occurs when the researcher selects the first sample purposively or randomly and thereafter decides to select every  $n^{\text{th}}$  sample. The basis of systematic sampling is an equally spaced or prescribed interval between each sample. For example every 50<sup>th</sup> person from a list of 5000 will represent the sample size to win a lucky draw prize (William, 2006)

Non-random sampling is widely used as a case selection method in qualitative research, or for quantitative studies of a preliminary and exploratory nature where random sampling is too costly, or where it is the only feasible alternative (William, 2006). We can divide non-probability sampling methods into two broad types: *accidental* or *purposive*. Most sampling methods are purposive in nature because we usually approach the sampling problem with a specific plan in mind. The most important distinctions among these types of sampling methods are the ones between the different types of purposive sampling approaches. Purposive sampling ensures that the sample taken meets the criteria for what it is being used for. For example if a market research company requires a sample of 40 year old woman, only that specific criterion will be targeted. It can be deduced that sampling techniques available vary and examples are simple random sampling, stratified random sampling, systematic random sampling, convenience sampling and purposive sample (William, 2006). The techniques applicable for this study will be elaborated further in this chapter.

This study firstly required the use of soil sampling to investigate the objectives of this study. Soil sampling is a scientific sampling process and one must adhere to the following steps for contaminated soil sampling. The first step is a site – screening process. This assists in soil sampling being conducted in target areas of concern which is usually the most contaminated areas. Step two is the process of accumulating information on analytical requirements such as researching the

contaminant being tested for and identifying the key indicators that are being investigated for. Soil characteristics, such as soil type and porosity, should also be determined in order to further define subsurface conditions and to assess chemical movement along various pathways (Johnston, 1991).

Step three is the actual collection methods. These are described in the table below:

**Table 3.1: Collection methods for contaminated soil sampling (Johnston, 1991)**

<b>Collection method</b>	<b>Depth of collection</b>	<b>Applications</b>
Surface sampling	0-15cm	<ul style="list-style-type: none"> <li>▪ Recent spills</li> <li>▪ Low migration rates e.g.: clay soil</li> </ul>
Test Pit	0-5m	<ul style="list-style-type: none"> <li>▪ Shallow contamination</li> <li>▪ Complex stratigraphy</li> <li>▪ Heterogeneous fill</li> </ul>
Boreholes	0m to bedrock	<ul style="list-style-type: none"> <li>▪ Deep contamination</li> <li>▪ Dispersed spill</li> <li>▪ Prevents cross-contamination</li> <li>▪ Best method for identifying volatile contaminants</li> </ul>
<b>Other Soil Pile</b>	N/A	<ul style="list-style-type: none"> <li>▪ To determine contaminant levels of excavated soil that is potentially contaminated</li> </ul>
Tank Pit	N/A	<ul style="list-style-type: none"> <li>▪ After removal of underground</li> </ul>

As it is indicated above, there are several different methods which can be used to collect soil samples, depending upon the depth of the samples to be taken and the soil characteristics of the site. The researcher decides on which collection method to use and decides on a sampling technique to collect samples. In this

study the systematic and purposive soil sampling technique was applied, using a combination of test pit and surface sampling method.

**3.2.1 Systematic soil sampling:** is when selected soil units are at regular distances from each other. The sampling points must follow a fixed pattern and follow a fixed distance from each other. Although the sampling pattern is pre-determined, the first sample must be selected either randomly or purposively (Johnston, 1991).

**3.2.2 Purposive soil sampling:** Many environmental contaminants originate from a point source, and concentration reduces rapidly as distance from the source increases. In such an instance, a grid random sample is wasteful for estimating the distribution of contamination and instead purposive sampling is preferred. This method is cost effective and samples taken are those that are visibly contaminated from the source (Johnston, 1991).

After samples have been collected the next step is to analyse and interpret the data. The objective at this stage of the research is dependant on the paradigm selection of the researcher. For example a researcher with predictive research purpose using a classic experiment or survey approach will typically try to prove or disprove their original hypothesis. Finally, presenting the results would result in data being discussed as to the extent to which it proves or disproves the answers to the research questions (Gephart, 1999).

To meet the aims and objectives of this study, defined tools and methodologies are to be adopted to provide valid data to answer the research question. Before one can find results and data, one will need to find information on the subject and area as background information. Some of this information has been investigated in the literature review, and will be further discussed below in the subsequent paragraphs relating specific to the local site. Research can be conducted in many forms and must be decided by the researcher, so as to determine strategies of collating the required information. The discussions below will be based on the various paradigms related to research.

### **3.3 Research Paradigm**

There has been considerable interest in recent years in the role of philosophical assumptions and paradigms in doing research. A paradigm is essentially a worldview, a whole framework of beliefs, values and methods within which research takes place (Creswell, 1994). Prominent concerns were raised about the limits to quantitative data and methods were often associated with positivism, the prevailing paradigm.

#### **3.3.1 Positivism and Post positivism**

Positivism assumes an objective world hence it often searches for facts conceived in terms of specified correlations and associations among variables. Post positivism is consistent with positivism in assuming that an objective world exists but it assumes that the world might not be readily apprehended and that variable relations or facts might only be probabilistic and not deterministic. The positivist thus focuses on experimental and quantitative methods used to test and verify hypothesis and complements this process with some qualitative methods to gather broader information outside of readily measured variables (Creswell, 1994).

#### **3.3.2 Interpretivism and Constructivism**

Interpretive research is concerned with meaning and it seeks to understand definition of a situation as interpreted in a social context (Schwandt, 1994). Interpretive theory involves building a second order theory in contrast to positivism which is concerned with objective reality. Interpretivists assume that knowledge and meanings are acts of interpretation. Constructivism extends this concern to argue that knowledge and truth are the result of perspective, hence all truths are relative.

In this process data collection and representation are accomplished with informant interviewing, ethnography, or description of cultures based on intimate knowledge and participation (van Maanen, 1988). This is meaning versus measurement methodology.

### **3.3.3 Critical Postmodernism**

The third paradigm of interest, critical postmodernism is a combination of two somewhat different worldviews. Critical theory and post-modern scholarship are the two worldviews. Critical theory is a tradition developed by the Frankfurt School in Germany based on the German tradition of philosophical and political thought stemming from Marx, Kant, Hegel and Max Weber (Kincheloe and McLaren, 1994). Critical theorists differ from Marx's orthodoxy on many issues but maintain a focus on the changing nature of capitalism and the forms of domination, injustice and conquered capitalism produced.

The assumption of the critical theory is that the material world we encounter is both real and is produced by and through capitalist modes of production. Capitalism contains a basic inequality which operates as a social value and social structure. The owner of capital is given the right to make decisions about labourer's dependant on wage. Therefore the task of this paradigm is to deconstruct discourse to reveal hidden structures of domination. It seeks to re-examine important events, identifies contradictions, alienation and co-modification to reveal forms of domination and exploitation (Berger, 1966).

All three paradigms listed above are somewhat separate but not greatly distant from each other. They do play an instrumental role in shaping research methodology.

### **3.4 Research Methodology**

The application of research methods or techniques enables the researcher to gather, organize and analyze data quantitatively or qualitatively. Deciding on the research methods that one will explore to execute one's investigation will forge the path to collect the information that is required to draw up a research plan. A research plan depends on what information you need to collect in order to make decisions and draw logical conclusions pertaining to the research question (McNamara, 1997).

Key factors that are significant in deciding on the research methods include: The researcher needs to identify the purpose, for which the research is being undertaken. This involves what the objectives of the study are trying to decide. It is also important to know who the audiences that the information is being collected for, are; so as to ensure the appropriate levels of research sophistication can be adopted. For example if the target audience are rural people, the relevant ethnic languages must be used to communicate and collate data (McNamara, 1997).

A research pre-plan will enable the researcher to be selective with respect to the deliverance of information. Sources of information will influence the methodologies to be implemented. The methods or techniques required to access information can also be documented in the research plan. Such examples of methods of data collection include questionnaires, interviews, examining documentation, observation, laboratory experiments *etc* (McNamara, 1997). There are generally certain limitations to every research method and this can be identified and modified in the research process.

The research methods applied to this particular investigation will be described below:



### **3.4.1 Enterprise Risk Assessment and Management Paradigm**

A Risk Assessment is a qualitative or/and quantitative evaluation of the environmental and/or health risk resulting from exposure to a chemical or physical agent. Over the years it became evident that the only alternative to Risk Management was crisis management, which was always more expensive, time consuming and embarrassing. In the early 1990's concerns with risks changed and with changing legislation and knowledge, large organizations began to realize that risks could lead to organizational collapse. Due to these factors in the changing world, a new Risk Assessment and Management Paradigm were developed in 2004. The Risk Assessment process therefore underwent the continual review process and incorporated a new aspect to internally audit risks. This whole new process was termed the Enterprise wide Risk Assessment and Management Paradigm ([www.eirm.net](http://www.eirm.net)).

The Enterprisewide Risk Assessment and Management Paradigm provides a framework for a researcher conducting a Risk Assessment to effectively deal with uncertainty and associated risk, thereby enhancing the value of the Risk Assessment ( Nel, 2007).

This new process has been researched and drafted by a team globally and provides researchers with a set of new guidelines to identify potential events and risks that may affect the respective entities and is the basic format on how to identify, assess and manage risks to any business. A specialized Matrix has been created for health, safety and environmental impacts respectively to analyze the risk estimation using one universal format. The application of a universal format allows for risk assessments to follow a specific trend, and for findings to be judged using the same set matrix worldwide. This Enterprisewide Risk Assessment environmental matrix was adopted for use in this study to assess the extent of the environmental risk from creosote bleedings at the Howick Pole Yard. The principles of the Enterprisewide Risk Assessment and

Management Paradigm include being purposive, interdisciplinary, practical and focused.

### **3.4.2 Environmental Risk**

Environmental Risk is the way of describing the possibility of an environmental accident (such as spills of wastes or chemicals polluting soil) occurring. Environmental liability is the threat that an environmental accident or disaster may cause. For example a spill that occurs in a factory with no procedures to deal with spills will have a greater environmental liability in the eyes of an insurance company, than a company that does have emergency procedures in place (Nel, 2007).

Environmental risk and liability are two general terms that may be used to describe the readiness and preparedness of organizations and individuals to deal with and respond to, environmental disasters, problems and accidents. Risk must be evaluated in order to quantify the level and type of remedial actions required to reduce or eliminate the risks (McNamara, 1997).

It is therefore most important that risks and liabilities be identified so that precautionary measures and plans can be prepared, beforehand, to deal with the eventualities, should they occur, or to provide corrective action timeously, if environmental damage has already occurred. As such this study endorses creosote as a possible environmental liability currently at the Eskom wood-pole yard in Howick.

### **3.4.3 Environmental Risk Assessment**

An Environmental Risk Assessment (ERA) is a process of identifying and evaluating the adverse effects on the environment caused by an environmental risk. A risk assessment is the actual procedure in which the risks posed by inherent hazards involved in processes or situations are estimated either quantitatively or qualitatively. It is a process for evaluating and predicting the likelihood and extent of harm in quantitative and qualitative terms that may result from a health, safety or environmental hazard. An environmental exposure to the chemical is predicted and compared to a predicted no-effect concentration, supplying risk ratios for the different media (Nel, 2007)

The fundamental regulatory approach to an ERA is to achieve one of three goals.

- **Prevention:** to minimize or reduce future releases that contribute to any negative environmental impacts
- **Corrective Action:** to restore to a condition that is protective of human health and the environment; and
- **Enforcement:** encourage industry to implement prevention and restoration activities in the event of negative environmental impacts being proven by an organizations aspects and impacts

Environmental Risk Assessment is the characterization of the potential adverse health and negative environmental impacts resulting from human and ecological exposures to environmental hazards (Nel, 2007). The risk assessment process is complex. The steps in the risk assessment process are:

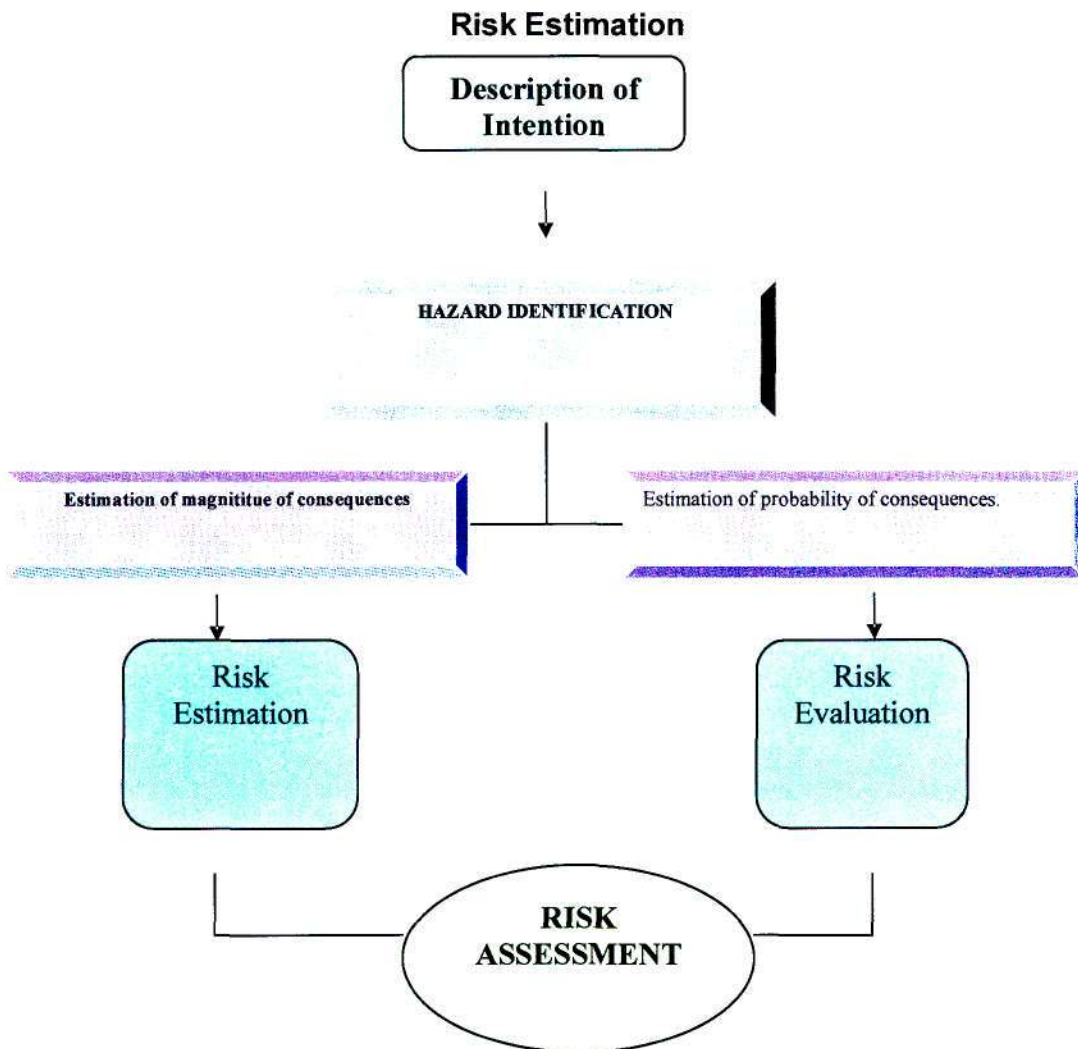
- **Hazard Identification** is the analysis of an environmental situation to ascertain if there is the potential for an exposure of an organism (including a human) or ecosystem to an environmental stressor that may cause harm.

- **Dose-response assessment** is the process of characterizing the relation between the dose of an agent received by a receptor (organism or ecosystem) and the incidence of an adverse effect on that receptor.
- **Exposure assessment** is the process of measuring or estimating the intensity, frequency, or duration of a human or ecological exposure to agents that are currently in the environment, or may be present in the future.
- **Risk characterization** is the process of estimating the incidence of an adverse effect under the conditions of exposure described in the exposure assessment. It also includes the narrative description of the assessment, including uncertainties in the preceding steps. Each step requires the collection of data (such as the collection of lead concentrations in soil or water) and/or the use of mathematical models (such as ones that describe the movement of contaminants in the environment or define the cancer incidence from exposure to levels of uranium). Risk assessments have now become part of the analysis that a proposed new chemical or other product must undergo before it may be placed on the market.

Pollutants in the environment do have the potential to harm humans and the receiving environment, but risk involves both severity and probability. There may be a large release of hundreds of kilograms of a chemical that is not very hazardous (high probability, low severity). That chemical will not cause significant harm to the environment. Alternatively, there might be one kilogram of a chemical that is very toxic that could pose to be much more hazardous (low probability, high severity) (Nel, 2007).

This study will use the tool of the ERA to determine the potential impacts of Creosote bleedings specifically on the quality of soil.

**Figure 3.1** Diagram of Risk Assessment Process



(Nel, 2007)

### **3.4.4 Risk Management**

The goals of Risk Management are to:

- Develop, analyze and compare regulatory and non regulatory options and to select and implement the optimal decisions that minimize or eliminate the risks
- Risk Management combines the three steps; risk evaluation, emission and exposure control and monitoring.

There are many hazards in the world around us. Hazards are sources with the potential to cause harm. A hazard however requires an incident with a pathway to become a risk (Nel, 2007). An incident or ongoing condition is any occurrence that has the potential to result in adverse consequences to people and the environment. This risk can have a severity and probability of occurring. In the case of this study, Creosote is the identified hazard, with the likelihood of degrading soil and the subsequent potential to contaminate water bodies. Likelihood is used as a qualitative description of probability or frequency in relation to how likely it is that something will occur.

The risk evaluation is concerned with determining the significance of the estimated risks and includes the element of risk perception. Therefore summarized Risk Assessment is the gathering of information available about risks and the formulation of a judgment about them. This judgment may facilitate a qualified judgment, or allow a quantified judgment to be made about the tolerance level of a risk (CEM, 2007). To tolerate means that we do not ignore it, but rather we review and reduce the risk as low as is practicably possible. This can be achieved by the implementation of mitigation measures.

### 3.4.5 The Risk Assessment Matrix

A risk assessment matrix is demonstrated below (Fig 3.1). Significant findings from a study are further analyzed as follows.

A horizontal axis being the y axis is used to determine the severity of impact. For health and safety risk assessments, one must refer to the effect on community and public reaction column. For environmental risk assessments, one must use the y axis labeled environmental impact. There is one of 7 possible ratings that the researcher can use to rate the finding. These are allocated a score from 7-1 respectively, ranging from disastrous impact to no impact.

The vertical axis being the x axis is used to determine the frequency of the impact. The researcher can either use the frequency of the impact column (which is the first column) alone or in conjunction with the recurrence of interval column to allocate a score to the x axis. There is one of 7 possible ratings that the researcher can use. These are allocated a score from 7-1, ranging from frequently to highly unlikely.

When the respective scores are allocated on the x and y axis, the researcher then uses the matrix to find the column where the x and y axis meet. For example: an incident with an environmental impact identified to be a disaster is given a y axis score of 7. That same incident's frequency of impact is allocated to be frequently and is therefore given an x axis score of 7. Combining the x and y axis, that incident is given a total score of 14. This is RED in the matrix and demonstrates a highly significant risk that is intolerable and generally requires operation to stop until action is taken.

The orange is very similar to red and demonstrates a significant environmental risk that requires urgent action to reduce the risk to a tolerable level. The yellow indicates that a risk does occur, however is currently as low as is reasonably

practicable. The situation needs to be maintained and monitored to ensure that the incident does not move from a yellow into an orange column. The green indicates that there is currently no significant environment risk.



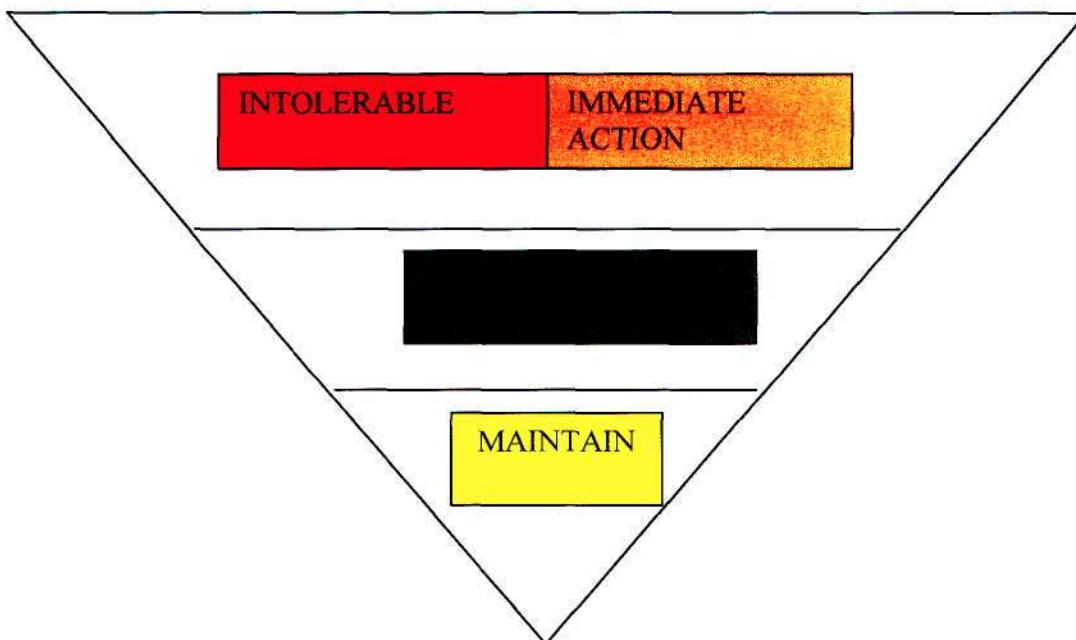
# Risk Assessment Matrix

Calculated significance of risk							Weight number	Severity of impact	Effect on community	Public reaction	Environmental impact
8	9	10	11	12	13	14			7	More than 10 fatalities	Demands to cease business
7	8	9	10	11	12	13	6	More than 1 fatality	National pressure	Unacceptable widespread	
6	7	8	9	10	11	12	5	One fatality	National press reaction	Significant widespread	
	6	7	8	9	10	11	4	Hospitalisation	Local press coverage	Significant local	
		6	7	8	9	10	3	Illness / injury	Minor local reaction	Limited local	
			6	7	8	9	2	None	Little reaction	Insignificant	
				6	7	8	1	None	None	None	
1	2	3	4	5	6	7	<b>Weight number</b>				
Frequency of impact											
Highly unlikely	Unlikely	Rare	Possible	Often	Likely	Frequently	<b>Frequency for Safety, Environment, Emergencies</b>				
1:1000	1:50	1:20	1:10	1:5	1:1	10:1	<b>Recurrence interval</b>				

Figure 3.2: The Risk Assessment Matrix (CEM, NW University; 2007)

### Figure 3.3: The Risk Estimation Triangle

The Enterprise Risk Assessment and Management Paradigm influence the formation of the Risk Estimation Triangle which is used to complement the Risk Assessment Matrix. The Risk estimation triangle provides a framework to find practical analysis of the risk factor. The matrix has been designed to allocate the risk factor a score that falls under one of the shaded colours below. This allows for a uniform assessment of risks based on the set criteria of the matrix as provided by the Enterprise Risk Assessment and Management Paradigm. The researcher will use this technique to analyze the findings and categorize findings as intolerable, immediate action, as low as is reasonably practicable (Alarp) and to maintain a situation as there is currently insignificant risk. These decisions are made easier by the colour coding of the calculated significance of risk (Nel, 2007).



### **3.5 Description of the Risk Estimation Triangle**

**3.5.1 INTOLERABLE:** A level of risk that is as high as to require significant and urgent actions to reduce the magnitude. If these risk levels cannot be reduced to ALARP or tolerable level, the project objective and operating philosophy must be reviewed by management.

**3.5.2 IMMEDIATE ACTION:** The level of risk is high and requires an immediate mitigation measure to reduce it to a tolerable value.

**3.5.3 ALARP (as low as is reasonably practicable):** Efforts must be made to reduce risks to a tolerable level that does not incur additional costs to the organization.

**3.5.4 MAINTAIN:** A level of risk that is as low as to not require actions to reduce its magnitude further, but which will be managed and monitored by the site using a management system.

**3.6 Qualitative Research:** Qualitative research involves an in-depth understanding of human behavior and the reasons that govern human behavior. Unlike quantitative research, qualitative research relies on reasons behind various aspects of behavior. Three techniques of the various techniques of qualitative research were used in this study. These are the following techniques:

**3.6.1 Case Study:** This qualitative technique attempts to shed light on a phenomenon by studying in-depth a case example of the phenomena. The case can be an individual person, an event, a group, or an institution. The conceptual framework of this study reviewed four international case studies that were available on PAH contamination on soil.

**3.6.2 Secondary analysis of data:** is the reanalysis of data that was originally compiled by another researcher for purposes other than the present research. In this study, the Risk Based report by Geomeasure Group was reviewed. Geomeasure Group investigated the Geohydrological impacts of creosote at Howick in 2005. Since their report creosote drippings have increased and the quantity of poles stored has increased as well.

Furthermore, National legislation was reviewed in detail to investigate the consequences and recommendations in terms of South African law on pollution of the natural environment. Various articles and books were reviewed and the internet was researched for the compilation of the background information of the study.

**3.6.3 Historiography:** is the method of doing historical research or gathering and analyzing historical evidence. There are four types of historical evidence: primary sources, secondary sources, running records, and recollections. In this study, secondary sources included investigating literature from the library, internet and other information sources such as article, magazines and books Primary Data sources, methods and techniques included conducting interviews

with Eskom Distribution staff and other individuals associated with the creosote industry. These included Eskom Senior Environmental Manager, Mr. Troy Govender, Distribution Senior Environmental Advisor, Mr. Phillip Mvemve, the pole warehouse manager, Mr. Angus Currie, Director of the South African Wood Pole Association, Mr. Riaz Asmal, Distribution Technology and Quality manager and several owners of creosote manufacturing companies who requested the confidentiality of their identities.

Personal interviews were conducted based on the following themes

- Brief explanation of Eskom environmental policy;
- Views on the possibility of soil degradation from creosote drippings;
- Recent observations pertaining to increased creosote bleedings;
- Knowledge of hydrocarbons and their effects on the receiving environments;
- Practical and possible mitigation measures to prevent further spillage of hydrocarbons on the environment; and
- To understand commitment to adopt measures to mitigate possible soil contamination.

These interviews provided the researcher with an understanding of Eskom protocols and subsequent review of practical, realistic environmental problems associated in finding the balance between Eskom electrification and environmental protection.

### **3.7 Quantitative Methodology**

The first step of the research process is identifying the research topic. The researcher then sifts through a broad research area to clarify a precise set of ideas or concepts. At the completion of this the researcher should be able to write the research topic in the form of a question or a problem. The researcher then proceeds with the literature review. During this process the research topic is

further refined and a clearer understanding of the research question or problem is obtained.

Quantitative research is mostly encountered as part of formal or conclusive research but is also sometimes used when conducting exploratory research. Quantitative research techniques are part of primary research ([www.social.htm.co.za](http://www.social.htm.co.za)). Quantitative research is based on statements such as “anything that exists in a certain quantity and can be measured” (Custer, 1996). The ideals of quantitative research call for procedures that are public, that use precise definitions, that use objectivity-seeking methods for data collection and analysis, that are replicable so that findings can be confirmed or proved invalid, and that are systematic and cumulative-all resulting in knowledge useful for explaining, predicting, and controlling the effects of teaching on student outcomes (Gage, 1994). The data is gathered using more structured research techniques and objectivity. The most common quantitative research techniques include according to (Strauss, 1987) includes:

- Observation technique
- Experimentation
- Survey technique

**3.7.1 Observation Technique:** Observation is a primary method of collecting data by human, mechanical, electrical or electronic means. Observation techniques can be part of qualitative research as well as quantitative research techniques (Gage, 1994). The basis of this study began with the observed increase in creosote bleedings at the Howick Pole Yard.

While this observation was visible, the observation technique does not provide us with any insights into what potential impacts can occur from various indicators that were polluting the soil. Additional information can be obtained by asking people directly or indirectly to clarify the time period of the creosote drippings so as to verify the observation at the time of site visits. For this reason, informal

interviews were held to confirm creosote bleeding status with the Howick site staff. Additional ad-hoc interviews were conducted with Angus Currie, Chief Director of the South African Wood Preservation Association to understand the creosote coating process, Mr. Brian Cowan CSIR analyst of Polycyclic Aromatic Hydrocarbons and Troy Govender. "The human eye is badly adapted to measurement, but well to comparison" (Burger, 2004). The researcher visually analyzed aspects of the study area in terms of the value conferred on it due to its intrinsic quality and the construction impacts on an environmental, social and economic level.

Quantitative research, long held to be the only form of research that was statistically valid and reliable, is now being used in conjunction with qualitative research methods in studies that cannot adequately describe or fully interpret a situation. The two are so intertwined that a study of quantitative research is nearly impossible without referring to both qualitative and quantitative methods. "A primary goal of research is to achieve understanding, and then to develop models that approximate 'truth' and 'reality'. This poses serious challenges to social science researchers since truth and reality tend to be socially constructed. In other words, what is meaningful, true, and real to one in some situations may not be so for others" (Custer, 1996). For purposes of instructional technology, a social science, both quantitative as well as qualitative methods of research are necessary.

To compare and examine the qualitative data described in the conceptual framework in this study, there was a need to quantify the data and this was done by the soil sampling process, where soil was collected and submitted to the laboratory for analysis.

As such, both qualitative and quantitative methods are used appropriately within the research paradigm. This study therefore used the above mentioned techniques from both, qualitative and quantitative research processes to gather

the data required to meet the aims and objectives of this report. Instead of either ignoring or defending a particular research paradigm, it is possible and more instructive to see qualitative and quantitative methods as part of a continuum of research techniques, all of which are appropriate depending on the research objective (Strauss, 1987).

### **3.7.2 Experimentation:**

Scientific progress requires asking meaningful questions and conducting careful experiments. The experiment is a cornerstone in the empirical approach to acquiring deeper knowledge about the physical world (Johnston, 1991). This study applied a field experiment technique in the collection of soil samples and these soil samples further underwent laboratory experiments to determine the level of contaminants present.

### **3.8. Soil sampling:**

A soil test, the best available guide to the application of fertilizers and other nutrient sources, is also an excellent diagnostic tool for problem soils (Jeffrey, 1999). A soil test was therefore the proposed route to follow to analyse the objectives of this study. Soil samples were therefore used to determine whether the creosote bleedings impacted negatively on soil quality.

The first sample was taken using a purposive soil sample. Purposive soil sampling is when the sampler selects the location of the sample based on judgment. A classical example of purposive sampling is the way in which a soil surveyor samples the soil in free survey and uses judgment based on landform and vegetation (Lark, 2003). In this study the first sample was taken at the source of the creosote bleedings onto the soil. Sample one was taken at three depths, 60mm, 100mm and 1200mm. The requirement to analyze soil depths



stemmed from the need to determine whether the contaminants were infiltrating into the soil.

Four additional samples were taken using the systematic sampling technique. At a 10m interval from sample one, which was taken at the source; samples were taken in a North, South, West and East direction, 10m apart. Time and money was the most critical factors that limited the number of samples. This is therefore one of the limitations of this study. A total of 15 samples were taken and submitted to the laboratory for analysis.

Tools used were the hand auger, spade, collection bottles, and stationery for labeling and note taking. In addition, transport was required to visit the site and a research assistant was required to assist with the soil sampling. It was important to wash all tools, so that no residue of left over chemicals from a previous study is transferred into this study. In addition safety requirements were necessary as creosote is a hazardous substance. Dermal contact must be avoided, hence the usage of gloves was necessary and availability of detergents was required to wash hands thoroughly after sampling. No food or drink intake was allowed during the sampling process.

### **3.8.1 Control Sample**

There is an assumption in research that if change occurs in soil quality it does not necessarily result from a specific contaminant alone such as creosote bleedings. Other variables could also impact on soil quality. As such, control sample of soil not exposed to creosote bleedings were taken for this study. Due to time and financial constraints, one control sample was taken at the three depths, 1km away from the source near a virgin area

### **3.9 Laboratory Analysis**

Laboratory analysis is a reliable tool to provide quantifiable data. Laboratory analysis was used to determine the amount of residual moisture in soil, and to identify the chemical constituents of the residual moisture. In the case of the creosote contaminated soil, the assumption is that the residual moisture contains high content of hydrocarbons. Samples were analyzed by the laboratory for the presence of the 15 PAH indicators described in the previous chapter.

The concise methodology was not disclosed by the laboratory in terms of their confidentiality contract. The CSIR have mentioned that they will use an in-house GC-MS method, AM186 based on the US EPA 8270. This is a target compounds analysis and is given in Appendix IV. The CSIR holds SANAS accreditation for this analysis. Samples of soil from the Howick Pole Yard were forwarded to the CSIR on the 3<sup>rd</sup> of August 2007 for analysis.

### **3.10 Study Area**

Eastern Region (one of the 6 Eskom Distribution Regions) follows the geographic boundary of Kwa-Zulu Natal province but excludes the Durban Metropolitan Area. The Eastern Region is made up of 4 area offices located in Empangeni, Margate, Newcastle and Pietermaritzburg. The main functions are customer services (billing, collection of revenue, *etc*) and engineering (planning, designing, surveying, construction, operations and maintenance of powerlines and substations below 132kV and associated infrastructure for providing electricity) ([www.eskom.co.za](http://www.eskom.co.za)). The Eskom Eastern region operates pole storage yards at 4 sites in Kwa-Zulu Natal at Marburg, Vryheid, Empangeni and Howick. The study area chosen for the purpose of this report is the Howick pole yard located in Howick, Kwa-Zulu Natal (see figure 3.3).

This study area is approximately 3km from the Midmar Dam and 14km away from the city of Pietermaritzburg. The site is located off the N3 freeway, approximately 1.5km from the Howick off-ramp. Size of study area of site is

approximately 3072m<sup>2</sup>. Some 15000- 30 000 poles are being stored at this site per annum. Pole sizes range from 5m long to 16 m long in length. The co-ordinates of the site are 29°31.5' S 30° 14.8' E (Locality Plan, 2007).

### **3.11 Eskom Holdings (Pty Ltd)**

As Eskom is the owner of the pole storage yard that is being used as the case study, it is necessary to provide back-ground information on Eskom to give a broader understanding of the organization. The description of Eskom first begins with an overview of Eskom Pty Limited Holdings. This is the corporate unit that officiates instructions to its other divisions being Generation, Transmission and Distribution.

South Africa's electricity parastatal, Eskom, produces about 60% of all electricity generated on the African continent, yet in 1995 only some 30 percent of S.A's urban black population and about 10 percent of blacks in rural areas had access to electricity. They were forced to primarily rely on coal-fired stoves and other proportionately more expensive forms of energy, like paraffin. A major environmental problem is that an estimated half of South Africa's population still relies on the un-sustainable use of fuel wood for their energy requirements (Bekenstein *et al*, 1996). While fuel wood is usually available from natural resources at no cost, there are enormous hidden costs attached to its use such as air pollution and deforestation. This clearly depicts the need behind S.A's government's quest to improve access to reliable and affordable energy services, again demonstrating the inextricable relationship between development and the environment.

In compliance to the above clause of Sustainable Development, Eskom has adopted an Environmental Management System based on ISO 14001. This is an international policy which highlights the need for a multi-disciplinary approach to address the need to protect biological diversity, while providing for the economic welfare of the people. Some of the tools Eskom uses to ensure Sustainable

Development include EMS, EIAs, EMPs, environmental capacity building, inter alia. EIA's are the main tool for new developments such as powerstations, powerlines and associated infrastructure. The EIA in Eskom is the actual methodology to enforce economic, social and environmental pillars of sustainable development (Eskom Legend, 2002)

When Eskom electrifies an area, the social aspect is usually addressed by training local people from the community to either install the infrastructure and/or maintain the systems. This then creates employment opportunities in the area.

The environmental benefit is the reduction of smoke due to less burning of wood as a source of energy, and as such preservation of the natural resource base that was previously overexploited. Eskom also undertakes to perform an Environmental Impact Assessment, to ensure that new power lines do not disturb the ecology of the area (Eskom, 2004).

On the economic side, cost effective technologies are put into place and an appropriate tariff structure is defined in consultation with the local communities involved. The local economy is stimulated from the provision of electricity during the construction of the powerlines and when the development is operating, in terms of jobs, etc ([www.eskom.co.za](http://www.eskom.co.za)).

### **3.11.1 Eskom- Generation**

Eskom Generation Division operates 24 power stations throughout South Africa. These include coal-fired, nuclear, hydro, pumped storage and gas turbine facilities. Eskom generation capacity is concentrated in the 9 coal-fired power stations although both the Koeberg nuclear power station and 3 pumped storage stations contribute significantly to total output (Eskom Intranet, 2004)

### **3.11.2 Eskom Transmission**

Eskom Transmission owns and operates the national electricity grid, which connects the power stations and large urban and industrial areas, as well as all neighboring states. Transmission develops and operates all electricity infrastructures above 132kV (Eskom Intranet, 2004)

### **3.11.3 Eskom Distribution**

Eskom Distribution is an electricity distribution utility that serves 3.3million customers across the whole of South Africa. Eskom Distribution concerned with the marketing, engineering, sales and distribution of electricity throughout S.A. Distribution is divided regionally into seven regions roughly following the boundaries of the nine provinces. The current focus is on the electrification of rural areas and townships neglected in the past ([www.eskom.co.za](http://www.eskom.co.za)).

**Figure 3.4:** Map of Kwa-Zulu Natal, the region that the study area is located.

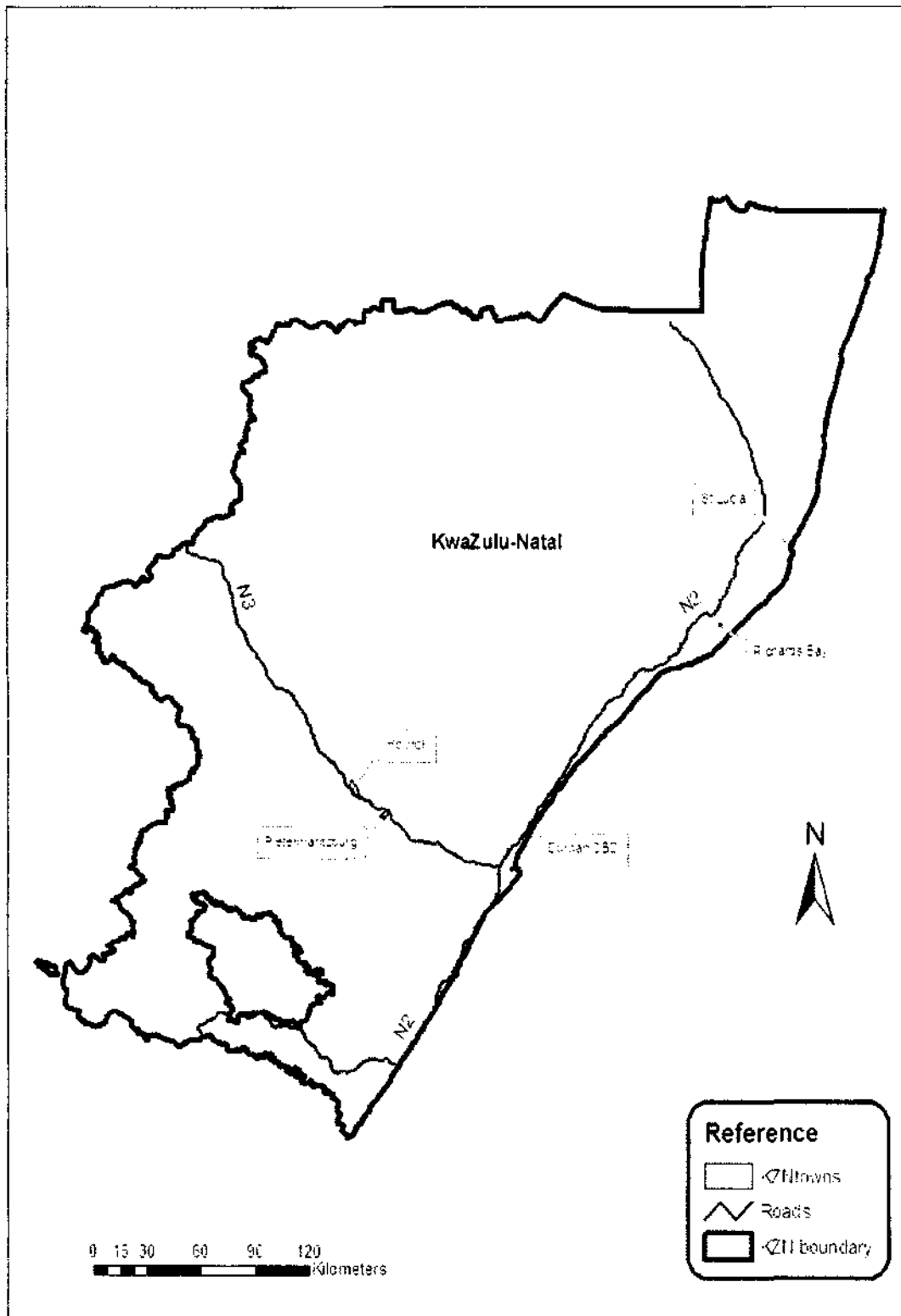
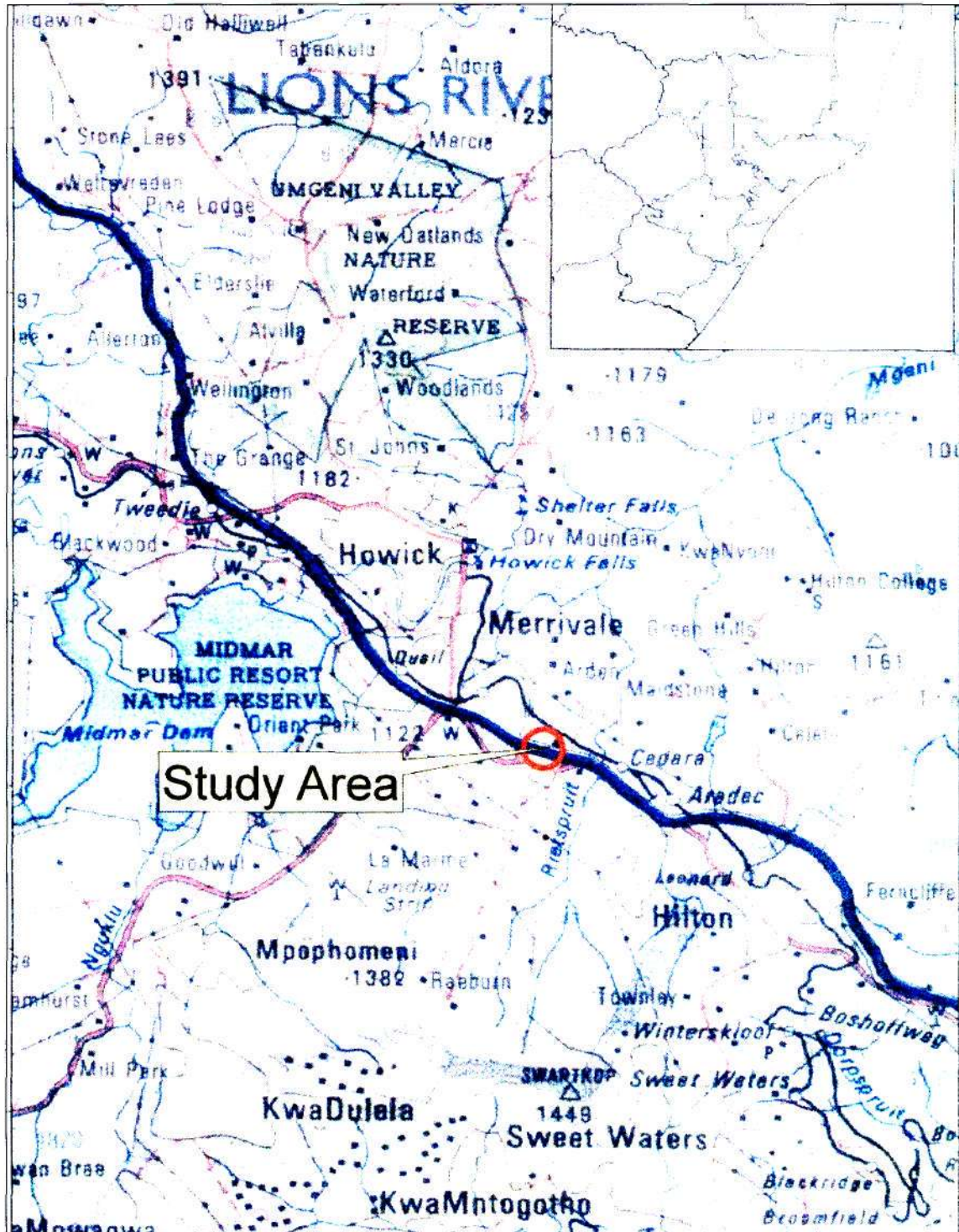


Figure 3.5: Map of the site-specific study area at Howick, from the N3 freeway.



### **3.12. The bio-physical environment of the study area**

The Bio resource group of this area is known as Moist Midlands Mistbelt. Lying at an altitude range of 900m to 1400m above sea level, it is generally a hilly, rolling country with a high percentage of arable land, approximately 47% being suitable for cropping. The climate is humid with an annual rainfall of 800 to 1280 mm. Heavy mists are common and an important feature providing additional moisture to the area, particularly to forests. The mean annual temperature is 17 degrees Celsius (DEAT, 1999).

Soils: The potential of the soils of this bio-resource group are high, in spite of the fact that the inherent nutrient status is very low. Particular problems are P-fixation and Al-toxicity. Soils are highly leached and this has an important bearing on the economy of the group (DEAT, 1999). We can deduce from DEAT's analysis, any further contamination must be avoided.

### **3.13 Soil Classification of the study area**

The region is underlain by sediments of the Volksrust formation in the Ecca series of the Karoo sequence, which have been intruded by numerous dolerite sills and dykes. The Volksrust formation is a secondary or fractured rock aquifer with moderate and median yields of water supply. The indurated contact zones between the sediments and dolerite intrusions are intensely fractured and this enhances storage and transmissivities (Geomeasure Groups, 2006). Given the high rainfall in the area, and the soil type, there exists a very high likelihood for leaching of creosote that has accumulated from the creosote bleedings of the wooden poles during storage. This enhances the context of this study.



### **3.14 Soil composition**

A small sample of the soil was mixed with 3 quarters of distilled water on a tall flat bottomed straight sided glass container.

This mixture of soil and 3 quarters full of water was left to settle for one day. The laws of gravity took over and it was found that a portion of the soil dissolved in the water. This provided evidence of semi solubility of the soil particles (Camp, 1997).

Furthermore, very distinct clay soil was identified. Soils with high clay contents have several properties which may lead to movement of contaminants from farm land. Surface structure can become degraded in clay soils, forming a crust. Crusting limits infiltration and increases runoff. When wet, clay soils are easily compacted, which also increases runoff. The runoff may contain contaminants and could affect the quality of surface and ground water. Clay-sized sediment, because of its very small size, is very slow to settle out of dugouts, streams and lakes.

This literature review in this report made mention that creosote in the soil can be dissolved in high volumes of rainfall and be transported to water drainage systems or leach into ground water supplies. In South Africa, 25 percent of the population are still dependant on borehole groundwater for access to drinking water. Boreholes are narrow shafts drilled into the ground, vertically or horizontally for the extraction of ground water and various other purposes (Nel, 2006). If present trends in reduced quality of water supply statistics continue, we can expect to see widespread reliance on groundwater in the years ahead. The National Water Act of 1998 regards groundwater as an integral part of the hydrological cycle, providing the essential baseflow recharge to all our rivers and streams ([www.search.gov.za](http://www.search.gov.za)). Contaminating groundwater sources can therefore lead to negative health implications to all borehole water users.



Plate 3.1: Creosote Wooden Poles stacked at the Howick Pole Yard



Plate 3.2: Creosote bleedings mixed with rainfall



Plate 3.3: Creosote Bleedings from wooden utility poles at Howick



Plate 3.4: Exit drain at the Howick Pole yard

### **3.15 Limitations and assumptions of the study**

The study was conducted in a site specific area, hence assumptions do hold, on the basis of this area's specific rainfall, soil classification and quantity of creosote bleedings from the stored wooden utility poles. The impacts can therefore be under-estimated or over-estimated in other areas of occurrence.

A cost factor could pose a considerable limitation to the study. Soil samples sent for laboratory analysis, cost R975-00 per sample, which capped the number of samples that one can afford to test. In view of the high costs of laboratory analysis, only one control sample was taken and analyzed at the different depths.

The Howick Pole yard was fenced and securely locked. Access to the yard was through authorization from the warehouse manager.

The researcher had to ensure that the ideal weather conditions were present for sampling purposes. Dry weather conditions were necessary for soil samples.

### **3.16 Conclusion**

The purpose of this report is to use the data from the methodology described to summarize and synthesize the impacts of creosote bleedings on soil at the Howick pole yard. This information can then further be used as a basis to identify if such a risk is prevalent in other locations from various end-users who require creosote wooden poles for their organizational activities, such as Telkom and municipalities.

The benefit of the knowledge to be discovered from this research methodology is to provide additional information to the currently limited research base on the impacts of creosote on the natural environment. With the information that will be disclosed from the laboratory analysis, we can be quantifiably equipped to confirm or prove invalid the hypothesis of this study. Using the data collected in

the methodologies described above; the three objectives highlighted in the introductory chapter will be analyzed in the penultimate chapter. In addressing the objectives of the study, the researcher will also present recommendations and a concluding chapter.

## **CHAPTER FOUR: RESULTS AND ANALYSIS**

### **4.1 Introduction:**

In this report up until now, discussions were based on issues regarding the research topic, literature review, selection of research design and collection of data by means of application of the methods discussed. The most important stage of the research process however, involves the analysis and interpretation of the data.

The data received from the CSIR laboratories will be presented in the form of tables and graphs. Data display is a systematic, visual representation of information which provides a descriptive explanatory framework (Welman, 2006).

The environmental exposure of creosote bleedings on the soil at the Howick pole yard will be assessed under the worst case dispersion conditions in the discussions. The screening levels used in the Risk Assessment are intended to assess chronic exposures and its potential environmental impacts.

### **4.2 Analysis of Results**

Qualitative and quantitative research methodologies were adopted in this study as described in the previous chapter. These methods were used to gather the required data to meet the overall aims and objectives of this study. The analysis of the soil sampling, being the quantitative method and the personal interviews which is a qualitative method will be described in further detail below:

#### **4.2.1 Soil Sampling Analysis:**

Six samples were collected at three different depths *i.e.*: 60mm, 100mm and 1200mm. Five of these samples represented the experiment aspect while the sixth sample was the control. The CSIR used an in-house GC-MS method AM186 based on the US EPA 8270 methodology to test for the presence of PAH indicators.

Any decision and conclusion taken on this study is bound to be criticized, so sound records are important to show that due attention was given to various concerns and that the chosen decision was made in good faith. A conclusion needs to be justifiable in terms of the knowledge obtained at the time of the research and the record of data and subsequent analysis described in this chapter provides evidence for decision making. The likelihood of the occurrence of a risk may be quantified by the implementation of a set research methodology. The soil analysis will quantify the research data to test for set indicators. the magnitude of the risk can be debatable based on different perspectives. Some qualitative expressions of magnitude include; low, minor, moderate, major and critical. The risk assessment tool is used to analyze the magnitude using set a criteria (Nel, 2007) .The uniform criterion reduces subjectivity by providing set criteria to choose from. The decision of magnitude rests in the colour of the block on the risk assessment matrix, and different options chosen based on varying interpretations generally still fall in line with the same colour. The analysis of the data using the matrix will be demonstrated later.

These concepts of exposure routes may assist one to estimate the magnitude of consequences and gives an indication of how severe a risk is to the environment. The exposure analysis should take account of the intensity, duration and extent of exposure. In assessing the magnitude it is important to take into consideration the vulnerable receptors that include infants, sensitive species and threatened habitats. For this study, analysis of the data collated from the soil laboratory analysis in collaboration with information accumulated in the conceptual

framework and the research methodologies discussed in chapter three, will be the combined knowledge used to fill the environmental matrix discussed. The most credible magnitude is assessed by the combination of the worst case scenario and the most probable case scenario which is the two criteria adopted by the matrix.

#### **4.2.2 Personal Interviews Analysis:**

The results of the personal interviews conducted can be summarized as follows:

##### **Eskom Senior Environmental Manager, Mr. Troy Govender, Distribution:**

The interview held with Mr. Govender indicated that Eskom environmental department was equally concerned with regard to the increasing creosote bleedings observed at the pole yards. This resulted in increasing odours in the air, and Eskom Eastern region had already received a public complaint from neighbours in the Howick area with regards to odours.

Mr. Govender advised that the Geomeasures group had been recruited to conduct geohydrological studies to assess the situation and in 2004, their conclusion was that the issue was not significant. The problem of creosote drippings however, has continued since and the findings of this report was requested for Eskom review, so as to further understand the potential risks associated with the problem.

##### **Mr. Phillip Mvemve, the pole warehouse manager:**

Philip Mvemve confirmed to the researcher that in the last three years, increasing number of poles are arriving wet. He indicated that this was not the case previously as he was working at the Howick warehouse for more than 15 years. Mr. Mvemve indicated that his current staff complained about the increasing odours from the creosote as a result of the increasing bleedings from the poles



being stored. He acknowledged that the environmental department of the region has been monitoring this incident.

**Mr. Angus Currie, Director of the South African Wood Pole Association:** Mr. Angus Currie agreed that the recent creosote bleedings observed around the country was of significant concern. Mr. Currie indicated that internationally, the specification for creosote was revised recently. It was now evident, that the specifications on the new texture tested in Europe, was not suitable for South African climate. The heat in South Africa was accelerating the run-off of the product, combined with the possibility that manufacturers were fast tracking the drying periods to meet the new demand.

**Mr. Riaz Asmal, Distribution Technology and Quality manager:**

Mr. Riaz Asmal was responsible for technology and quality in the Eastern region. He indicated that Eskom has a procedure for creosote wood poles (Appendix III). Pending confirmation of the environmental department and technical department, if the qualities of the poles are not up to Eskom standards, a certificate of non-compliance can be sent to the responsible manufacturers providing moist poles which were bleeding excessively.

**Creosote manufacturing companies who requested the confidentiality of their identities:**

Two manufacturers were interviewed. The interviewees acknowledged that the poles are being sent moist to the utilities. They indicated that the new creosote specification has resulted in a new texture of creosote that was much weaker and hence the occurrence of bleedings. Companies confirmed that no utility had yet served them with any warnings on the quality of the poles or the bleedings from the poles that they send to the respective warehouses.

### **4.3 Presentation of Data**

The data obtained from the techniques described in the previous chapter is presented in tables and graphical forms. The table 4.1 is very comprehensive in that it reflects data for each of the fifteen PAH indicators of the six samples at the various depths. This table in effect provides a comprehensive summary of the laboratory data. This will be followed by graphical representation of the laboratory data. The difference however, is that each of the fifteen graphs will reflect data of a separate PAH indicator at the various depths. The data analysis for each indicator will follow immediately after each graph.

**Table 4.1: Concentration of Indicators ( $\mu\text{g}/\text{kg}$ ) per sample per depth (mm)**

INDICATORS	Sample One			Sample Two			Sample Three			Sample Four			Sample Five			Sample Six		
	60mm	100mm	1200mm	60mm	100mm	1200mm	60mm	100mm	1200mm	60mm	100mm	1200mm	60mm	100mm	1200mm	60mm	100mm	1200mm
Naphthalene	120000	80000	5000	0	0	0	8900	900	7	0	0	0	0	0	0	0	0	0
Acenaphthylene	28000	0	0	0	0	0	2500	800	90	0	0	0	0	0	0	0	0	0
Acenaphthene	1100000	400000	12000	0	0	0	42000	12000	38	0	0	0	0	0	0	0	0	0
Flourene	1200000	720000	25000	0	0	0	45000	10000	1000	0	0	0	0	0	0	0	0	0
Phenanthrene	3000000	90000	10000	280	0	0	110000	46000	0	0	0	0	0	0	0	0	0	0
Anthracene	870 000	66000	44000	380	0	0	36000	11000	0	150	0	0	0	0	0	0	0	0
Flouranthene	1800000	500000	16000	670	92	0	150000	33000	0	380	0	0	0	0	0	0	0	0
Pyrene	800000	46000	12000	700	71	0	100000	10000	670	200	0	0	700	0	0	0	0	0
Benzo(a)anthracene	350000	260000	90000	400	71	0	37000	10000	2000	400	0	0	400	0	0	0	0	0
Chrysene	330000	30000	7000	1200	98	0	48000	12000	2000	1200	0	0	250	0	0	0	0	0
Benzo (b) + (k) Florenthane	200000	70000	30000	2600	300	0	51000	22000	5000	2600	500	0	1200	0	0	0	0	0
Benzo(a) pyrene	88000	15000	0	890	99	0	23000	2700	0	620	300	0	300	0	0	0	0	0
Indeno 1, 2, 3, cd- pyrene	33000	12000	0	1000	0	0	14000	9000	200	870	600	0	0	0	0	0	0	0
Dibenz(a,h) anthracene	9500	0	0	220	0	0	4000	1000	0	211	0	0	0	0	0	0	0	0
Benzo(g,h,i) perylene	28000	9000	0	1000	0	0	12000	2900	0	990	200	0	350	0	0	0	0	0
<b>CALCULATED PAH CONTENT</b>	<b>9086500</b>	<b>2298000</b>	<b>251000</b>	<b>9340</b>	<b>731</b>	<b>0</b>	<b>683400</b>	<b>183300</b>	<b>11005</b>	<b>7621</b>	<b>1600</b>	<b>0</b>	<b>3200</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>

al PAH per sample	SAMPLE ONE	SAMPLE TWO	SAMPLE THREE	SAMPLE FOUR	SAMPLE FIVE	SAMPLE SIX
		11635500	10071	877705	9221	3200

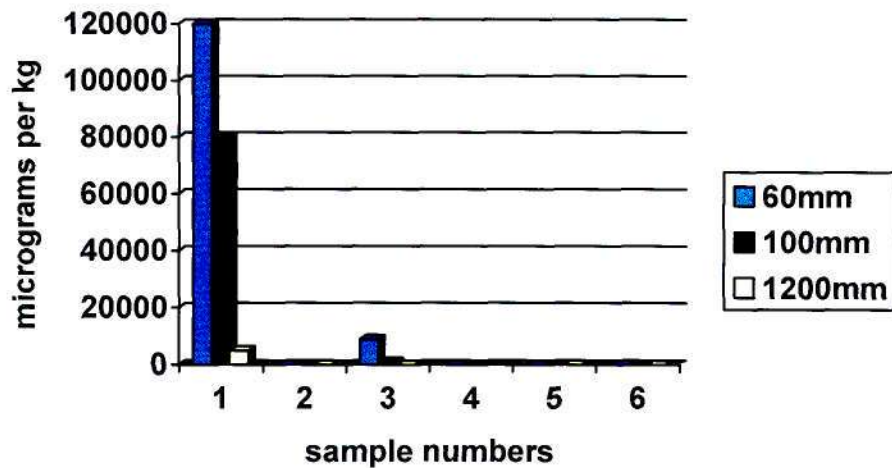
#### **4.4 Description of Table 4.1**

The table demonstrates the concentration of the individual PAH indicators that combine to form total PAH. The concentration is measured in micrograms per kg ( $\mu\text{g}/\text{kg}$ ), per sample, per depth. The calculated PAH concentration per sample is indicated at the bottom row in each sample.

The quantity of concentration among the various constituents however, is unevenly distributed. Some samples had high levels of PAH indicators, while in other sample depths there were no traces of PAH indicators. The evidence in the table indicates that at the 60mm depth of this study, in sample one and three, the highest levels of PAH concentration was present, that well exceeded the maximum permissible level of PAH to be found in soil. The 100mm depth demonstrate a reduction of concentration value from the initial concentration values at the 60mm depth in all samples. Samples one and three, in fact, show the highest concentration levels of PAH in all three depths. In samples two, four and five, all 15 indicators were absent at the 1200mm depth, while in samples one and three the concentration values greatly reduced at the same depth. The control sample, 6, showed no trace of the indicators.

The data above will be presented graphically and be further analyzed and described as per depth for each indicator.

**Figure 4.4.1 Analysis of the concentration of Naphthalene in the soil samples**

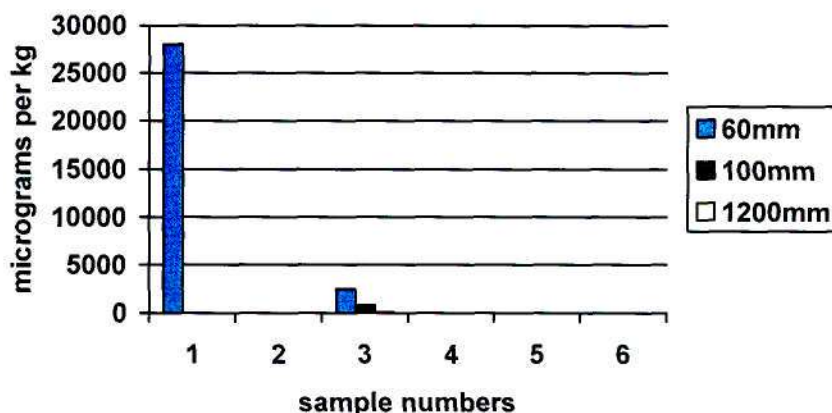


The highest concentration of Naphthalene being 120000 µg/kg was found in sample one at the 60mm depth. In South Africa the acceptable level of Naphthalene in the soil is 380 µg/kg. This was 318 times greater than the acceptable level of naphthalene in soil. At the 100mm depth, this quantity decreased to 80000 µg/kg and reduced at the 1200mm depth to 5000µg/kg which still well exceeded the permissible levels. In sample three, the highest concentration of naphthalene was 8900 µg/kg which was also above the acceptable levels of naphthalene in soil. At the depth of 100mm, the concentration present was 900 µg/kg at the 1200mm depth; the amount of naphthalene present was 47 µg/kg. Samples two, four and five indicated zero concentration of naphthalene. Since this agent is not carcinogenic, the possible health affects to humans from the high concentration in sample one is hemolytic anaemia.

From the above evidence, it is apparent that if the creosote was possibly biodegrading in the soil, the concentration level of the initial contaminant at the 60mm depth impacted on the rate of reduction in the lower depths. No traces of naphthalene were detected in the control sample.



**Figure 4.4.2 Analysis of the concentration of Acenaphthylene in the soil samples**

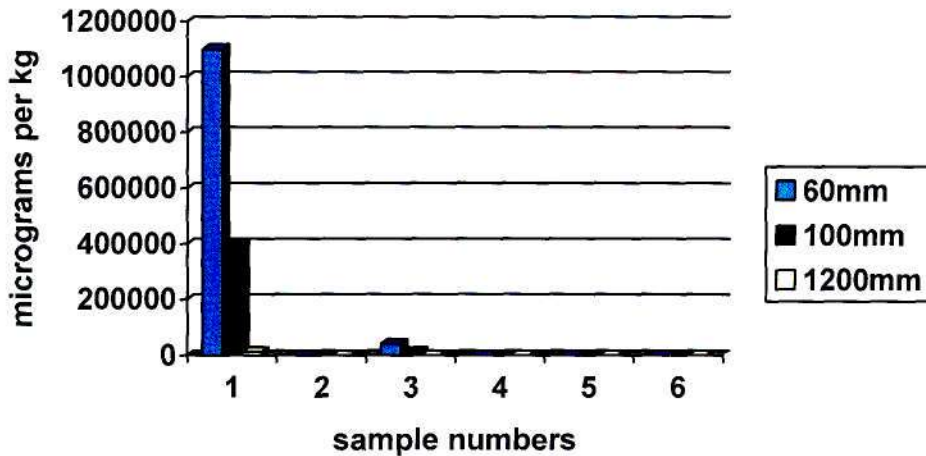


In sample one, at the 60mm depth, a concentration of 28000 µg/kg acenaphthylene was detected. None was detected at the remaining two depths of sample one. Sample three shows low levels of contamination. The largest contamination level in sample three was found at the 60mm depth, being 2500 µg/Kg, and reduced to 800 µg/kg at the 100mm depth and 90 µg/kg at the depth of 1200mm depth. No concentration of acenaphthylene was present in samples two, four and five. From the data above it is evident that acenaphthylene as an individual contaminant of soil was minimal at the Howick pole yard. PAH however, does not exist in isolation as it is found in two or more bonds. Therefore, the ability for acenaphthylene to bond with the other PAH components, some of which are highly carcinogenic is still a concern.

No traces of acenaphthylene were detected in the control sample.

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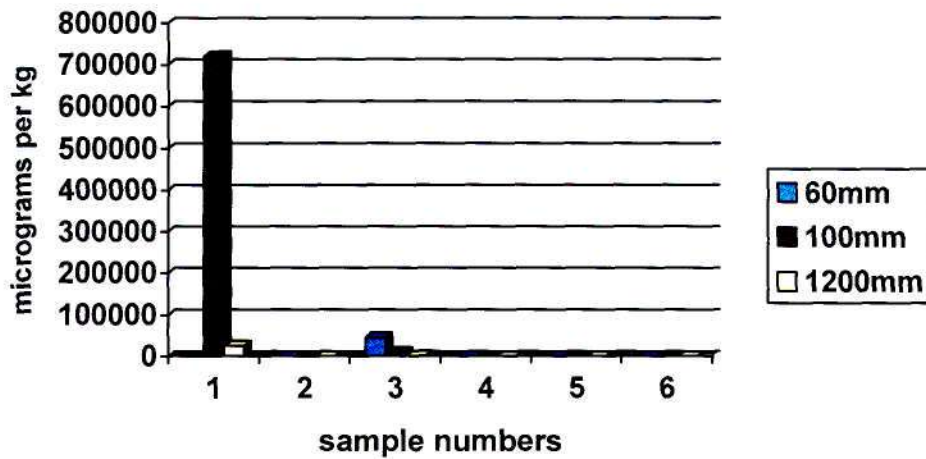
**Figure 4.4.3 Analysis of the concentration of Acenaphthene in the soil samples**



Extremely high concentration levels of acenaphthene were found in sample one at the 60mm and 100mm depths. The values ranged from 1100000 µg/kg to 400000 µg/Kg respectively. At the 60mm depth; the concentration was approximately one hundred and ten times larger than the acceptable level of 10000µg/Kg of contamination in soils. This sample indicated that creosote bleedings from wooden poles at the Howick warehouse is undoubtedly causing soil pollution with potential to impact negatively on humans and other species exposed to these soils. Although the concentration significantly reduced in sample one at the 1200mm depth, the acenaphthene concentration present was 12000 µg/Kg which is still above the acceptable level of contaminants to be found in soil. Sample three also showed high levels of contamination of 42000 µg/Kg at the 60mm depth, and at the 100mm depth was 12000µg/Kg, and further decreased to 38 µg/Kg at the 1200mm depth. No traces were present in samples 2, 4 and 5.

There was no evidence of acenaphthene contamination in the control sample.

Figure 4.4.4 Analysis of the concentration of Flourene in the soil samples

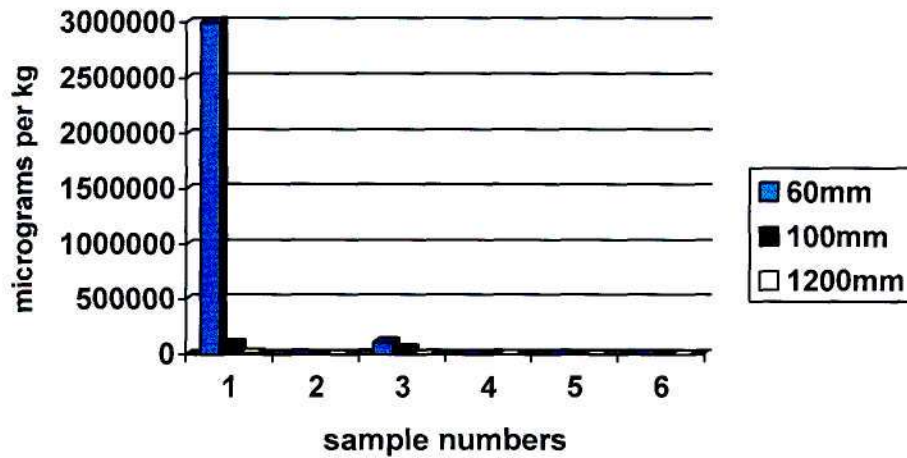


Concentration levels of flourene found in sample one ranged from 1200000 µg/Kg at the depth of 60mm, 72000 µg/kg at the 100mm depth to 12000 µg/Kg at the depth of 1200mm. In sample one at all three depths the concentration was above the acceptable level of contaminant to be found in the soil which is 10000µg/kg. Sample three showed a concentration of 42000 µg/kg at the 60mm depth which was reduced to 12000 µg/kg in the 100mm depth and 1000 µg/kg at the 1200mm depth Flourene is a non-carcinogenic element and therefore high concentrations on the soil may have no impacts on humans. Flourene does however have the ability to bond with other harmful indicators of the PAH composition and thus poses a potential for problems. No traces were found in sample, 2, 4 and 5.

Concentration of flourene in the control sample was undetected.

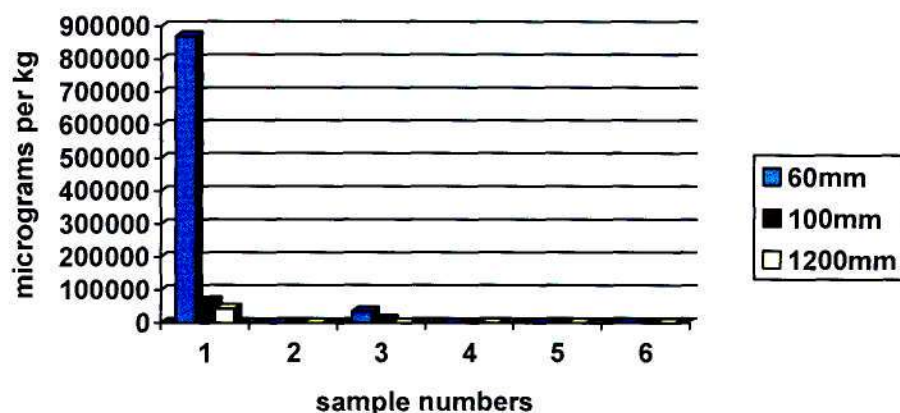


**Figure 4.4.5: Analysis of the concentration of Phenanthrene in the soil samples**



A high concentration of phenanthrene was found in sample one at all three depths. Using  $10000\mu\text{g}/\text{Kg}$  as an acceptable level, it is clear that the  $3000000\mu\text{g}/\text{Kg}$  found in the 60mm depth exceeds this by 300 times and the concentration found at the 100mm depth of  $900000\mu\text{g}/\text{kg}$  exceeds the acceptable level by 90 times. It can thus be deduced that since phenanthrene primarily causes skin damage, there is a great possibility of soil in the site to cause skin damage to humans exposed to sample one. Concentration in sample two at the 60mm depth was  $2800\mu\text{g}/\text{kg}$  which was 0.028 times lower than the acceptable level and no traces of phenanthrene was present in them same sample at the 100mm and 1200mm depths. In sample three at the depths of 60mm and 100mm, a concentration of  $110000\mu\text{g}/\text{kg}$  and  $46000\mu\text{g}/\text{kg}$  were detected respectively. This is a 110 and 46 times greater than the quantity of this contaminant allowed in the soil respectively. In sample three at the 1200mm depth, all traces of acenaphthene appeared to have been removed as none was detected by the laboratory analysis. Sample four and five showed no evidence of the presence of Phenanthrene. The control sample showed no trace of the phenanthrene concentration.

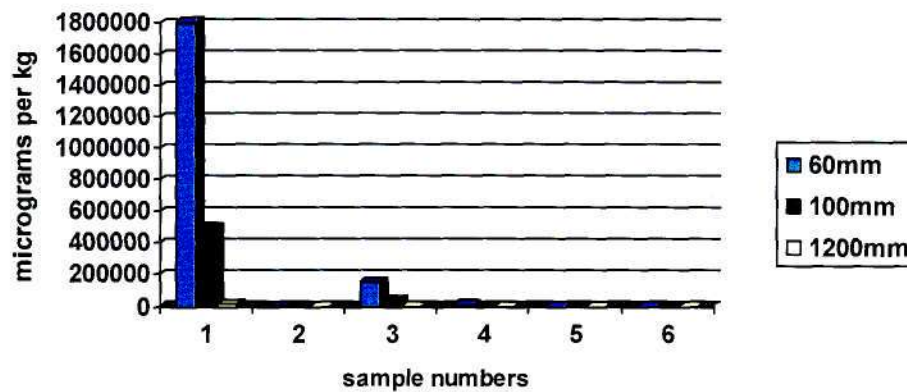
**Figure 4.4.6: Analysis of the concentration of Anthracene in the soil samples**



The highest concentration of anthracene was detected in sample one at the 60mm depth comprising of 870000  $\mu\text{g}/\text{kg}$ . This concentration value exceeded the acceptable contaminant level in soil by 87 times. The 100mm depth also exceeded the acceptable contaminant level by 6.6 times with the concentration value of 66 000  $\mu\text{g}/\text{kg}$  and the 1200mm depth with concentration of 44000  $\mu\text{g}/\text{kg}$  exceeded the acceptable level by 4.4 times. 380  $\mu\text{g}/\text{kg}$  of anthracene was found at the 60mm depth in sample two which was within the acceptable levels of contaminant to be found in soil.

The remaining depths in sample two found no traces of the contaminant. In sample three the largest concentration was found in the 60mm depth of 36 000  $\mu\text{g}/\text{kg}$ , while the 100mm depth indicated a concentration of 11 000  $\mu\text{g}/\text{kg}$  and no trace of the indicator was present in the 1200mm. The level of initial concentration of the contaminant seems to impacts on the rate of reduction as the indicator permeates into the soil depth. The 60 mm depth of sample four also found a low concentration of anthracene of 150  $\mu\text{g}/\text{kg}$  while the remaining depths of sample four and all depths of sample five was clear of any concentration of anthracene. No concentration levels of anthracene were apparent in the control sample.

**Figure 4.4.7: Analysis of the concentration of Flouranthene in the soil samples**

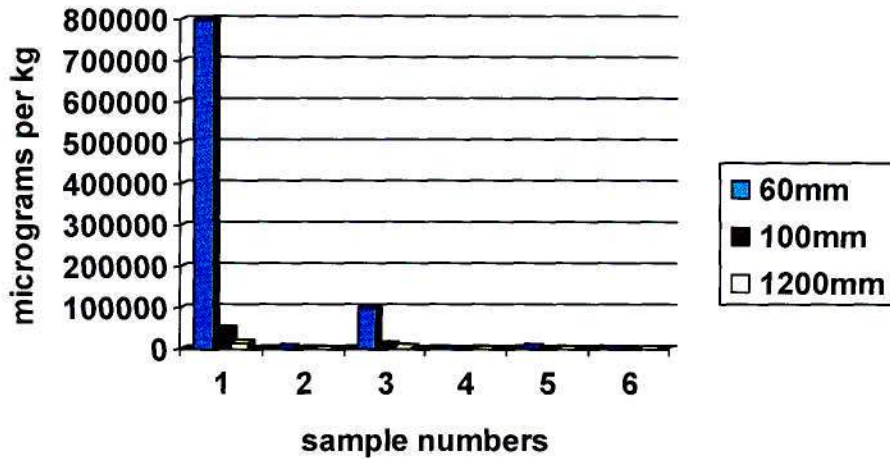


Flourenthene is also known to be a skin irritant. Extremely high concentration levels of Flouranthene was found on the surface at a depth of 60mm of sample one, being 1800000 µg/Kg. This amount exceeds the acceptable levels of PAH by 180 times. 500000 µg/kg was found at the 100mm depth which is also 50 times greater than what is allowed in the soil. At the 1200mm depth of sample one, the concentration decreased to 12000 µg/Kg which is still above the acceptable level of contamination. Sample 3 at a surface depth of 60mm also showed high contamination being 150000 µg/Kg, while at the 100mm, 33000µg/Kg was found and at the 1200mm depth no traces were found. High exposures to phenanthrene and flourenthene from sample one and three, particularly at the surface show high likelihood to cause skin irritation to humans exposed to this soil.

In sample two, the 60mm depth indicated a concentration of 670µg/kg and the 100mm indicated a concentration of 92 µg/kg. Both these figures are well within the acceptable level range. No concentration was present at the 1200mm depth of sample two. A low concentration of 380 µg/kg was indicative in the 60mm depth of sample four while the balance of the depths was clear of any level of contamination. No concentration of flouranthene was found in sample five and the control sample.



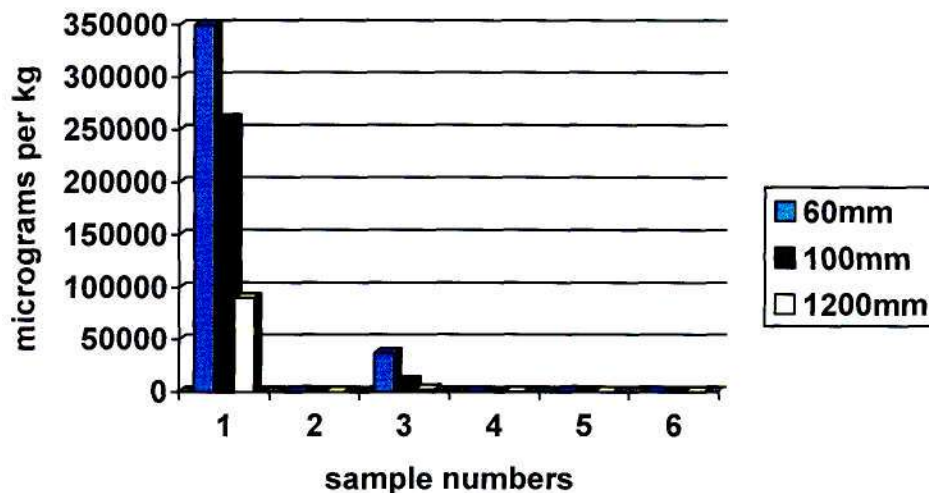
**Figure 4.4.8: Analysis of the concentration of Pyrene in the soil samples**



The highest concentration of pyrene being 800000 µg/kg was found in sample one at the 60mm depth. It was reduced to 46000 µg/kg in the 100mm depth and at a depth of 1200mm further reduced to 12000 µg/kg. The allowed quantity of pyrene in the soil is 650 µg/kg. These values well exceed this acceptable level of contaminant to be present in the soil. Two depths in sample two showed levels of contamination with a concentration of 700 µg/kg at the 60mm depth and 71 µg/kg concentrations at the 100mm depths. No pyrene concentration was present in sample two at the 1200mm depth.

Sample three indicated a high concentration of the indicator at the 60mm depth consisting of 100000 µg/kg. An unacceptable level was detected at the 100mm depth of 10000 µg/kg and a concentration just above the acceptable amount was present in the 1200mm depth of 670 µg/kg in sample three. Sample four and five indicated low concentration levels at the 60 mm depth. Sample four had a concentration of 200 µg/kg and sample five had a concentration of 700 µg/kg. The remaining depths of sample four and five indicated no traces of pyrene. Concentration of pyrene in the control sample at all three depths was absent.

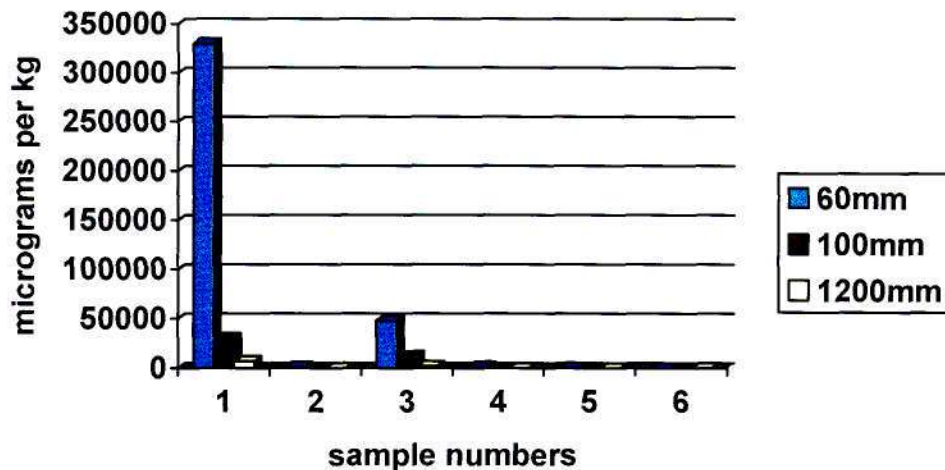
**Figure 4.4.9: Analysis of the concentration of Benzo (a) anthracene in the soil samples**



Concentrations of 350000 µg/ Kg, 260000 µg/Kg, and 90000 µg/Kg was found in sample one at depths of 60mm, 100mm, and 1200mm respectively. At the 60mm depth in sample three. The concentration at a depth of 60mm in sample three was 37000 µg/Kg, while the other two depths (100mm and 1200mm) were characterized by 10000 µg/kg and 2000 µg/kg respectively. Sample, 2, 4 and 5 showed low levels of contamination of Benzo (a) anthracene. Sample two at the 60mm depth had a concentration of 400µg/kg, the 100mm depth had a concentration of 71 µg/kg and the 1200 had none. At the 60mm depth of sample four and five, 400 µg/kg was present in both samples respectively, while the balance of the samples in the remaining depths indicated the absence of any benzo (a) anthracene concentrations.

There were no traces of benzo (a) anthracene evident from the laboratory analysis of the control sample.

**Figure 4.4.10: Analysis of the concentration of Chrysene in the soil samples**

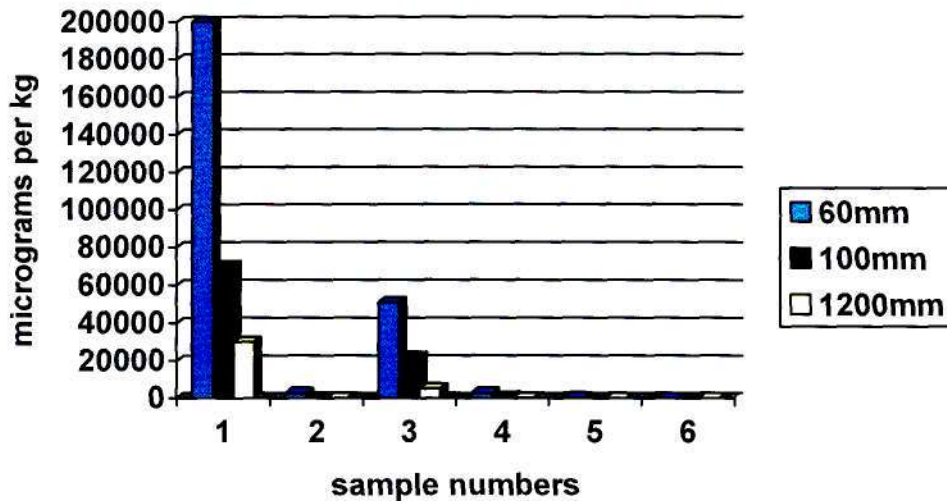


The highest concentration of chrysene being 330000 µg/kg was found in sample one at the 60mm depth. The 100mm depth of the same sample contained 30 000 µg/kg which was three times above the acceptable level. Chrysene was greatly reduced at 1200mm of sample to 7000 µg/kg which was within the acceptable levels. Very low concentration levels were found in sample 2, 4 and 5 at the various depths. Sample two and four showed the presence of 1200 µg/kg each at the 60 mm depth while sample five's 60mm depth contained 250 µg/kg. At the 100mm depth in sample two, 98µg/kg of chrysene was detected and at the remaining depths in sample two , four and five no traces of the indicator was present. In sample 3, higher levels were present from 48000 µg/Kg at the 60mm depth, 12 000 µg/kg at the 100mm depths but dropped well below the acceptable levels at the 1200 depth to 2000µg/kg. In the control sample, there were no traces of chrysene.

The data thus far indicates that there is definitely a spread of PAH among the soil samples. The quantity of concentration among the various constituents however, is unevenly distributed. Some samples had high levels of PAH constituents, while in other sample there were no traces of PAH that occurred.



**Figure 4.4.11: Analysis of the concentration of Benzo (b) + (k) Flourenthane in the soil samples**

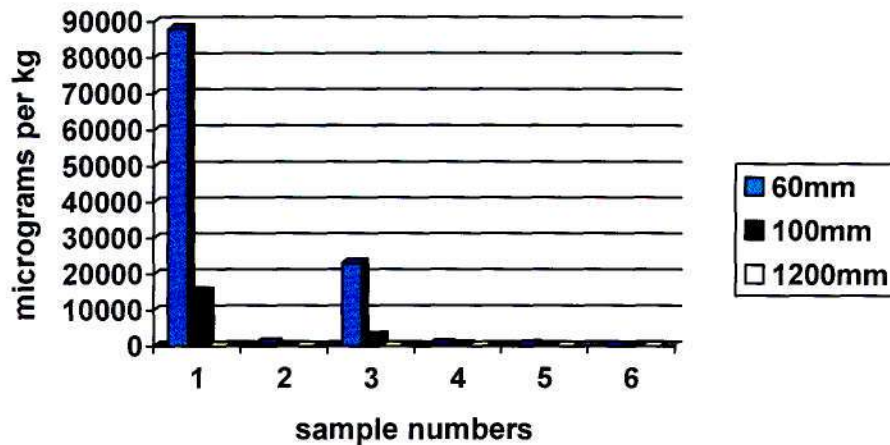


At various depths in sample one and three, the concentration levels of benzo (b) + (k) flouranthene exceeded the maximum permissible levels to be found in the soil. Concentration values at the 60 mm depth were 200000 µg/kg in sample one and 51000 µg/kg in sample three. The 100 mm depth indicated a concentration of 70000 µg/kg in sample one and the third sample showed a concentration value of 23 000 µg/kg at the same depth. The final depth of 1200mm indicated concentration values of 30000 µg/kg in sample one and in sample three was reduced to 5000 µg/kg.

A low level of concentration in comparison to the minimum permissible levels allowed in soil was found in sample two, four and five at the 60mm depth. Sample two and four had a value of 2600 µg/kg at the first depth sampled, and sample five had a concentration of 1200 µg/kg at the same depth. The 100mm depth indicated reduced concentration levels of 300 µg/kg and 500 µg/kg for sample two and four respectively. The remaining depths in sample two, four and five indicated no traces of benzo (b) + (k) flouranthene.

The control sample was absent from any presence of the above contaminant.

**Figure 4.4.12: Analysis of the concentration of Benzo (a) pyrene in the soil samples**

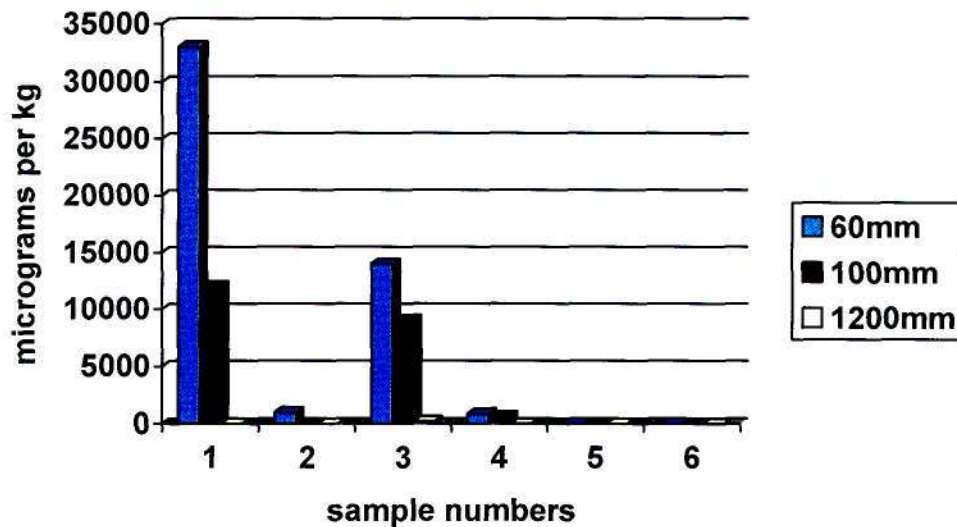


The highest concentration of benzo (a) pyrene being 88000 µg/kg was found in sample one at the 60mm depth. The South African acceptable level of benzo (a) pyrene is 50µg/kg. This quantity found in sample one at the 60mm depth is 1760 times greater than the acceptable level of benzo (a) pyrene allowed in soil. Sample one at a 100mm depth, showed a reduced concentration value of 15000 µg/kg .This was still above the acceptable permissible level of the contaminant to be found in soil. The 1200 depth of sample one showed no traces of the contaminant.

Sample two at all the values ranged from 890 µg/kg, 99 µg/ kg and zero at the respective depths of 60mm, 100mm, and 1200mm. The 60mm and 100mm depth were above the acceptable level to be found in the soil. A slightly higher concentration value was present in sample three at the 60mm depth being 23000 µg/kg, while the 100mm depth reduced to 2700 µg/kg, and no contaminant was present at the 1200mm depth. Sample four had low concentrations of 620 µg/kg at the 60mm depth, 300 µg/kg in the 100mm depth with no concentration of benzo (a) pyrene at the1200mm depth. The only trace of benzo (a) pyrene in sample five was found at the 60 mm depth of 300 µg/kg. There was no evidence of benzo (a) pyrene in the control sample.



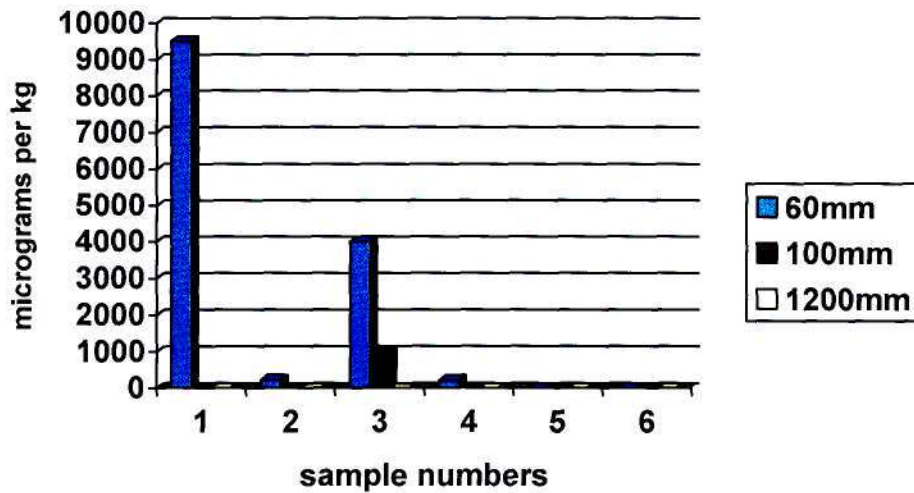
**Figure 4.4.13: Analysis of the concentration of Indeno 1, 2, 3, cd- pyrene in the soil samples**



Samples one, two, three and four were characterized by various concentrations of indeno 1, 2, 3, cd-pyrene contamination at the different depths. In sample one; concentrations were 33000µg and 12000 µg/kg at the 60mm and 100mm depth respectively. No trace of the contaminant was found at the 1200mm depth. Concentration of 1000 µg/kg was found in sample two at the 60mm depth and the remaining two depths were absent from indeno 1, 2, 3 , cd-pyrene contamination. At the 60mm depth and 100mm depth, sample three showed a concentration of 14000 µg/kg and 9000 µg/kg respectively. A low concentration of 200 µg/kg was found at the 1200mm depth. Sample four showed a concentration of 870 at the 100mm depth, 600 at the 100mm depth and was absent in the 1200mm depth. There was no presence of the contaminant in sample five and the control sample.

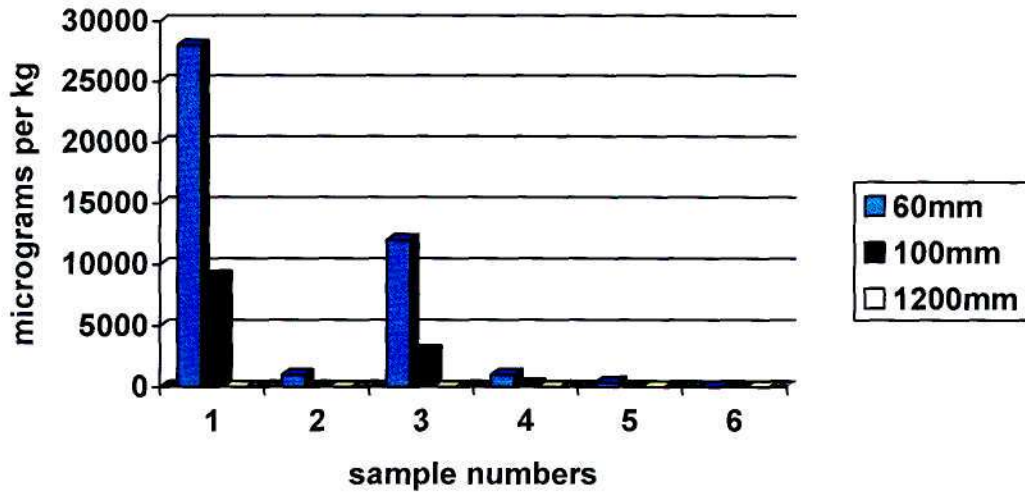
Sample one was taken at the source where the actual rack of wooden poles was stored at the Howick Warehouse. Sample one is therefore a strong reflection of the quantity of PAH in the creosote that bleeds into the soil particles.

**Figure 4.4.14: Analysis of the concentration of Dibenza (a, h) anthracene in the soil samples**



All samples at all depths contained concentration levels of Dibenza (a, h) anthracene that were below the permissible level allowed in soil. Sample one at a 60mm depth showed a concentration value of 9500 µg/kg, while no other traces were present at the remaining two depths. At the depth of 60mm in sample two, 220 µg/kg was present and the remaining two depths showed absence of the contaminant. The 60mm depth of sample three showed evidence of 4000 µg/kg and at the 100mm depth 1000 µg/kg was noted. There was no contaminant present at the 1200mm depth. In sample four, the 60mm depth showed a concentration of 211 µg/kg of dibenza (a, h) anthracene, and the remaining two depths was free from the presence of dibenza (a, h) anthracene. Sample five and the control sample showed no evidence of dibenza (a, h) anthracene at all three depths.

**Figure 4.4.15: Analysis of the concentration of Benzo (g, h, i) perylene in the soil samples**



In sample one at the 60mm depth, a concentration of the contaminant was found to be 28000 µg/kg. The 100mm depth of sample one demonstrated the presence of the contaminant at a value of 9000 µg/kg. None was present at the 1200mm depth in sample one. In sample two, a low concentration of 1000 µg/kg was found at the 60mm depth, being. The remaining depths was absent from any concentration of the contaminant in sample two. 12000 µg/kg of benzo (g, h, i) perylene was found at the 60mm depth of sample three, and 2900 µg/kg was found at the 100mm depth. No traces of the indicator were present at the 1200mm depth. Sample four demonstrated a 990 µg/kg of the indicator at the 60mm depth and 200 µg/kg at the 100mm depth. There was no concentration values present at the 1200mm depth. Sample five and the control sample at all three depths demonstrated no evidence of the contaminant.

## **4.5 Risk Assessment Analysis**

The first step in analyzing the data using the Risk Assessment tool is to identify the contaminant, pathways and receptors in this study. These three factors must be present for a hazard to actually pose a potential risk. A hazard is the intrinsic potential for an agent, activity or process to lead to a sudden incident or an ongoing condition that can harm the environment (Nel, 2007).

### **4.5.1 Contaminant:**

In this study, the contaminant is Creosote. The reason for this contaminant being classified as such is as a result of the harmful chemicals used in its manufacturing. These, among them, include polycyclic aromatic hydrocarbons which are also a constituent of well recognized pollutants such as petrol and oil. The International Agency for Research on cancer and the US EPA have determined that creosote is likely to be a probable human carcinogen ([www.sawpa.co.za](http://www.sawpa.co.za)).

### **4.5.2 Pathways:**

The contaminant is bleeding onto soil, and soil infiltration is one pathway. Rainfall can result in surface water drainage and wash creosote bleedings from the soil into storm water systems. Consideration must also be given to the likelihood of sub-soil pathways available from subsurface water sources. This creates various pathways to carry the hazard from one source to another.

### **4.5.3 Receptors:**

Receptors include site staff and microbes that live in the soil necessary for soil fertility and plant growth. If significant creosote bleedings occur and infiltrate the soil into ground water, the off-site water users can also be affected and are other potential receptors.

An ongoing condition is present in the Howick pole yard, as poles are continuously being brought into the warehouse and stored until transported for

electricity infrastructure usage. Observations indicate that these poles are continuously bleeding. This ongoing condition has the potential to result in adverse consequence to people and the environment. At this stage it is important to assess the severity of the consequences of this ongoing condition.

#### **4.6 Process to determine findings and calculation of risks**

The laboratory analysis of the soil samples provided quantifiable evidence for the researcher to determine the concentrations levels of each indicator in the soil per depth, and the total calculated amount of PAH present per sample, per depth. This information will be used to identify the possible risks present from the level of contamination found. These risks are the findings of this study. The findings will further be analyzed using the Risk Assessment Matrix to calculate the significance of the risk. The risk assessment matrix allocates a score to the finding using the criteria in figure 3.1.

This score will be plotted onto the matrix and will fall in line with a particular colour. The colour has been explained in the risk estimation triangle in figure 3.2, and guides the researcher in the application of mitigation measures, based on the significance of the risk.

This process ensures that the researcher meets the aim of the research to investigate using the Environmental Risk Assessment tool to determine the environmental impacts of creosote exposure from creosote bleedings on soil, during wooden pole storage - a case study of the Eskom Distribution Eastern Region Howick Pole Warehouse.

The risks identified from the information in the laboratory analysis are the following:

(I) Dermal contact *via* direct handling and contact of PAH contaminated soils exist. Exposure to soils that are contaminated with PAH beyond that of acceptable limits can pose a very serious threat. Analysis of soils indicates that some soil samples, especially at depths of 60mm and 100mm were contaminated beyond the critical limit. Several of the indicators of PAH as stated in earlier chapter were recognized as carcinogenic. These indicators are present in the soil. **Finding one concludes that: soils at the Howick Warehouse have a possibility to be carcinogenic.**

(II) The quality of soil at the Howick pole yard is being degraded continuously by the continuous addition of PAH to the soil via the creosote bleedings. PAH is not a natural component of soil, thus any traces of PAH in soil will change the natural composition of soil, and hence cause soil degradation. Although the indicators in the graphical presentation were analysed for their individual impacts, it must be stated that the PAH content in the soil is the calculated sum of all the indicators present in the samples. In sample one for example a calculated PAH content at the 60 mm depth is 9086500 µg/kg. This statistic confirms that creosote bleedings are contaminating soil by the addition of PAH. **Finding two concludes that: creosote bleedings from storage of wooden utility poles at the Howick warehouse cause soil degradation.**

(III) It appears that the creosote is being biodegraded at lower soil depths. The initial quantity of contamination however, impacts on the level of biodegradation. PAH from the soils entering water bodies through soil infiltration and sub-surface runoff remains a potential risk. This is derived from evidence in sample one and three, where at the 1200mm depth, calculated PAH content exceeded the south African permissible quantity of PAH allowed in soil. **Finding three concludes: creosote bleedings from stored wooden poles at the Howick warehouse has the likelihood to contaminate ground and surface water.**



This study will analyze the above findings further using the Risk Assessment Matrix. The matrix determines the severity of the finding.

#### 4.6 Calculated significance of Risk

The Risk Assessment Matrix was used to assess the above findings from the data obtained in this study:

**Finding one:** Soils at the Howick Warehouse have a possibility to be carcinogenic.

8	9	10	11	12	13	14	7	Disaster
7	8	9	10	11	12	13	6	Unacceptable Widespread
6	7	8	9	10	11	12	5	Significant Widespread
5	6	7	8	9	10	11	4	Significant local
4	5	6	7	8	9	10	3	Limited local
3	4	5	6	7	8	9	2	insignificant
2	3	4	5	6	7	8	1	None
1	2	3	4	5	6	7	Weight number	
Highly unlikely	unlikely	rare	possible	often	likely	frequently		

Using the extract from the matrix above, the environmental risk calculation was conducted as follows. Of the seven possible environmental impacts on the y axis of the risk assessment model, the fourth option was chosen as most suitable for this finding. Based on the presentation of the data above, a significant environmental impact is possible at a local level. The basis for this conclusion is justified in the presence of carcinogenic agents in the soil from the laboratory

analysis at the study area in quantities well above the acceptable limits for soil samples. The weight number obtained on the y axis is a 4. The x-axis of the risk assessment model provides criteria to determine the frequency of impact. There are 7 options again, to rate the above finding. The most suitable option chosen is option 6 whereby the finding is rated to be likely. The weight on the axis is 6.

The chosen x and y axis are then used on the risk model to determine a calculated risk of 10 which falls under the orange shading. Using the information on the risk estimation triangle, the orange requires immediate action to reduce the quantity of carcinogenic agents in the soil to an acceptable level.

**Finding Two:** Creosote bleedings from storage of wooden utility poles at the Howick warehouse cause soil degradation.

8	9	10	11	12	13	14	7	Disaster
7	8	9	10	11	12	13	6	Unacceptable Widespread
6	7	8	9	10	11	12	5	Significant Widespread
5	6	7	8	9	10	11	4	Significant local
4	5	6	7	8	9	10	3	Limited local
3	4	5	6	7	8	9	2	insignificant
2	3	4	5	6	7	8	1	None
1	2	3	4	5	6	7	Weight number	
Highly unlikely	unlikely	rare	possible	often	likely	frequently		

Using the above extract from the risk matrix, the calculation of the significance of the risk was done as follows. The environmental impact based on the



presentation of data indicates that the severity of the finding is significant to the local environment. The weight number of this is rated as a 4 on the y axis indicated in blue below. The frequency of the impact from the presentation of the data is awarded a rating of likely. This gives a weight number of 6, indicated in blue below. The tabulation of data justifies this rating by the high presence of PAH in the soil in the soil samples at the study area. The total PAH content in table 4.1 provides this evidence.

The total calculation of the significance of the risk is given where the x and y axis meet. A rating of 10 is thus derived which falls under the orange column of the risk assessment model. Using the risk estimation triangle colours to analyse the risk factor, it is evident that the finding requires immediate action. A measure is requiring to be put into place immediately to reduce the high risk factor on the degradation of the quality of soil.

**Finding Three:** Creosote bleedings from stored wooden poles at the Howick warehouse has the likelihood to contaminate ground and surface water.

8	9	10	11	12	13	14	7	Disaster
7	8	9	10	11	12	13	6	Unacceptable Widespread
6	7	8	9	10	11	12	5	Significant Widespread
5	6	7	8	9	10	11	4	Significant local
4	5	6	7	8	9	10	3	Limited local
3	4	5	6	7	8	9	2	insignificant
2	3	4	5	6	7	8	1	None
1	2	3	4	5	6	7	Weight number	
Highly unlikely	unlikely	rare	possible	often	likely	frequently		

The calculation of the significance of the risk of the final finding was conducted as follows. Of the 7 options present, the environmental impact pertaining to the severity of the impact of the finding was significant widespread, as there is no control of the flow of water, and creosote contaminates surface water or ground water will flow to other areas far away from the source and would affect the environment far and wide. This allocated a weight number of 5 on the y axis.

The frequency of impact, based on the presentation of data indicates that the finding is possible. This finding can be confirmed by water quality analysis of the stream that the storm water runs into as well as ground water analysis. In the absence of such data, the available evidence from the tabulation of the lab analysis of the soil samples indicates that PAH is infiltrating into the soil. In samples one and three, at the 1200mm depth, concentration values of the indicators greatly exceeded the acceptable level of PAH to be present in the soil. The frequency of impact based on the presentation of data, thus rates the finding as possible. The allocated weight number on the x axis is 4. The calculated risk has a score of 9 and falls under the orange column. The risk estimation triangle requires one at this stage to immediately address the situation by the application of mitigation measures.

#### **4.7 Conclusion**

This chapter contained the interpretation of the statistical results presented in terms of the research problem introduced at the beginning of the report. The meaning of the statistics in light of the research purpose was explained in terms of the application of the Risk Assessment matrix and Risk Estimation triangle, which are internationally acceptable tools for conducting a Risk Assessment. Critics argue that the risk matrix and estimation triangle allows for a level of subjectivity. The soil analysis data however provide quantitative evidence to back the qualitative methods to validate the final conclusion of this study in the next chapter.

Using the conservative conditions of comparison, it can be deduced from the data that at the source of the creosote bleedings from stock piled wooden poles, high levels of PAH soil contamination exists. This deduction is made from sample 1 which was the sample taken at the source. It is apparent that the contamination at the source is the highest. PAH is still present in other samples apart from sample one, and this shows evidence of PAH migration through various possible pathways. Recommendations need to be forwarded to minimize the environmental impact from soils contaminated with creosote bleedings. The final chapter will address recommendations to minimize soil contamination from creosote bleedings at the Howick Pole Yard.

## **CHAPTER: 5**

### **DISCUSSION, RECOMMENDATIONS & CONCLUSION**

#### **5.1 Introduction**

Environmental Management is not, as the phrase could suggest, the management of the environment as such but rather the management of man's interaction with and impact upon the environment (Berg *et al*, 1995). This study thus attempted to calculate the significance of risks from the interaction of human activity on the physical environment, which in turn could impact on human health. The study in this report reviewed the impacts of creosote bleedings from wooden utility poles on soil quality as a way to promote environmental management. In meeting the objectives of the study, recommendations to minimize any negative impacts on the environment will be discussed in this chapter. The need for such environmental management can be viewed from a variety of perspectives already discussed in the conceptual framework. As with all management functions, effective management tools, standards and systems are required and the Risk Assessment was the chosen tool for this study.

Using this tool the data collected was analysed in the previous chapter and will further be discussed in this concluding chapter.

#### **5.2 Discussion**

The overall objective of this study was to investigate the potential impacts of soil contamination by PAH from increasing creosote bleedings observed at the Eskom Howick warehouse. The laboratory analysis that was presented in the previous chapter confirmed that PAH was indeed present in the soil at the Howick warehouse from the creosote bleedings. The control sample, one kilometer away from the source of the bleedings found no traces of PAH. It can

thus be concluded that any level of PAH in the soil samples was as a result of creosote bleedings.

The PAH was broken down into 15 indicators which were tested for in the soil samples and the laboratory determined in what concentration of micrograms per kg were the indicators present. A study by S Goel in 2006, concluded that the minimum acceptable level of any of the PAH indicators in the soil should be 10 000 micrograms per kg. From the presentation of the data, it has been identified that several indicators at the various depths surpassed the minimal acceptable level. As such, if this soil is ingested, or exposed to dermal contact, there is a possibility of the PAH present in the soil can cause cancer. Apart from the likelihood of soil high in PAH to cause cancer, an indicator in isolation can cause possible health effects such as skin irritation and allergies.

The studies reviewed in the literature review indicated that risks of high concentration of PAH have immediate and far reaching consequences on the biophysical environment and local communities. Therefore the high concentration of PAH found at the Howick warehouse from creosote bleedings poses the immediate risk degrading soil quality, and this polluted soil has the likelihood to cause health defects on those exposed. Continuous creosote bleedings can result in depleting the fertility of soil and subsequently impact on the country's agricultural produce. This can arise from different organizations that use wooden poles in the application of their core business daily, and as such can accumulatively contribute to the contamination of soil from the creosote bleedings.

Although the study showed evidence in the presentation of data that PAH indicators were biodegrading at lower soil depths, the quantity of initial contamination at the surface did impact on the rate of biodegradation. As such,

there is a likelihood that large concentrations of PAH can eventually permeate into the soil and contaminate ground water facilities. This can have extremely negative impacts on people that depend on ground water for drinking purposes, and farmers that use borehole water to water their agricultural plantations.

Using the information from the literature review, combined with the laboratory analysis, the environmental risk assessment status of the findings calculated the risks to be classified in the yellow and orange column of the risk estimation triangle. Two risks that were identified during the study thus required to be minimized where possible by the application of mitigation measures, and the other risk which was rated in the orange column required immediate action. Possible action plans and mitigation measures will follow below.

### **5.3 Recommendations**

It is evident from the results that Eskom should take responsibility for soil contamination by PAH. In accordance to the National Water Act 36 of 1998, section 19 and the National Environmental Management Act 107 of 1998 section 30, Eskom is required to take regulatory action aimed at the prevention of pollution and the protection of staff and community against the risk of pollution. These sections in the legislation place a duty and positive obligation to take all reasonable measures to prevent pollution from occurring, recurring and continuing (NEMA, 1998). It also requires the minimization and remediation of pollution where harm has already been caused to an acceptable state of land. The following recommendations below were guided by the legal requirement from legislature for Eskom's implementation, so as to enforce sound environmental management. These recommendations are based on the findings at the Eskom Howick warehouse, but are not limited to be used by Eskom alone. Other industrial organizations that store and use wooden poles that are preserved by creosote should also adopt these mitigation measures to reduce the pollution of soil from creosote bleedings.

The study has confirmed that the bleeding creosote wooden poles are impacting negatively on soil. PAH's are chemically versatile and have the potential to become a carcinogen, dependant on the concentration, the duration (how long) and the route or pathway of exposure (breathing, eating, drinking, skin contact). Soil and water contamination subsequently impacts on plants and animals and human life. In view of this likelihood, Eskom (and other organizations) should prevent creosote bleedings in one or a combination of the following ways:

**(i)** Stringent measures should be placed on all contractors who manufacture creosote poles to ensure that creosote poles are properly dried before they are transported to the wood-pole warehouse. This can be done via the submission of a written warning, and the enforcement of a penalty to ensure compliance of this instruction from Eskom. Regular monitoring of poles is required to derive conclusive evidence that the creosote bleedings, which is a recent observation no longer occurs.

**(ii)** In the event that manufacturers are unable to ensure that poles are 100% dry before transporting them to the warehouse, Eskom should invest in building impermeable containment facilities for wood-pole storage to prevent the bleeding creosote from entrance into the natural environment.

**(iii)** It was observed in this study that most bleedings occurred from the ends of the poles on either side of the pole. Eskom can as a temporary measure keep dip trays of soak pads at the ends of these poles for the creosote to drain into, so as to prevent the creosote from infiltrating the soil. A pad saturated with creosote require disposal at a class H Hazardous waste disposal site.

**(iv)** Considering hydrocarbons such as PAH's are similar constituents found in oil, Eskom should treat spills as they would oil spills. Eskom needs to bioremediate contaminated areas. Bioremediation products that use harmless live bacteria to degrade are currently available on the market such as Ecosorb

and can be used to rehabilitate the areas that are currently contaminated. From the study it was evident that there is limited creosote constituents found at a depth of 1200mm. It is assumed therefore that the microbes in the soil are biodegrading the PAH constituents. This process can be accelerated by the use of products that are 100% cellulose, since such products meet all safety and environmental standards. Surface clean-up is necessary as a minimal measure as contamination decreased with soil depth.

**(vi)** All staff that is working with the creosote wood poles must be advised of the potential dangers of PAH through dermal contact and **MUST** use protective gloves and clothing when working with the wooden poles on site at the Howick pole-yard and on site where poles are being used for infrastructure development.

**(vii)** Continual monitoring of the situation needs to take place by an Eskom environmental representative. The creosote bleedings need to be managed and maintained so as to prevent the risk from escalating from a risk evaluation of 8 to a higher figure.

#### **5.4 Conclusions**

Environmental risks that may lead to physical consequences in terms of human life, health, and the natural built in environment must always be researched to promote effective environmental management. This study identified one possible risk to Eskom's business from recently observed creosote bleedings as a result of this incident causing greater environmental damage through cumulative impacts. A risk assessment was therefore conducted to identify and explore the types, intensities, and the likelihood of undesired consequences related to the risk. This was needed to make a cautious and practical judgment of a lurking hazard and determine the tolerability and acceptability of the risk.



In conceptual terms, hazards characterize the inherent properties of the risk agent. In terms of this study, the constituents that make up the creosote are extremely hazardous in nature and their impact on non target organisms was concerning, which encouraged the need for this research report. Risk affects describe the potential effects that these hazards are likely to cause on specific targets. In this study the hazard became the increasing bleedings of creosote which was likely to cause harm onto soil quality. Although the framework of the research aimed to address the physical environmental risks, the secondary implications can be extended to impact on human health.

South African regulations stemming from the Duty of Care principle in NEMA prompted the need for such a study. The early identification of any risk to the community and an organization helps determine the probability of occurrence and assists in making better decisions on developing effective contingency plans. The qualitative and quantitative research methods used to address the aims and objectives of this study built an overarching framework to indicate that increasing creosote bleedings is concerning and required recommendations to minimize the likely impacts.

This study, as with most research was faced with some limitations that have been addressed in chapter three. Despite these limitations of the study, the findings from the research conducted at the time of the study were able to address the objectives of this report.

The application of the laboratory analysis of the soil samples demonstrated in quantitative terms that soil contamination was occurring from the increased creosote bleedings at the Howick Pole Yard. While the Risk evaluation proved this was a significant soil contamination, the data statistics available from the soil sampling demonstrated that some samples were highly contaminated, while other samples had zero contamination. It was apparent from this analysis, that soil directly contaminated by the creosote drippings were significantly

contaminated, however soils away from the source of contamination had no levels of PAH contamination. It is deduced from this that limited mobility of the creosote bleedings are occurring. Therefore contaminated soil can be bioremediated, and this will serve as an effective preventative measure.

From the information of this study, there is sufficient evidence to prove that creosote should be treated with the same level of significance that legislation allocates to oil spills. It is recommended by the researcher, that legislation should promote creosote spills and oil spills alike, as the hydrocarbons that make up their respective constituents are similar, such as PAH which is found in both substances.

In conclusion, this study provides a structured gathering of information available on the risks associated from the increasing creosote bleedings at the Howick Pole yard. The overall view of the study is that despite the initial concerns, the current risk can be controlled, if the recommendations above are implemented. This will reduce the physical contamination that has the likelihood to lead to health and social impacts, and give credibility to effective environmental management. After the implementation of the above recommendations, the residual risk which is typically the risk left after risk reduction and implementing control measures is no longer a significant threat to the physical environment.

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### **Appendix I: Material Safety Data Sheet of Creosote**

**Appendix II: Minimum Requirements for the handling, classification and disposal of Hazardous material, (DWAF, 2006)**


**Appendix III: Eskom Procedure on Creosote wooden poles**

**Appendix IV: CSIR acknowledgement of samples**



## APPENDIX I

### Material Safety Data Sheet of Creosote

 SUPRACHEM		CREOSOTE	
MATERIAL SAFETY DATA SHEET		COPY NO	Page 1 of 8

### 1. PRODUCT AND COMPANY IDENTIFICATION

**Product name & code:** Creosote -  
 BSS 144 Type 2 (1000010028) (bulk), BSS 144 Type 2 (1000010029) (205 L), BSS 144 Type 2 (1000010030) (25 L), BSS 144 Type 2 (1000010031) (5 L), SABS 1290 (1000010032) (bulk), SABS 538 (1000010033) (bulk), SABS 538 (1000010034) (1000 L), SABS 538 (1000010035) (205 L), SABS 538 (1000010036) (25 L), SABS 538 (1000010037) (5 L)

**Product type:** Wood Preservative

**Name of supplier:** SUPRACHEM (Pty) Ltd

**Address:** Iscor site, Delfos Boulevard  
 Vanderbijlpark  
 ☒ 10202, Staal 1906

**Contact numbers:** ☎ (016) 889-6401 / +27 16 889-6401

**Telefax:** (016) 889-9252 / +27 16 889-9252

**Emergency telephone number:** (016) 889-6401

### 2. COMPOSITION/INFORMATION ON INGREDIENTS

**Preparation description:** Suprachem creosote consists of preparations blended from the products derived from the distillation of crude coal tar. It is used mainly as a wood preservative for transmission and fencing poles and other timber for outdoor use. Creosote is a black viscous liquid and can be brushed on or applied by means of pressure impregnation.


**Chemical Nature:** Selected distillation fractions of aromatic oils are blended to conform to specifications. Oils are aromatic and are generally not compatible with aliphatic or paraffinic oils. The product contains a variety of hydrocarbons such as phenol and polycyclic aromatic hydrocarbons such as benzo(a)pyrene, benzanthracene and phenol derivatives.

**Classification and hazard labelling:** Flammable liquid.

### 3. HAZARD IDENTIFICATION

**Human health hazards:** Vapours cause moderate irritations such that personnel will find high concentrations unpleasant. The effect is temporary.

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 SUPRACHEM		CREOSOTE	
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The liquid is a severe skin irritant and may cause pain and second-degree burns after a few minutes' contact. Creosote is classified as harmful. The IARC (International Agency for Research on Cancer) stated that there is sufficient evidence for the carcinogenicity of creosote in experimental animals and limited evidence in humans.

**Environmental hazards:** Although it is biodegradable, it can act as a water pollutant. Fouling to shoreline.

**Safety hazards:** Vapour-air mixtures are explosive above 95°C. Provide general and local exhaust ventilation systems equipped with high-efficiency particulate filters to maintain airborne concentrations below the limits. Creosote is classified as a material that must be exposed to relatively high ambient temperatures before ignition can occur.

#### 4. FIRST AID MEASURES

**Inhalation:** Remove to fresh air. Support breathing if needed. Call doctor if symptoms persist.

**Skin contact:** Remove contaminated clothes and rinse skin with water for at least 15 minutes.

**Eye contact:** Gently lift the eyelids and flush immediately and continuously with copious amounts of water; consult a physician immediately. Do not let patient rub eyes or keep them tightly closed.

**Ingestion:** Do not induce vomiting. Keep patient warm and transport to hospital.


**Note to physician:** Treat symptomatically. Liberal amounts of neat oil or olive oil can be used on skin burns. Cresol may be detected in urine.

#### 5. FIRE-FIGHTING MEASURES

**Extinguishing media:** For small fires, use foam, carbon dioxide (CO<sub>2</sub>) or dry chemical powder. For large fires, use fog or foam. Use water spray to cool containers exposed to fire.

**Specific methods:** Stay away from ends of tanks. Immediately leave the area if you hear a rising sound from venting safety device. Isolate area

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 <b>SUPRACHEM</b>		<b>CREOSOTE</b>	
<b>MATERIAL SAFETY DATA SHEET</b>		<b>COPY NO</b>	Page 3 of 8

(if possible) for 500 metres in all directions if fire involves tank, rail truck or tanker.

**Protective equipment:** Proper protective equipment, including breathing apparatus and gloves.

**Other information:** Vapours may travel to an ignition source and flash back. Containers may explode due to the heat generated by the fire.

**6. ACCIDENTAL RELEASE MEASURES**

**Personal precautions:** Ventilate contaminated area thoroughly. Evacuate all non-essential personnel. Remove ignition sources.

**Environmental precautions:** Isolate the source of the spill material and ensure that no further discharge occurs, if safe to do so. Prevent from spreading or entering into drains, ditches or rivers by using sand, sawdust or inert absorbent.

**Methods for cleaning up:** Absorb spilled liquid with sand, sawdust or inert absorbent. Collect liquid in sealable containers for disposal.

**7. HANDLING AND STORAGE**

**Handling:** Avoid frequent or prolonged inhalation, contact with skin and eyes. After working with creosote or creosoted products and before eating, drinking or smoking, wash exposed areas thoroughly. Keep away from open flames or sparks.

**Precautions:** To be stored in closed containers. Overheating and pressure build-up must be avoided. Electrical equipment must be flameproof and earthed.


**Storage:** Keep away from sources of ignition. Use lowest practicable storage temperatures to minimise fume generation.

**Recommended material:** Mild steel.

**8. EXPOSURE CONTROLS/PERSONAL PROTECTION**

**Engineering control** Use engineering controls to keep airborne concentrations

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 <b>SUPRACHEM</b>		<b>CREOSOTE</b>	
<b>MATERIAL SAFETY DATA SHEET</b>		<b>COPY NO</b>	Page 4 of 8

**measures :** below the exposure limits. Locate emergency equipment at well-marked and clearly identified stations in case emergency escape is necessary.

**Occupational exposure standards :** TWA OEL-RL (Time-Weighted Average, Occupational Exposure Limit - Recommended Limit) : 0.14 mg/m<sup>3</sup> of coal tar pitch volatiles (as cyclohexane solubles).

#### Personal protective equipment -

- Respiratory protection:** Wear a fresh-air mask to counter the risk of inhaling vapours.
- Hand protection:** Solvent-resistant rubber or plastic gloves.
- Eye protection :** Chemical safety goggles and/or face shield.
- Skin and body protection :** Overalls or a neoprene apron and barrier cream.


**Hygiene measures :** If creosote accumulate on clothes, launder before reuse. Wash work clothes separately from household clothing. Dispose of soiled gloves. Wash exposed body areas thoroughly before eating, drinking or smoking. Shower after work.

### 9. PHYSICAL AND CHEMICAL PROPERTIES

- Physical state:** Liquid at ambient temperature
- Colour:** Dark brown to black
- Odour:** Strong coal tar odour
- Boiling point:** > 180°C
- Flash point:** 95°C min
- Autoignition temperature:** 336°C
- Vapour density:** > 1 (Air = 1)
- Explosion properties:** No data.
- Density:** 1.003 kg/l min @ 25°C
- Solubility -**
- water :** Insoluble
  - solvents :** Soluble

### 10. STABILITY AND REACTIVITY

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 <b>SUPRACHEM</b>		<b>CREOSOTE</b>	
<b>MATERIAL SAFETY DATA SHEET</b>		<b>COPY NO</b>	Page 5 of 8

**Stability :** Product in cold state is stable. Heating may cause volatile flammable vapours to be given off.

**Conditions to avoid:** Avoid contact with oxidising materials.

**Hazardous decomposition products :** Dense fumes are formed on decomposition with overheating.

## 11. TOXICOLOGICAL INFORMATION

**Summary of hazards :** Exposure to large amounts of coal tar creosote can cause harmful effects on the skin, eyes, nervous system and kidneys. Longer-term exposure to lower levels of coal tar creosote can also result in damage to the skin, such as reddening, blistering or peeling.

### Acute toxicity -

**Oral:** The LD50 oral rate of creosote is 4 000 ppm.

**Inhalation:** No deaths (Rats exposed, IRI Project No. 415805). Observable sub-lethal effects included depressed respiration rate.

**Eye irritation:** Vapours can be a slight irritant.

**Skin irritation:** A severe skin irritant. May cause pain and second-degree burns after a few minutes contact.

**Respiratory irritation:** Vapours cause moderate irritation of nose and throat.

**Chronic toxicity:** Increased risk of skin cancer.

**Medical conditions aggravated by long term exposure :** Chronic respiratory or skin diseases.

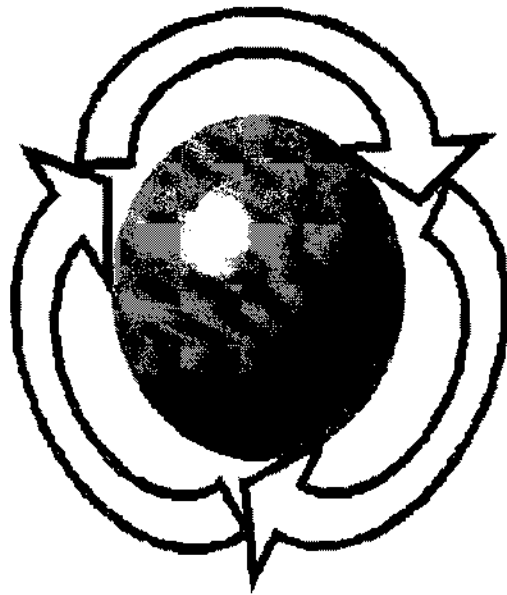
**Carcinogen:** Repeated contact over long periods of time may be responsible for the development of cutaneous neoplasms. Skin cancer has been produced in experimental animals. There are no validated published epidemiological studies showing whether workers exposed to creosote have suffered from an increased risk of skin cancer, although there are a number of case reports.

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## **APPENDIX II**

### **Minimum Requirements for the handling, classification and disposal of Hazardous material, (DWAF, 2006)**

**MINIMUM REQUIREMENTS  
FOR THE HANDLING, CLASSIFICATION  
AND DISPOSAL OF HAZARDOUS WASTE**



DEPARTMENT OF WATER AFFAIRS AND FORESTRY



Second Edition 1998



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# THE WASTE MANAGEMENT SERIES

This document forms part of the Waste Management Series, produced by the Department of Water Affairs & Forestry. Thus far, the series comprises:

**Document 1:** *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste.*

**Document 2:** *Minimum Requirements for Waste Disposal by Landfill.*

**Document 3:** *Minimum Requirements for the Monitoring of Water Quality at Waste Management Facilities.*

**Document 1,** *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste,* sets out the waste classification system. In this, wastes are placed in two classes, General or Hazardous, according to their inherent toxicological properties. Hazardous wastes are further subdivided, according to the risk that they may pose at disposal, using a hazard rating. In this way, a less hazardous waste is distinguished from an extremely hazardous waste. Wastes with a hazard rating of 1 or 2 are very or extremely hazardous, while wastes with a hazard rating of 3 or 4 are of moderate or low hazard. The requirements for pre-treatment and disposal are appropriately set in accordance with the waste classification. Hazardous waste prevention and minimisation are briefly addressed, because of their importance, as is handling, transportation and storage.

**Document 2,** *Minimum Requirements for Waste Disposal by Landfill,* addresses landfill classification, and the siting, investigation, design, operation and monitoring of landfill sites. In the landfill classification system, a landfill is classified in terms of waste class, size of operation, and potential for significant leachate generation, all of which influence the risk it poses to the environment. Graded requirements are then set for all aspects of landfilling, including public participation.

**Document 3,** *Minimum Requirements for the Monitoring of Water Quality at Waste Management Facilities,* addresses the monitoring of water quality at and around waste disposal facilities.

The Department intends extending the Waste Management Series. At the time of writing, the National Waste Management Strategy was being formulated, as a joint venture between the Department of Water Affairs & Forestry, the Department of Environment and Tourism, and DANCED. Initially, three baseline study documents were drafted by South African consultants to provide data regarding waste generation, community waste and litter, and waste disposal sites in South Africa. These will form part of the series. Further work being carried out by Danish and South African consultants, assisted by Departmental staff will generate strategy documents which will also form part of the series.

Other documents envisaged for the series include Minimum Requirements for waste disposal site auditing, and training of operators and managers of waste management facilities.

## HAZARDOUS WASTE CLASSIFICATION TABLES

S.I.N.	WASTE STREAM/ CAS NUMBER	EXAMPLE INDUSTRIAL GROUP	SABS 0228 CLASS/ DANGER GROUP	HAZARD RATING	ACCEPTABLE ENVIRON. RISK ppm	DISPOSAL ALLOWED g/ha/m	PREFERRED TECHNOLOGY	ALLOWED TECH- NOLOGY	UNACCEPTABLE TECHNOLOGY
1088	Acetal [105-57-7]	F2	3.1(II)	3/4	0.1	151	RCY, INC	LFB	LWT
1089	Acetaldehyde [75-07-0]	F2	3.1(I)	3/4	5.3	8030	RCY, INC	LFB	LWT
2790	Acetic Acid Solution [64-19-7]	F2	8(II/III)	3/4	8.8	13333	RCY, INC	NCR	LWT, pH<6
1090	Acetone (S) [67-64-1]	F6	3.1(II)	4/NT	610	924242	RCY, INC	LFB	LWT
1648	Acetonitrile [75-05-8]	F3	3.2(II)	4/NT	100	151515	RCY, INC	LFB	LWT
2310	Acetylacetone [123-54-6]	F4	3.3(III)	3/4	2.9	4393	RCY, INC	LFB	LWT
1717	Acetyl Chloride [75-36-5]	F2	3.2(II)	3	4.2	6363	RCY, INC	HNR	LWT
1092	Acrolein [107-02-8]	F7	6.1(I)	1	0.008	12	RCY, INC	ENC, LFB, CTR	LWT
2607	Acrolein Dimer [100-73-2]	F7	3.3(III)	3/4	1.0	1515	RCY, INC	LFB, CTR	LWT
2074	Acrylamide [79-06-1]	F7	6.1(III)	2	0.1	151	RCY, INC	LFC	-
2218	Acrylic Acid [79-10-7]	F7	8(II)	4/NT	13	19696	RCY, INC	NCR, LFB	LWT, pH<6
1093	Acrylonitrile [107-13-1]	F7	3.2(I)	2	1.4	2121	RCY, INC	ENC, LFB	LWT
-	Alachlor [15972-60-8]	A1	-	2	0.18	273	RCY, INC	ENC, LFC	-
1170	Alcohol [64-17-5]	C2	3.2(II)	4/NT	700	1060606	RCY, INC	LFB	LWT
2761	Aldrin [309-00-2]	A1	6.1(II/III)	1	0.0004	0.606	RCY, INC	ENC, LFC	-
-	Aluminium [7429-90-5]	B2	-	2	0.39	591	RCY, IML	ENC, PRN	LWT

S.L.N.	WASTE STREAM/ CAS NUMBER	EXAMPLE INDUSTRIAL GROUP	SABS 0228 CLASS/ DANGER GROUP	HAZARD RATING	ACCEPTABLE ENVIRON. RISK ppm	DISPOSAL ALLOWED g/ha/m	PREFERRED TECHNOLOGY	ALLOWED TECH- NOLOGY	UNACCEPTABLE TECHNOLOGY
1726	Aluminium Chloride [7446-70-0]	F7	8(II)	3/4	10	15151	RCY, IML	HNR	LWT, pH<6
1397	Aluminium Phosphide [20859-73-8]	A1	4.3(I)	1	0.1	<151	INC	CTR (toxic gas)	LWT
1711	Aminodimethylbenzenes [1300-73-8]	F3	6.1(II)	3/4	1	151	RCY, INC	LFC, LFB	-
1841	1-Aminoethanol [75-39-8]	F3	9(III)	-	-	-	RCY, INC	NCR, LFB	LWT
2512	Aminophenols [27598-85-2]	F3	6.1(III)	2/3	0.2	303	RCY, INC	NCR, LFB	LWT
2672	Ammonia Solutions [1336-21-6]	F2	8(III)	1	0.0024	3,63	RCY	NCR	LWT
8214	Ammonium Chloride [12125-02-9]	G3	9(III)	4	10.9	16515	RCY	LFC, LFB	-
2859	Ammonium metavanadate [7803-55-6]	D2	6.1(II)	2/3	0.15	227	RCY, IML	ENC, LFC	-
2590	Amosite [12172-73-5]	E3	9(III)	1	-	-	IML	LFC (bagged wet)	-
1104	Amyl acetate [628-63-7]	F2	3.3(III)	3/4	6.5	9848	RCY, INC	LFB	LWT
1105	Amyl Alcohol [71-41-0]	F1	3.2(II)	4/NT	47	71212	RCY, INC	LFB	LWT
1547	Aniline [142-04-1]	F7	6.1(II)	4	13.4	20303	RCY, INC	LFC, LFB	-
1548	Aniline Hydrochloride [62-53-3]	F7	6.1(III)	2	0.55	833	RCY, INC	LFC	-
2222	Anisole [100-66-3]	F3	3.3(III)	3/4	1.0	1515	RCY, INC	LFB	LWT
1549	Antimony [7440-36-0]	B2	6.1(II)	2	0.07	106	RCY, IML	ENC, PRN	LWT
1733	Antimony Chloride [10025-91-9]	F1	8(II)	3	1.0	1515	RCY, IML	HNR	LWT
1558	Arsenic [7440-38-2]	G2	6.1(II)	2	0.43	651	RCY, IML	ENC, LFC	-

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1553	Arsenic Acid [7778-39-4]	G2	6.1(I)	2	0.43	651	RCY, IML	ENC, PRN	LWT
1561	Arsenic Trioxide [1327-53-3]	B2	6.1(II)	2	0.43	651	RCY, IML	ENC, PRN	LWT
2212	Asbestos blue [1332-21-4]	E3	9(II)	1	-	-	IML	LFC (bagged wet)	-
2590	Asbestos white [12001-29-5]	E3	9(III)	1	-	-	IML	LFC (bagged wet)	-
1564	Barium [7440-39-3]	E1	-	3	7.8	11818	RCY, IML	PRN	LWT
1446	Barium nitrate [10022-31-8]	F8	5.1(II)	2/3	0.1	151	RCY, IML	ENC, PRN	LWT
-	Benzaldehyde [100-52-7]	F2	3.4(IV)	2/3	0.11	166	RCY, INC	ENC, LFB	LWT
1114	Benzene [71-43-2]	F2	3.2(II)	3	2.2	3333	RCY, INC	ENC, LFB	LWT
2225	Benzenesulphonyl Chloride [98-09-9]	F3	8(III)	2	0.3	454	RCY, INC	CTR, HNR	LWT
2337	Benzenethiol [108-98-5]	F9	6.1(I)	1/2	<0.5	<757	RCY, INC	ENC, LFC, OCR	-
1885	Benzidine [92-87-5]	F3	6.1(II)	2	0.1	151	RCY, INC	ENC, LFC	-
1993	Benzine [8030-30-6]	F1	3.1(II)	2	0.22	334	RCY, INC	LFB	LWT
8240	Benzo(a)pyrene [50-32-8]	F1	9	1	0.005	7.57	RCY, INC	ENC, LFC	-
2224	Benzonitrile [100-47-0]	F7	6.1(II)	3/4	7.8	11818	RCY, INC	LFC, LFB	-
2587	Benzoquinone [106-51-4]	H1	6.1(II)	1	0.0045	6.818	RCY, INC	ENC, LFC	-
3102	Benzoyl Peroxide [94-36-0]	F6	5.2(II)	3	1.0	1515	RCY, INC	RCR, LFB	LWT
1738	Benzyl Chloride [100-44-7]	F3	6.1(II)	2	0.6	909	RCY, INC	LFC, LFB	-

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2208	Bleaching Powder [7778-54-3]	F10	5.1(III)	2	0.18	272	RCY	RCR	LWT
2514	Bromobenzene [100-86-1]	F2	3.3(III)	2/3	0.946	1433	RCY, INC	LFB	LWT
2783	Bromophos-ethyl [4824-78-6]	F9	6.1(III)	1	0.014	21	RCY, INC	ENC, LFC	-
2588	Bromoxynil [1689-84-5]	F9	6.1(III)	1	0.015	22.7	RCY, INC	ENC, LFC	-
1570	Brucine [357-57-3]	K2	6.1(I)	3/4	2	3030	RCY, INC	ENC, LFC	-
2346	Butanedione [431-03-8]	F3	3.2(II)	3	1	1515	RCY, INC	LFB	LWT
1120	Butanols (S) [71-36-3, 78-92-2, 75-65-0]	F2	3.2(II)	4/NT	430	651515	RCY, INC	LFB	LWT
1193	2-Butanone (S) [78-93-3]	F2	3.2(II)	4/NT	322	487878	RCY, INC	LFB	LWT
1129	n-Butyl Aldehyde [123-72-8]	F3	3.2(II)	3/4	2.58	3909	RCY, INC	LFB	LWT
1127	Butyl Chlorides [109-69-3, 78-86-4, 507-20-0]	F7	3.2(II)	3/4	9.7	14696	RCY, INC	LFB	LWT
1149	Butyl Ethers [142-96-1, 6863-58-4]	C2	3.3(III)	3/4	5.2	7878	RCY, INC	LFB	LWT
2347	Butyl Mercaptans [109-79-5, 13-53-1, 75-66-1]	F2	3.1(II)	2/3	0.55	833	RCY, INC	OCR	LWT
2352	Butyl Vinyl Ether [111-34-2]	F3	3.2(II)	3	1.0	1515	RCY, INC	LFB	LWT
2820	n-Butyric Acid [107-92-6]	H2	8(III)	4/NT	20	30303	RCY, INC	NCR	LWT, pH<6
2411	Butyronitrile [109-74-0]	F3	3.2(II)	2/3	0.1	151	RCY, INC	ENC, LFB	LWT
1572	Cacodylic Acid [75-60-5]	F9	6.1(II)	4NT	100	15115	RCY, INC	NCR	LWT, pH<6
2570	Cadmium [7440-43-9]	D4	6.1(I)	1	0.031	47	RCY, IML	PRN	LWT

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-	Cadmium Chloride [10108-64-2]	D4	-	1	0.031	47	RCY, IML	PRN	LWT
1544	Caffeine [58-08-2]	F6	6.1(III)	2/3	0.1	151	RCY, INC	ENC, LFC	-
1573	Calcium Arsenate [7778-44-1]	F9	6.1(II)			-	RCY, INC	ENC, LFC	-
1403	Calcium Cyanamide [156-62-7]	D1	4.3(III)	2	0.1	151	RCY, INC	CTR (flam. gas)	LWT
1575	Calcium Cyanide [592-01-8]	D2	6.1(I)	1	0.05	76	RCY, INC	OCR	LWT
-	Calcium Fluoride [7789-75-5]	D1	-	3	1.0	1515	RCY	LFC	-
1748	Calcium Hypochlorite [7778-54-3]	F10	5.1(II)	2	0.18	272	RCY	RCR	LWT
2717	Camphor [76-22-2]	F6	4.1(III)	4/NT	11	16666	RCY, INC	LFC, LFB	-
8035	Captab/Captan [133-06-2]	F9	9	1	0.03	45	RCY, INC	ENC, LFC	-
2757	Carbaryl [63-25-2]	L2	6.1(III)	1	0.06	90	RCY, INC	ENC, LFC	-
2757	Carbofuran [1563-66-2]	L2	6.1(III)	1	0.028	42	RCY, INC	HNR, LFC	LWT
1311	Carbon Disulphide (S) [75-15-0]	F3	3.1(I)	4	13.5	20454	RCY, INC	LFB	LWT
1707	Carbonic Acid, Dithallium salt [6533-73-9]	D2	6.1(II)	1	0.1	<151	RCY, IML	ENC, LFC	-
1846	Carbon Tetrachloride (S,M) [56-23-5]	F2	6.1(II)	2	0.1	151	RCY, INC	LFC, LFB	-
1824	Caustic Soda Solution [1310-73-2]	A3	8(II)	3	3.3	5000	RCY	NCR	LWT, pH>12
2996	Chlordane [57-74-9]	A1	6.1(III)	1	0.007	10.6	RCY, INC	ENC, LFC	-
2996	Chlordimeform [6164-98-3]	A1	6.1(III)	3/4	1.17	1772	RCY, INC	LFC	-
1750	Chloroacetic acid [79-11-8]	F3	8(II)	2	0.1	151	RCY, INC	NCR	LWT, pH<6

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2019	2- and 3-Chloroanilines [95-51-2, 108-42-9]	F3	6.1(II)	2/3	0.1	151	RCY, INC	ENC, LFC, LFB	-
2018	4-Chloroaniline [106-47-8]	F3	6.1(II)	2	1.2	1818	RCY, INC	LFC, LFB	-
1134	Chlorobenzene (S) [108-90-7]	F4	3.3(III)	3/4	4.5	6818	RCY, INC	LFB	LWT
2669	Chlorocresols solid/liquid [59-50-7]	F6	6.1(II)	1	0.001	1.5	RCY, INC	ENC, LFC, LFB	-
1135	2-Chloroethanol [107-07-3]	F9	6.1(II)	2	0.1	0.04	RCY, INC	ENC, LFB	LWT
1888	Chloroform [67-66-3]	F6	6.1(II)	1	0.1	0.04	RCY, INC	LFC	-
2237	Chloronitroanilines [121-87-9, 89-63-4, 6283-25-6, 635-22-3]	H1	6.1(III)	2	1	7.04	RCY, INC	ENC, LFC	-
1578	Chloronitrobenzene [88-73-3]	H1	6.1(II)	2/3	0.12	0.845	RCY, INC	ENC, LFC, LFB	-
2020	4-Chlorophenol [106-48-9]	F6	6.1(III)	3	0.19	287	RCY, INC	ENC, LFC, LFB	-
2238	Chlorotoluenes [25168-05-2]	F3	3.3(III)	1	0.59	893	RCY, INC	ENC, LFB	LWT
2239	Chlorotoluidines [95-74-9, 616-65-6]	F6	6.1(III)	1	1	1515	RCY, INC	ENC, LFC	-
2783	Chlorpyrifos [2921-88-2]	A1	6.1(III)	1	0.0003	0.45	RCY, INC	ENC, LFC	-
-	Chromium (III) [7440-47-3]	B2	-	3	4.7	7121	RCY	CTR	LWT
1755	Chromium (VI) [7738-94-5]	D4	8(II)	1	0.02	30	RCY	RCR	LWT, pH<6
-	Cobalt [7440-48-4]	B2	-	2	6.9	10454	RCY	CTR	LWT
2775	Copper [7440-50-8]	D4	6.1(III)	2	0.1	151	RCY, IML	ENC, PRN	LWT

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1585	Copper Acetoarsenite [12002-03-8]	H3	6.1(II)	1	0.1	<151	RCY, IML	ENC, PRN	LWT
2775	Copper Oxychloride [1332-40-7]	F9	6.1(III)	2	0.22	333	RCY, IML	PRN	LWT
2811	Copper Sulphate [7758-99-8]	F9	6.1(III)	1	0.01	15	RCY, IML	PRN	LWT, pH<6
2076	Cresols solid/liquid (S) [1319-77-3]	K1	6.1(II)	2/3	0.4	606	RCY, INC	LFC, LFB	-
2022	Cresylic Acid [1319-77-3]	F2	6.1(II)	2/3	0.4	606	RCY, INC	ENC, NCR, LFB	LWT, pH<6
1143	Crotonaldehyde [4170-30-3]	C2	3.2(II)	2/3	0.13	196	RCY, INC	ENC, LFB	LWT
1403	Cyanamide [420-04-2]	D1	4.3(III)	2	0.1	151	RCY, INC	CTR (flam. gas)	LWT
1588	Cyanide [151-50-8, 143-33-9]	D4	6.1(I)	1	0.0053	8.0	RCY, CTR	OCR	INC
2670	Cyanuric Chloride [108-77-0]	F10	8(III)	2	0.1	151	RCY, INC	RCR	LWT
1145	Cyclohexane [110-82-7]	F1	3.1(II)	3/4	9.3	14090	RCY, INC	LFB	LWT
-	Cyclohexanol [108-93-0]	F7	3.4(IV)	4/NT	72	109090	RCY, INC	LFC, LFB	-
1915	Cyclohexanone (S) [108-94-1]	F7	3.3(III)	4/NT	52.7	79848	RCY, INC	LFC, LFB	-
2046	Cymenes [99-87-6]	F2	3.3(III)	3	1	1515	RCY, INC	LFB	LWT
2761	DDT [50-29-3]	A1	6.1(III)	1	0.0007	1.06	RCY, INC	ENC, LFC	-
-	Decanol [112-30-1]	F6	-	3	2.3	3485	INC	LFC	-
1147	Decalin [91-17-8]	F4	3.3(III)	3	1	1515	RCY, INC	LFB	LWT
2783	Demeton [8065-48-3]	A1	6.1(III)	1	0.01	15	RCY, INC	ENC, LFC	-



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1673	<b>Diaminobenzenes</b> [95-54-5, 108-45-2, 106-50-3]	H2	6.1(III)	2/3	0.574	869	RCY, INC	ENC, LFC	-
1148	<b>Diacetone Alcohol</b> [123-42-2]	F7	3.3(III)	4	42	63636	RCY, INC	LFB	LWT
3082	<b>Di-n-butylphthalate</b> [84-74-2]	F8	9(III)	2	1	1515	RCY, INC	ENC, LFC, LFB	-
3018	<b>Dichlofenthion</b> [97-17-6]	F9	6.1(III)	2	0.1	151	RCY, INC	ENC, LFC, LFB	-
1764	<b>Dichloroacetic Acid</b> [79-43-6]	F9	8(II)	3/4	1	1515	RCY, INC	NCR	LWT, pH<6
1590	<b>Dichloroanilines</b> [608-27-5, 554-00-7, 95-82-9, 95-76-1, 626-43-7]	F2	6.1(II)	2	0.7	1060	RCY, INC	ENC, LFC, LFB	-
1591	<b>1,2-Dichlorobenzene (S)</b> [95-50-1]	F3	6.1(III)	4	1.7	2575	RCY, INC	LFC, LFB	-
-	<b>1,3-Dichlorobenzene</b> [541-73-1]	F3	6.1(III)	4	0.78	1181	RCY, INC	LFC, LFB	-
1592	<b>1,4-Dichlorobenzene</b> [106-46-7]	F3	6.1(III)	4	3.37	5106	RCY, INC	LFC	-
2362	<b>1,1-Dichloroethane</b> [75-34-3]	F3	3.2(II)	4	48	72727	RCY, INC	LFB	LWT
1184	<b>1,2-Dichloroethane</b> [107-06-2]	F3	3.2(II)	3	6.5	20454	RCY, INC	ENC, LFB	LWT
2465	<b>Dichloroisocyanuric Acid Salts</b> [2782-57-2]	F10	5.1(II)	3/4	1	1515	RCY, INC	RCR	LWT
1593	<b>Dichloromethane (S)</b> [75-09-2]	D3	6.1(III)	4/NT	14	21210	RCY, INC	LFC, LFB	-
2020	<b>Dichlorophenols</b> [576-24-0, 120-83-2, 583-78-8]	F9	6.1(III)	2/3	0.5	757	RCY, INC	ENC, LFC, LFB	-
1886	<b>Dichlorotoluene</b> [98-87-3]	F3	6.1(II)	2	0.58	878	RCY, INC	ENC, LFC, LFB	-
2783	<b>Dichlorvos</b> [62-73-7]	F9	6.1(II)	1	0.09	136	RCY, INC	ENC, LFC	-

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2783	Dicrotophos [141-66-2]	F9	6.1(II)	2	20	30300	RCY, INC	ENC, LFC	-
2761	Dieldrin [60-57-1]	A1	6.1(II)	1	0.0006	0.9	RCY, INC	ENC, LFC	-
2686	Diethylaminoethanol [100-37-8]	F3	3.3(III)	3/4	1	1515	RCY, INC	NCR, LFB	LWT
2432	N,N-Diethylaniline [91-66-7]	F3	6.1(III)	3/4	1	1515	RCY, INC	LFC, LFB	-
-	Diethylene glycol monoethyl ether [111-77-3]	H1	3.4(IV)	4/NT	750	1136363	RCY, INC	LFC, LFB	-
1155	Diethyl ether (S) [60-29-7]	K1	3.1(I)	4/NT	260	393939	RCY, INC	LFB	LWT
1156	Diethyl ketone [96-22-0]	F3	3.2(II)	4/NT	154	233333	RCY, INC	LFB	LWT
8233	Diethyl phthalate [84-66-2]	F7	9(III)	3/4	3	4545	RCY, INC	LFC, LFB	-
2991	Dimetan [122-15-6]	F9	6.1(III)	2/3	0.1	151	RCY, INC	ENC, LFC	-
1160	Dimethylamine solution [124-40-3]	F2	3.1(II)	3/4	4	6060	RCY, INC	NCR	LWT
2253	N,N-Dimethylaniline [121-69-7]	F7	6.1(II)	3/4	1	1515	RCY, INC	LFC, LFB	-
1163	1,1-Dimethylhydrazine [57-14-7]	C2	6.1(I)	2	2.65	3939	RCY, INC	OCR, NCR, LFB	LWT
2382	1,2-Dimethylhydrazine [540-73-8]	C2	3.2(II)	1	0.1	<151	RCY, INC	CTR, LFB (Care!)	LWT
8081	Dimethyl Nitrosamine [62-75-9]	F7	9(II)	1	8.8	8.8	RCY, INC	LFC, CTR	-
-	Dimethyl Sulfoxide [67-68-5]	F3	3.4(IV)	4/NT	10	15151	RCY, INC	LFC, LFB	-
2991	Dimetilan [644-64-4]	A1	6.1(II)	1	0.1	<151	RCY, INC	ENC, LFC, HNR	-
1596	2,4-Dinitroaniline [97-02-9]	F3	6.1(II)	3	1.42	2151	RCY, INC	LFC	-

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2779	Dinoseb [88-85-7]	A1	6.1(II)	1	0.0032	4.8	RCY, INC	ENC, NCR	LWT, pH<6
2779	Dinoseb Acetate [2813-95-8]	A1	6.1(III)	2/3	0.1	151	RCY, INC	ENC, LFC	-
2779	Dinoterb [1420-07-1]	A1	6.1(III)	1	0.00034	0.51	RCY, INC	ENC, NCR	LWT, pH<6
2779	Dinoterb Acetate [3204-27-1]	A1	6.1(III)	1	0.0039	5.9	RCY, INC	ENC, LFC	-
1165	1,4-Dioxane [123-91-1]	F7	3.2(II)	4/NT	670	101515	RCY, INC	LFB	LWT
2489	Diphenylmethane-4,4- diisocyanate [101-68-8]	F7	6.1(III)	3	10	15151	RCY, INC	CTR, LFB, HNR	-
3016	Diquat [85-00-7]	A1	6.1(III)	3/4	2.1	3181	RCY, INC	LFB	-
2761	Endosulfan [115-29-7]	A1	6.1(III)	1	0.0003	0.45	RCY, INC	ENC, HNR, LFC	-
2761	Endrin [72-20-8]	A1	6.1(I)	1	0.00007	0.106	RCY, INC	ENC, LFC, LFB	-
2023	Epichlorohydrin [106-89-8]	F3	6.1(II)	2	1.8	2728	RCY, INC	LFC, LFL	LWT
2363	Ethanthiol [75-08-1]	F3	3.1(I)	3/4	1	1515	RCY, INC	OCR, (Care!)	LWT
2491	Ethanolamine [141-43-5]	F3	8(III)	4/NT	17	25757	RCY, INC	LFB, NCR	LWT
1173	Ethyl Acetate (S) [141-78-6]	F3	3.2(II)	2/3	21.2	32121	RCY, INC	LFB	LWT
1917	Ethyl Acrylate [140-88-5]	F4	3.2(II)	3/4	2	3030	RCY, INC	LFB	-
2270	Ethylamine aqueous [75-04-7]	F2	3.1(II)	3/4	4	6060	RCY, INC	NCR, LFB	LWT
2273	2-Ethylaniline [578-54-1]	F3	6.1(III)	3/4	7.5	11363	RCY, INC	LFC, LFB	-
2272	N-Ethylaniline [103-69-5]	F3	6.1(III)	3/4	3.1	4696	RCY, INC	LFB, LFC	-

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1175	Ethylbenzene (S) [100-41-4]	F7	3.2(II)	3	1.2	1818	INC	LFC	-
2404	Ethyl cyanide [107-12-0]	F3	3.2(II)	1/2	0.1	<151	RCY, INC	LFB	LWT
1184	Ethylene chloride [107-06-2]	F3	3.2(II)	4/NT	13.5	20454	RCY, INC	LFB	LWT
1604	Ethylenediamine [107-15-3]	F2	8(II)	3/4	23	34848	RCY, INC	LFB, NCR	LWT
8293	Ethylenediamine-tetraacetic Acid (EDTA) [60-00-4]	F10	9(>III)	4/NT	12.9	19545	RCY, INC	NCR	LWT, pH<6
1171	Ethyleneglycol monomethyl ether [109-86-4]	C2	3.3(III)	4/NT	1552	2351515	RCY, INC	LFB	LWT
1190	Ethyl Formate [109-94-4]	A2	3.1(II)	3/4	1	1515	RCY, INC	LFB	LWT
1191	2-Ethylhexanol [104-76-7]	F7	3.3(III)	3	3.2	4848	INC	LFC	-
2525	Ethyl Oxalate [95-92-1]	F6	6.1(III)	2	0.1	151	RCY, INC	ENC, LFC, LFB	-
1195	Ethyl Propionate [105-37-3]	F4	3.2(II)	3/4	5.6	8484	RCY, INC	LFB	LWT
1196	Ethyltrichlorosilane [115-21-9]	F7	3.2(II)	3	1	1515	RCY, INC	HNR (flam. gas)	LWT
2783	Fenthion [55-38-9]	A1	6.1(III)	1	0.07	106	RCY, INC	ENC, LFC	-
1773	Ferric Chloride [7705-08-0]	F10	8(III)	3	9	13636	RCY, IML	PRN	LWT, pH<6
1466	Ferric Nitrate [10421-48-4]	H1	5.1(III)	3	9	13636	RCY, IML	PRN	LWT, pH<6
8102	Ferrous Chloride [7758-94-3]	F10	9	3	9	13636	RCY, IML	PRN	LWT, pH<6
2941	Fluoroanilines [348-54-9, 371-40-4]	F3	6.1(III)	2/3	0.25	378	RCY, INC	ENC, LFC, LFB	-
1198	Formaldehyde solutions [50-00-0]	F7	3.3(III)	2	0.9	1364	RCY, INC	LFB	-

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1199	Furfural [98-01-1]	F3	3.3(III)	3/4	3.2	4848	RCY, INC	LFB	LWT
2761	Heptachlor [76-44-8]	F9	6.1(II)	1	0.0007	1.06	RCY, INC	ENC, LFC	-
1206	Heptanes [142-82-5]	F3	3.2(II)	4	37,5	56818	RCY, INC	LFB	LWT
2729	Hexachlorobenzene [118-74-1]	F3	6.1(III)	2	0.032	48	RCY, INC	ENC, LFC	-
2279	Hexachlorobutadiene [87-68-3]	F3	6.1(III)	1	0.009	13.6	RCY, INC	ENC, LFC	-
8092	Hexachloroethane [67-72-1]	F8	9(>II)	2	0.14	212	RCY, INC	ENC, LFC	-
2875	Hexachlorophene [70-30-4]	F6	6.1(III)	1	0.01	15	RCY, INC	ENC, LFC	-
2280	Hexamethylenediamine [124-09-4]	F7	8(III)	3	1	1515	RCY, INC	LFC, NCR	-
1208	Hexanes [110-54-3]	A2	3.1(II)	1	0.4	606	RCY, INC	LFB	LWT
-	2-Hexanone [591-78-6]	F3	-	4	43.0	65152	RCY, INC	LFB	LWT
2030	Hydrazine hydrate [7803-57-8]	F9	8(II)	2	0,1	151	RCY, INC	OCR (Care!)	LWT
1787	Hydriodic Acid solution [10034-85-2]	F3	8(II)	-	-	-	RCY	NCR	LWT, pH<6
1788	Hydrobromic Acid solution [10035-10-6]	F3	8(II)	-	-	-	RCY	NCR	LWT, pH<6
1789	Hydrochloric Acid solution [7647-01-0]	D4	8(II)	3	1	1515	RCY	NCR	LWT, pH<6
1051	Hydrocyanic Acid solution [74-90-8]	D4	6.1(I)	1	0.0057	8.6	RCY, INC	OCR	LWT
1790	Hydrofluoric Acid solution [7664-39-3]	F3	8(I/II)	-	-	-	RCY	NCR, PRN	LWT, pH<6
2014	Hydrogen peroxide, aqueous [7722-84-1]	H3	5.1(II)	3	4.2	6363	RCY	RCR	LWT
2662	Hydroquinone [123-31-9]	F5	6.1(III)	1	0,0097	14.6	RCY, INC	ENC, LFC	-

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2865	Hydroxylamine Sulphate [10039-54-0]	F5	8(III)	2	0,72	1090	RCY, INC	OCR	LWT
2644	Iodomethane [74-88-4]	F3	6.1(II)	2/3	0,1	151	RCY, INC	ENC, LFC, LFB	-
-	Iron [7439-89-6]	D1	-	3	9	13636	RCY, IML	PRN	-
2757	Isolan [119-38-0]	A1	6.1(II)	1	0,1	<151	RCY, INC	LFC, LFB	-
1219	Isopropanol [67-63-0]	F2	3.2(II)	4/NT	1040	1575757	RCY, INC	LFB	LWT
1918	Isopropylbenzene [98-82-8]	F3	3.3(III)	3	5.0	7576	RCY, INC	LFB	LWT
-	Lead [7439-92-1]	G2	-	2	0.1	151	RCY	ENC, IML	LWT
1616	Lead acetate [301-04-2]	H1	6.1(III)	3/4	40	60606	RCY, IML	PRN	LWT
1617	Lead arsenates [7784-40-9]	A1	6.1(II)	1	10	15151	RCY, IML	ENC, LFC	-
1872	Lead dioxide [1309-60-0]	G3	5.1(III)	2	0.1	151	RCY, IML	ENC, LFC	-
1794	Lead Sulphate [7446-14-2]	G3	8(II)	2	0.1	151	RCY, IML	ENC, NCR	LWT, pH<6
2761	Lindane [58-89-9]	A1	6.1(III)	1	0,0027	4.09	RCY, INC	ENC, LFC	-
2723	Magnesium Chlorate [10326-21-3]	A1	5.1(II)	4	10	15151	RCY	LFC (Wet)	-
3082	Malathion [121-75-5]	A1	9(III)	1	0,01	15	RCY, INC	ENC, LFC	-
2215	Maleic Anhydride [108-31-6]	F7	8(III)	3	15	22727	RCY, INC	HNR	LWT
2647	Malononitrile [109-77-3]	F3	6.1(II)	2	0.1	242	RCY, INC	ENC, LFC, LFB	-
2210	Maneb [12427-38-2]	A1	4.2(III)	2	0,18	272	RCY, INC	ENC, LFC	-

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-	Manganese [7439-96-5]	D2	-	2	0.3	454	RCY, IML	ENC. PRN	LWT
-	Manganese Chloride [7773-01-5]	H1	-	2	0.3	454	RCY, IML	ENC. PRN	LWT
-	Manganese Dioxide [1313-13-9]	C3	-	2	0.3	454	RCY, IML	LFC	-
1940	Mercaptoacetic Acid [68-11-1]	F3	8(II)	2	0,1	151	RCY, INC	ENC. OCR, NCR	LWT, pH<6
1629	Mercuric Acetate [1600-27-7]	F9	6.1(II)	1	0,0009	1.36	RCY, IML	ENC. PRN	LWT
1624	Mercuric Chloride [7487-94-7]	F7	6.1(II)	1	0,0009	1.36	RCY, IML	ENC. PRN	LWT
1641	Mercuric Oxide [21908-53-2]	F7	6.1(II)	1	0,0009	1.36	RCY, IML	ENC. PRN	LWT
3077	Mercurous Chloride [7546-30-7]	F6	9(III)	1	0,0009	1.36	RCY, IML	ENC, LFC	-
2809	Mercury metal [7439-97-6]	G2	8(III)	1	0.022	24	RCY, IML	ENC. OCR	LWT
1229	Mesityl Oxide [141-79-7]	F4	3.3(III)	4/NT	54	81818	RCY, INC	LFB	LWT
1332	Metaldehyde [9002-91-9]	F9	4.1(III)	4/NT	10	15151	RCY, INC	LFC	-
2823	Methacrylic Acid [79-41-4]	F3	8(III)	2/3	0.1	151	RCY, INC	NCR	LWT, pH<6
1230	Methanol (S) [67-56-1]	F3	3.2(II)	NT	800	1212121	RCY, INC	LFB	LWT
2757	Methomyl [16752-77-5]	A1	6.1(II)	2	0.34	515	RCY, INC	ENC, LFC	LWT
8095	Methoxychlor [72-43-5]	A1	9	1	0.0007	1.06	RCY, INC	ENC, LFC	-
1919	Methylacrylate [96-33-3]	F7	3.2(II)	2/3	0.1	151	RCY, INC	ENC. LFB	LWT
1235	Methylamine aqueous [74-89-5]	F2	3.2(II)	3/4	2	3030	RCY, INC	NCR, LFB	LWT
2938	Methyl Benzoate [93-58-3]	F6	6.1(III)	2/3	0.461	698	RCY, INC	ENC. LFC,	-

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								LFB	
2295	Methyl Chloroacetate [96-34-4]	F3	6.1(II)	2	0.1	151	RCY, INC	ENC, LFB	LWT
1193	Methyl Ethyl Ketone (S) [78-93-3]	F2	3.2(II)	4/NT	322	487878	RCY, INC	LFB	LWT
1244	Methylhydrazine [60-34-4]	F3	6.1(I)	2	0.258	390	RCY, INC	OCR	LWT
1247	Methyl Methacrylate [80-62-6]	F9	3.2(II)	4/NT	15.9	24090	RCY, INC	LFB, CTR	LWT
3082	Methyl Salicylate [119-36-8]	F6	9(III)	2/3	1	<1515	RCY, INC	LFC, LFB	-
2618	Methylstyrenes [98-83-9]	F7	3.3(III)	3	1	1515	RCY, INC	LFB, CTR	LWT
1251	Methyl Vinyl Ketone [78-94-4]	F3	3.2(II)	2/3	1	<1515	RCY, INC	ENC, LFB	LWT
2783	Mevinphos [7786-34-7]	A1	6.1(I)	1	0.0034	5.15	RCY, INC	ENC, LFC	-
1300	Mineral Turpentine [8030-30-6]	F4	3.2(II)	3	1.1	1666	RCY, INC	LFB	LWT
2996	Mirex [2385-85-5]	A2	6.1(III)	1	0.02	30	RCY, INC	ENC, LFC, LFB	-
1134	Monochlorobenzene [108-90-7]	F4	6.1(III)	3	2.4	3636	RCY, INC	LFC	-
1334	Naphthalene [91-20-3]	F3	4.1(III)	2/3	0.38	575	RCY, INC	LFC	-
1256	Naphtha solvent [8030-30-6]	F4	3.2(II)	2	0.2	1666	RCY, INC	LFB	LWT
-	Nickel [7440-02-0]	D4	-	2	1.14	1727	RCY, IML	ENC, PRN	LWT
8323	Nickel Chloride [7718-54-9]	D4	9(III)	2/3	1.2	1818	RCY, IML	PRN	LWT, pH<6
1654	Nicotine [54-11-5]	A2	6.1(II)	2	0.4	606	RCY, INC	ENC, LFC	-
1662	Nitrobenzene (S) [98-95-3]	F3	6.1(II)	3/4	4.3	6515	RCY, INC	LFC, LFB	-



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2446	Nitrocresols [4920-77-8]	F3	6.1(III)	3/4	4.61	6984	RCY, INC	LFC, LFB	-
2842	Nitroethane [79-24-3]	F7	3.3(III)	3/4	1	1515	RCY, INC	LFB	-
0143	Nitroglycerine [55-63-0]	F8	1.1D	2/3	0.1	151	DBI	-	LFL
1261	Nitromethane [75-52-5]	C2	3.3(II)	2/3	0.5	>757	RCY, INC	ENC, LFB	LWT
1663	Nitrophenols [25154-55-6]	F3	6.1(III)	3/4	4.6	6969	RCY, INC	LFC, LFB	-
1664	Nitrotoluenes [99-08-1, 1321-12-6]	F3	6.1(II)	3/4	3.0	4545	RCY, INC	LFC, LFB	-
3082	Nonylphenol [25154-52-3]	F2	9(III)	1	0.014	21.2	RCY, INC	ENC, LFC, LFB	-
-	1-Octanol [111-87-5]	F6	3.4	3	2.3	3485	RCY, INC	LFB	-
2271	2-Octanone [111-13-7]	A2	3.3(III)	3	3.59	5439	RCY, INC	LFB	-
-	Octanoic Acid [124-07-2]	F6	-	3	4.7	7121	RCY, INC	LFB	-
1805	Orthophosphoric Acid [7664-38-2]	F2	8(III)	3	1	1515	RCY	NCR	LWT, pH<6
2471	Osmium Tetroxide [20816-12-0]	F11	6.1(I)	2	0.1	151	RCY	RCR	LWT
1040	Oxirane [75-21-8]	F2	2(2.3)	3/4	9	1363	RCY, INC	HNR	LFL
2213	Paraformaldehyde [30525-89-4]	A2	4.1	3	3.1	4696	RCY, INC	LFC	-
3016	Paraquat [4685-14-7]	A2	6.1(II)	3/4	3.2	4848	RCY, INC	LFC, HNR	-
3018	Parathion [56-38-2]	A2	6.1(II)	1	0.019	28	RCY, INC	ENC, LFC, HNR	-
1265	Pentane [109-66-0]	F3	3.1(I/II)	3/4	10	15151	RCY, INC	LFB	LWT

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1897	Perchloroethylene [127-18-4]	L1	6.1(III)	1	0.1	151	RCY, INC	ENC, LFB	LWT
1873	Perchloric Acid [7601-90-3]	D4	5.1(I)	4	200	303030	RCY	NCR	LWT, pH<6
2902	Permethrin [52645-53-1]	F9	6.1(I)	1	0.0006	0.909	RCY, INC	ENC, LFC, LFR	-
1271	Petroleum Ether [8030-30-6]	F4	3.1(I/II)	3	1.1	1666	RCY, INC	LFB	LWT
1300	Petroleum Thinners [8006-64-2]	F4	3.2(II)	4	10	15151	RCY, INC	LFB	LWT
1671	Phenol [108-95-2]	F3	6.1(II)	3	2.3	3485	RCY, INC	LFC, LFB	-
1338	Phosphorus-red [7723-14-0]	F8	4.1(III)	1	0.1	<151	RCY, INC	OCR	LWT
1381	Phosphorus-white/yellow [7723-14-0]	F8	4.2(I)	1	0.1	<151	RCY, INC	OCR (Care!)	LWT
2214	Phthalic Anhydride [85-44-9]	F7	8(III)	3/4	1	1515	RCY, INC	HNR	LWT
2313	Picolines $\alpha, \beta, \gamma$ [1333-41-1]	F3	3.3(III)	3/4	1	1515	RCY, INC	LFB	LWT
2579	Piperazine [110-85-0]	F6	8(III)	3	1	1515	RCY, INC	LFB, NCR	LWT
2401	Piperidine [110-89-4]	F7	3.2(II)	2/3	0.1	151	RCY, INC	ENC, LFB, NCR	LWT
2315	Polychlorinated biphenyls [1336-36-3]	C3	9(II)	1	0.002	3.0	RCY, INC	ENC. CTR, LFC	-
1680	Potassium Cyanide [151-50-8]	D2	6.1(I)	1	0.009	13.6	RCY	ENC, OCR	LWT
2811	Potassium Dichromate [7778-50-9]	H2	6.1(III)	3/4	2.5	3787	RCY, IML	ENC. RCR	LWT
1812	Potassium Fluoride [7789-23-3]	E1	6.1(III)	2/3	0.1	151	RCY, IML	ENC. PRN	LWT
1811	Potassium Hydrogen Fluoride [7789-29-9]	E1	8(II)	2/3	0.1	151	RCY	ENC, NCR,	LWT, pH<6

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1830	Sulphuric Acid [7664-93-9]	F2	8(II)	4	10	15151	RCY	NCR	LWT, pH<6
2783	Systox [8065-48-3]	A1	6.1(I)	1	0.01	15	RCY, INC	ENC, LFC	-
3000	2,4,5-T [93-76-5]	A1	6.1(III)	3/4	35	53030	RCY, INC	LFC	-
3020	TBTO (Tributyltin oxide) [56-35-9]	F4	6.1	1	0.0003	0.464	RCY, INC	ENC, LFC, LFB	-
-	Tebuthiuron [34014-18-1]	A1	6.1	4	11.2	16970	RCY, INC	ENC, LFC	-
2783	Terbufos [13071-79-9]	A1	6.1(I)	1	0.0004	0.606	RCY, INC	ENC, LFC, LFB	-
1702	Tetrachloroethane [79-34-5]	F4	6.1(II)	3/4	3.7	5606	RCY, INC	LFB, LFC	-
1897	Tetrachloroethylene (S) [127-18-4]	H1	6.1(III)	1	0.1	151	RCY, INC	LFB, LFC	-
1649	Tetraethyl Lead [78-00-2]	C2	6.1(I)	1	0.002	3.03	RCY, INC	WTL, LFB	LWT
2056	Tetrahydrofuran [109-99-9]	F4	3.2(II)	3	5	7576	RCY, INC	LFB	LWT
1649	Tetramethyl Lead [75-74-1]	C2	6.1(I)	3/4	1.35	2045	RCY, INC	WTL, LFB	LWT
2727	Thallium Nitrate [10102-45-1]	F11	6.1(II)	1/2	0.1	151	RCY, IML	ENC, LFC	-
1940	Thioglycolic Acid [68-11-1]	F6	8(II)	2	0.5	>757	RCY, INC	OCR, NCR	LWT, pH<6
2811	Thiosemicarbazide [79-19-6]	F3	9(III)	3	2.5	3788	RCY, INC	LFC	-
1838	Titanium Tetrachloride [7550-45-0]	F7	8(II)	2	0.73	1106	RCY	HNR	LWT
1294	Toluene (S) [108-88-3]	F2	3.2(II)	3	1.3	1969	RCY, INC	LFB	LWT
2078	Toluene Diisocyanate [584-84-9]	F7	6.1(II)	2	0.1	151	RCY, INC	CTR, LFB, HNR	LWT

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1301	Vinyl Acetate [108-05-4]	F7	3.2(II)	3/4	1.8	2727	RCY, INC	LFB	LWT
1085	Vinyl Bromide [593-60-2]	F7	2(2.1)	3	1	1515	RCY, INC	-	LFL
1086	Vinyl Chloride [75-01-4]	F7	2(2.1)	2	0.1	151	RCY, INC	-	LFL
3026	Warfarin [81-81-2]	A1	6.1(I)	1	1.2	1818	RCY, INC	LFC	-
1307	Xylenes (S) [1330-20-7, 95-47-6, 106-42-3, 108-38-3]	C2	3.2(II)	3	1.1	1667	RCY, INC	LFB	LWT
-	Zinc [7440-66-4]	D1	-	2	0.7	1061	RCY, IML	PRN	LWT
1840	Zinc Chloride [7646-85-7]	F3	8(III)	3	1	1515	RCY, IML	PRN	LWT
-	Zirconium [7440-67-2]	F8	-	3	2	3030	RCY, IML	PRN	LWT

## **APPENDIX III**

### **Eskom Procedure on Creosote wooden poles**

Document Classification: **Controlled Disclosure**

Title: <b>PROTOCOL FOR TESTING OF NEW AND EXISTING CHEMICALS AS LIFE EXTENSION TREATMENTS FOR ESKOM WOODEN UTILITY POLES</b>	Reference: <b>34-330</b>
	Document Type: <b>DSP</b>
	Revision: <b>A</b>
	Effective date: <b>OCTOBER 2006</b>
	Total pages: <b>8</b>
	Revision date: <b>OCTOBER 2009</b>

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COMPILED BY	APPROVED BY	FUNCTIONAL RESP	AUTHORISED BY
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**PROTOCOL FOR TESTING OF NEW AND  
EXISTING CHEMICALS AS LIFE  
EXTENSION TREATMENTS FOR ESKOM  
WOODEN UTILITY POLES**

Reference: 34-330  
Revision: A  
Page: 2 of 8

## 1. Introduction

Preservative-treated wooden poles are used extensively to support utility wood pole lines throughout South Africa and other parts of the world. Over time these poles become susceptible to fungal and termite attacks, causing pole failure. Apart from the costly process of replacing poles, failures could also result in fires and other health and safety risks.

Premature or early failure of in-service wooden poles can be prevented by the timeous application of a remedial / supplemental wood preservative with the objective of preventing decay and extending the service life of the treated poles.

It is important that any testing of remedial / supplemental treatment products for wooden poles follow this protocol so as to provide extensive and accurate data to Eskom that approves such products

### Revision history

Date	Rev.	Remarks
Oct'06	A	First issue.

### Authorisation

This document has been seen and accepted by:

Name	Designation
M N Bailey	Corporate Divisional Technology Manager
A Bekker	Plant Technologies Manager
R Stephen	Lines Study Committee Chairperson

## 2. Objectives

This protocol provides a set framework for testing of new remedial / supplemental treatment chemicals and a guideline for re-formatting of any existing trials.

The main objective of testing any remedial / supplemental chemical is to determine the extent of distribution and concentration of the active ingredients and therefore the suitability to fit in with the 10 year inspection and treatment cycle which is an established component of Eskom's wood pole management strategy.

It is a prerequisite that any trial shall consist of the two main categories of wood species that are extensively used by Eskom and shall therefore include both Gum and Pine species.

If the remedial / supplemental chemical being tested is intended for internal use, then a selection of stubs (outlined below) shall be used exclusively for that application, likewise any external pole treatment shall only be applied on stubs established for that purpose. This will provide the advantage of individually monitoring internally and externally applied chemicals. Should a combination of external and internal treatment be required, then an additional test of the combined application shall be done.

### **3. Time periods**

Stubs shall be primarily treated and remedially treated with the test chemicals at predetermined doses and be analysed over set periods up to at least 7 years. The intermediate testing and evaluation periods shall be one, three and five years with a final test and evaluation after seven years, which should provide information on how the loading and distribution of the actives have changed over time. A predetermined experimental lay-out and inspection schedule shall be drawn up to include a full set of stubs for each inspection and evaluation period.

### **4. Materials and methods**

#### **4.1 Experimental lay-out**

For each inspection and evaluation period (See 3 above), a minimum of 5 stub samples per chemical treatment and one control shall be established for each wood species. If design variations of remedial / supplemental chemicals and the application thereof are included in the trial, then an additional test are required. Only representative utility pole stub diameters shall be used i.e. 180-220mm ground-line diameters and stub lengths of at least 2.1metres shall be used.

The purpose of the control is to have a parallel test running of a stub without the remedial / supplemental chemical treatment so that it can be checked for fungal decay

All the stubs shall be clearly numbered and be kiln dried and creosote treated in accordance with Eskom specification DISSCAADY (using the latest published revision). The top ends of all test stubs, including the controls, shall be covered with a metal cap before installation.

Planting depth of the stub shall be 800mm below the natural ground-line. The natural ground-line position shall be clearly and permanently marked on each stub for future reference.

For internal treatments, holes shall be drilled at a downward angle of approximately 20 degrees to the vertical and their dosages recorded. The pattern of drilling around the pole, the dosage rates applied and full details of the application procedure shall be clearly recorded.

In the case of external type bandage/paste treatments, this shall be applied strictly in accordance with the manufacturer's recommendations. The quantity applied and full details of the application procedure shall be clearly recorded.

The site soil conditions shall be recorded (e.g. sand or clay, drainage, etc.).

#### **4.2 Evaluation procedure and method**

For each of the predetermined testing and evaluation periods (See section 3) and species of poles, the required number of treated stubs and controls shall all be removed and destructively evaluated as more fully described below.

##### **4.2.1 Selection and preparation of test samples**

###### **4.2.1.1 Preparation and cutting of sample discs**

Seven core samples per sample disc shall be taken at seven different positions, using a hole saw yielding an effective core diameter of 20mm diameter. One sample core shall be taken from the centre of the disc, a second composite sample (3 discs) approximately 40mm from the centre and a third composite sample (3 discs) approximately 80mm from the centre as illustrated and more fully described in the figure below.



For each remedial / supplemental treatment product under test, five test stubs plus one control per pole species shall be removed and the surface thoroughly cleaned to remove all soil, contaminants or any remains of externally applied chemicals before cutting of sample discs.

The following positions for removal of sample discs from the selected test stubs shall be marked out, starting at the natural ground-line mark (See 4.1):

- a) Two sample disc positions at 100mm intervals above ground-line (marked as +1 and + 2), i.e. a total length of 200mm above the ground-line, and
- b) Ten sample disc positions at 50mm intervals below ground-line (marked as -1 to - 10), i.e. a total length of 500mm below the ground-line.

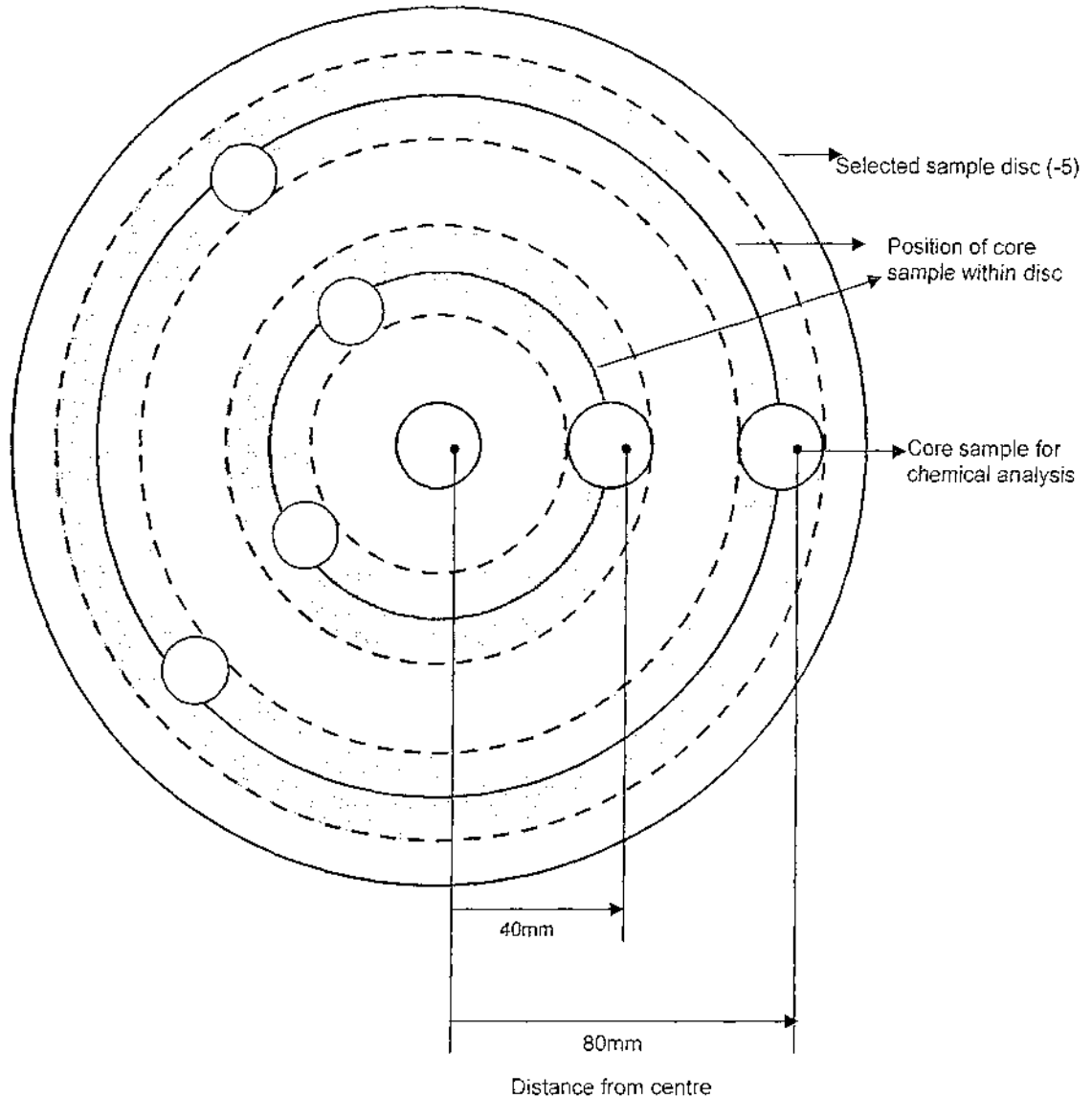
The sample discs shall then be cut using a chain saw to yield two sample discs taken above ground-line having an effective thickness of 85 to 90mm each and the ten sample discs taken below ground-line having an effective thickness of 35 to 40mm each. All sample discs shall be clearly identified with the relevant stub number, test site, pole species, chemicals product and disc position codes.

#### **4.2.1.2 Selection of sample discs for chemical analysis**

A sample disc from the 200 to 250mm position below ground level, marked as "- 5", shall be selected from each of the five test stubs per pole species representing each remedial / supplement treatment product being tested.

Composite samples from the 5 test stubs per chemical product per pole species shall be prepared for chemical analysis to determine the active ingredient content at three different positions within each disc (See 4.2.1.3 below).

Position of 3 core samples to be taken from sample discs



**Important:** Core sample shall be taken anywhere within the shaded zone indicated above without drilling into any treatment hole and shall be done on a random basis without the use of a chemical indicator, i.e. position of the core samples shall be determined on the unsprayed surface of a disc. Positions containing knots or resinous areas shall also be avoided.

The sampling system shall be photographed and recorded.

Core samples taken from each position as described above shall be ground up and thoroughly mixed together as a representative composite sample for the 5 test stubs per chemical product per pole species, i.e. a total of 3 composite samples shall be prepared for chemical analysis (See 4.2.2.2 below).

## 4.2.2 Evaluation of product performance

### 4.2.2.1 Visual evaluation of diffusion patterns

The upper surface of each sample disc, as prepared and described under 4.2.1.1, shall be allowed to surface dry and then sprayed with an approved chemical indicator in order to visually observe and evaluate the active ingredient diffusion / distribution patterns obtained on the different cross-sectional surfaces after each exposure test period. (It is important that the chemical indicator used has not exceeded its expiry date and that it is applied strictly in accordance with the directions for use.)

### 4.2.2.2 Chemical analysis of selected sample discs

The 3 composite samples as prepared and described under 4.2.1.3, shall be submitted to an approved laboratory for chemical analysis to determine the active ingredient content in ppm at the three different positions within each set of five sample discs.

## 5. Results and discussion

Evaluation and discussion of the test results shall focus on trends and averages regarding diffusion patterns and active ingredient loadings achieved, rather than individual cases.

The following active ingredient concentrations are the minimum toxic threshold levels for adequate control of fungal decay in wood and the tests should show average loadings in the below ground segment exceeding these levels for the majority of the 7 year testing period.

Boron = 300ppm Fluoride = 700ppm

Where multiple active ingredients are used, additional tests can be provided to demonstrate the effect of synergy on reducing of the threshold levels given above.

### 5.1 Diffusion patterns

The visual evaluation of the diffusion patterns obtained on the different cross-sectional upper surfaces of discs selected and prepared and as more fully described under 4.2.1.1 and 4.2.2.1, shall be done by taking digital photographs of each sample disc.

### 5.2 Chemical analysis

The results obtained from chemical analysis performed on the composite samples prepared from three different positions within each set of the selected sample discs as described under 4.2.1.2, 4.2.1.3 and 4.2.2.2 shall be presented in a table similar to the one below.

### 5.3 Results of chemical analysis from selected composite samples

(Conducted by "Laboratory Name")

Sample no. / Identification	Active ingredient content in ppm			
	Centre of disc	± 40mm from centre of disc	± 80mm from centre of disc	Average of 3 measurements
No. 1 – 5 / TSC – 5, etc				

Where:

No. 1 – 5 = Sample disc numbers represented by the composite sample.

TSC(-5) = Test site (T), Pole species (S), Chemical product (C), Disc no. (-5).

**Note:**

- a) In the case of boron containing chemical products, the active ingredient content shall be expressed as elemental boron (B) in ppm.
- b) In the case of fluoride containing chemical products, the active ingredient content shall be expressed as elemental fluoride (F) in ppm.

The official test report issued by the approved laboratory shall also be attached for reference purposes.

## **6. Acceptance criteria**


At the end of the 7 year test period a minimum average concentration of 300 ppm shall be in the wood for each specie of wood. Failing this the product will not be accepted and will need to be redesigned and retested from the beginning

## **7. Conclusions**

In comparing one test period to another, conclusions shall be derived regarding increasing or declining active ingredient loadings and effectiveness shall be referenced by comparison to typical fungitoxic threshold levels given above (See 5).

## Annex A

## Impact assessment

	Impact assessment		
	Document title:	Protocol for testing of new and existing chemicals as life extension treatments for Eskom wooden utility poles	
	Document no:	34-330	Revision no: A
<b>Activity</b>	<b>Detail</b>		
What training is required to implement this document? (e.g. Awareness training, practical / on job, module.)	XXX		
Who will require training? (State designations.)	XXX		
What prerequisites are needed for students?	XXX		
What equipment will be required for training? (Computers etc.)	XXX		
What special tools will be required for training?	XXX		
What special requirements are needed for the trainer?	XXX		
Time period for training to be completed?	XXX		
What special tools / equipment will be needed to be purchased by the Region to effectively implement?	XXX		
Are there stock numbers available for the new equipment?	XXX		
Does the document affect the budget?	XXX		
Time period for implementation of requirements after training is completed?	XXX		
Does the Buyers Guide or Buyers List need updating?	XXX		
What Buyer's Guides have been created?	XXX		
Was Training & Development consulted w.r.t training requirements?	XXX		
Were the critical points in the document determined?	XXX		
Is any training material available on the subject in this document?	XXX		
	Total implementation period		
	Total training cost		
	Total cost of tools / equipment		
	Total cost involved		
Comments:			
Assessment Compiled by:		Recommended by (Functional Responsibility):	
Name:	B P Hill	Name:	R Stephen
Designation:	Senior Engineer	Designation:	Lines Study Comm. Chairman
Dept:	Plant Technologies IARC	Dept:	Eastern Region
Date:	October 2006	Date:	October 2006

## APPENDIX IV

### CSIR acknowledgement of samples



T0010

## 5. ANALYTICAL METHODS

Polycyclic aromatic hydrocarbons were determined using an in-house GC-MS method AM 186 (based on US EPA method 8270).

## 6. RESULTS

The polycyclic aromatic hydrocarbons results are given in Appendix 1. This is a target compound analysis. The list of target compounds is included with the results.

We trust these results will meet with your approval. Please let us know if you require any further information.

Yours faithfully,

**B G Cowan (Pr. Sci. Nat)**  
Laboratory Manager  
CSEA, Knowledge Services  
CSIR

\* "Not SANAS Accredited"

*This report relates only to samples tested and to conditions, which prevailed when samples were received. The certificate may not be reproduced, except in full, without the written approval of the Laboratory Manager*



T0010

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*Date:* 05 October, 2007

*SANAS Testing Laboratory Number: T0010*

### CERTIFICATE OF ANALYSIS

Eskom Distributio North West  
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**ATTENTION: Ms S Thulasaie**

Dear Ms Thulasaie

**SUBJECT: DETERMINATION OF POLYCYCLIC AROMATIC HYDROCARBONS (PAH)  
IN SOIL SAMPLES**

#### **1. INTRODUCTION**

This report details the results for the analysis of soil samples received on 22 August 2007.

#### **2. DISCLAIMER**

Tests marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this laboratory. Opinions and interpretations expressed herein are outside the scope of SANAS accreditation.

#### **3. SAMPLE RECEIPT AND HANDLING**

Six soil samples were received in 250 ml plastic bottles. On receipt, the samples were transferred to a refrigerator where they were kept until analysed.

#### **4. ANALYSES REQUESTED**

The determination of polycyclic aromatic hydrocarbons (PAHs) was required.

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